NR467 DT JULY 2025

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

NR467 - JULY 2025

CONSOLIDATED JULY 2025 EDITION
PARTS A - B - C - D - E - F

STEEL SHIPS

BUREAU VERITAS

BUREAU VERITAS
RULES FOR THE CLASSIFICATION OF STEEL SHIPS

NR467 - JULY 2025

This document contains the consolidated January 2025 edition, Part A to Part F.

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These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The latest version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

PART A

CLASSIFICATION AND SURVEYS

NR467 A DT R24 JULY 2025

PART B

HULL AND STABILITY

NR467 B DT R19 JULY 2025

PART C

MACHINERY, ELECTRICITY, AUTOMATION AND FIRE PROTECTION

NR467 C DT R19 JULY 2025

PART D

SERVICE NOTATIONS

NR467 D DT R19 JULY 2025

PART E

SERVICE NOTATIONS FOR OFFSHORE/WIND FARM SERVICE VESSELS AND TUGS

NR467 E DT R10 JULY 2025

PART F

ADDITIONAL CLASS NOTATIONS

NR467 F DT R19 JULY 2025

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NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part A
Classification and Surveys

Chapter 1	Principles of Classification and Class Notations
Chapter 2	Assignment, Maintenance, Suspension and Withdrawal of Class
Chapter 3	Scope of Surveys (All Ships)
Chapter 4	Scope of Surveys in Respect of the Different Services of Ships
Chapter 5	Scope of Surveys Related to Additional Class Notations
Chapter 6	Retroactive Requirements for Existing Ships

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Table of Content

Chapter 1 Principles of Classification and Class Notations

Section 1 General Principles of Classification

1 Principles of classification 26

1.1 Purpose of the Rules
1.2 General definitions
1.3 Meaning of classification, scope and limits
1.4 Request for services
1.5 Register of ships

2 Rules 28

2.1 Effective date
2.2 Equivalence
2.3 Novel features
2.4 Disagreement and appeal

3 Duties of the Interested Parties 28

3.1 International and national regulations
3.2 Surveyor's intervention
3.3 Operation and maintenance of ships
3.4 Flag and Port State Control inspections
3.5 Use of measuring equipment and of service suppliers
3.6 Spare parts
3.7 Quality system audits

4 Application of statutory requirements by the Society 30

4.1 International and national regulations

Section 2 Classification Notations

1 General 31

1.1 Purpose of the classification notations
1.2 Types of notations assigned

2 Class symbol 31

2.1 General

3 Construction marks 32

3.1 General
3.2 List of construction marks

4 Service notations and corresponding additional service features 32

4.1 General
4.2 Cargo ships
4.3 Bulk, ore and combination carriers
4.4 Ships carrying liquid cargo in bulk
4.5 Ships carrying passengers
4.6 High speed crafts (HSC)
4.7 Offshore patrol vessels
4.8 Fishing vessels
4.9 Icebreaker ships
4.10 Tugs
4.11 Working ships
4.12 Offshore and/or wind farm service vessels
4.13 Ships for dredging activities
4.14 Barge and pontoon
4.15 Miscellaneous units
4.16 Miscellaneous service features

Table of Content

5 Navigation and operating area notations 58

5.1 Navigation notations
5.2 List of navigation notations
5.3 Operating area notations

6 Additional class notations 61

6.1 General
6.2 VeriSTAR and STAR notations
6.3 Availability of machinery (AVM)
6.4 Automated machinery systems (AUT)
6.5 Integrated and digital systems
6.6 Monitoring equipment
6.7 Comfort on board ships and habitability
6.8 Environmental protection
6.9 Refrigerating installations
6.10 Navigation in cold environment
6.11 Navigation in polar waters
6.12 Lifting appliances
6.13 Emergency response service (ERS)
6.14 Protection against chemical, biological, radiological or nuclear risks
6.15 Manoeuvring, mooring, anchoring and position keeping
6.16 Cargo operation, securing and safety
6.17 Additional notations for stability
6.18 Additional notations for hull structure assessment
6.19 Additional notations for fire protection
6.20 Electric propulsion or electric power supply
6.21 Cyber security
6.22 Sustainable ships
6.23 Smart systems (SMART)
6.24 Corrosion protection
6.25 Other additional class notations
6.26 System fitted but not required by the rules

7 Other notations 89

7.1

8 Diving systems 89

8.1 General

Appendix 1 Notations Assigned According to Editions of the Rules Former to June 2000 Edition

1 Application for surveys and correspondence with current notations 91

1.1 General
1.2 Phasing out from former to current notations
1.3 Application of scope of surveys
1.4 Correspondence between former and current notations

Chapter 2 Assignment, Maintenance, Suspension and Withdrawal of Class

Section 1 Assignment of Class

1 General 96

1.1

2 New building procedure 96

2.1 Ships surveyed by the Society during construction
2.2 Other cases
2.3 Documentation

Table of Content

3 Ships classed after construction 97

3.1 General
3.2 Ships classed with a Classification Society subject to compliance with QSCS, reported as compliant by the Losing Society
3.3 Non-compliant ships

4 Date of initial classification 101

4.1 Definitions

5 Reassignment of class 101

5.1

Section 2 Maintenance of Class

1 General principles of surveys 102

1.1 Survey types
1.2 Change of periodicity, postponement or advance of surveys
1.3 Extension of scope of survey
1.4 General procedure of survey
1.5 Appointment of another Surveyor
1.6 Alterations or additions to approved systems

2 Definitions and procedures related to surveys 104

2.1 General
2.2 Terminology related to hull survey
2.3 Procedures for thickness measurements
2.4 Agreement of firms for in-water survey
2.5 Preparations and conditions for surveys
2.6 Access to structures
2.7 Equipment for surveys
2.8 Rescue and emergency response equipment
2.9 Surveys at sea and anchorage
2.10 Repairs and maintenance during voyage
2.11 Repairs
2.12 Remote Inspection Techniques (RIT)
2.13 Remote survey

3 Certificate of Classification: issue, validity, endorsement and renewal 111

3.1 Issue of Certificate of Classification
3.2 Validity of Certificate of Classification, maintenance of class
3.3 Endorsement of Certificate of Classification
3.4 Status of surveys and conditions of class

4 Class renewal survey 111

4.1 General principles
4.2 Normal survey system (SS)
4.3 Continuous survey system (CS)
4.4 Planned maintenance survey system for machinery (PMS)

5 Other periodical surveys 113

5.1 General
5.2 Annual surveys
5.3 Intermediate surveys
5.4 Bottom survey
5.5 Tailshaft survey
5.6 Boiler survey
5.7 Links between anniversary dates and annual surveys, intermediate surveys and class renewal surveys

Table of Content

6 Occasional surveys 117

6.1 General
6.2 Damage and repair surveys
6.3 Port State Control survey
6.4 Conversions, alterations and repairs
6.5 Quality System audits
6.6 Unscheduled surveys

7 Change of ownership 118

7.1

8 Lay-up and re-commissioning 118

8.1 General principles

9 Safety Management System 119

9.1

Section 3 Suspension and Withdrawal of Class

1 General 120

1.1 Discontinuance of class
1.2 Suspension of class
1.3 Withdrawal of class
1.4 Suspension/withdrawal of additional class notations

Appendix 1 Planned Maintenance Survey System

1 General 122

1.1

2 Conditions and procedures for the review of the system 122

2.1 General
2.2 Documentation
2.3 Information on board
2.4 List of items

3 Implementation of the system 123

3.1

4 Retention and withdrawal of the system 123

4.1

5 Surveys 123

5.1 Implementation survey
5.2 Annual audit and confirmatory surveys
5.3 Damage and repairs

Appendix 2 CSM and PMS Systems: Surveys Carried out by the Chief Engineer

1 Conditions 125

1.1

2 Limits of the interventions 125

2.1

3 Procedure for carrying out surveys 125

3.1 General
3.2 Main diesel engines
3.3 Auxiliary diesel engines
3.4 Reciprocating compressors
3.5 Coolers, condensers, heaters
3.6 Electrical switchboard
3.7 a.c. and d.c. generators
3.8 Other items (pumps, electric motors, etc.)

Table of Content

4	Records of surveys carried out	126
	4.1	
5	Confirmatory survey	127
	5.1	
6	Suspension of the Chief Engineer's authorization	127
	6.1	

Appendix 3 Thickness Measurements: Extent, Determination of Locations, Acceptance Criteria

1	General	128
	1.1 Aim of the Appendix	
	1.2 Scope of the Appendix	
2	Rule requirements for the extent of measurements	128
	2.1 General	
	2.2 Class renewal survey: all ships except those submitted to ESP or equivalent	
	2.3 Class renewal survey: ships submitted to ESP or equivalent	
3	Number and locations of measurements	130
	3.1 General	
	3.2 Locations of points	
4	Acceptance criteria for thickness measurements	142
	4.1 General	
	4.2 Criteria	
	4.3 Local and global strength criteria based on percentage of acceptable wastage	
	4.4 Buckling strength criterion	
	4.5 Acceptance criteria based on net scantling approach	
	4.6 Pitting	
	4.7 Acceptance criteria for CSR ships	
	4.8 Hull supporting structure of shipboard fittings associated with towing and mooring	
	4.9 Ice strengthened structures for ships assigned with additional class notation for navigation in polar waters	

Appendix 4 Condition Monitoring and Condition Based Maintenance

1	General	156
	1.1 Application	
	1.2 Definitions	
	1.3 Condition monitoring (CM)	
	1.4 Condition based maintenance (CBM)	
2	Procedures and conditions for approval of CM and CBM	157
	2.1 Onboard responsibility	
	2.2 Equipment and systems requirements	
	2.3 Documentation and information	
	2.4 Approval validity	
3	Surveys	158
	3.1 Installation survey	
	3.2 Implementation survey	
	3.3 Annual audit	
	3.4 Damage and repairs	

Appendix 5 Remote Classification Surveys

1	General	160
	1.1 Scope	
	1.2 Application	
	1.3 Definitions	

2 Requirements for equivalency 160
2.1 General
2.2 Eligibility of the remote survey
2.3 Planning of the remote survey
2.4 Performance of the remote survey
2.5 Assessment of the remote survey
3 Scope and procedures 161
3.1 Scope - eligible survey items
3.2 Procedures
3.3 Hardware and ICT solution
3.4 Requirements for connectivity
4 Information and Communication Technology (ICT) 163
4.1 General
4.2 Hardware
4.3 Internet connectivity (coverage and speed)
4.4 Software and data security
5 Recording of evidence and reporting of survey 164
5.1 Recording of evidence
5.2 Reporting of remote survey

Chapter 3 Scope of Surveys (All Ships)

Section 1 Annual Survey
1 General 167
1.1
2 Hull 167
2.1 Hull and hull equipment
2.2 Survey of watertight cable transits
2.3 Hatch covers and coamings
3 Machinery and systems 169
3.1 General machinery installations
3.2 Boilers
3.3 Electrical machinery and equipment
3.4 Fire protection, detection and extinction
3.5 General emergency alarm system

Section 2 Intermediate Survey
1 General 174
1.1
2 Hull 174
2.1

Section 3 Class Renewal Survey
1 General 176
1.1
2 Hull and hull equipment 176
2.1 Bottom survey in dry condition
2.2 Decks, hatch covers and equipment
2.3 Survey of watertight cable transits
2.4 Holds and other dry compartments

2.5 Tanks
2.6 Thickness measurements
2.7 Independent cargo tanks

3 Machinery and systems 181

3.1 General
3.2 Main and auxiliary engines and turbines
3.3 Reduction gears, main thrust and intermediate shaft(s)
3.4 Pumps and other machinery items
3.5 Systems in machinery spaces
3.6 Electrical equipment and installations
3.7 Controls
3.8 Fire protection, detection and extinction
3.9 Hold, ballast and dry spaces water level detectors
3.10 Availability of pumping systems

Section 4 Bottom Survey

1 General 187

1.1

2 Bottom survey in dry condition 187

2.1 General requirements
2.2 Bottom survey held within the scope of class renewal survey

3 Bottom in-water survey 187

3.1 General

Section 5 Tailshaft Survey

1 Survey of tailshafts 189

1.1 General
1.2 Complete survey
1.3 Modified survey

2 Periodical survey of other propulsion systems 190

2.1 Rotating and azimuth thrusters
2.2 Vertical axis propellers
2.3 Pump jet systems
2.4 Pod propulsion systems

3 Survey of propeller shafts and tube shafts 191

3.1 General
3.2 Oil lubricated shafts or closed loop system fresh water lubricated shafts (closed system)
3.3 Water lubricated shafts (open systems)

Section 6 Boiler Survey

1 Steam boilers 199

1.1

2 Thermal oil heaters 200

2.1

Section 7 Hull Survey for New Construction

1 General 201

1.1

2 Documentation to be available for the Surveyor during construction 201

2.1

3 Ship construction file 201

3.1 Ship Construction File (SCF) for all ships, except those specified in [1.1.3]
3.2 Ship Construction File (SCF) for ships as specified in [1.1.3]

4 Newbuilding survey planning 207
4.1
5 Examination and test plan for newbuilding activities 208
5.1 Applicable to all ships
5.2 Applicable for ships as specified in [1.1.3]
6 Design transparency 209
6.1 Applicable for ships as specified in [1.1.3]

Section 8 Survey of Watertight Cable Transits
1 General 210
1.1 Application
2 Cable Transit Seal Systems Register 210
2.1 New construction
2.2 Vessel in service
3 Installation and maintenance of Watertight Cable transits 210
3.1

Appendix 1 Class Requirements and Surveys of Laid-up Ships
1 General 211
1.1
2 Safety conditions 211
2.1
3 Preservation measures for lay-up and maintenance 212
3.1 General
3.2 Exposed parts of the hull
3.3 Internal spaces
3.4 Deck fittings
3.5 Machinery
3.6 Electrical installations
3.7 Steering gear
3.8 Boilers
3.9 Automated installation
4 Lay-up site and mooring arrangements 215
4.1 General
4.2 Recommendations for the lay-up site
4.3 Recommendations for the mooring arrangements
4.4 Review of the mooring arrangements
5 Surveys 216
5.1 Laying-up survey
5.2 Annual lay-up condition survey
5.3 Re-commissioning survey

Chapter 4 Scope of Surveys in Respect of the Different Services of Ships

Section 1 General
1 General 219
1.1

Table of Content

2 Service notations and/or additional service features subject to additional surveys 219

2.1

Section 2 Single Skin and Double Skin Bulk Carriers

1 General 221

1.1 Application
1.2 Documentation on board
1.3 Reporting and evaluation of surveys
1.4 Conditions for survey
1.5 Access to structures

2 Annual survey 224

2.1 General
2.2 Hatch covers and coamings, weather decks
2.3 Cargo holds
2.4 Ballast tanks
2.5 Double-skin void spaces

3 Intermediate survey 227

3.1 Ships 10 years of age or less
3.2 Ships between 10 and 15 years of age
3.3 Ships over 15 years of age

4 Class renewal survey 229

4.1 Survey programme and preparation for survey
4.2 Survey planning meeting
4.3 Scope of survey
4.4 Hatch covers and coamings
4.5 Overall and close-up surveys
4.6 Thickness measurements
4.7 Tank testing

Section 3 Oil Tankers and Combination Carriers

1 General 242

1.1 Application
1.2 Documentation on board
1.3 Reporting and evaluation of surveys
1.4 Conditions for survey
1.5 Access to structures

2 Annual survey - Hull items 244

2.1 General
2.2 Weather decks
2.3 Cargo pump rooms and pipe tunnels
2.4 Ballast tanks
2.5 Emergency towing arrangement
2.6 Safe access to tanker bows
2.7 Means of access
2.8 Coating systems

3 Annual survey - Cargo machinery items 245

3.1 Cargo area and cargo pump rooms
3.2 Instrumentation and safety devices
3.3 Fire-fighting systems in cargo area
3.4 Inert gas system

4 Intermediate survey - Hull items 246

4.1 General
4.2 Ships between 5 and 10 years of age
4.3 Ships between 10 and 15 years of age
4.4 Ships over 15 years of age

5 Intermediate survey - Cargo machinery items 247
5.1 Cargo area and cargo pump rooms
5.2 Inert gas system
6 Class renewal survey - Hull items 248
6.1 Survey programme and preparation for hull survey
6.2 Survey planning meeting
6.3 Scope of survey
6.4 Overall and close-up surveys
6.5 Thickness measurements
6.6 Tank testing
6.7 Cargo piping, area and pump rooms
6.8 Emergency towing arrangement
7 Class renewal survey - Cargo machinery items 258
7.1 Cargo area and cargo pump rooms
7.2 Fire-fighting systems in cargo area
7.3 Inert gas system

Section 4 Chemical Tankers

1 General 259
1.1 Application
1.2 Documentation on board
1.3 Reporting and evaluation of surveys
1.4 Conditions for survey
1.5 Access to structures
2 Annual survey - Hull items 260
2.1 General
2.2 Weather decks
2.3 Cargo pump rooms and pipe tunnels
2.4 Ballast tanks
2.5 Emergency towing arrangement
3 Annual survey - Cargo machinery items 261
3.1 Cargo area and cargo pump rooms
3.2 Instrumentation and safety devices
3.3 Fire-fighting systems in cargo area
3.4 Inert gas system and inert/padding/ drying gas
4 Intermediate survey - Hull items 263
4.1 General
4.2 Ships between 5 and 10 years of age
4.3 Ships between 10 and 15 years of age
4.4 Ships over 15 years of age
5 Intermediate survey - Cargo machinery items 263
5.1 Cargo area and cargo pump rooms
5.2 Inert gas system
5.3 Personnel protection
6 Class renewal survey - Hull items 264
6.1 Survey program and preparation for survey
6.2 Survey planning meeting
6.3 Scope of survey
6.4 Overall and close-up surveys
6.5 Thickness measurements
6.6 Tank testing
6.7 Cargo piping, cargo pump rooms and cargo tanks
6.8 Emergency towing arrangement

7 Class renewal survey - Cargo machinery items 272
7.1 Cargo area and cargo pump rooms
7.2 Fire-fighting systems in cargo area
7.3 Inert gas system
7.4 Personnel protection
8 Methanol bunkering 273
8.1 Application
8.2 General
8.3 Annual survey
8.4 Class renewal surveys

Section 5 Liquefied Gas Carriers
1 General 274
1.1 Application
2 Annual survey - Hull items 274
2.1 General
2.2 Weather decks and suspect areas
2.3 Cargo handling rooms and piping
2.4 Other arrangements or devices
2.5 Ballast tanks
2.6 Emergency towing arrangement
3 Annual survey - Cargo machinery items 276
3.1 Cargo area and cargo pump rooms
3.2 Instrumentation and safety devices
3.3 Fire-fighting systems in cargo area
3.4 Environmental control for cargo containment systems
4 Intermediate survey - Hull items 277
4.1 General
4.2 Weather decks, cargo handling rooms and piping
4.3 Ballast tanks
5 Intermediate survey - Cargo machinery items 278
5.1 General
5.2 Cargo area and cargo pump rooms
5.3 Instrumentation and safety devices
5.4 Inert gas system
5.5 Personnel protection
6 Class renewal survey - Hull items 279
6.1 Preparation for survey
6.2 Survey programme
6.3 Scope of survey
6.4 Overall and close-up surveys
6.5 Thickness measurements
6.6 Tank testing
6.7 Cargo tank structure
6.8 Weather decks, cargo handling rooms and piping
6.9 Emergency towing arrangement
7 Class renewal survey - Cargo machinery items 283
7.1 Cargo area, cargo pump rooms, cargo compressor rooms
7.2 Fire-fighting systems in cargo area
7.3 Inert gas system
7.4 Personnel protection
8 First loaded voyage of ships carrying liquefied natural gases (LNG) in bulk 284
8.1

9 Revaporization installation 284
9.1 Application
9.2 Annual survey
9.3 Intermediate survey
9.4 Class renewal survey
10 STL-SPM 287
10.1 Application
10.2 Annual survey
10.3 Intermediate survey
10.4 Class renewal survey
10.5 Bottom survey
11 Bunkering installations 289
11.1 Application
11.2 General
11.3 Annual surveys
11.4 Class renewal surveys

Section 6 Ro-Ro Cargo Ships and Pure Car and/or Truck Carriers, Passenger Ships and Ro-Ro Passenger Ships

1 General 290
1.1
2 Ro-ro cargo ships and pure car and/or truck carriers - Annual survey 290
2.1 Shell and inner doors
2.2 Internal platforms and ramps
2.3 Fire protection, detection and extinction
3 Ro-ro cargo ships and pure car and/or truck carriers - Class renewal survey 292
3.1 Shell and inner doors
3.2 Internal platforms and ramps
3.3 Fire protection, detection and extinction
4 Passenger ships - Annual survey 292
4.1 Watertight bulkheads
4.2 Openings in shell plating
4.3 Miscellaneous
5 Passenger ships - Class renewal survey 293
5.1
6 Ro-ro passenger ships - Annual and class renewal surveys 293
6.1

Section 7 General Cargo Ships

1 General 294
1.1 Application
1.2 Reporting and evaluation of surveys
2 Annual survey 294
2.1 General
2.2 Hatch covers and coamings
2.3 Cargo holds
2.4 Ballast tanks
3 Intermediate survey 295
3.1 General
3.2 Ships 15 years of age or less
3.3 Ships over 15 years of age

4 Class renewal survey 296

4.1 Preparation for survey
4.2 Scope of survey
4.3 Hatch covers and coamings
4.4 Overall and close-up surveys
4.5 Thickness measurements
4.6 Tank testing

Section 8 Other Service Notations

1 General 302

1.1

2 Container ship or ship equipped for carriage of containers 302

2.1 Annual survey
2.2 Class renewal survey

3 Livestock carrier 303

3.1 Annual survey
3.2 Class renewal survey

4 FLS tanker 303

4.1 Annual survey - Hull items
4.2 Annual survey - Cargo machinery items
4.3 Intermediate survey - Hull items
4.4 Intermediate survey - Cargo machinery items
4.5 Class renewal survey - Hull items
4.6 Class renewal survey - Cargo machinery items

5 Dredging units 305

5.1 Annual survey
5.2 Class renewal survey

6 Tug, salvage tug, escort tug 306

6.1 Annual survey
6.2 Class renewal survey

7 Supply vessel 307

7.1 General
7.2 Annual survey - Hull items
7.3 Annual survey - Cargo machinery items
7.4 Intermediate survey - Hull items
7.5 Intermediate survey - Cargo machinery items
7.6 Class renewal survey - Hull items
7.7 Class renewal survey - Cargo machinery items

8 Fire-fighting ship 309

8.1 Annual survey
8.2 Class renewal survey

9 Oil recovery ship 310

9.1 Annual survey
9.2 Class renewal survey

10 Anchor handling vessel 311

10.1 Annual survey
10.2 Class renewal survey

11 Cable laying ship 311

11.1 Annual survey
11.2 Class renewal survey

12 Lifting 311
12.1 General
12.2 Annual survey
12.3 Class renewal survey
13 Diving support-integrated and diving support-portable 312
13.1 Annual survey
13.2 Class renewal survey
14 Fishing vessel 313
14.1 Annual survey
14.2 Class renewal survey
15 Standby and rescue vessel 313
15.1 Annual survey - Rescue arrangement, survivors accommodation and safety equipment
15.2 Annual survey - Towing arrangements
15.3 Class renewal survey - Rescue arrangement, survivors accommodation and safety equipment
15.4 Class renewal survey - Towing arrangements
16 Yacht and charter yacht 313
16.1 Intermediate survey
16.2 Class renewal survey
17 Semi-submersible cargo ship 313
17.1 Annual survey
17.2 Intermediate survey
17.3 Class renewal survey
18 Diving systems 314
18.1 Surveys
19 Pipe laying ship 314
19.1 Annual survey
19.2 Class renewal survey

Section 9 Ships using Low Flashpoint Liquid or Gas Fuels
1 General 315
1.1 Application
2 Annual survey - Hull items 315
2.1 General
2.2 Gas related spaces, fuel preparation and handling rooms and piping
2.3 Fuel storage, bunkering and supply systems
3 Annual survey - Gas fuel machinery items 316
3.1 Control, monitoring and safety systems
3.2 Fuel handling piping, machinery and equipment
3.3 Ventilating systems
3.4 Hazardous areas
4 Intermediate survey 316
4.1 General
5 Class renewal survey - Hull items 316
5.1 General
5.2 Fuel handling and piping
5.3 Fuel valves
5.4 Pressure relief valves
5.5 Fuel storage tanks

6 Class renewal survey - Gas fuel machinery items 317
6.1 Fuel handling equipment
6.2 Electrical equipment
6.3 Safety systems
7 Hydrogen fuel 318
7.1 General
7.2 Annual survey
7.3 Class renewal survey

Section 10 Ships using Fuel Cells
1 General 319
1.1 Application
2 Annual surveys 319
2.1 General
2.2 Fuel cell spaces
2.3 Fuel cell installation system
3 Intermediate surveys 320
3.1 General
4 Class renewal surveys 320
4.1 General

Section 11 Ships using Onboard Carbon Capture and Storage Systems
1 General 321
1.1 Application
2 Annual survey 321
2.1 General
2.2 Solvent system
2.3 Carbon capture system
2.4 CO2 storage system
3 Class renewal surveys 322
3.1 General
3.2 Solvent system
3.3 Carbon capture system
3.4 CO2 Storage system

Section 12 Ships using Wind Propulsion Systems
1 General 324
1.1
2 Annual survey 324
2.1 General
2.2 Systems less than 18 months old
2.3 Systems 18 months old or more
3 Class renewal survey 325
3.1 General
3.2 Safety rigging parts
3.3 Operating rigging parts
3.4 Drive system

Section 13 Ships using Battery Systems
1 General 327
1.1 Application
1.2 Annual survey
1.3 Class renewal survey

Table of Content

Appendix 1 Oil Tanker Longitudinal Strength Assessment

1 General 328

1.1

2 Evaluation of longitudinal strength 328

2.1 Application
2.2 Transverse sectional areas
2.3 Transverse section modulus
2.4 Calculation criteria of section modulus

3 Sampling method of thickness measurements 328

3.1 Extent of evaluation
3.2 Sampling method of thickness measurements
3.3 Additional measurements
3.4 Repair methods

Chapter 5 Scope of Surveys Related to Additional Class Notations

Section 1 General

1 General 331

1.1

2 Additional class notations subject to additional surveys 331

2.1

Section 2 VeriSTAR and STAR Notations

1 General 334

1.1 Application

2 VeriSTAR-HULL SIS 334

2.1 General
2.2 Class renewal survey

3 STAR-HULL 335

3.1 General
3.2 Class renewal survey
3.3 Suspension and withdrawal of the notation

4 STAR-MACH SIS 336

4.1 General
4.2 Annual audit and confirmatory surveys
4.3 Re-approval of the Maintenance Plan

Section 3 Availability of Machinery

1 General 338

1.1

2 Annual survey 338

2.1

3 Class renewal survey 338

3.1

Section 4 Automated Machinery Systems

1 General 339

1.1

2 Annual survey 339
2.1
3 Class renewal survey 339
3.1

Section 5 Integrated and Digital Systems
1 General 340
1.1
2 Annual survey 340
2.1 All notations
2.2 Notations SYS-NEQ and SYS-NEQ-1
2.3 Notation SYS-COM
2.4 Notations SYS-IBS and SYS-IBS-1
2.5 Notations ASYNC-COM, SYNC-COM, ASYNC-COM-R and SYNC-COM-R
2.6 Notations DATA-INFRA and DATA-INFRA-STAND
2.7 Notation DATA-CENTRIC
3 Class renewal survey 342
3.1 Notations SYS-NEQ, SYS-NEQ-1, SYS-COM, SYS-IBS and SYS-IBS-1
3.2 Notations ASYNC-COM, SYNC-COM, ASYNC-COM-R and SYNC-COM-R
3.3 Notations DATA-INFRA and DATA-INFRA-STAND
3.4 Notation DATA-CENTRIC

Section 6 Monitoring Equipment
1 General 343
1.1 Application
2 MON-HULL 343
2.1 Annual and class renewal survey
3 MON-SHAFT 343
3.1 Tailshaft survey
4 MON-ICE L(i) and MON-ICE G 343
4.1 Annual survey
5 Real-time emissions reporting (REALTIME) 344
5.1 Annual survey
5.2 Class renewal survey

Section 7 Comfort on Board and Habitability
1 General 345
1.1
1.2 Annual survey
1.3 Class renewal survey

Section 8 Environmental Protection
1 General 346
1.1 Application
2 Prevention of sea pollution 346
2.1 First annual survey
2.2 Annual survey
2.3 Class renewal survey

3 Prevention of air pollution 347
3.1 Annual survey
3.2 Class renewal survey
3.3 Ultra-low emission vessel (ULEV)
3.4 Continuous emission monitoring system (CEMS)
3.5 Exhaust Gas Measurement (EXGEM)
4 Ship Energy Efficiency Management Plan (SEEMP) 349
4.1 Intermediate and class renewal surveys
5 VCS 349
5.1 Annual survey
5.2 Class renewal survey

Section 9 Refrigerating Installations
1 General 351
1.1
2 Annual survey 351
2.1 General
2.2 Refrigerating plant
2.3 Refrigerated spaces
2.4 Instrumentation and safety devices
2.5 Notation -AIRCONT
3 Class renewal survey 352
3.1 General
3.2 Refrigerating plant
3.3 Refrigerated spaces
3.4 Instrumentation and safety devices
3.5 Notation -AIRCONT

Section 10 Navigation in Cold Environment
1 General 354
1.1
2 ICE, ICE CLASS and YOUNG ICE notations 354
2.1
2.2 Class renewal survey
3 COLD DI, COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE) 354
3.1 General
3.2 Annual survey
3.3 Class renewal survey
4 COLD CARGO 356
4.1 General
4.2 Annual survey
4.3 Class renewal survey

Section 11 Protection against Chemical, Biological, Radiological and Nuclear Risk
1 General 357
1.1
2 Chemical, biological, radiological or nuclear hazards 357
2.1 General
2.2 Annual survey
2.3 Class renewal survey

3 Biological risk control 358
3.1 General
3.2 BIORISK MANAGED
3.3 BIORISK SECURED

Section 12 Manoeuvring, Mooring, Anchoring and Position Keeping
1 General 359
1.1
2 Heading control 359
2.1 General
2.2 Annual survey
2.3 Class renewal survey
3 SPM 359
3.1 Annual survey
3.2 Class renewal survey
4 DYNAPOS 360
4.1 Annual survey
4.2 Class renewal survey

Section 13 Cargo Operation, Securing and Safety
1 General 362
1.1
2 CARGOCONTROL 362
2.1 General
2.2 Annual survey
2.3 Class renewal survey
3 EVOC 362
3.1 General
3.2 Annual survey
3.3 Class renewal survey
4 PaRoll1 and PaRoll2 363
4.1 Annual survey
5 LI-LASHING 363
5.1 Annual survey
5.2 Class Renewal survey

Section 14 Additional Notations for Hull Structure Assessment
1 General 364
1.1
2 STRENGTHBOTTOM 364
2.1 Dry-docking survey
3 GRABLOADING and GRAB[X] 364
3.1 Class renewal survey

Section 15 Electric Propulsion or Electric Power Supply
1 General 365
1.1
2 Electric Hybrid 365
2.1 General
2.2 Annual survey
2.3 Class renewal survey

3 Hybrid mechanical propulsion (HMPS) 366
3.1 General
3.2 Annual survey
3.3 Class renewal survey
4 Onshore power supply (OPS) 366
4.1 General
4.2 Annual survey
4.3 Class renewal survey

Section 16 Additional Notations for Fire Protection
1 General 367
1.1
2 Enhanced fire protection 367
2.1 General
2.2 Annual survey
3 Enhanced cargo fire protection on container ships 367
3.1 General
3.2 Annual survey
3.3 Class renewal survey
4 COVENT 368
4.1 Annual survey
4.2 Class renewal survey
5 Electrical Vehicle Fire Protection 368
5.1 General
5.2 Annual survey
5.3 Class renewal survey

Section 17 Additional Notations for Computer Based Systems and Cyber Security
1 General 370
1.1
2 CYBER 370
2.1 General
2.2 Annual surveys
2.3 Intermediate surveys
2.4 Class renewal surveys
3 SMART( ) 371
3.1 Application
3.2 Annual surveys
3.3 Class renewal survey

Section 18 Additional Notations for Corrosion Protection
1 General 375
1.1
2 Annual survey 375
2.1 All notations

Section 19 Other Notations
1 General 376
1.1
2 Permanent means of access (ACCESS) 376
2.1 Annual survey, intermediate survey and class renewal survey

3 Helideck (HEL) 376

3.1 Application
3.2 Annual surveys

4 Offshore Access System (OAS) 377

4.1 Application
4.2 Periodical surveys

5 Offshore handling systems (OHS) 377

5.1 Application
5.2 Periodical surveys

Chapter 6 Retroactive Requirements for Existing Ships

Section 1 General

1 General 379

1.1
1.2 List of retroactive rule requirements

Section 2 Bulk Carriers, Ore Carriers and Combination Carriers

1 Foremost cargo hold requirements 380

1.1 Application
1.2 Schedule for compliance
1.3 Scantlings of the vertically corrugated transverse watertight bulkhead between the two foremost cargo holds
1.4 Allowable hold loading of the foremost cargo hold with the same hold flooded
1.5 Damage stability

2 Loading instruments and loading manuals 382

2.1 Loading instruments
2.2 Loading manuals

3 Strength requirements for fore deck fittings and equipment, strength and securing of small hatches on the exposed fore deck 382

3.1 Application and requirements
3.2 Schedule for compliance

4 Cargo hatch cover securing arrangements for bulk carriers 383

4.1 Application and requirements
4.2 Schedule for compliance

5 Renewal criteria for side shell frames and brackets in single side skin bulk carriers and single side skin OBO carriers 383

5.1 Application and requirements
5.2 Schedule for compliance
5.3 Requirements for the gauging of side shell frames and brackets

6 Hold, ballast and dry space water level detectors 387

6.1 Application and requirements
6.2 Schedule for compliance

7 Availability of pumping systems 387

7.1 Application and requirements
7.2 Schedule for compliance

8 Restriction from sailing with any hold empty 387

8.1 Application and requirements

Table of Content

Section 3 Ro-ro Passenger Ships

1 General 389

1.1 Application

2 Increased stability and watertight integrity 389

2.1

Section 4 Cargo Ships

1 Strength requirements for fore deck fittings and equipment, strength and securing of small hatches on the exposed fore deck 390

1.1 Application and requirements
1.2 Schedule for compliance

2 Water level detectors on single hold cargo ships other than bulk carriers 390

2.1 Application and requirements
2.2 Schedule for compliance

Section 5 Ships with Ice Classes

1 General 392

1.1 Application

2 Requirements to maintain ice classes 392

2.1

3 Ice class draught marking 393

3.1

Appendix 1 Technical Retroactive Requirements for Bulk Carriers and Other Types of Ships

1 General 394

1.1

2 Evaluation of scantlings of the transverse watertight vertically corrugated bulkheads between the two foremost cargo holds 394

2.1 Application and definitions
2.2 Load model
2.3 Bending moment and shear force in the bulkhead corrugations
2.4 Strength criteria
2.5 Local details
2.6 Steel renewal

3 Guidance on renewal/reinforcement of the transverse watertight vertically corrugated bulkhead between the two foremost cargo holds 403

3.1

4 Evaluation of allowable hold loading of the foremost cargo hold with the same cargo hold flooded 405

4.1 Application and definitions
4.2 Load model
4.3 Shear capacity of the double bottom of the foremost cargo hold
4.4 Allowable hold loading

5 Renewal criteria for side shell frames and brackets in single side skin bulk carriers and single side skin OBO carriers not built in accordance with Part II, Chapter 8, Section 8-03 of the 1st April 1998 edition of the Rules or subsequent editions 408

5.1 Application and symbols
5.2 Ice strengthened ships
5.3 Criteria for renewal
5.4 Other measures
5.5 Strength check criteria

Table of Content

6	Cargo hatch cover securing arrangements for bulk carriers not built in accordance with edition 2003 of Pt B, Ch 9, Sec 7	417
	6.1 Application 6.2 Securing devices 6.3 Stoppers 6.4 Materials and welding	
7	Guidance on loading/unloading sequences	418
	7.1	
8	Water level detectors on single hold cargo ships other than bulk carriers	418
	8.1 Application 8.2 Water level detectors	

CHAPTER 1
PRINCIPLES OF CLASSIFICATION AND CLASS NOTATIONS

Section 1 General Principles of Classification

Section 2 Classification Notations

Appendix 1 Notations Assigned According to Editions of the Rules Former to June 2000 Edition

Section 1 General Principles of Classification

1 Principles of classification

1.1 Purpose of the Rules

1.1.1 The Rules published by the Society give the requirements for the assignment and the maintenance of classification for seagoing ships.

Note 1: The general conditions of classification are laid down in the Marine & Offshore General Conditions.

1.1.2 The application criteria of the different parts of the present Rules are the following:

- Part A - Classification and Surveys applies to all ships.
- Part B - Hull and Stability, Part C - Machinery and Systems, Part D and Part E - Service Notations apply to seagoing ships whose hull is of welded steel construction. Where necessary, the extent of application is more precisely defined in each chapter of these parts of the Rules.
- Part F - Additional Class Notations applies, at the request of the Interested Party, to all ships.

The classification of ships other than those dealt with in the above-mentioned Parts B, C, D, E and F is covered by specific Rules published by the Society.

1.1.3 Classification of diving systems

The classification of the diving systems is covered by Rule Note NR610, Rules for the Classification of Diving Systems.

Unless otherwise specified, the provisions of the present Rules apply, “diving system” being to be understood when reference is made to “ship”.

In case of discrepancy between the requirements of the present Rules and those of NR610, the latter prevail.

1.2 General definitions

1.2.1 The following general definitions are used in these Rules:

- Society means the Classification Society with which the ship is classed.
- Rules means these Rules for the Classification of Ships and documents issued by the Society serving the same purpose.
- Surveyor means technical staff acting on behalf of the Society to perform tasks in relation to classification and survey duties.
- Survey means an intervention by the Surveyor for assignment or maintenance of class as defined in Part A, Chapter 2, or interventions by the Surveyor within the limits of the tasks delegated by the Administrations.
- Administration means the Government of the State whose flag the ship is entitled to fly or the State under whose authority the ship is operating in the specific case.
- Owner means the Registered Owner or the Disponent Owner or the Manager or any other party having the responsibility to keep the ship seaworthy, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2.
- Interested Party means a party, other than the Society, having responsibility for the classification of the ship, such as the Owners of a ship and his representatives, or the Shipbuilder, or the Engine Builder, or the Supplier of parts to be tested.
- Approval means the review by the Society of documents, procedures or other items related to classification, verifying solely their compliance with the relevant Rules requirements, or other referential where requested.
- Essential service is intended to mean a service necessary for a ship to proceed at sea, be steered or manoeuvred, or undertake activities connected with its operation, and for the safety of life, as far as class is concerned.
- Gross tonnage (GT) is the measure of the overall size of a ship as determined in accordance with the provisions of the 1969 International Convention on Tonnage Measurement of Ships. It is expressed as a figure without units.

1.2.2 Definition of date of “contract for construction”:

The date of “contract for construction” of a ship is the date on which the contract to build the ship is signed between the Owner and the Shipbuilder. This date is normally to be declared to the Society by the Interested Party applying for the assignment of class to a new ship. For ships “contracted for construction” on or after 1st April 2006, this date and the construction numbers (i.e. hull numbers) of all the ships included in the contract, are to be declared to the Society by the Interested Party applying for the assignment of class to a new ship.

The date of “contract of construction” of a series of ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the Owner and the Shipbuilder.

For the purpose of this definition, ships built under a single contract for construction are considered a "series of ships" if they are built to the same approved plans for classification purposes. However, ships within a series may have design alterations from the original design provided:

- Such alterations do not affect matters related to classification, or
- If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective Owner and the Shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.

The optional ships will be considered part of the same series of ships if the option is exercised not later than 1 year after the contract to build the series was signed.

If a contract for construction is later amended to include additional ships or additional options, the date of "contract for construction" for such ships is the date on which the amendment to the contract is signed between the Owner and the Shipbuilder. The amendment to the contract is to be considered as a "new contract" to which the above applies.

If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified ship or ships, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

1.3 Meaning of classification, scope and limits

1.3.1 The classification process consists of:

- the development of Rules, guidance notes and other documents relevant to the ship, structure, material, equipment, machinery and other items covered by such documents
- the review of plans and calculations and the surveys, checks and tests intended to demonstrate that the ship meets the Rules (refer to Ch 2, Sec 1)
- the assignment of class (see Ch 2, Sec 1) and issue of a Certificate of Classification, where compliance with the above Rules is found
- the periodical, occasional and class renewal surveys performed to record that the ship in service meets the conditions for maintenance of class (see Ch 2, Sec 2).

1.3.2 The Rules, surveys performed, reports, certificates and other documents issued by the Society, are in no way intended to replace or alleviate the duties and responsibilities of other parties such as Administrations, Designers, Shipbuilders, Manufacturers, Repairers, Suppliers, Contractors or Sub-contractors, actual or prospective Owners or Operators, Charterers, Brokers, Cargo-owners and Underwriters.

The activities of such parties which fall outside the scope of the classification as set out in the Rules, such as design, engineering, manufacturing, operating alternatives, choice of type and power of machinery and equipment, number and qualification of crew or operating personnel, lines of the ship, trim, hull vibrations, spare parts including their number, location and fastening arrangements, life-saving appliances, and maintenance equipment, remain therefore the responsibility of those parties, even if these matters may be given consideration for classification according to the type of ship or additional class notation assigned.

1.3.3 Unless otherwise specified, the Rules do not deal with structures, pressure vessels, machinery and equipment which are not permanently installed and used solely for operational activities such as dredging or heavy load lifting, workshops or welding equipment, except for their effect on the classification-related matters, as declared by the Interested Party, such as fire protection and ship's general strength.

During periods of construction, modification or repair, the unit is solely under the responsibility of the builder or the repair yard. As an example, the builder or repair yard is to ensure that the construction, modification or repair activities are compatible with the design strength of the ship and that no permanent deformations are sustained.

Note 1: Refer to [3.3] as regards the Owner's responsibility for maintenance and operation of the ship in relation to the maintenance of class.

1.3.4 The class assigned to a ship by the Society following its interventions, and the survey system implemented for the maintenance of class, are embodied in a Certificate of Classification and noted in the Register of ships.

At a certain date the class of a ship is maintained or regular when no surveys are overdue, when the conditions for suspension of class are not met and when the class is not withdrawn nor suspended. Otherwise the class is irregular. Attention is drawn on the fact that a ship holding a valid Certificate of Classification may be in an irregular class position.

1.4 Request for services

1.4.1 Requests for interventions by the Society, such as surveys during construction, surveys of ships in service, tests, etc., are in principle to be submitted in writing and signed by the Interested Party. Such request implies that the applicant will abide by all the relevant requirements of the Rules, including the Marine & Offshore General Conditions.

The Society reserves the right to refuse or withdraw the class of any ship for which any applicable requirement of the Rules is not complied with.

1.4.2 For a new building project vessel of a design already approved by an initial IACS Society, the Society may accept to class the vessel in accordance with a Memorandum of Understanding (MoU) adopted by the Society and the Shipyard, and if applicable the Ship Owner.

1.5 Register of ships

1.5.1 A Register of Ships is published periodically by the Society. This publication, which is updated by the Society, contains the names of ships which have received the Certificate of Classification, as well as particulars of the class assigned and information concerning each ship.

2 Rules

2.1 Effective date

2.1.1 The effective date of entry into force of any amendments to the Rules is indicated on the inside front page of the Rules or in the relevant Section.

2.1.2 In principle, the applicable Rules for assignment of class to a new ship are those in force at the date of contract for construction.

2.1.3 Special consideration may be given to applying new or modified rule requirements which entered into force subsequent to the date of contract for construction, at the discretion of the Society and in the following cases:

- when a justified written request is received from the party applying for classification
- when the keel is not yet laid and more than one year has elapsed since the contract for construction was signed
- where it is intended to use existing previously approved plans for a new contract.

2.1.4 The above procedures for application of the Rules are, in principle, also applicable to existing ships in the case of major conversions and, in the case of alterations, to the altered parts of the ship.

2.1.5 The rule requirements related to assignment, maintenance and withdrawal of the class of ships already in operation, as detailed in Part A, Chapter 2 to Part A, Chapter 5, are applicable from the date of their entry into force.

2.2 Equivalence

2.2.1 The Society may consider the acceptance of alternatives to these Rules, provided that they are deemed to be equivalent to the Rules to the satisfaction to the Society.

2.2.2 If deemed necessary, the Society may require that engineering analysis, assessment and approval of the alternative design and arrangement be carried out in accordance with IMO MSC.1/Circ.1002 as amended, IMO MSC/Circ.1212 as amended and IMO MSC.1/Circ.1455 as amended, as applicable.

2.3 Novel features

2.3.1 The Society may consider the classification of ships based on or applying novel design principles or features, to which the Rules are not directly applicable, on the basis of experiments, calculations or other supporting information provided to the Society. Specific limitations may then be indicated on a memorandum.

2.4 Disagreement and appeal

2.4.1 Any technical disagreement with the Surveyor in connection with the performance of his duties should be raised by the Interested Party as soon as possible.

The Interested Party may appeal in writing to the Society, which will subsequently consider the matter and announce its decision according to its established procedure.

3 Duties of the Interested Parties

3.1 International and national regulations

3.1.1 The classification of a ship does not relieve the Interested Party from compliance with any requirements issued by Administrations.

Note 1: Attention is drawn on the prohibition of asbestos on-board ships (new ships, modified parts of existing ships) and other National Regulations, as applicable.

Note 2: From the 1st January 2023, newly identified asbestos on board by the Society acting as the Recognized Organization for ISM/MLC/IHM is to be reported to the Owner, the Flag Administration and the Recognized Organization classing the vessel and responsible for the main statutory certificates, as per the Society's procedure.

3.2 Surveyor's intervention

3.2.1 Surveyors are to be given free access at all times to ships which are classed or being classed, shipyards and works, to carry out their interventions within the scope of assignment or maintenance of class, or within the scope of interventions carried out on behalf of Administrations, when so delegated.

Free access is also to be given to auditors accompanying the Surveyors of the Society within the scope of the audits as required in pursuance of the Society's internal Quality System or as required by external organizations.

3.2.2 Interested Parties are to take the necessary measures for the Surveyors' inspections and testing to be carried out safely. Interested Parties - irrespective of the nature of the service provided by the Surveyors of the Society or others acting on its behalf - assume with respect to such Surveyors all the responsibility of an employer for his workforce such as to meet the provisions of applicable legislation. As a rule, the Surveyor is to be constantly accompanied during surveys by personnel of the Interested Party.

Interested Parties are to inform promptly the Surveyor of defects or problems in relation to class.

Refer also to Ch 2, Sec 2, [2.5] to Ch 2, Sec 2, [2.9].

3.2.3 The Certificate of Classification and/or other documents issued by the Society remain the property of the Society. All certificates and documents necessary to the Surveyor's interventions are to be made available by the Interested Party to the Surveyor on request.

3.2.4 During the phases of ship design and construction, due consideration should be given to rule requirements in respect of all necessary arrangements for access to spaces and structures with a view to carrying out class surveys. Arrangements of a special nature are to be brought to the attention of the Society.

3.3 Operation and maintenance of ships

3.3.1 The classification of a ship is based on the understanding that the ship is loaded and operated in a proper manner by competent and qualified crew or operating personnel according to the environmental, loading, operating and other criteria on which classification is based.

In particular, it will be assumed that the draught of the ship in operating conditions will not exceed that corresponding to the freeboard assigned or the maximum approved for the classification, that the ship will be properly loaded taking into account both its stability and the stresses imposed on its structures and that cargoes will be properly stowed and suitably secured and that the speed and course of the ship are adapted to the prevailing sea and weather conditions according to the normal prudent seamanship.

3.3.2 Ships are to be maintained at all times, at the diligence of the Owners, in proper condition complying with international safety and pollution prevention regulations.

3.3.3 Any document issued by the Society in relation to its interventions reflects the condition of the ship as found at the time and within the scope of the survey. It is the Interested Party's responsibility to ensure proper maintenance of the ship until the next survey required by the Rules. It is the duty of the Interested Party to inform the Surveyor when he boards the ship of any events or circumstances affecting the class.

3.4 Flag and Port State Control inspections

3.4.1 Where defects are found further to an inspection by an Administration in pursuance of Port State Control or similar programmes, Owners are to:

- inform the Society about any deficiency related to the class of the ship or to the statutory certificates issued by the Society on behalf of the flag Administration, and provide its action plan for rectification of these deficiencies. It will be verified by next attending Surveyors that deficiencies are rectified and/or that the necessary repair work is carried out within due time.
- immediately report the outcome of this inspection to the Society when the ship is detained, and ask to the Society to perform an occasional survey.

3.5 Use of measuring equipment and of service suppliers

3.5.1 General

Firms providing services on behalf of the Interested Party, such as measurements, tests and servicing of safety systems and equipment, the results of which may form the basis for the Surveyor's decisions, are subject to the acceptance of the Society, as deemed necessary.

The equipment used during tests and inspections in workshops, shipyards and on board ships, the results of which may form the basis for the Surveyor's decisions, is to be customary for the checks to be performed. Firms are to individually identify and calibrate to a national or international standard each piece of such equipment.

Note 1: Refer to Rule Note NR 533 Approval of Service Suppliers.

3.5.2 Simple measuring equipment

The Surveyor may accept simple measuring equipment (e.g. rulers, tape measures, weld gauges, micrometers) without individual identification or confirmation of calibration, provided it is of standard commercial design, properly maintained and periodically compared with other similar equipment or test pieces.

3.5.3 Shipboard measuring equipment

The Surveyor may accept measuring equipment fitted on board a ship (e.g. pressure, temperature or rpm gauges and meters) and used in examination of shipboard machinery and/or equipment based either on calibration records or comparison of readings with multiple instruments.

3.6 Spare parts

3.6.1 It is the Owner's responsibility to decide whether and which spare parts are to be carried on board.

3.6.2 As spare parts are outside the scope of classification, the Surveyor will not check that they are kept on board, maintained in a satisfactory condition, or suitably protected and lashed.

However, in the case of repairs or replacement, the spare parts used are to meet the requirements of the Rules as far as practicable; refer to Ch 2, Sec 2, [6.4.2].

3.7 Quality system audits

3.7.1 Attention is drawn to the possibility that auditors external to the Society may attend surveys and audits carried out by the Society and that this attendance shall not be obstructed.

4 Application of statutory requirements by the Society

4.1 International and national regulations

4.1.1 Where requirements of International Conventions, such as SOLAS, ILLC, MARPOL, ILO or of IMO Assembly Resolutions, are quoted as excerpts, they are printed in italic type replacing the word "Administration" with "Society".

These requirements are quoted for ease of reference.

4.1.2 When authorised by the Administration concerned, the Society will act on its behalf within the limits of such authorisation. In this respect, the Society will take into account the relevant national requirements, survey the ship, report and issue or contribute to the issue of the corresponding certificates.

The above surveys do not fall within the scope of the classification of ships, even though their scope may overlap in part and may be carried out concurrently with surveys for assignment or maintenance of class.

4.1.3 In the case of a discrepancy between the provisions of the applicable international and national regulations and those of the Rules, normally, the former take precedence. However, the Society reserves the right to call for the necessary adaptation to preserve the intention of the Rules or to apply the provisions of [1.4.1].

4.1.4 In statutory matters, when authorized by the Administration concerned and acting on its behalf, the Society applies the available IACS Unified Interpretations (UIs), unless provided with written instruction to apply a different interpretation by the flag Administration.

Section 2 Classification Notations

1 General

1.1 Purpose of the classification notations

1.1.1 The classification notations give the scope according to which the class of the ship has been based and refer to the specific rule requirements which are to be complied with for their assignment. In particular, the classification notations are assigned according to the type, service and navigation of the ship and other criteria which have been provided by the Interested Party, when applying for classification.

The Society may change the classification notations at any time, when the information available shows that the requested or already assigned notations are not suitable for the intended service, navigation and any other criteria taken into account for classification.

Note 1: Reference should be made to Ch 1, Sec 1, [1.3] on the limits of classification and its meaning.

1.1.2 The classification notations assigned to a ship are indicated on the Certificate of Classification, as well as in the Register of Ships published by the Society.

1.1.3 The classification notations assigned to ships and units, other than those covered in Parts B, C, D, E and F, which are to comply with specific Rules published by the Society are given in Ch 1, App 1.

1.1.4 The classification notations applicable to existing ships conform to the Rules of the Society in force at the date of assignment of class, as indicated in Ch 2, Sec 1. However, the classification notations of existing ships may be updated according to the current Rules, as far as applicable.

1.1.5 The classification notations applicable to diving systems are defined in NR610, Rules for the Classification of Diving Systems. The requirements in [1.2] and from Articles [2] to [7] are not applicable to diving systems.

The diving systems are assigned with one of the service notations defined in [8].

1.2 Types of notations assigned

1.2.1 The types of classification notations assigned to a ship are the following:

a) class symbol

b) construction marks

c) service notations with additional service features, as applicable

d) navigation notations

e) operating area notations (optional)

f) additional class notations (optional).

The different classification notations and their conditions of assignment are listed in Articles [2] to [6], according to their types.

1.2.2 As an example, the classification notations assigned to a ship may be as follows (the kind of notation shown in brackets does not form part of the classification notation indicated in the Register of Ships and on the Certificate of Classification):

I ✠ HULL ✠ MACH

(class symbol, construction marks)

oil tanker chemical tanker ESP-Flash point > 60°C

(service notation and additional service features)

unrestricted navigation

(navigation notation)

✠ SYS-IBS-1

(additional class notation)

2 Class symbol

2.1 General

2.1.1 The class symbol expresses the degree of compliance of the ship with the rule requirements as regards its construction and maintenance. There is one class symbol, which is compulsory for every classed ship.

2.1.2 The class symbol **I** is assigned to ships built in accordance with the requirements of the Rules or other rules recognised as equivalent, and maintained in a condition considered satisfactory by the Society.

The period of class (or interval between class renewal surveys) assigned to class symbol **I** ships is maximum 5 years, see Ch 2, Sec 2, [4].

Note 1: The class symbol **I** is to be understood as being the highest class granted by the Society.

2.1.3 The class symbol **II** is assigned to ships which do not meet all requirements for class symbol **I**, but are deemed acceptable to be entered into the Register of Ships.

The period of class assigned to class symbol **II** ships is maximum 3 years, see Ch 2, Sec 2, [4].

2.1.4 Except for special cases, class is assigned to a ship only when the hull, propulsion and auxiliary machinery installations, and equipment providing essential services have all been reviewed in relation to the requirements of the Rules.

3 Construction marks

3.1 General

3.1.1 The construction mark identifies the procedure under which the ship and its main equipment or arrangements have been surveyed for initial assignment of the class. The procedures under which the ship is assigned one of the construction marks are detailed in Ch 2, Sec 1.

3.1.2 One of the construction marks defined below is assigned separately to the hull of the ship and its appendages, to the machinery installation, and to some installations for which an additional classification notation (see [6] below) is assigned.

The construction mark is placed before the symbol **HULL** for the hull, before the symbol **MACH** for the machinery installations, and before the additional class notation granted, when such a notation is eligible for a construction mark.

If the ship has no machinery installations covered by classification, the symbol **MACH** is not granted and the construction mark will be only placed before the symbol **HULL**.

Note 1: for ships assigned with the service notation **yacht** or **charter yacht** and having a length less than 24 m, see additional requirements defined in NR500.

3.1.3 The construction marks refer to the original condition of the ship. However, the Society may change the construction mark where the ship is subjected to repairs, conversion or alterations.

3.2 List of construction marks

3.2.1 The mark ✠ is assigned to the relevant part of the ship, when it has been surveyed by the Society during its construction in compliance with the new building procedure detailed in Ch 2, Sec 1, [2.1], or when it is changing class from an IACS Society at ship's delivery or when class is being added to an IACS Society's class at ship's delivery in accordance with specific procedures.

3.2.2 The mark ✠ is assigned to the relevant part of the ship, when the latter is classed after construction in compliance with the procedure detailed in Ch 2, Sec 1, [3.2] and it is changing class from an IACS Society at the time of the admission to class.

3.2.3 The mark • is assigned to the relevant part of the ship, where the procedure for the assignment of classification is other than those detailed in [3.2.1] and [3.2.2], but however deemed acceptable.

4 Service notations and corresponding additional service features

4.1 General

4.1.1 The service notations define the type and/or service of the ship which have been considered for its classification, according to the request for classification signed by the Interested Party. At least one service notation is to be assigned to every classed ship.

Note 1: The service notations applicable to existing ships conform to the Rules of the Society in force at the date of assignment of class. However, the service notations of existing ships may be updated according to the current Rules, as far as applicable, at the request of the Interested Party.

4.1.2 The assignment of any service notation to a new ship is subject to compliance with the general rule requirements laid down in Part B and Part C of the present Rules and in NR216 Materials and Welding, and, for some service notations, with the additional requirements laid down in the corresponding Chapter of Part D and Part E.

Note 1: For a service notation defined in a Rule Note, the assignment of this service notation to a new ship is subject to compliance with the general rule requirements laid down in Part B and Part C of the present Rules and in NR216 Materials and Welding, and with the additional requirements laid down in the relevant Rule Note and, if relevant, with the requirements laid down in:

- NR600 Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m
- NR566 Hull Arrangement, Stability and Systems for Ships less than 500 GT.

4.1.3 A ship may be assigned several different service notations. In such case, the specific rule requirements applicable to each service notation are to be complied with. However, if there is any conflict in the application of the requirements applicable to different service notations, the Society reserves the right to apply the most appropriate requirements or to refuse the assignment of one of the requested service notations.

4.1.4 A service notation may be completed by one or more additional service features, giving further precision regarding the type of service of the ship, for which specific rule requirements are applied.

4.1.5 The different service notations which may be assigned to a ship are listed in [4.2] to [4.16], according to the category to which they belong. These service notations are also listed in Tab 1 and Tab 2, where the correspondence between the service notation assigned by the Society and the type of ship defined by the International Conventions is also given for information.

As a rule, all notations in [4.2], [4.3], [4.4] and [4.5] are only to be assigned to self-propelled units.

Table 1 : List of service notations and additional service features

Service notation [ref. in Part A] **Additional service feature**	Reference Reference	Corresponding type of ship according to Conventions and/or Codes
anchor handling [4.11.2]	Part E, Chapter 2	Cargo ship (SOLAS, Reg I/2(g))
asphalt carrier [4.4.3]	Part D, Chapter 7	
barge [4.14.1]	Part D, Chapter 14	
tug combined	Pt E, Ch 1, Sec 4	
type of cargo **(1)**	–	
bulk carrier [4.3]	Part D, Chapter 4	Cargo ship (SOLAS, Reg I/2(g)) Bulk carrier (SOLAS, Reg XII/1)
ESP	Part D, Chapter 4 SOLAS, Reg IX/1.6 SOLAS, Reg XI-1/2	
BC-A or **BC-B** or **BC-C** **(2)**	Part D, Chapter 4	
nonhomload **(3)**	–	
CSR	NR606 **(4)** or NR522	
GRAB [X] **(5)**	NR606 **(4)** or NR522, Ch 12, Sec 1	
CPS(WBT) **(6)**	NR530	
heavycargo [AREA1, X1 kN/m² - ...]	Pt B, Ch 5, Sec 6	
cement carrier [4.3.7]	Part D, Chapter 17	Cargo ship (SOLAS, Reg I/2 (g))
chemical tanker [4.4.4]	Part D, Chapter 8	Chemical tanker (SOLAS, Reg.II-2/3.11, Reg.VII / 8.2) Chemical tanker (MARPOL Annex II, Reg 1/16.1) when noxious liquid substances are loaded
ESP **IMO Type 1**, **IMO Type 2**, **IMO Type 3** **Methanol bunkering** type of cargo **(1)**	NR620	
combination carrier/OBO ESP [4.3.4]	Part D, Chapter 6	Combination carrier (SOLAS, Reg II-2/3.14) Tanker (SOLAS, Reg I/2(h)) Bulk carrier (SOLAS, Reg IX/1.6, Reg XII/1) Oil tanker - Combination carrier (MARPOL Annex I, Reg I/1.8)
combination carrier/OOC ESP [4.3.5]	Part D, Chapter 6	Combination carrier (SOLAS, Reg II-2/3.14) Tanker (SOLAS, Reg I/2(h)) Bulk carrier (SOLAS, Reg IX/1.6, Reg XII/1) Oil tanker - Combination carrier (MARPOL Annex I, Reg I/1.8)
container ship [4.2.6]	Part D, Chapter 2	Cargo ship (SOLAS, Reg I/2(g))
WhiSp1 or **WhiSp2**	Pt D, Ch 2, Sec 4	
crew transfer vessel [4.15.4]	NR490	
deck ship [4.2.8]	–	Cargo ship (SOLAS, Reg I/2(g))
diving support-integrated [4.11.5] **diving support-capable** [4.11.5] **diving support-portable** [4.11.5]	Part E, Chapter 7	
DD or **SD**	–	
dredger [4.13]	Part D, Chapter 13	Cargo ship (SOLAS, Reg I/2(g))
EOC		

Service notation [ref. in Part A] **Additional service feature**	Reference Reference	Corresponding type of ship according to Conventions and/or Codes
escort tug [4.10.4]	Part E, Chapter 1	Cargo ship (SOLAS, Reg I/2(g))
barge combined	Pt E, Ch 1, Sec 4	
(design bollard pull = [T_{BP}/9,81] t)	Pt E, Ch 1, Sec 1	
(design maximum braking force = [$T_{X,MAX}$/9,81] t)	Pt E, Ch 1, Sec 1	
(design maximum escort speed = [V_{MAX}] kN)	Pt E, Ch 1, Sec 1	
(design maximum steering force = [$T_{Y,MAX}$/9,81] t)	Pt E, Ch 1, Sec 1	
(standardized design bollard pull = [T_{BP}/9,81] t)	Pt E, Ch 1, Sec 1	
fire-fighting [4.11.3]	Part E, Chapter 4	Cargo ship (SOLAS, Reg I/2(g))
1, **2**, **3** or **E**	Pt E, Ch 4, Sec 3	
water spraying	Pt E, Ch 4, Sec 4	
fishing vessel [4.8.1]	Part D, Chapter 15	Fishing vessel (SOLAS, Reg I/2(i)). To be noted that SOLAS Convention does not apply to such ships
F	Pt D, Ch 15, Sec 6	
ED	European Directive 97/70/EC as amended	
TORRE	Torremolinos International Convention for the Safety of Fishing Vessels as amended	
FLS tanker [4.4.6]	Part D, Chapter 7	Tanker (SOLAS, Reg I/2(h)) NLS Tanker (MARPOL, Annex II, Reg 1/16.2), when noxious liquid substances are loaded
flash point > 60°C	Part D, Chapter 7	
type of cargo **(1)**		
FSRU or **FSU-LNG** [4.15.5]	NR645	
([cargo type], [ship type], [cargo containment system type], [P_{design}], [T_{min}])	–	
general cargo ship [4.2.2]	–	Cargo ship (SOLAS, Reg I/2(g))
equipped for carriage of containers	Part D, Chapter 2	
nonhomload **(3)**	Pt D, Ch 4, Sec 3	
occasional dry bulk cargo	IMO Res.MSC 277(85) para. 1.6 and 1.7	
heavycargo [AREA1, X1 kN/m² - ...]	Pt B, Ch 5, Sec 6	
hopper dredger or **hopper unit** [4.13]	Part D, Chapter 13	Cargo ship (SOLAS, Reg I/2(g))
EOC		
HSC or **HSC-CAT A** or **HSC-CAT B** [4.6.1] **(7)**	NR396 UNITAS	High-speed craft (SOLAS, Chapter X), 2000 HSC Code
icebreaker [4.9] **(8)**	NR527	
launch or **seagoing launch** [4.15.2]	NR600 and NR566	(non-convention ship)
light ship [4.6.2] **(7)**	Part B and Part C or NR566, and NR396, Chapter 3 and Chapter 6	
liquefied gas carrier [4.4.5]	Part D, Chapter 9	Tanker (SOLAS, Reg I/2(h)) Gas carrier (SOLAS, Reg II-1/3.20, Reg II-2/3.25, Reg VII /11.2)
([cargo type], [ship type], [cargo containment system type], [P_{design}], [T_{min}])	–	
BOG-reliquefaction	Pt D, Ch 9, Sec 1, [7]	
subcooling	Pt D, Ch 9, Sec 1, [7]	
REGAS	NR645, Sec 10	
STL-SPM	Pt D, Ch 9, Sec 1, [8]	
LNG bunkering **(9)**	NR620	
Ammonia bunkering **(10)**	NR620	
liquefied gas carrier - FSRU or **liquefied gas carrier - FSU** [4.15.5]	NR645	
([cargo type], [ship type], [cargo containment system type], [P_{design}], [T_{min}])	–	
livestock carrier [4.2.7]	Part D, Chapter 3	Cargo ship (SOLAS, Reg I/2(g))

Service notation [ref. in Part A] **Additional service feature**	Reference Reference	Corresponding type of ship according to Conventions and/or Codes
offshore construction barge ( ) [4.12.2]	**(11)**	
offshore construction vessel ( ) [4.12.3]	**(11)**	
offshore support vessel ( ) [4.12.4]	**(11)**	
oil recovery [4.11.4]	Part E, Chapter 5	
OILTREAT		
SECOND-LINE		
oil storage service [4.4.9]	–	
oil tanker [4.4.2]	Part D, Chapter 7	Tanker (SOLAS, Reg I/2(h)) Oil tanker (MARPOL Annex I, Reg I/1.5)
ESP	Part D, Chapter 7 SOLAS, Reg II-1/2.22, SOLAS, Reg XI-1/2	
flash point > 60°C	Part D, Chapter 7	
asphalt carrier	Part D, Chapter 7	
CSR	NR606 **(4)** or NR523	
CPS(WBT) **(6)**	NR530	
OPV [4.7.1]	Part D, Chapter 16	
ore carrier ESP [4.3.3]	Part D, Chapter 5	Cargo ship (SOLAS, Reg I/2(g)) Bulk carrier (SOLAS, Reg IX/1.6, Reg XII/1)
passenger ship [4.5.2]	Part D, Chapter 11	Passenger ship (SOLAS, Reg. I/2(f))
≤ 36 passengers		
SRTP	Part D, Chapter 11	
PCTC or **PCC** [4.2.4]	Part D, Chapter 1	Cargo ship (SOLAS, Reg I/2(g))
pontoon, **pontoon - crane** [4.14.2]	Part D, Chapter 14	
refrigerated cargo ship [4.2.5]	**(12)**	Cargo ship (SOLAS, Reg I/2(g))
equipped for carriage of containers	Part D, Chapter 2	
ro-ro cargo ship [4.2.3]	Part D, Chapter 1	Cargo ship (SOLAS, Reg I/2(g))
equipped for carriage of containers	Part D, Chapter 2	
ro-ro passenger ship [4.5.3]	Part D, Chapter 12	Passenger ship (SOLAS, Reg. I/2(f)) Ro-ro passenger ship (SOLAS, Reg II-2/3.42)
≤ 36 passengers		
SRTP	Part D, Chapter 12	
salvage tug [4.10.3]	Part E, Chapter 1	Cargo ship (SOLAS, Reg I/2(g))
barge combined	Pt E, Ch 1, Sec 4	
(design bollard pull = [T_{BP}/9,81] t)	Pt E, Ch 1, Sec 1	
(standardized design bollard pull = [T_{BP}/9,81] t)	Pt E, Ch 1, Sec 1	
self-unloading bulk carrier ESP [4.3.6]	Part D, Chapter 4	Cargo ship (SOLAS, Reg I/2(g)) Bulk carrier (SOLAS, Reg IX/1.6, Reg XII/1)
heavycargo [AREA1, X1 kN/m² - ...]	Pt B, Ch 5, Sec 6	
nonhomload **(3)**	–	
semi-submersible cargo ship [4.2.9]	Part E, Chapter 9	Cargo ship (SOLAS, Reg I/2(g))
heavycargo [AREA1, X1 kN/m² - ...]	Pt B, Ch 5, Sec 6	
special service [4.15.1] **(7)**	**(13)**	
split hopper dredger or **split hopper unit** [4.13]	Part D, Chapter 13	Cargo ship (SOLAS, Reg I/2(g))
EOC		
tanker [4.4.7] **(1)**	Part D, Chapter 10	Cargo ship (SOLAS, Reg I/2(g))
type of cargo		
tug [4.10.2]	Part E, Chapter 1	Cargo ship (SOLAS, Reg I/2(g))
barge combined	Pt E, Ch 1, Sec 4	
(design bollard pull = [T_{BP}/9,81] t)	Pt E, Ch 1, Sec 1	
(standardized design bollard pull = [T_{BP}/9,81] t)	Pt E, Ch 1, Sec 1	
USV [4.15.6] **(14)**	NR681	
wind farm installation vessel ( ) [4.12.3]	**(11)**	
wind farm operation vessel ( ) [4.12.4]	**(11)**	
yacht or **charter yacht** [4.15.3]	NR500	
motor or **sailing**	NR500	
S or **C** or **A** or **W** **(15)**	NR500	

Service notation [ref. in Part A] **Additional service feature**	Reference Reference	Corresponding type of ship according to Conventions and/or Codes
OTHER ADDITIONAL SERVICE FEATURES		Remarks
no propulsion [4.16.1]	Part D, Chapter 14	For any non-propelled units other than **barge** or **pontoon**
assisted propulsion [4.16.2]	–	
WIND PROPULSION [4.16.3] **(16)**	NR206	Service feature to be completed by **-1** or **-2**
ammoniafuel [4.16.4]	NR671	Service feature to be completed by one of the following notations: **singlefuel**, **dualfuel** Service feature may be completed by one of the following notations: **-aux**, **-prop**.
CNGfuel [4.16.4]	NR529 or Part D, Chapter 9	
hydrogenfuel [4.16.4]	NR678	
LFPfuel [4.16.4]	NR529 or Part D, Chapter 9 or NR670	
LNGfuel [4.16.4]	NR529 or Part D, Chapter 9	
LPGfuel [4.16.4]	NR647 or Part D, Chapter 9	
methanolfuel [4.16.4]	NR670	
fuelcell [4.16.5]	NR547	
battery system [4.16.6]	Pt C, Ch 2, Sec 7	Service feature may be completed by the notation **-ZE**
CBM or **[CBM]** or **CBM-P** or **[CBM-P]** [4.16.16]	–	
CPS(WBT) [4.16.12] **(6)**	NR530	
CYBER RESILIENT [4.16.14]	NR659	
heavycargo [AREA1, X1 kN/m² - ...] [4.16.11]	Pt B, Ch 5, Sec 6	
IPxxx [4.16.9]	–	
OCC [4.16.17]	Pt C, Ch 1, Sec 12	
POLAR CAT-A or **POLAR CAT-B** or **POLAR CAT-C** [4.16.10]	NR527	for ships operating in polar waters (as defined in SOLAS and MARPOL)
POWERGEN( ) [4.16.13]	NR656	Service feature to be completed between bracket by **OIL**, **LNG/NG** or **DUALFUEL**
SPxxx [4.16.8]	–	
SW-Registry [4.16.15]	Pt C, Ch 3, Sec 3	
Tier III [4.16.7]	–	

(1) For ships intended to carry only one type of cargo.

(2) Additional indications: for **BC-A**: **(holds a, b, ..., ... may be empty)** and **(Block-loading)** if applicable; for **BC-A** or **BC-B** and if x.y is less than 3 t/m^3: **(maximum cargo density x.y t/m^3)**; for **BC-A**, **BC-B** or **BC-C**: **(no MP)** if applicable.

(3) Completed with indication of the different maximum loads allowed in each hold and which holds may be empty, if appropriate.

(4) Bulk carriers and Oil tankers assigned with the additional service feature **CSR** contracted for new construction on or after 1 July 2015 are to comply with the requirements of NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

(5) Ships assigned the service notation **bulk carrier CSR** completed by the additional service features **BC-A** or **BC-B**, are always to be assigned the additional service feature **GRAB[X]**.

(6) Ships assigned the additional service feature **CSR** and contracted for construction on or after 8 December 2006 are always to be assigned the additional service feature **CPS(WBT)**.

(7) The type of service may be specified after the service notation, e.g. **light ship/fast passenger vessel**, **light ship/fast cargo vessel, light ship/fast patrol vessel**.

(8) **icebreaker** may be completed by **1**, **2**, **3**, **4**, **5**, **6** or **7**.

(9) **LNG bunkering** may be completed by **RE**, **Initial-CD**, **IG Supply** and **BOG**

(10) **Ammonia bunkering** may be completed by **RE**, **IG Supply**, **BOG**, **Effluent recovery** and **VPS**

(11) These notations are not linked with technical requirements but are always completed by other service notation(s) to define applicable requirements as defined in [4.12] and listed in Tab 2.

(12) No additional requirements are specified in Part D for this service notation; however requirements of Part F, Chapter 7 for the assignment of the additional class notation **REF-CARGO** are to be applied.

(13) These ships are considered on a case by case basis by the Society according to their type of service.

(14) The type of service is to be specified after the service notation.

(15) Corresponding to hull material as defined in NR500.

(16) For any ship equipped with a wind propulsion system except ships assigned the service notation **yacht** or **charter yacht**.
For ships assigned the service notation **yacht** or **charter yacht**, reference is made to [6.25.5].

4.2 Cargo ships

4.2.1 The service notations related to self-propelled ships intended for the carriage of cargo are listed in [4.2.2] to [4.2.9].

4.2.2 The service notation **general cargo ship** is assigned to ships intended to carry general cargo.

The service notation may be completed by the following additional service feature, as applicable:

- **equipped for carriage of containers**, where the ship's fixed arrangements comply with the applicable rule requirements in Part D, Chapter 2.
- **heavycargo [AREA1, X1 kN/m² - AREA2, X2 kN/m² - ...]**, as defined in [4.16.11].
- **nonhomload**, when the ship has been designed in such a way that the cargo spaces may be loaded non-homogeneously, including cases where some holds may be empty, at a draught up to the scantling draught and fulfil the appropriate rule requirements for general strength, and when the corresponding loading conditions are listed in the reviewed loading manual. This notation may be completed with the indication of the different maximum loads allowed in each hold and which holds may be empty, if appropriate.
- **occasional dry bulk cargo**, for ships the keels of which are laid or which are at a similar stage of construction on or after the 1st July 2010, and which occasionally carry dry cargoes in bulk, as described in IMO Res.MSC 277(85), paragraphs 1.6 and 1.7.

The additional requirements of Ch 4, Sec 7 are applicable to these ships.

4.2.3 The service notation **ro-ro cargo ship** is assigned to ships specially intended to carry vehicles, trains or loads on wheeled beds. The additional requirements of Ch 4, Sec 6 and Part D, Chapter 1 are applicable to these ships. The service notation may be completed by the additional service feature **equipped for carriage of containers**, where the ship's fixed arrangements comply with the applicable requirements of Part D, Chapter 2.

4.2.4 The service notations **PCTC** (pure car and truck carrier) or **PCC** (pure car carrier) are assigned to ships with high number of decks, specially intended to carry unoccupied road vehicles without cargo, as cargo.

The additional requirements of Ch 4, Sec 6 and Part D, Chapter 1 are applicable to these ships.

Note 1: Ships assigned the service notation **PCT Carrier** before 1st July 2023, are to be assigned the service notation **PCTC** at the first renewal survey held after 1 July 2023, or before upon request from the Owner.

4.2.5 The service notation **refrigerated cargo ship** is assigned to ships specially intended to carry refrigerated cargo. No additional requirements are specified in Part D for this service notation; however, the requirements of Part F, Chapter 7 for the assignment of the additional class notation **REF-CARGO** are to be applied. The service notation may be completed by the additional service feature **equipped for carriage of containers**, where the ship's fixed arrangements comply with the applicable rule requirements in Part D, Chapter 2.

4.2.6 The service notation **container ship** is assigned to ships specially intended to carry containers in holds or on decks. The additional requirements of Ch 4, Sec 8, [2] and Part D, Chapter 2 are applicable to these ships.

For container ships complying with the requirements of Pt D, Ch 2, Sec 4, the service notation is to be completed by the additional service features **WhiSp1** or **WhiSp2**.

4.2.7 The service notation **livestock carrier** is assigned to ships specially intended to carry livestock. The additional requirements of Ch 4, Sec 8, [3] and Part D, Chapter 3 are applicable to these ships.

4.2.8 The service notation **deck ship** is assigned to ships specially intended to carry cargo exclusively on the deck.

Note 1: A ship with service notation **deck ship** is usually but not necessarily a self-propelled unit intended for unrestricted navigation.

4.2.9 The service notation **semi-submersible cargo ship** is assigned to ships intended to perform loading and unloading operations of a floating cargo by submersion of the freeboard deck in accordance with the requirements Part E, Chapter 9.

The service notation **semi-submersible cargo ship** is completed by the additional service feature **heavycargo [AREA 1, X1 kN/m2 - ...]** as defined in [4.16.11].

One of the additional class notations **LI-HG-S2** or **LI-HG-S3** is to be assigned.

The service notation **semi-submersible cargo ship** is always completed by the additional class notation **SDS**.

The additional requirements of Ch 4, Sec 8, [17] are applicable to these ships.

4.3 Bulk, ore and combination carriers

4.3.1 The service notations related to self-propelled ships specially intended for the carriage of dry cargo in bulk and the applicable requirements for the assignment of these notations are listed in:

- [4.3.2] for the service notation **bulk carrier ESP**
- [4.3.3] for the service notation **ore carrier ESP**
- [4.3.4] for the service notation **combination carrier/OBO ESP**
- [4.3.5] for the service notation **combination carrier/OOC ESP**
- [4.3.6] for the service notation **self-unloading bulk carrier ESP**
- [4.3.7] for the service notation **cement carrier**
- Part D, Chapter 4 for the service notation **bulk carrier** when the ship does not meet the forthcoming conditions.

The service notations described in [4.3.2] to [4.3.6] are always completed by the additional service feature **ESP**, which means that these ships are submitted to the Enhanced Survey Program as laid down in:

- Ch 4, Sec 2 for the service notations described in [4.3.2], [4.3.3] and [4.3.6]
- Ch 4, Sec 2 and Ch 4, Sec 3 for the service notations described in [4.3.4] and [4.3.5].

For ships assigned the service notation **bulk carrier** (without the additional service feature **ESP**), the additional requirements of Ch 4, Sec 7 are applicable.

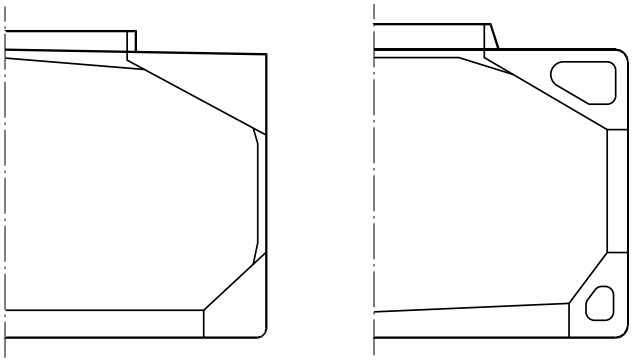
Note 1: Self-propelled ships are ships with mechanical means of propulsion not requiring assistance from another ship during normal operation.

4.3.2 The service notation **bulk carrier ESP** is assigned to sea going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo length area and intended primarily to carry dry cargoes in bulk. Typical midship sections are illustrated in Fig 1, or a midship section deemed equivalent by the Society. The additional requirements of Part D, Chapter 4 are applicable to these ships.

The service notation **bulk carrier ESP** is always completed by one of the following additional service features, for bulk carriers of length greater than or equal to 150 m contracted for new construction on or after 1 July 2003:

- **BC-A**, for bulk carriers designed to carry dry bulk cargoes of density 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions
- **BC-B**, for bulk carriers designed to carry dry bulk cargoes of density 1.0 t/m^3 and above with all cargo holds loaded in addition to **BC-C** conditions
- **BC-C**, for bulk carriers designed to carry dry bulk cargoes of density less than 1.0 t/m^3.

Figure 1 : Typical midship sections of ships with service notation bulk carrier ESP



Left: Single side skin construction

Right: Double side skin construction.

The additional service feature **BC-A** is completed with the indication of the allowed combination of specified empty holds, as follows: **(holds a, b, ..., ... may be empty)**.

If limitations are to be observed during operation:

- the additional service features **BC-A** and **BC-B** are completed, when the maximum cargo density is less than 3.0 t/m^3, with the indication of the maximum density of cargo that the ship is allowed to carry, as follows:
  (maximum cargo density x.y t/m^3)
- the additional service features **BC-A**, **BC-B** and **BC-C** are completed by the following indication when the vessel has not been designed for loading and unloading in multiple ports: **(no MP)**.
- the additional service feature **BC-A** is completed by the notation **(Block-loading)** when the ship is intended to operate in alternate block load condition, according to Common Structural Rules for Bulk Carriers and Double Hull Oil Tankers (Rule Note NR606), Pt 1, Ch 1, Sec 1, [3.2.1]. The requirements for **(Block-loading)** notation are defined in NR606, Pt 1, Ch 4, Sec 8, [4.2.3].

Examples:

bulk carrier BC-A (maximum cargo density 2.5 t/m^3; holds 2, 4, 6 may be empty) ESP

bulk carrier BC-B (maximum cargo density 2.5 t/m^3; no MP) ESP

bulk carrier BC-C (no MP) ESP

For ships contracted for new construction before 1 July 2003 or for ships contracted for new construction on or after 1 July 2003 but less than 150 m in length, the service notation **bulk carrier ESP** may be completed by the additional service features **heavycargo** or **nonhomload** defined under [4.2.2].

The service notation **bulk carrier ESP** is always completed by the additional service feature **CSR** for bulk carriers of length greater than or equal to 90 m contracted for new construction on or after 1 April 2006.

Bulk carriers assigned with the additional service feature **CSR** are to comply with the requirements of:

- the Common Structural Rules for Bulk Carriers (Rule Note NR522), when contracted for construction on or after 1 April 2006 and before 1 July 2015. The elements not dealt with in NR522 are to comply with the requirements of Part B, Part C and Part D of the Rules for the Classification of Steel Ships.

Note 1: Hybrid bulk carriers, where at least one cargo hold is constructed with hopper tank and topside tank, are covered by NR522. The structural strength of members in holds constructed without hopper tank and/or topside tank is to comply with the strength criteria defined in NR522.

- the Common Structural Rules for Bulk Carriers and Oil Tankers (Rule Note NR606) when contracted for construction on or after 1 July 2015.The elements not dealt with in NR522 are to comply with the requirements of Part B, Part C and Part D of the Rules for the Classification of Steel Ships.

Bulk carriers assigned with the additional service feature **CSR** and with holds designed for loading/unloading by grabs having a maximum specific weight up to [X] tons are assigned the notation **GRAB [X]** according to NR522 (Common Structural Rules for Bulk Carriers), Ch 1, Sec 1, [3.2.1] or NR606 (Common Structural Rules for Bulk Carriers and Oil Tankers), Pt 1, Ch 1, Sec 1, [3.2.2], as applicable. The requirements for **GRAB [X]** notation are given in NR522, Ch 12, Sec 1 or NR606, Pt 2, Ch 1, Sec 6, as applicable.

For bulk carriers assigned with the additional service feature **CSR**, and one of the additional service features **BC-A** or **BC-B**, these additional service features are always completed by the additional service feature **GRAB [X]**. For these ships, the requirements for the **GRAB [X]** notation are to be complied with for an unladen grab weight X equal to or greater than 20 tons.

For bulk carriers assigned with the additional service feature **CSR** others than above, the additional class notation **GRAB [X]** may be assigned on a voluntary basis (refer to [6.13.2], item a)).

Bulk carriers assigned with the additional service feature **CSR** are to comply with the requirements for maintenance of class, thickness measurements and acceptance criteria given in NR522, Chapter 13 or NR606, Part 1, Chapter 13 as applicable.

For bulk carriers assigned with the additional service feature **CSR** and contracted for construction on or after 8 December 2006, this additional service feature is always completed by the additional service feature **CPS(WBT)** for which the rule requirements of NR530 Coating Performance Standard, applicable to ships complying with the requirements of the Common Structural Rules for Bulk Carriers or the Common Structural Rules for Double Hull Oil Tankers and related to protective coatings in dedicated seawater ballast tanks of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of length greater than or equal to 150 m, are applied.

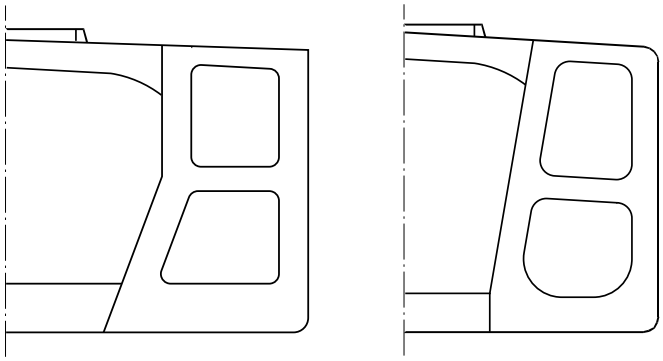
Example:

bulk carrier CSR CPS(WBT) BC-A (maximum cargo density 2.5 t/m^3; holds 2, 4, 6 may be empty) ESP GRAB [20]

Note 2: Attention is drawn on the coating condition which is surveyed as per the requirements of Ch 4, Sec 2 for ships in service.

4.3.3 The service notation **ore carrier ESP** is assigned to sea going self-propelled ships which are constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds only. Typical midship sections are illustrated in Fig 2, or a midship section deemed equivalent by the Society. The additional requirements of Part D, Chapter 5 are applicable to these ships.

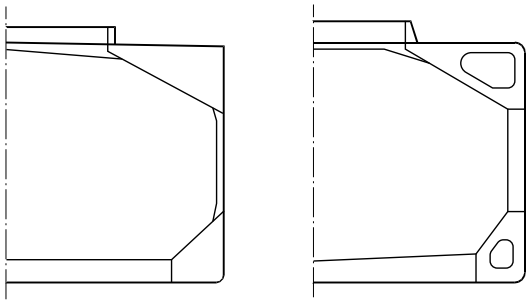
Figure 2 : Typical midship sections of ship with service notation ore carrier ESP



4.3.4 The service notation **combination carrier/OBO ESP** is assigned to sea going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in the cargo length area, and intended primarily to carry oil or dry cargoes, including ore, in bulk. Typical midship sections are illustrated in Fig 3, or a midship section deemed equivalent by the Society. The additional requirements of Part D, Chapter 6 are applicable to these ships.

Note 1: Ships assigned with the service notation **combination carrier/ OBO ESP** that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phase out.

Figure 3 : Typical midship sections of ship with service notation combination carrier/OBO ESP



Left: Single side skin construction

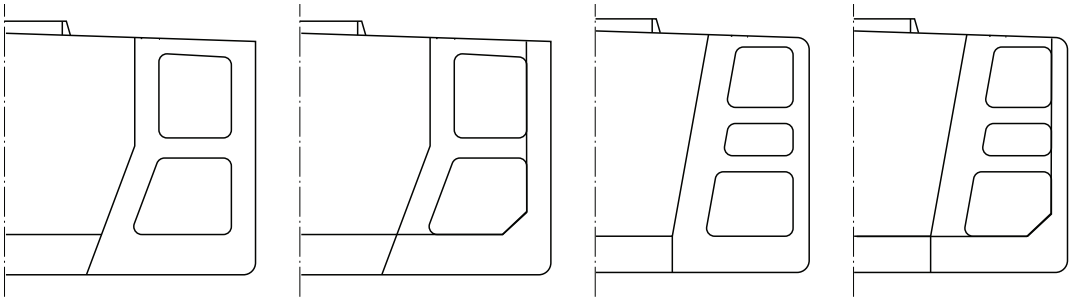
Right: Double side skin construction.

4.3.5 The service notation **combination carrier/OOC ESP** is assigned to sea going self-propelled ships which are constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds or oil cargoes in centre holds and wing tanks. Typical midship sections are illustrated in Fig 4, or a midship section deemed equivalent by the Society. The additional requirements of Part D, Chapter 6 are applicable to these ships.

Note 1: "combination carrier" is a general term applied to ships intended for the carriage of both oil and dry cargoes in bulk; these cargoes are not carried simultaneously, with the exception of oily mixture retained in slop tanks.

Note 2: Ships assigned with the service notation **combination carrier/OOC ESP** that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phase out.

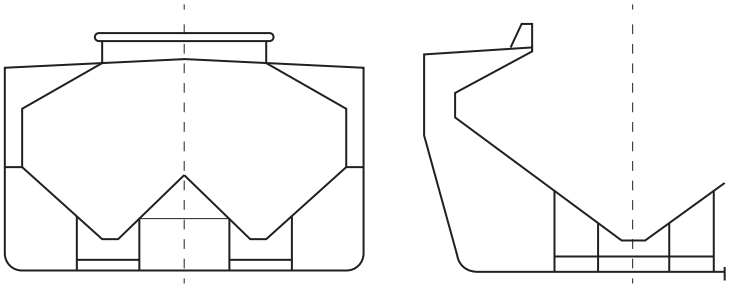
Figure 4 : Typical midship sections of ships with service notation combination carrier/OOC ESP



4.3.6 The service notation **self-unloading bulk carrier ESP** is assigned to sea going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks with single or double side skin construction in cargo area and intended primarily to carry and self-unload dry cargoes in bulk. Typical midship sections are given in Fig 5, or a midship section deemed equivalent by the Society. The additional requirements of Part D, Chapter 4 are applicable to these ships.

The service notation **self-unloading bulk carrier ESP** may be completed by the additional service feature **heavycargo** or **nonhomload** defined in [4.2.2].

Figure 5 : Typical midship sections of ship with service notation self-unloading bulk carrier ESP

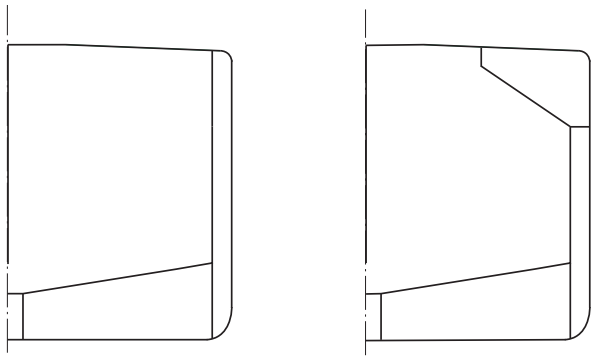


4.3.7 The service notation **cement carrier** is assigned to ships which are constructed with single deck and exclusively intended to carry cement in bulk.

Typical midship sections are illustrated in Fig 6, or a midship section deemed equivalent by the Society.

The additional requirements of Part D, Chapter 17 are applicable to these ships.

Figure 6 : Typical midship sections of ships with service notation cement carrier



4.4 Ships carrying liquid cargo in bulk

4.4.1 The service notations related to self-propelled ships intended for the carriage of liquid cargo in bulk are listed in [4.4.2] to [4.4.9].

4.4.2 The service notation **oil tanker** is assigned to sea going self-propelled ships which are constructed generally with integral tanks and intended primarily to carry in bulk crude oil, other oil products, or oil-like substances having any flash point, or liquid at atmospheric pressure and ambient temperature (or thus maintained by heating). This notation may be assigned to tankers of both single and double hull construction, as well as tankers with alternative structural arrangements, e.g. mid-deck designs.

The service notation may be completed by the additional service feature **flash point > 60°C**, as applicable, where the ship is intended to carry only such type of products, under certain conditions.

The service notation may be completed by the additional service feature **asphalt carrier**, where the ship is intended to carry such type of products, under certain conditions. The maximum cargo temperature is to be indicated on the Certificate of Classification.

The additional requirements of Part D, Chapter 7 are applicable to these ships.

For ships with integral cargo tanks, the service notation **oil tanker** is always completed by the additional service feature **ESP** (i.e. **oil tanker ESP**), which means that these ships are submitted to the Enhanced Survey Program as laid down in Ch 4, Sec 3. Typical midship sections are illustrated in Fig 7.

The service notation **oil tanker ESP** is always completed by the additional service feature **CSR** for double hull oil tankers of length greater than or equal to 150 m and contracted for new construction on or after 1 April 2006.

Oil tankers assigned with the additional service feature **CSR** are to comply with the requirements of:

- the Common Structural Rules for Double Hull Oil Tankers (Rule Note NR523), when contracted for construction on or after 1 April 2006 and before 1 July 2015. The elements not dealt with in NR523 are to comply with the requirements of Part B, Part C and Part D of the Rules for the Classification of Steel Ships.
- the Common Structural Rules for Bulk Carriers and Oil Tankers (Rule Note NR606), when contracted for construction on or after 1 July 2015. The elements not dealt with in NR523 are to comply with the requirements of Part B, Part C and Part D of the Rules for the Classification of Steel Ships.

Oil tankers assigned with the additional service feature **CSR** are to comply with the requirements for ship in operation renewal criteria given in NR523, Section 12, or NR606, Part 1, Chapter 13, as applicable, related to the allowable thickness diminution for hull structure.

For oil tankers assigned with the additional service feature **CSR** and contracted for construction on or after 8 December 2006, this additional service feature is always completed by the additional service feature **CPS(WBT)** for which the rule requirements of NR530 Coating Performance Standard, applicable to ships complying with the requirements of the Common Structural Rules for Bulk Carriers or the Common Structural Rules for Double Hull Oil Tankers and related to protective coatings in dedicated seawater ballast tanks of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of length greater than or equal to 150 m, are applied.

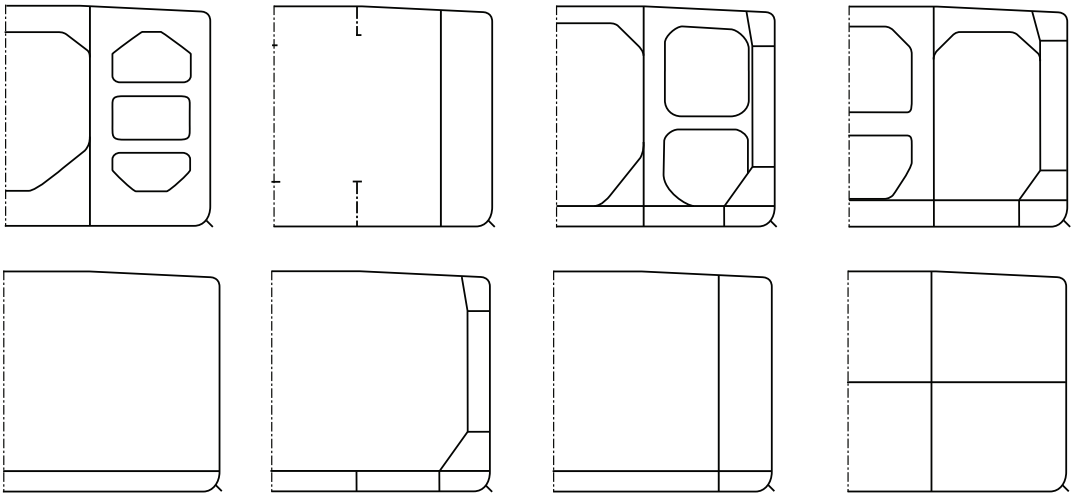
Example:

Oil tanker CSR CPS(WBT) ESP

Note 1: Attention is drawn on the coating condition which is surveyed as per the requirements of Ch 4, Sec 3 for ships in service.

Note 2: Ships assigned with the service notation **oil tanker ESP** that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phase out under MARPOL I/20 and/or MARPOL I/21.

Figure 7 : Typical midship sections of ships with service notation oil tanker ESP



4.4.3 The service notation **asphalt carrier** is assigned to sea going self-propelled ships which are constructed with independent (non-integral) cargo tanks, intended to carry only such type of products, under certain conditions. The additional requirements of Part D, Chapter 7 are applicable to these ships.

The maximum cargo temperature is to be indicated on the Certificate of Classification.

4.4.4 The service notation **chemical tanker** is assigned to sea going self-propelled ships which are intended primarily to carry chemicals in bulk and which are constructed with either integral tanks or independent tanks, including hybrid configurations (i.e. constructed with both integral and independent cargo tanks). This notation may be assigned to tankers of both single or double hull construction, as well as tankers with alternative structural arrangements. Typical midship sections are illustrated in Fig 8, or a midship section deemed equivalent by the Society.

For ships with integral cargo tanks, the service notation **chemical tanker** is always completed by the additional service feature **ESP** (i.e. **chemical tanker ESP**), which means that these ships are submitted to the Enhanced Survey Programme as laid down in Ch 4, Sec 4.The additional service feature **ESP** is not to be assigned to ships constructed with independent cargo tanks only.

The service notation **chemical tanker** is to be completed by the corresponding ship type **IMO Type 1**, **IMO Type 2** or **IMO Type 3**, as relevant and as defined in the IMO IBC Code as amended.

For ships intended to carry only one type of cargo, the service notation may be completed by the additional service feature indicating the type of product carried.

The list of products the ship is allowed to carry is attached to the Certificate of Classification or the Certificate of Fitness, where issued by the Society, including, where necessary, the maximum allowable specific gravity and/or temperature.

The service notation **chemical tanker** is to be completed by the additional service feature **Methanol bunkering** when intended to ensure the transfer of methanol cargo to ships for use as a fuel.

Example:

chemical tanker ESP IMO Type 1

chemical tanker IMO Type 3 - Molten Sulphur

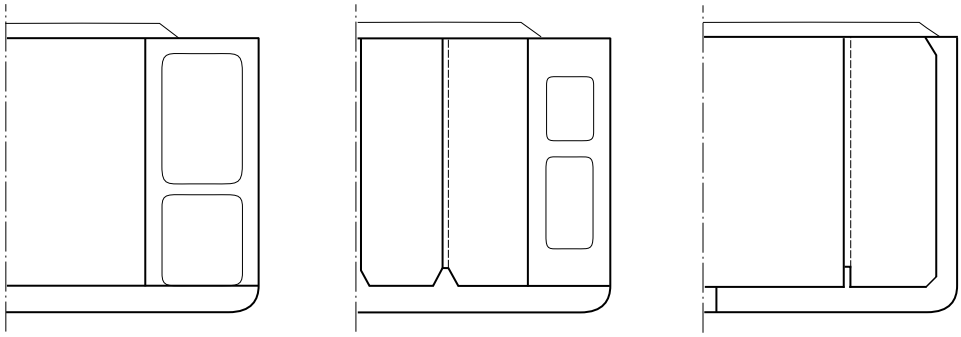
chemical tanker ESP IMO Type 2 Methanol bunkering

The requirements for the assignment of these notations are given in:

- Part D, Chapter 8, and
- in addition for the additional service feature **Methanol bunkering** in NR620.

The requirements for the maintenance of these notations are given in Ch 4, Sec 4.

Figure 8 : Typical midship sections of ships with service notation chemical tanker ESP



4.4.5 The service notation **liquefied gas carrier** is assigned to ships specially intended to carry liquefied gases or other substances listed in Pt D, Ch 9, Sec 1 of the Rules. The additional requirements of Ch 4, Sec 5 and Part D, Chapter 9 are applicable to these ships.

The list of products the ship is allowed to carry is attached to the Certificate of Classification or the Certificate of Fitness, where issued by the Society, including, where necessary, the conditions of transportation (pressure, temperature, filling limits).

The service notation is to be completed by the following additional service features indicating the cargo type, the IMO code ship type, the cargo containment system type, the cargo tank design pressure P_{design} and minimum temperature T_{min}: **([cargo type], [ship type], [cargo containment system type], [P_{design}], [T_{min}])** with:

- [cargo type] to be taken as one or several of the following:
  - **LCO2**, when carrying liquefied carbon dioxide
  - **LEG**, when carrying liquefied ethane gas (C_2H_6)
  - **LH2**, when carrying liquefied hydrogen
  - **LNG**, when carrying liquefied natural gas
  - **LNH3**, when carrying liquefied ammonia.
  - **LPG**, when carrying liquefied petroleum gas
- [ship type] to be taken as one of the following: **IMO Type 1G**, **IMO Type 2G**, **IMO Type 2PG** or **IMO Type 3G**
- [cargo containment system type] to be taken as one of the following: **Type A**, **Type B**, **Type C**, **Membrane**, **Semi-membrane** or **Integral tank**
- [P_{design}] the value of the maximum vapour pressure, in barg
- [T_{min}] the value of the minimum cargo temperature, in °C.

The service notation may be completed by the additional service feature **LNG bunkering** when intended to ensure the transfer of LNG cargo to ships for use as a fuel.

The service notation may be completed by the additional service feature **Ammonia bunkering** when intended to ensure the transfer of ammonia cargo to ships for use as a fuel.

The service notation is completed by the following additional service features, as applicable:

- for all liquefied gas carriers:
  - **BOG-reliquefaction**, where the ship is fitted with a reliquefaction installation. The requirements for the assignment of this additional service feature are given in Pt D, Ch 9, Sec 1, [7]
  - **subcooling**, where the ship is fitted with a cooling installation aiming at reducing the cargo temperature. The requirements for the assignment of this additional service feature are given in Pt D, Ch 9, Sec 1, [7]
  - **STL-SPM**, where the ship is used as re-gasification terminal and fitted forward with equipment for non permanent mooring or single buoy. The requirements for the assignment of this additional service feature are given in Pt D, Ch 9, Sec 1, [8].
- for liquefied gas carriers carrying liquefied natural gas:
  - **REGAS**, where the ship is fitted with an installation for revaporization of the liquefied natural gas. The requirements for the assignment of this additional service feature are given in NR645, Sec 10
- in addition, for liquefied gas carriers assigned the additional service feature **LNG bunkering** or **Ammonia bunkering**:
  - **RE**, where the ship is designed to receive LNG or LNH_3 from a gas fuelled ship for which the LNG or LNH_3 fuel tanks have to be emptied
  - **Initial-CD**, where the ship is designed for initial cooling down of the gas fuelled ship LNG fuel tank
  - **IG-Supply**, where the ship is designed to supply inert gas and dry air, to ensure gas freeing and aeration, to a gas fuelled ship complying with the IGF Code, paragraph 6.10.4
  - **BOG**, where the ship is designed to recover and manage the boil-off gas generated during the bunkering operation
  - **Effluent recovery**, where the ship is designed to recover effluents containing dissolved NH_3 fuel from the bunkered ship
  - **VPS**, where the ship is designed to manage the NH_3 vapor released in normal or failure operation.

Example:

liquefied gas carrier (LNG, IMO Type 2G, Membrane, 0,35 barg, –163°C) REGAS STL-SPM

liquefied gas carrier (LNG, IMO Type 2PG, Type C, 10 barg, -163°C) LNG bunkering REGAS RE Initial-CD

The requirements of Part D, Chapter 9 are applicable to these ships. In addition, the requirements for the assignment of the additional service feature **LNG bunkering** or **Ammonia bunkering** are given in NR 620.

The requirements for the maintenance of the service notation are given in Ch 4, Sec 5.

Note 1: Ships assigned the service notation **LNG bunkering ship** before 1st July 2023, are to be assigned the service notation **liquefied gas carrier** at the first renewal survey held after 1 July 2023, or before, upon request from the Owner.

4.4.6 The service notation **FLS tanker**, for ships specially intended to carry in bulk flammable liquid products other than those covered by the service notations **oil tanker**, **chemical tanker** or **liquefied gas carrier**.

The list of products the ship is allowed to carry may be attached to the Certificate of Classification, including, where necessary, the maximum allowable specific gravity and/or temperature.

The service notation may be completed by the additional service feature **flash point > 60°C**, where the ship is intended to carry only such type of products, under certain conditions.

For ships intended to carry only one type of cargo, the service notation may be completed by the additional service feature indicating the type of product carried.

The additional requirements of Ch 4, Sec 8, [4] and Part D, Chapter 7 are applicable to these ships.

4.4.7 The service notation **tanker** is assigned to ships intended to carry non-flammable liquid cargoes in bulk other than those covered by the service notations in [4.4.2] to [4.4.6], such as water.

The list of cargoes the ship is allowed to carry may be attached to the Certificate of Classification.

For ships intended to carry only one type of cargo, the service notation may be completed by the additional service feature indicating the type of product carried, e.g. **tanker-water**.

The additional requirements of Part D, Chapter 10 are applicable to these ships.

4.4.8 Refer also to [4.3.4] and [4.3.5] for **combination carrier** intended to carry alternatively oil products and dry cargo in bulk in cargo holds/tanks.

4.4.9 The service notation **oil storage service** is assigned on a case by case basis and subject to flag agreement, to ships formerly granted with the service notation **oil tanker ESP** and intended to be used as oil storage unit with the following restrictions:

- the ship is stationed at a single location, without transit or carriage of cargo between ports or different sites
- the use of the ship will be limited to storage in a dedicated single location. This location is to be situated in a sheltered area or an area enabling the ship to quickly move away from severe weather conditions
- the provisions provided when the ship is in its storage service period are no longer applicable if the ship leaves the dedicated storage service location, except when moving away from severer weather conditions
- when seeking shelter from severe weather conditions into a port of refuge, the ship is not allowed to discharge to a terminal, except on a case by case basis where repairs in a shipyard are required
- the ship may move without cargo on board to repair facilities or lay-up site, on a case-by-case basis
- the **ESP** notation has been withdrawn as far as the vessel is stationed as an oil storage unit and will be reinstated as soon as the vessel leaves the storage site to resume trading.

Periodical bottom surveys can be performed afloat and to this end the additional class notation **INWATERSURVEY** defined in [6.25.1] is to be granted.

The machinery part is to remain classed and the additional class notation **MON-SHAFT** defined in [6.6.3] is to be granted.

When granting the service notation **oil storage service**, a memorandum is to be endorsed in order to record the following:

- date of change in service notation,
- date of withdrawal of ESP notation together with Flag agreement references,
- location where the unit is stationed together with navigation notation.

When a ship starts its period as a storage service, the normal survey requirements are still applicable as follows:

- hull class renewal survey is carried out according to ESP requirements as laid down in Ch 4, Sec 3, [6], with a possibility to have the concurrent bottom inspection done afloat, provided that conditions laid down in Ch 3, Sec 4, [3] are met,
- other periodical surveys are carried out according to Part A, Chapter 3 as applicable.

When completing the storage service period, and before resuming trading, all surveys from which the ship has been relaxed during its storage period, have to be carried out, including possible surveys in drydock condition; upon completion of satisfactory surveys, the service notation **oil tanker ESP** will be reinstated to the ship and related surveys will become fully applicable.

Note 1: the mooring arrangements of the vessel, including their compliance with any authority's requirement, are left to the responsibility of the owner when granted the service notation **oil storage service**.

4.5 Ships carrying passengers

4.5.1 The service notations related to ships specially intended for the carriage of passengers are listed in [4.5.2] to [4.5.3].

4.5.2 The service notation **passenger ship** is assigned to ships intended to carry more than 12 passengers. The additional requirements of Ch 4, Sec 6 and Part D, Chapter 11 are applicable to these ships.

The service notation may be completed by the additional service feature ≤ **36 passengers**, where the ship is intended to carry only such a limited number of passengers.

The service notation is to be completed by the additional service feature **SRTP** for ships complying with the provisions of Part D, Chapter 11.

4.5.3 The service notation **ro-ro passenger ship** is assigned to ships intended to carry more than 12 passengers and specially equipped to load trains or wheeled vehicles. The additional requirements of Ch 4, Sec 6 and Part D, Chapter 12 are applicable to these ships.

The service notation may be completed by the additional service feature ≤ **36 passengers**, where the ship is intended to carry only such a limited number of passengers.

The service notation is to be completed by the additional service feature **SRTP** for ships complying with the provisions of Part D, Chapter 12.

4.6 High speed crafts (HSC)

4.6.1 The high speed crafts meeting the requirements of the Rules for the Construction and the Classification of High Speed Craft (NR396 UNITAS) are assigned the following service notations:

- For passenger ships which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge:
  - **HSC-CAT A** (or **high speed craft-CAT A**) for passenger ships defined as "Category A craft" in respect of the IMO International Code of Safety for High Speed Craft
  - **HSC-CAT B** (or **high speed craft-CAT B**) for passenger ships defined as "Category B craft" in respect of the IMO International Code of Safety for High Speed Craft
- For ships other than passenger ships and which do not proceed in the course of their voyage more than 8 h at operational speed from a place of refuge when fully laden:
  - **HSC** (or **high speed craft**)

  The type of service may be specified after the notation.

4.6.2 The service notation **light ship** is assigned to ships subject to compliance both with Chapter 3 and Chapter 6 of NR396 UNITAS Rules for the Classification of High Speed Craft, and with:

- for ships more than 500 GT: Part B and Part C of the present Rules, regarding stability and machinery installation
- for ships less than 500 GT: NR566 Hull Arrangement, Stability and Systems for Ships less than 500 GT.

The type of service may be specified after the service notation, e.g.:

light ship/fast passenger vessel

light ship/fast cargo vessel

light ship/fast patrol vessel.

These ships which are likely to operate at sea within specific limits may, under certain conditions, be granted an operating area notation. For the definition of operating area notation, reference should be made to [5.3].

4.7 Offshore patrol vessels

4.7.1 The service notation **OPV** is assigned to ships dedicated to patrol mission (i.e. smuggling, fishery inspection, customs-boarders protection...), with light weapon system and generally with no operational limit (neither weather condition restriction nor HS restriction). These ships could patrol at either low or high speed.

The additional requirements of Part D, Chapter 16 are applicable to these ships.

Note 1: For patrol craft operating only at high speed, the service notation **light ship/fast patrol vessel** is to be assigned in lieu of the notation **OPV** and relevant rules as stated in [4.6.2] and [5.2.8] apply.

4.8 Fishing vessels

4.8.1 The service notation **fishing vessel** is assigned to ships specially equipped for catching and storing fish or other living resources of the sea. The additional requirements of Ch 4, Sec 8, [14] and Part D, Chapter 15 are applicable to these ships.

The service notation **fishing vessel** may be completed by the following additional service features, as applicable:

- F, when the ship complies with the requirements of Pt D, Ch 15, Sec 6 related to fire prevention, ventilation systems and means of escape
- **TORRE**, when the Society has verified the compliance with the requirements for construction and equipment of fishing vessels of the Torremolinos International Convention for the Safety of Fishing Vessels, as amended
- **ED**, when the Society has verified the compliance with the requirements for construction and equipment of fishing vessels of the European Directive 97/70/EC, as amended.

Note 1: Units solely dedicated to service in a fishing flotilla by means of cold storage and/or transformation of fish are not covered by the service notation **fishing vessel**. They will be considered with the service notation **special service**.

4.9 Icebreaker ships

4.9.1 The service notation **icebreaker** is assigned to ships having an operational profile that includes escort or ice management functions, having powering and dimensions that allow them to undertake independent operations in ice covered waters.

The service notations dealt with under [4.9.2] are relevant to ships intended for navigation in ice-infested polar waters.

The requirements for the assignment of these service notations are given in NR527 Rules for the Classification of POLAR CLASS and ICEBREAKER Ships.

Ships complying with the requirements of NR527 and assigned one of the service notations **icebreaker** are also to comply with the requirements for the assignment of one of the additional class notations **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**.

4.9.2 The following service notations are assigned:

- **icebreaker 1** for summer/autumn operations without restrictions and for winter/spring operations in multi-year ice with 3,0 m max ice thickness
- **icebreaker 2** for summer/autumn operations in multi-year ice with 3,0 m max ice thickness and for winter/spring operations in second-year ice with 2,5 m max ice thickness
- **icebreaker 3** for summer/autumn operations in second-year ice with 2,5 m max ice thickness and for winter/spring operations in thick first-year ice with 1,8 m max ice thickness
- **icebreaker 4** for summer/autumn operations in thick first-year ice with 1,8 m max ice thickness and for winter/spring operations in medium first-year ice with 1,2 m max ice thickness
- **icebreaker 5** for summer/autumn operations in medium first-year ice with 1,2 m max ice thickness and for winter/spring operations in medium first-year ice with 1,0 m max ice thickness
- **icebreaker 6** for summer/autumn operations in medium first-year ice with 1,0 m max ice thickness and for winter/spring operations in medium first-year ice with 0,8 m max ice thickness
- **icebreaker 7** for summer/autumn operations in medium first-year ice with 0,8 m max ice thickness and for winter/spring operations in thin first-year ice with 0,6 m max ice thickness.

4.10 Tugs

4.10.1 General

Ships intended to tow and/or push other ships or units are assigned one of the service notation defined in [4.10.2], [4.10.3] or [4.10.4].

The additional requirements of Ch 4, Sec 8, [6] and Part E, Chapter 1 are applicable to these ships.

These service notations may be completed by the additional service feature **barge combined**, when the units are designed to be connected with barges and comply with the relevant requirements of Pt E, Ch 1, Sec 4. The barges to which the tug can be connected are specified in a memorandum.

These service notations are always completed by the additional service feature **(standardized design bollard pull = [T_{BP}/9,81] t)**.

Note 1: Ships contracted for construction before 1 July 2020 and not meeting the bollard pull test requirements for the assignment of the additional service feature **(standardized design bollard pull = [T_{BP}/9,81] t)** are assigned the additional service feature **(design bollard pull = [T_{BP}/9,81] t)**, subject to bollard pull tests being carried out according to a procedure accepted by the Society.

The requirements for the assignment and the maintenance of this additional service feature are given respectively in Part E, Chapter 1 and Ch 4, Sec 8, [6].

Ships granted with the additional service feature **(design bollard pull = [T_{BP}/9,81] t)** may be granted with the additional service feature **(standardized design bollard pull = [T_{BP}/9,81] t)** after having satisfactorily carried out the bollard pull test laid down in Pt E, Ch 1, App 1.

These ships which are likely to operate at sea within specific limits may, under certain conditions, be granted an operating area notation. For the definition of operating area notation, reference should be made to [5.3].

4.10.2 Tug

The service notation **tug** is assigned to ships specially equipped for towing and/or pushing.

Note 1: The service notation **tug** may also be used as an additional service notation combined with **offshore support vessel** or **wind farm operation vessel**.

4.10.3 Salvage tug

The service notation **salvage tug** is assigned to ships specially equipped for towing and/or pushing, having specific equipment for salvage.

4.10.4 Escort tug

The service notation **escort tug** is assigned to ships specially equipped for towing and/or pushing having specific equipment for escorting ships or units during navigation.

The service notation **escort tug** is always completed by the following additional service features:

- **(design maximum braking force = [$T_{X,MAX}$/9,81] t)**

  where the value $T_{X,MAX}$ is the highest rated braking force over the applicable range of loading conditions and escort speeds
- **(design maximum escort speed = [V_{MAX}] kn)**

  where the value V_{MAX} is the highest escort speed for which the escort tug is considered to perform escort operations
- **(design maximum steering force = [$T_{Y,MAX}$/9,81] t)**

  where the value $T_{Y,MAX}$ is the highest rated steering force over the applicable range of loading conditions and escort speeds.

4.11 Working ships

4.11.1 General

The service notations related to ships specially intended for different working services are listed in [4.11.2] to [4.11.5]. These service notations may be assigned directly to a ship or combined within the service notations **offshore construction vessel**, **wind farm installation vessel**, **offshore support vessel** or **wind farm operation vessel** defined in [4.12].

4.11.2 Anchor handling vessel

The service notation anchor handling is assigned to towing vessels and/or supply vessels equipped with winches for anchor handling, having an open stern to allow the decking of anchors and an appropriate thrust to perform the intended anchor handling operations, consisting in deployment, recovering and repositioning of anchors and the associated mooring lines of rigs or other vessels. The additional requirements of Ch 4, Sec 8, [10] and Part E, Chapter 2 are applicable to these ships.

Note 1: As a rule, the service notation tug is also to be assigned in combination with the service notation anchor handling vessel; the additional requirements of Ch 4, Sec 8, [6] and Part E, Chapter 1 are applicable to these ships

4.11.3 Fire-fighting ship

The service notation **fire-fighting** is assigned to ships specially intended and equipped for fighting fire. The additional requirements of Ch 4, Sec 8, [8] and Part E, Chapter 4 are applicable to these ships.

The service notation may be completed by the following additional service features, as applicable:

- **1** or **2** or **3**, when the ship complies with the applicable requirements of Pt E, Ch 4, Sec 3
- **E**, when the characteristics of the water fire-fighting system are not those required for the assignment of the additional service features **1**, **2** or **3**, and when the system is specially considered by the Society
- **water spraying**, when the ship is fitted with a water-spraying system complying with the applicable requirements of Pt E, Ch 4, Sec 4, [3].

4.11.4 Oil recovery ship

The service notation **oil recovery** is assigned to ships specially equipped with fixed installations and/or mobile equipment for the removal of oil from the sea surface and its retention on board, carriage and subsequent unloading. The additional requirements of Ch 4, Sec 8, [9] and Part E, Chapter 5 are applicable to these ships.

The service notation may be completed by the following additional service features, as applicable:

- **OILTREAT** may be assigned to ships designed and equipped to recover polluted water which is subjected to a chemical and/or a physical treatment, in order to separate the oil from the polluted water. The separated oil is to be stored and transported in dedicated tanks
- **SECOND-LINE** may be assigned to ships designed and equipped to recover polluted water in the event of spills of oils which have, at the time of recovery, a flash point exceeding 60°C (closed cup test). This service feature is not to be assigned to oil recovery ships carrying heated recovered oils within 15°C of their flash point.

4.11.5 Diving support

The following service notations are assigned to units specially intended for support of diving operation:

a) **Diving support-integrated,** for ships and units having a permanent diving system installed

b) **Diving support-capable**, for ships and units having a non-permanent diving system and when the diving equipment is not installed

c) **Diving support-portable**, for ships and units having a non-permanent diving system and when the diving equipment is installed.

The requirements for the assignment of these service notations are given in Part E, Chapter 7.

The service notations **diving support-integrated** and **diving support-portable** are to be completed by the following additional service features:

a) **DD**, when the ship is equipped with a deep diving system

b) **SD**, when the ship is equipped with a shallow diving system.

The additional requirements of Ch 4, Sec 8, [13] are applicable to ships or units assigned with the service notations **diving support-integrated** or **diving-support-portable**.

Note 1: The classification of the diving support units and the classification of the diving systems are independent. The diving systems are covered by NR610, Rules for the Classification of Diving Systems.

Note 2: For non-permanent diving systems, the notation **diving support-capable** is to be replaced by the temporary notation **diving support-portable** before conducting any diving operations. To this end, requirements of Part E, Chapter 7 are to be fulfilled allowing the service to become fully effective.

4.12 Offshore and/or wind farm service vessels

4.12.1 General

The following service notations are assigned to ships or units specially intended for offshore operations:

- **offshore construction barge ( )**, as defined in [4.12.2]
- **offshore construction vessel ( )** or **wind farm installation vessel ( )**, as defined in [4.12.3]
- **offshore support vessel ( )** or **wind farm operation vessel ( )**, as defined in [4.12.4]

with between brackets at least one or several of the relevant service notations defined in [4.10.2], [4.11] and [4.12.5] to [4.12.10].

The applicable list of service notations that may be combined between bracket with **offshore construction barge**, **offshore construction vessel**, **wind farm installation vessel**, **offshore support vessel** and **wind farm operation vessel** are indicated in Tab 2 and in [4.12.2], [4.12.3] or [4.12.4].

Ships assigned one of the above service notation and fitted with legs complying with Pt E, Ch 8, Sec 7, are eligible for the assignment of the additional service feature **self elevating**.

Note 1: The service notations listed in [4.12.5] to [4.12.10] are not considered as stand-alone service notations and can not be assigned without being associated with one of the service notation: **offshore construction barge**, **offshore construction vessel**, **wind farm installation vessel**, **offshore support vessel** or **wind farm operation vessel**.

4.12.2 Offshore construction barge

The service notation **offshore construction barge** is assigned to non-propelled units intended to perform construction operation offshore.

The service notation is to be completed with, between brackets and separated by a semicolon, one or several of the following service notations and their relevant additional service feature:

- **accommodation** (as defined in [4.12.5])
- **lifting** (as defined in [4.12.6])
- **pipe laying** (as defined in [4.12.7]).

The service notation **offshore construction barge** is to be complete by the additional service feature **-no propulsion** defined in [4.16.1].

Offshore construction barges fitted with legs are granted with the additional service feature **self elevating**, when found in compliance with the relevant requirements of Pt E, Ch 8, Sec 7. The requirements for the maintenance of the notation are given in NR445 Rules for the Classification of Offshore Units, Part A, Chapter 2, as applicable.

Example: **offshore construction barge (accommodation SP150; lifting) -no propulsion**.

4.12.3 Offshore construction vessel and wind farm installation vessel

The service notation **offshore construction vessel** is assigned to ship-shaped, self-propelled units intended to perform construction operations at sea.

The service notation **wind farm installation vessel** is assigned to ship-shaped, self-propelled units mainly intended to perform installation of offshore wind turbines or other construction operations at sea.

The service notation is to be completed with, between brackets and separated by a semicolon, one or several of the following service notations and their relevant additional service feature:

- **accommodation** (as defined in [4.12.5])
- **cable laying** (as defined in [4.12.8])
- **diving support** (as defined in [4.11.5])
- **lifting** (as defined in [4.12.6])
- **pipe laying** (as defined in [4.12.7]).

Offshore construction vessels and wind farm installation vessels fitted with legs are assigned the additional service feature **self elevating**, when found in compliance with the relevant requirements of Pt E, Ch 8, Sec 7. The requirements for the maintenance of the notation are given in NR445 Rules for the Classification of Offshore Units, Part A, Chapter 2, as applicable.

Table 2 : List of service notations and additional service features for offshore and wind farm service vessels

Service notation [ref. in Part A] **Additional service feature**	**Associated service notation** [ref. in Part A] **Additional service feature**	Reference Reference
offshore construction barge [4.12.2]	**accommodation** [4.12.5]	Part E, Chapter 11
	SPxxx or **SPxxx-capable** **IPxxx** or **IPxxx-capable** **MOU**	
	lifting [4.12.6]	Part E, Chapter 8
	pipe laying [4.12.7]	Part E, Chapter 12
offshore construction vessel, or **wind farm installation vessel** [4.12.3]	**accommodation** [4.12.5]	Part E, Chapter 11
	SPxxx or **SPxxx-capable** **IPxxx** or **IPxxx-capable** **MOU**	
	cable laying [4.12.8] **(1)**	Part E, Chapter 6
	diving support-integrated [4.11.5] **diving support-capable** [4.11.5] **diving support-portable** [4.11.5]	Part E, Chapter 7
	DD or **SD**	
	lifting [4.12.6]	Part E, Chapter 8
	pipe laying [4.12.7]	Part E, Chapter 12
offshore support vessel or **wind farm operation vessel** [4.12.4]	**accommodation** [4.12.5]	Part E, Chapter 11
	SPxxx or **SPxxx-capable** **IPxxx** or **IPxxx-capable** **MOU**	
	anchor handling [4.11.2]	Part E, Chapter 2
	diving support-integrated [4.11.5] **diving support-capable** [4.11.5] **diving support-portable** [4.11.5]	Part E, Chapter 7
	DD or **SD**	
	fire-fighting [4.11.3] **(1)**	Part E, Chapter 4
	1, **2**, **3** or **E** **water spraying**	Pt E, Ch 4, Sec 3 Pt E, Ch 4, Sec 4
	lifting [4.12.6]	Part E, Chapter 8
	oil recovery [4.11.4]	Part E, Chapter 5
	OILTREAT **SECOND-LINE**	
	standby rescue [4.12.9]	Part E, Chapter 10
	number of survivors **ship operation area**	
	supply [4.12.10] **(1)**	Part E, Chapter 3
	HNLS or **WELLSTIM** **(2)**	
	tug [4.10] **(1)**	Part E, Chapter 1
	(design bollard pull = [T_{BP}/9,81] t) **(standardized design bollard pull = [T_{BP}/9,81] t)**	Pt E, Ch 1, Sec 1
ADDITIONAL SERVICE FEATURES **(3)**		
no propulsion [4.16.1] **(4)**		Part D, Chapter 14
self elevating [4.12.2], [4.12.3] or [4.12.4]		Pt E, Ch 8, Sec 7
SRTP [4.16.8] **(5)**		Part D, Chapter 11

(1) For ships granted with the service notation **cable laying**, **fire-fighting**, **supply** or **tug**, the corresponding type of ship according to SOLAS (Reg 1/2(g)) may be cargo ship.

(2) May be completed by the following notation(s): **- FP ≤ 60°C**, **- toxic**, **- acids**, **- LG**.

(3) Other additional service features as listed in Tab 1 may be assigned to offshore service vessels and wind farm service vessels.

(4) Only for service notation **offshore construction barge**.

(5) Only completing the additional service feature **SPxxx** or **IPxxx**, when conditions are met as defined in respectively [4.16.8] or [4.16.9].

4.12.4 Offshore support vessel and wind farm operation vessel

The service notation **offshore support vessel** is assigned to ship-shaped, self-propelled units intended to perform inspection,light construction work, maintenance, repair or supply operations for an offshore installation.

The service notation **wind farm operation vessel** is assigned to ship-shaped,self-propelled units mainly intended to perform:

- inspection, light construction work, maintenance, repair or supply operations for wind farms
- support to wind farm installation operations.

The service notation is to be completed with, between brackets and separated by a semicolon, one or several of the following service notations and their relevant additional service feature:

- **accommodation** (as defined in [4.12.5])
- **anchor handling** (as defined in [4.11.2])
- **diving support** (as defined in [4.11.5])
- **fire-fighting** (as defined in [4.11.3])
- **lifting** (as defined in [4.12.6])
- **oil-recovery** (as defined in [4.11.4])
- **standby and rescue** (as defined in [4.12.9])
- **supply** (as defined in [4.12.10])
- **tug** (as defined in [4.10.2]).

Offshore support vessels and wind farm operation vessels fitted with legs are assigned the additional service feature **self elevating**, when found in compliance with the relevant requirements of Pt E, Ch 8, Sec 7. The requirements for the maintenance of the notation are given in NR445 Rules for the Classification of Offshore Units, Part A, Chapter 2, as applicable.

Example: **offshore support vessel (supply HNLS; fire-fighting 2; oil recovery OILTREAT) self elevating**.

4.12.5 Accommodation unit

In compliance with [4.12.2], [4.12.3] and [4.12.4] the service notation **accommodation** is assigned to ships intended to accommodate personnel working offshore.

This service notation **accommodation** is completed by at least one of the following additional service features:

a) when the ship complies with the IMO "Code of Safety for Special Purpose Ships" carrying more than twelve (12) special personnel:
   - **SPxxx**, when accommodation facilities are permanently installed on board and where **xxx** is the total number of persons on board, as defined in [4.16.8]
   - **SPxxx-capable**, when accommodation facilities may be added as separate modules during the service life of the ship and where **xxx** is the total number of persons on board once the modules have been added, as defined in [4.16.8].

b) when the ship complies with the IMO "Code of Safety for Ships carrying Industrial Personnel" carrying more that twelve (12) industrial personnel:
   - **IPxxx**, when accommodation facilities are permanently installed on board and where **xxx** is the total number of persons onboard, as defined in [4.16.9]
   - **IPxxx-capable**, when accommodation units may be added as separate modules during the service life of the ship and where **xxx** is the total number of persons on board once the modules have been added, as defined in [4.16.9]

The additional service features are completed by the additional service feature **MOU**, when the ship complies with the requirements of Ch.2 to 9 and Ch.13 of IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU Code).

For ships assigned **SPxxx** and **SPxxx-capable** or **IPxxx** and **IPxxx-capable** together, when modules are added or removed, the service features have to be adjusted accordingly. For example, for a ship assigned **SP100** and **SP200-capable**, when adding modules for 50 persons, the service features have then to be modified for **SP150** and **SP200-capable** or, when adding modules for 100 persons, **SP200** only.

For ships assigned **SPxxx-capable** or **IPxxx-capable** only, when adding modules, the service features have to be adjusted accordingly. For example, for ship assigned **SP100-capable**, when adding modules for 50 persons, the service features have then to be modified for **SP50** and **SP100-capable** or, when adding modules for 100 persons, **SP100** only.

The requirements for the assignment of this notation are given Part E, Chapter 11.

4.12.6 Lifting unit

In compliance with [4.12.2], [4.12.3] and [4.12.4], the service notation **lifting** is assigned to ships or unit intended to perform lifting operations at sea, engaged in an operation involving the raising or lowering of objects using vertical force by means of winches, cranes, A-frames or other lifting devices.

The requirements for the assignment and maintenance of this notation are given respectively in Part E, Chapter 8 and in Ch 4, Sec 8, [12].

Note 1: The service notation **lifting** can only be assigned to the ship if the corresponding lifting unit is covered by at least one of the additional class notations **ALM** or **OHS**.

4.12.7 Pipe laying unit

In compliance with [4.12.3] the service notation **pipe laying** is assigned to ships fitted with equipment used for assembling and installing rigid or flexible pipelines to the seabed.

The requirements for the assignment and maintenance of this notation are given respectively in Part E, Chapter 12 and in Ch 4, Sec 8, [19].

4.12.8 Cable laying ship

In compliance with [4.12.3] the service notation **cable laying** is assigned to ships specially equipped for the carriage and/or laying, hauling and repair of submarine cables. The additional requirements of Ch 4, Sec 8, [11] and Part E, Chapter 6 are applicable to these ships.

4.12.9 Standby and rescue vessel

In compliance with [4.12.4], ships complying with the requirements of Part E, Chapter 10 are eligible for the assignment of the service notation **standby rescue**.

This service notation is to be completed by the number of survivors that the vessel is intended to carry, as for example: **standby rescue (150 survivors)**.

Depending on the vessel operation area, the Society may adapt the requirements regarding the survivors accommodation and/or the safety equipment. In such a case, this service notation is to be also completed by the vessel operation area, as for example: **standby rescue (150 survivors, Guinea Gulf)**.

The additional requirements of Ch 4, Sec 8, [15] are applicable to these ships.

4.12.10 Supply vessel

In compliance with [4.12.4] the service notation **supply** is assigned to ships intended to support offshore operations by carrying deck cargoes and oil products (MARPOL Annex 1) in bulk with flash point not less than 60°C, cement, dry mud and non-hazardous liquid mud in underdeck tanks.

Where applicable, the service notation **supply** is to be completed by one or several of the following additional service features:

- **WELLSTIM**, for well stimulation vessels
- **HNLS**, for ships, other than well stimulation vessels, carrying hazardous and noxious substances in bulk for the servicing and resupplying of offshore platforms, mobile offshore drilling units and other offshore installations, including those employed in the search for and recovery of hydrocarbons from the sea-bed.

The additional service features **HNLS** and **WELLSTIM** are to be completed by one or several of the following notations when carriage of products mentioned below is considered:

- **-FP≤60°C**: when ship may carry products with a flash point equal to or less than 60°C
- **-toxic**: when ship may carry toxic products
- **-acids**: when ship may carry acid products.
- **-LG**: when ship may carry liquid carbon dioxide and liquid nitrogen.

The additional requirements of Ch 4, Sec 8, [7] and Part E, Chapter 3 are applicable to these ships.

4.13 Ships for dredging activities

4.13.1 Ships specially intended for dredging activities are assigned the following service notations:

- **dredger**, for ships specially equipped only for dredging activities (excluding carrying dredged material)
- **hopper dredger**, for ships specially equipped for dredging activities and carrying spoils or dredged material
- **hopper unit**, for ships specially equipped for carrying spoils or dredged material
- **split hopper unit**, for ships specially equipped for carrying spoils or dredged material and which open longitudinally, around hinges
- **split hopper dredger**, for ships specially equipped for dredging and for carrying spoils or dredged material and which open longitudinally, around hinges.

These ships are to be granted not less than one of the operating area notation defined in [5.3.2]. For the definition of operating area notation, reference is to be made to [5.3].

The additional service feature **EOC** (Enhanced Operating Conditions) is granted to:

- ships greater than 90 m in length and assigned the service notation **dredger**
- ships greater than 65 m in length and assigned one of the service notation **hopper dredger**, **hopper unit**, **split hopper dredger** or **split hopper unit**

when specific fatigue calculations are performed, according to the applicable requirements of Pt D, Ch 13, Sec 2, to allow enhanced operational limits, unless no operating area notation other than **unrestricted dredging area (T = x m)** as defined in [5.3.2], is assigned.

The additional requirements of Ch 4, Sec 8, [5] and Part D, Chapter 13 are applicable to these ships.

4.14 Barge and pontoon

4.14.1 Barge

The service notation **barge** is assigned to non-propelled units intended to carry, inside holds or tanks, dry or liquid cargo except liquefied gases or other substances listed in Pt D, Ch 9, Sec 1.

The additional requirements of Part D, Chapter 14 are applicable to these ships.

For ships intended to carry only one type of cargo, the service notation may be completed by an additional service feature indicating the type of product carried e.g. **barge - oil**, **barge - general cargo**, **barge - chemical**.

This service notation may be completed by the additional service feature **tug combined** when the units are designed to be connected with tugs and comply with the relevant requirements of Pt E, Ch 1, Sec 4. The tugs to which the barge can be connected are specified in a memorandum.

4.14.2 Pontoon

The service notation **pontoon** is assigned to non-propelled units intended to carry cargo and/or equipment on deck only. When a crane is permanently fitted on board, the crane is to be certified and the service notation **pontoon - crane** is granted. The additional requirements of Part D, Chapter 14 are applicable to these ships.

4.15 Miscellaneous units

4.15.1 Special service

The service notation **special service** is assigned to ships which, due to the peculiar characteristics of their activity, are not covered by any of the notations mentioned above. The classification requirements of such units are considered by the Society on a case by case basis.

This service notation may apply, for instance, to ships engaged in research, expeditions and survey, ships for training of marine personnel, whale and fish factory ships not engaged in catching, ships processing other living resources of the sea, and other ships with design features and modes of operation which may be referred to the same group of ships.

An additional service feature may be specified after the notation (e.g. **special service-training**, **special service-fish factory**) to identify the particular service in which the ship is intended to trade. The scope and criteria of classification of such units are indicated in a memorandum.

4.15.2 Launch

The launches or motorboats with a length not exceeding 24 m and meeting the requirements of both NR566 Hull Arrangement, Stability and Systems for Ships less than 500 GT and NR600 Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m are assigned the following service notations:

- **seagoing launch**, for units intended for seagoing service, limited at a wind force not exceeding 6 Beaufort scale
- **launch**, for units intended for operation in ports, roadsteads, bays and generally calm stretches of water, limited at a wind force not exceeding 4 Beaufort scale.

Note 1: Ships that are assigned the service notation **launch** or **seagoing launch** are not assigned a navigation notation.

4.15.3 Yacht and charter yacht

The service notation **yacht** or **charter yacht** is assigned to ship intended for pleasure cruising, as follows:

- **yacht**, when the ship is not engaged in trade
- **charter yacht**, when the ship is engaged in trade.

The service notation **yacht** or **charter yacht** is always completed by one of the following additional service features, as applicable:

- **motor** for units propelled by propulsion engine
- **sailing** for units with a sail propulsion, including those assisted by auxiliary propulsion engine.

Examples:

yacht-motor

yacht-sailing

charter yacht-motor

charter yacht-sailing

The service notation **yacht** or **charter yacht** is always completed by one of the additional service feature, as applicable:

- **S** when the hull is made of steel material
- **C** when the hull is made of composite material
- **A** when the hull is made of aluminium
- **W** when the hull is made of wood material.

Example:

yacht-motor-S

The requirements for the assignment of these notations are given in NR500, Rules For The Classification and the Certification of Yachts.

The requirements for the maintenance of these notations are given in NR500, Rules For The Classification and the Certification of Yachts and in Ch 4, Sec 8, [16].

In accordance with NR206, upon request, the additional service feature **WIND PROPULSION-1** or **WIND PROPULSION-2** may be assigned in addition to the additional service feature **sailing**. The requirements for the assignment and maintenance of these additional service features are given respectively in NR206 and Ch 4, Sec 12.

4.15.4 Crew transfer vessels

The service notation **crew transfer vessel** is assigned to ships less than 500 GT, dedicated to:

- transport offshore personnel from harbours to moored offshore installations or ships,or
- transfer of personnel from shore to offshore wind farms or from mother ships or accommodation units at site to offshore wind farms,

proceeding in the course of their voyage not more than four hours at operational speed from a place of refuge, and meeting the requirements of NR490, Rules for the Classification of Crew Transfer Vessels.

Ships which do not fulfil the minimum speed criteria given in NR490, Sec 1, [1], are not to be assigned the above service notation.

These ships which are likely to operate at sea within specific limits may, under certain conditions, be granted an operating area notation. For the definition of operating area notation, reference should be made to [5.3].

4.15.5 FSRUs and FSUs

The requirements for the assignment of a service notation for Floating Storage Regasification Units (FSRUs) and Floating gas Storage Units (FSUs) are given in NR645 Rules for the Classification of Floating Storage Regasification Units and Floating gas Storage Units.

The following service notations may be assigned to FSRUs and FSUs, as relevant:

- **liquefied gas carrier - FSRU**, when the floating unit is designed to operate as a regasification unit with the possibility of trading LNG in a navigation mode
- **liquefied gas carrier - FSU**, when the floating unit is designed to operate as a storage unit with the possibility of trading LNG in a navigation mode
- **FSRU**, when the floating unit is designed to operate as a regasification unit permanently moored without trading LNG
- **FSU-LNG**, when the floating unit is designed to operate as a storage unit permanently moored without trading LNG.

Note 1: Typical notations to be assigned to complete the service notations are described in NR645.

These service notations are to be completed by the additional service feature **([cargo type], [ship type], [cargo containment system type], [cargo tank design pressure], [minimum temperature])** as defined in [4.4.5].

The requirements for the maintenance of these notations are given in NR645 and in:

- Ch 4, Sec 5, for units granted with **liquefied gas carrier - FSRU** or **liquefied gas carrier - FSU** notation
- NR445 Rules for the Classification of Offshore Units, for units granted with **FSRU** or **FSU-LNG** notation,

as applicable.

4.15.6 Unmanned surface vessel (USV)

The service notation **USV** is assigned to unmanned surface units.

The type of service is to be specified after the service notation.

Example: **USV /hydrographic survey ship**

The scope of application and the requirements for the assignment of this service notation are given in NR681 Rules for Unmanned Surface Vessels (USV).

4.15.7 Other units

For ships or other floating units intended to be classed with other service notations, reference is to be made to the specific Rules of the Society, and in particular:

- Rules for the Classification of Naval Ships (NR483)
- Rules for the Classification of Offshore Units (NR445)
- Rules for the Classification of Harbour Equipment (NR612).

Note 1: The service notation **floating dock** may have been assigned to units contracted for construction before 1 July 2024 and is not applicable to units contracted for construction on or after 1 July 2024. For units contracted for construction on or after 1 July 2024, reference is to be made to NR612.

4.15.8 Inland navigation vessels

For ships and units intended for navigation in inland waters, reference is to be made to the Rules for the Classification of Inland Navigation Vessels (NR217).

4.16 Miscellaneous service features

4.16.1 Non-propelled units

Any non-propelled units other than those covered by the service notations listed in [4.14.1] and [4.14.2] will be assigned the additional service feature **no propulsion**, to be added to their own service notation, e.g. **dredger - no propulsion**.

4.16.2 Assisted propulsion units

Any units having a propulsion system not enabling them to proceed at a speed greater than 7 knots, used for short transit voyages, will be assigned the additional service feature **assisted propulsion** to be added to their own service notation, e.g. **dredger - assisted propulsion**.

4.16.3 Ships with wind propulsion systems

Ships equipped with a wind propulsion system as defined in NR206, Sec 1, [2.1], and assigned a service notation other than **yacht** or **charter yacht**, are to be assigned one of the following additional service features:

- **WIND PROPULSION-1** when the safety rigging parts of the wind propulsion system are included in the scope of classification
- **WIND PROPULSION-2** when both the safety and the operating rigging parts of the wind propulsion system are included in the scope of classification.

The requirements for the assignment of these notations are given in NR206, Wind Propulsion Systems.

The requirements for the maintenance of these notations are given in Ch 4, Sec 12.

Note 1: The safety rigging parts and operating rigging parts are defined in NR206 Sec 1 [2.2].

4.16.4 Ships with low flashpoint liquid or gas fuelled propulsion

The service notation is to be completed by one or more of the following additional service features, as applicable:

- **LNGFuel,** for ships fitted with engines, fuel cells or gas turbines using natural gas as fuel, stored in liquefied form
- **CNGFuel,** for ships fitted with engines, fuel cells or gas turbines using compressed natural gas as fuel
- **LPGFuel,** for ships fitted with engines, fuel cells or gas turbines using petroleum gas as fuel, in liquefied or gaseous form
- **methanolfuel,** for ships fitted with engines, fuel cells or gas turbines using methanol as fuel
- **ammoniafuel,** for ships fitted with engines, fuel cells or gas turbines using ammonia as fuel
- **hydrogenfuel**, for ships fitted with engines, fuel cells or gas turbines using hydrogen as fuel
- **LFPFuel,** for ships fitted with engines, fuel cells or gas turbines using a low flashpoint fuel different from the fuels mentioned above.

Note 1: Natural gas means gaseous mixture consisting mainly of methane and which may also contain smaller amounts of ethane, propane and butane.

Note 2: Petroleum gas means gaseous mixture consisting mainly of propane and butane.

Each additional service feature is to be completed by one of the following notations:

- **singlefuel** for ships fitted with engines, fuel cells or gas turbines using only the fuel considered
- **dualfuel** for ships fitted with engines or gas turbines using both the fuel considered and fuel oil.

The notations **singlefuel** or **dualfuel** may be completed by:

- **-aux**, when the ship uses the fuel considered only for the generating set
- **-prop**, when the ship uses the fuel considered only for the propulsion system.

Note 3: **-aux** and **-prop** are not added to **singlefuel** or **dualfuel** when both auxiliaries and propulsion are using the same fuel considered.

The requirements for the assignment of these additional service features are given in:

- Pt D, Ch 9, Sec 1, [1.1.6] for gas carriers
- NR529 Gas-fuelled Ships
- NR647 LPG-fuelled Ships
- NR670 Methanol & Ethanol-fuelled Ships
- NR671 Ammonia-fuelled Ships
- NR678 Hydrogen-fuelled Ships.

The additional requirements of Ch 4, Sec 9 are applicable to these ships, except gas carriers using their cargo as fuel, for which the applicable requirements are given in Ch 4, Sec 5.

The additional service feature **LFPfuel** is assigned to ships fitted with engines, fuel cells or gas turbines using a low flashpoint liquid fuel or gas different from the fuels mentioned above when this has been specially considered by the Society.

Examples:

CNGfuel singlefuel -prop

ammoniafuel dualfuel

methanolfuel dualfuel -aux LNGfuel singlefuel -prop

Subject to compliance with the requirements of [4.16.5], the above additional service features are completed with **fuelcell**, when the ship is fitted with a fuel cell system.

4.16.5 Ships fitted with a fuel cell power installation

The additional service feature **fuelcell** is to be assigned to ships fitted with a fuel cell power installation.

The requirements for the assignment and the maintenance of this additional service feature are given respectively in NR547 Ship using Fuel Cells and in Ch 4, Sec 10.

Prior to the assignment of the additional service feature **fuelcell** and with respect to the primary fuel considered, granting of at least one of the additional service feature listed in [4.16.4] is mandatory.

The primary fuel or fuels used by the fuel cell are to be indicated in a memorandum.

Examples:

LNGfuel dualfuel fuelcell

LFPfuel singlefuel -aux fuelcell

The additional requirements of Ch 4, Sec 9 are applicable to these ships, except gas carriers using their cargo as fuel, for which the applicable requirements are given in Ch 4, Sec 5.

4.16.6 Electric ships

Ships relying only on batteries for propulsion and/or main source of electrical power are to be assigned the additional service feature **battery system**.

For ships relying only on batteries for electrical power supply, including emergency power supply and propulsion, the additional service feature **battery system** may be completed by **-ZE**.

For other ships, designed, built and equipped according to the requirements given in Pt C, Ch 2, Sec 7, [5] for the use of batteries for propulsion and/or electric power supply, the additional service feature **battery system** may be assigned upon request.

The requirements for the assignment of this notation are given in Pt C, Ch 2, Sec 7.

The requirements for the maintenance of this notation are given in Ch 4, Sec 13.

4.16.7 Tier III

The additional service feature **Tier III** is assigned to ships for which the main engine and auxiliary engines are issued with an EIAPP certificate (Engine International Air Pollution Prevention Certificate) stating compliance with Tier III according to the applicable Marpol Convention requirements.

4.16.8 Special purpose ships (SPxxx)

Ships complying with the IMO Code of Safety for Special Purpose Ships carrying more than twelve (12) special personnel are to be assigned the additional service feature **SPxxx**, where **xxx** is the total number of persons onboard including crew, special personnel and passengers (maximum twelve).

The requirements for the assignment of this additional service feature consist of:

- the general requirements of the present Rules, and
- the additional requirements given in:
  - Pt B, Ch 2, Sec 1; Pt B, Ch 2, Sec 2; Pt B, Ch 3, Sec 1; Pt B, Ch 3, Sec 3 and Pt B, Ch 3, App 2 for stability
  - Pt C, Ch 1, Sec 10 and Pt C, Ch 1, Sec 14 for machinery and systems
  - Pt C, Ch 2, Sec 3 for electrical installations and automation, and
  - Pt C, Ch 4, Sec 1 for fire protection, detection and extinction.

The additional service feature **SPxxx** is to be completed by the additional service feature **SRTP** when:

- **xxx** is greater than 240 and
- L_{LL} as defined in Pt B, Ch 1, Sec 3, [2.1.2] is greater than or equal to 120 m or the ship includes three or more main vertical zones as defined in Pt C, Ch 4, Sec 1, [2.31].

4.16.9 Ships carrying industrial personnel (IPxxx)

Ships complying with IMO Code of Safety for Ships carrying industrial personnel with more than twelve (12) industrial personnel are to be assigned the additional service feature **IPxxx**, where **xxx** is the total number persons on board including crew, passengers, special personnel and industrial personnel.

The requirements for the assignment of this additional service feature consist of:

- the general requirements of the present Rules, and

- the specific requirements given in:
  - Pt B, Ch 2, Sec 1; Pt B, Ch 2, Sec 2; Pt B, Ch 3, Sec 1; Pt B, Ch 3, Sec 3 and Pt B, Ch 3, App 2 for stability
  - Pt C, Ch 1, Sec 10 and Pt C, Ch 1, Sec 14 for machinery and systems
  - Pt C, Ch 2, Sec 3 for electrical installations and automation, and
  - Pt C, Ch 4, Sec 1 for fire protection, detection and extinction.

Additional requirements are to be applied to ships assigned the following service notations:

- **oil tanker** or **FLS tanker**, see Pt D, Ch 7, Sec 1, [1.2.1]
- **chemical tanker**, see Pt D, Ch 8, Sec 1, [2.1]
- **liquefied gas carrier**, see Pt D, Ch 9 Sec 1, [3.3]
- **supply**, see Pt E, Ch 3, Sec 1, [1.5.1].

The additional service feature **IPxxx** is to be completed by the additional service feature **SRTP** when:

- **xxx** is greater than 240, and
- L_{LL} as defined in Pt B, Ch 1, Sec 3, [2.1.2] is greater than or equal to120 m or the ship includes three or more main vertical zones as defined in Pt C, Ch 4, Sec 1, [2.31].

4.16.10 Ships operating in polar waters

The following additional service features are assigned to ships which are in compliance with the corresponding ship category according to the IMO International Code for Ships Operating in Polar Waters (Polar Code):

- **POLAR CAT-A** for ships defined as “Category A” ships in respect of the IMO International Code for Ships Operating in Polar Waters
- **POLAR CAT-B** for ships defined as “Category B” ships in respect of the IMO International Code for Ships Operating in Polar Waters
- **POLAR CAT-C** for ships defined as “Category C” ships in respect of the IMO International Code for Ships Operating in Polar Waters.

The requirements for the assignment of these additional service features are detailed in NR527, Rules for the Classification of Ships Operating in Polar Waters and Icebreakers.

4.16.11 Carriage of heavy cargo

When the double bottom and/or hatch covers and/or other cargo areas designed to support heavy cargoes fulfil the appropriate rule requirements, the additional service feature **heavycargo [AREA1, X1 kN/m² - AREA2, X2 kN/m² - ...]** may complete the service notation of a ship. The values Xi indicate the maximum allowable local pressures on the various zones AREAi where the cargo is intended to be stowed.

The requirements for the assignment of this additional service feature are given in Pt B, Ch 5, Sec 6, [6.1.2].

4.16.12 Coating performance standard

The additional service feature **CPS(WBT)** is assigned to the following ships:

- bulk carriers assigned with the additional service feature **CSR** and contracted for construction on or after 8 December 2006, for which the rule requirements of NR530 Coating Performance Standard, applicable to ships complying with the requirements of the Common Structural Rules for Bulk Carriers or the Common Structural Rules for Double Hull Oil Tankers and related to protective coatings in dedicated seawater ballast tanks of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of length greater than or equal to 150 m, are applied
- oil tankers assigned with the additional service feature **CSR** and contracted for construction on or after 8 December 2006, for which the rule requirements of NR530 Coating Performance Standard, applicable to ships complying with the requirements of the Common Structural Rules for Bulk Carriers or the Common Structural Rules for Double Hull Oil Tankers and related to protective coatings in dedicated seawater ballast tanks of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of length greater than or equal to 150 m, are applied
- ships complying with IMO resolution MSC.215(82), as amended, and contracted for construction on of after 1 July 2008.

Note 1: For other ships complying with the requirements of NR530 Coating Performance Standard, reference is made to [6.24.4] for the possible assignment of the additional class notation **CPS(WBT)**.

4.16.13 Power generation

The additional service features:

- **POWERGEN(OIL)**
- **POWERGEN(LNG/NG)**
- **POWERGEN(DUALFUEL)**

are assigned to units fitted with power generation equipment to serve as a power generation resource.

The requirements for the assignment of these additional service features are given in NR656.

4.16.14 Cyber security

The following ships equipped with computer-based systems are to comply with the requirements of NR659, Chapter 3 and, as applicable with the requirements of NR659, chapter 5:

a) Passenger ships (including passenger high-speed craft) engaged on international voyages

As a rule, this includes:

- ships assigned one of the service notations listed in [4.5]
- ships assigned one of the service notations **HSC CAT-A**, **HSA CAT-B** or **light ship/fast passenger vessel** (see [4.6.1] and [4.6.2])
- ships assigned the service notation **charter yacht** and carrying more than 12 passengers (see [4.15.3])

b) Cargo ships of 500 GT and upwards engaged on international voyages

As a rule, this includes:

- ships assigned one of the service notations listed in [4.2], [4.3], [4.4], [4.9], [4.10], [4.11] or [4.13]
- ships assigned one of the service notations **liquefied gas carrier -FSRU** or **liquefied gas carrier -FSU** (see [4.15.5])

c) High speed crafts of 500 GT and upwards engaged on international voyages

As a rule, this includes:

- ships assigned one of the service notations **HSC** or **light ship/fast cargo vessel** (see [4.6.1] and [4.6.2])

d) Self-propelled, ship-shaped units of 500 GT and upwards engaged in construction (i.e wind turbine installation, maintenance and repair, crane units, drilling tenders, accommodation, etc)

As a rule, this includes:

- units assigned the service notation **offshore construction vessel** or **wind farm installation vessel** (see [4.12.3])
- units assigned the service notation **offshore support vessel** or **wind farm operation vessel** (see [4.12.4]).

These ships are to be assigned the additional service feature **CYBER RESILIENT**.

The requirements for the assignment of the additional service feature are given in NR659 Rules on Cyber Security for the Classification of Marine Units.

The requirements for the maintenance of this notation are given in Ch 5, Sec 17.

Note 1: For ships of 500 GT and upwards assigned the service notation **special service**, and engaged on international voyages, the Society is to decide on a case-by-case basis the application of the additional service feature **CYBER RESILIENT**.

Note 2: Ships complying with the requirements of NR659 Chapter 4 may be assigned the additional class notation **CYBER SECURE**, as defined in [6.21.1], in addition to the additional service feature **CYBER RESILIENT**.

4.16.15 Computerized systems

The additional service feature **SW-Registry** is assigned to ships contracted for construction on or after 1st July 2017, provided with a software registry meeting the related requirements laid down in Pt C, Ch 3, Sec 3 for the assignment and those laid down in Ch 3, Sec 1 and Ch 3, Sec 3 for the maintenance of the software registry.

This additional service feature **SW-Registry** is assigned to existing ships provided with a software registry in compliance with the related requirements laid down in Pt C, Ch 3, Sec 3; requirements for the maintenance of the notation are indicated in Ch 3, Sec 1 and Ch 3, Sec 3.

4.16.16 Condition based maintenance

The additional service features **CBM** and **[CBM]** are assigned to ships where a Planned Maintenance Survey system for machinery (PMS) is implemented and on which at least one machinery item is to be surveyed under a Condition Based Maintenance scheme, according to the requirements of Ch 2, Sec 2, [4.4] and Ch 2, App 4.

The additional service features **CBM-P** and **[CBM-P]** are assigned in lieu of the notations **CBM** and **[CBM]** when the CBM scheme relies on at least one predictive condition monitoring system as defined in NI684.

The additional service features **[CBM]** and **[CBM-P]** are assigned to ships after the Owner's application for the CBM scheme has been received by the Society.

The additional service features **[CBM]** and **[CBM-P]** are replaced by respectively **CBM** or **CBM-P** when the installation survey and the implementation survey are carried out and found satisfactory in accordance with Ch 2, App 4, [3.1] and Ch 2, App 4, [3.2].

Consideration may be given by the Society, on a case by case basis, to withdraw **[CBM]** or **[CBM-P]** in case of significant delay for the Owner's request for the installation survey.

Note 1: See NI684 "Guideline for Condition Based Maintenance" for further details on requirements and class workflow.

The requirements for the assignment and maintenance of these additional service features are given in Ch 2, App 4.

4.16.17 Onboard carbon capture and storage system (OCC)

The additional service feature **OCC** is to be assigned to ships fitted with a carbon capture and storage (CCS) system intended to separate the carbon dioxide (CO_2) from the ship engine exhaust gases and store it on board.

The requirements for the assignment and maintenance of this additional service feature are given respectively in Pt C, Ch 1, Sec 12 and Ch 4, Sec 11.

5 Navigation and operating area notations

5.1 Navigation notations

5.1.1 Every classed ship is to be assigned one navigation notation as listed in [5.2], except those with the service notations **launch** or **seagoing launch**.

5.1.2 The assignment of a navigation notation, including the reduction of scantlings or specific arrangements for restricted navigation notations, is subject to compliance with the requirements laid down in Part B, Part C, Part D and Part E of the Rules and in NR216 Materials and Welding.

5.1.3 The assignment of a navigation notation does not absolve the Interested Party from compliance with any international and national regulations established by the Administrations for a ship operating in national waters, or a specific area, or a navigation zone. Neither does it waive the requirements in Ch 1, Sec 1, [3.3.1].

5.2 List of navigation notations

5.2.1 The navigation notation **unrestricted navigation** is assigned to a ship intended to operate in any area and any period of the year.

5.2.2 The navigation notation **summer zone** is assigned to ships intended to operate only within the geographical limits as defined in ILLC 1966 for the Summer zones.

5.2.3 The navigation notation **tropical zone** is assigned to ships intended to operate only within the geographical limits as defined in ILLC 1966 for the Tropical zones.

5.2.4 The navigation notation **coastal area** is assigned to ships intended to operate only within 20 nautical miles from the shore and with a maximum sailing time of six hours from a port of refuge or safe sheltered anchorage.

5.2.5 The navigation notation **sheltered area** is assigned to ships intended to operate in sheltered waters, i.e. harbours, estuaries, roadsteads, bays, lagoons and generally calm stretches of water and when the wind force does not exceed 6 Beaufort scale.

5.2.6 In specific cases, the designation of the geographical area and/or the most unfavourable sea conditions considered may be added to the navigation notation.

5.2.7 The navigation notation **temporary unrestricted navigation** may be assigned, in addition to the navigation notations defined in [5.2.2], [5.2.3], [5.2.4] and [5.2.5] to service ships for which the period of unrestricted navigation may be chosen to satisfy the conditions defined in a memorandum.

When a favourable weather situation is included amongst these conditions, the voyages are to be such as the ship can be put in a port or a sheltered anchorage in about 12 hours from any point of its route.

Note 1: Before any voyage covered by the navigation notation **temporary unrestricted navigation**, the ship is to be submitted to an occasional survey, during which the Surveyor checks that the intended voyage and the ship's specific condition, if any, comply with the conditions defined in a memorandum.

5.2.8 For ships assigned the service notation:

- **HSC-CAT A**, **HSC-CAT B**, or **HSC** as defined in [4.6.1]
- **light ship**, as defined in [4.6.2], or
- **crew transfer vessel**, as defined in [4.15.4]

as a rule, one of the following navigation notations is to be assigned to such units and is corresponding to sea areas where the significant wave height H.S. is not to exceed for more than 10 per cent of the year the following values:

- **sea area 1**: 0,5 m
- **sea area 2**: 2,5 m
- **sea area 3**: 4,0 m
- **sea area 4**: no limitation.

The shipyard's table of the maximum allowed ship speed relative to the sea states, characterised by their significant wave height, is indicated in a memorandum.

5.2.9 For ships assigned the service notation **yacht** or **charter yacht**, as a rule, one of the following navigation notations is to be assigned:

- **unrestricted navigation**, as defined in [5.2.1]
- **coastal area**, as defined in [5.2.4]
- **sheltered area**, as defined in [5.2.5].

Ships assigned the service notation **charter yacht** and under 300 GT intended to operate only within 60 nautical miles from shore may be assigned the navigation notation **navigation limited to 60 nautical miles**.The designation of the sea condition and the indication of any exemptions are defined in a memorandum.

Note 1: At the request of the Interested Party and on a voluntary basis, the navigation notation **navigation limited to 60 nautical miles** may be assigned to a ship assigned the service notation **yacht** and under 300 GT.

5.3 Operating area notations

5.3.1 The operating area notation expresses the specified area where some service units are likely to operate at sea within specific restrictions which are different from normal navigation conditions.

The operating area notations defined in [5.3.2] are, in principle, solely granted to ships for dredging activities as defined in [4.13].

The operating area notations defined in [5.3.3] are, in principle, solely granted to tugs as defined in [4.10].

The operating area notation defined in [5.3.4] is, in principle, solely granted to crew transfer vessels and light ships as defined, respectively, in [4.15.4] and [4.6.2].

This operating area notation is indicated after the navigation notation.

Example: **unrestricted navigation** - **"operating area notation"**

5.3.2 Operating areas for ships intended for dredging activities

At least one operating area notations is to be assigned to a unit granted with a service notation as specified in [4.13].

a) for units designed to operate specific dredging situations at sea without specific limits:

unrestricted dredging area (T= x m)

where (T= x m) indicates the maximum allowable draught x, in m, corresponding to the dredging situation, as defined in Pt D, Ch 13, Sec 2, [3.1.1].

example: **unrestricted dredging area (T= 5,00 m)**

b) for units designed to operate specific dredging situations at sea under specific limits:

- units which are not granted the additional service feature **EOC**: one or several notations for standard dredging conditions defined in Tab 3, as applicable
- units assigned with the additional service feature **EOC**: one or several notations for enhaced dredging conditions defined in Tab 4, as applicable.

5.3.3 Operating areas for tugs

The following operating area notations may be assigned:

- **operating within 5 miles from shore** for ships granted with the service notation **tug** or **escort tug** which are specially equipped to assist ships and/or floating units while entering or leaving port, within 5 miles from shore, and limited to operate from a single and fixed port.
- **operating ≤ 4h from a place of refuge** for ships granted with the service notation **tug** or **escort tug** which do not proceed in the course of their voyage for more than four hours at operational speed from any naturally or artificially sheltered area which may be used as a shelter by the tug under conditions likely to endanger its safety.
- **escort service limited to non-exposed waters** for ships granted with the service notation **escort tug** which are operating in non-exposed waters, where the environmental impact on the escort service is negligible. In general, waters are considered as non-exposed where the wind fetch is not more than 6 nautical miles and the significant wave height is not more than 1,0 m.

5.3.4 Operating area for crew transfer vessels and light ships

The following operating area notation may be assigned to ships with service notation **crew transfer vessel** or **light ship**:

- **assisted operating area** for ships operating within an area where it has been demonstrated to the satisfaction of the Society that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within 4 hours. For ships operating in harsh environmental conditions, a reduced time of rescue may be required to the satisfaction of Society.

The operating area is to be specified by the party applying for classification and is to be indicated in a memorandum.

Table 3 : Operating area notation for standard dredging conditions under specific limits

Ship length	Operational limits	Operating area notation
less or equal to 110 m	• within 8 miles from shore • over 8 miles from shore with Hs ≤ 1,5 m	**dredging ≤ 8 miles from shore or Hs ≤ 1,5 m (T= x m)**
	• within 15 miles from shore • over 15 miles from shore with Hs ≤ 2,5 m	**dredging ≤ 15 miles from shore or Hs ≤ 2,5 m (T= x m)**
more than 110 m and less or equal to 150 m	• within 8 miles from shore • over 8 miles from shore with Hs ≤ 2,0 m	**dredging ≤ 8 miles from shore or Hs ≤ 2,0 m (T= x m)**
	• within 15 miles from shore • over 15 miles from shore with Hs ≤ 3,0 m	**dredging ≤ 15 miles from shore or Hs ≤ 3,0 m (T= x m)**
more than 150 m	• within 8 miles from shore • over 8 miles from shore with Hs ≤ 2,0 m	**dredging ≤ 8 miles from shore or Hs ≤ 2,0 m (T= x m)**
	• within 15 miles from shore • over 15 miles from shore with Hs ≤ 3,5 m	**dredging ≤ 15 miles from shore or Hs ≤ 3,5 m (T= x m)**
Note 1: Hs is the maximum allowable significant wave height during the service. (T= x m) indicates the maximum allowable draught x, in m, corresponding to the dredging situation, as defined in Pt D, Ch 13, Sec 2, [3.1.1]. example: **dredging ≤ 8 miles from shore or Hs ≤ 1,5 m (T= 4,50 m)**		

Table 4 : Operating area notation for enhanced dredging conditions under specific limits

Operational limits	Operating area notation
• within 8 miles from shore • over 8 miles from shore with Hs ≤ 1,0 m	**dredging ≤ 8 miles from shore or Hs ≤ 1,0 m (T= x m)**
• within 8 miles from shore • over 8 miles from shore with Hs ≤ 1,5 m	**dredging ≤ 8 miles from shore or Hs ≤ 1,5 m (T= x m)**
• within 8 miles from shore • over 8 miles from shore with Hs ≤ 2,0 m	**dredging ≤ 8 miles from shore or Hs ≤ 2,0 m (T= x m)**
• within 8 miles from shore • over 8 miles from shore with Hs ≤ 2,5 m	**dredging ≤ 8 miles from shore or Hs ≤ 2,5 m (T= x m)**
• within 8 miles from shore • over 8 miles from shore with Hs ≤ 3,0 m	**dredging ≤ 8 miles from shore or Hs ≤ 3,0 m (T= x m)**
• within 8 miles from shore • over 8 miles from shore with Hs ≤ 3,5 m	**dredging ≤ 8 miles from shore or Hs ≤ 3,5 m (T= x m)**
• within 15 miles from shore • over 15 miles from shore with Hs ≤ 2,5 m	**dredging ≤ 15 miles from shore or Hs ≤ 2,5 m (T= x m)**
• within 15 miles from shore • over 15 miles from shore with Hs ≤ 3,0 m	**dredging ≤ 15 miles from shore or Hs ≤ 3,0 m (T= x m)**
• within 15 miles from shore • over 15 miles from shore with Hs ≤ 3,5 m	**dredging ≤ 15 miles from shore or Hs ≤ 3,5 m (T= x m)**
• within 15 miles from shore • over 15 miles from shore with Hs ≤ 4,0 m	**dredging ≤ 15 miles from shore or Hs ≤ 4,0 m (T= x m)**
• within 15 miles from shore • over 15 miles from shore with Hs ≤ 4,5 m	**dredging ≤ 15 miles from shore or Hs ≤ 4,5 m (T= x m)**
• within 15 miles from shore • over 15 miles from shore with Hs ≤ 5,0 m	**dredging ≤ 15 miles from shore or Hs ≤ 5,0 m (T= x m)**
Note 1: Hs is the maximum allowable significant wave height during the service. (T= x m) indicates the maximum allowable draught x, in m, corresponding to the dredging situation, as defined in Pt D, Ch 13, Sec 2, [3.1.1]. example: **dredging ≤ 15 miles from shore or Hs ≤ 3,0 m (T= 5,00 m)**	

6 Additional class notations

6.1 General

6.1.1 An additional class notation expresses the classification of additional equipment or specific arrangement, which has been requested by the Interested Party.

6.1.2 The assignment of such an additional class notation is subject to the compliance with additional rule requirements, which are detailed in Part F of the Rules.

6.1.3 Some additional class notations are assigned a construction mark, according to the principles given in [3.1.2]. This is indicated in the definition of the relevant additional class notations.

6.1.4 The different additional class notations which may be assigned to a ship are listed in [6.2] to [6.26], according to the category to which they belong. These additional class notations are also listed in alphabetical order in Tab 5.

Table 5 : List of additional class notations

Additional class notation	Definition in	Reference in NR467 or to other Rule Notes	Remarks
ACCESS	[6.25.2]	Pt F, Ch 15, Sec 4	
ALM (1) **(ALM) (1)** **ALM-EN (1)** **ALM-SUBSEA (1)** **ALP (1)** **(ALP) (1)**	[6.12]	NR526	**ALP**, **ALM, ALM-EN** and **ALM-SUBSEA** may be completed by **-MR**
AMMONIAFUEL-PREPARED	[6.25.10]	NR671	**AMMONIAFUEL-PREPARED** may be completed, between brackets, by one, more or all of the following notations: **S**, **A**, **T**, **H**, **P**, **B**
ASYNC-COM	[6.5.6]	Pt F, Ch 4, Sec 3	**ASYNC-COM** may be completed by **-R**
AUT-CCS (1)	[6.4.3]	Pt F, Ch 3, Sec 2	
AUT-IMS (1)	[6.4.5]	Pt F, Ch 3, Sec 4	**AUT-IMS** may be completed by **-HWIL**
AUT-PORT (1)	[6.4.4]	Pt F, Ch 3, Sec 3	
AUT-UMS (1)	[6.4.2]	Pt F, Ch 3, Sec 1	
AVM-APS (1)	[6.3.2]	Pt F, Ch 2, Sec 1	
AVM-DPS (1)	[6.3.3]	Pt F, Ch 2, Sec 2	**AVM-DPS** may be completed by the additional suffix **/P** and/or **/NS** **AVM-DPS** and **AVM-IPS** may be completed by the additional suffix **/NS**
AVM-IPS (1)	[6.3.4]	Pt F, Ch 2, Sec 3	
AVM-FIRE (1)	[6.3.5]	Pt F, Ch 2, Sec 4	**AVM-FIRE** is assigned alone or in addition to **AVM-APS** or **AVM-DPS**
AWT-A **AWT-B** **AWT-A/B**	[6.8.3]	Part F, Chapter 9	
BIOFUEL READY	[6.8.20]	Pt F, Ch 9, Sec 13	
BIORISK MANAGED **BIORISK SECURED**	[6.14.2]	Pt F, Ch 10, Sec 6	
BLUS **SLUS**	[6.16.3]	Pt F, Ch 12, Sec 2	
BWE	[6.8.4]	Part F, Chapter 9	
BWT	[6.8.5]	Part F, Chapter 9	
CARGOCONTROL	[6.16.5]	Pt F, Ch 12, Sec 4	
CBRN	[6.14.1]	Part F, Chapter 10	**CBRN** may be completed by **-WASHDOWN** and/or **-AIR BLAST RESISTANCE**
CLEANSHIP	[6.8.1]	Part F, Chapter 9	**CLEANSHIP** may be completed by **CEMS**.
CLEANSHIP SUPER ( )	[6.8.2]	Part F, Chapter 9	between brackets, at least 3 eligible notations are to be assigned among the following ones: **AWT-A**, **AWT-B**, **AWT-A/B**, **BWT**, **GWT**, **GWT-B**, **OPS( )**, **NDO -x days**, **NOX-x%**, **OWS-x ppm**, **SOX-x%**. **CLEANSHIP SUPER ( )** may be completed by **CEMS**
COLD CARGO	[6.10.5]	Pt F, Ch 8, Sec 4	

Additional class notation	Definition in	Reference in NR467 or to other Rule Notes	Remarks
COLD DI **COLD BASIC (H t_{DH}, E t_{DE})** **COLD (H t_{DH}, E t_{DE})**	[6.10.4]	Pt F, Ch 8, Sec 4	
COMF+	[6.7.4]	Part F, Chapter 6	**COMF+** is to be complemented by the selected performance indexes (Sound insulation index/ Impact index/ Emergence/ Intermittent noise/ Intelligibility) grade **y** is equal to **1**, **2**, or **3** grade **y'** is equal to **1**, **2**, **3**, **1PK**, **2PK** or **3PK** **COMF** notations may be completed by **-SIS**
COMF-NOISE y	[6.7.2]		
COMF-VIB y'	[6.7.3]		
COMF-NOISE-Crew y **COMF-NOISE-Pax y** **COMF-VIB-Crew y'** **COMF-VIB-Pax y'**	[6.7.5]		
COVENT	[6.19.3]	Pt F, Ch 13, Sec 3	
CPS(COT)	[6.24.1]	NR530	cargo oil tanks of crude oil tankers of 5 000 tonnes deadweight (DWT) and above
CPS(MFT)	[6.24.2]	NR530	
CPS(VSP)	[6.24.3]	NR530	
CPS(WBT)	[6.24.4]	NR530	on a voluntary basis for ships other than bulk carriers **CSR** or oil tankers **CSR** contracted for construction on or after 8 December 2006
CYBER MANAGED **CYBER RESILIENT (1)** **CYBER SECURE (1)**	[6.21.1]	NR659	
DATA-CENTRIC	[6.5.8]	NR690	
DATA-INFRA	[6.5.7]	Pt F, Ch 4, Sec 4	**DATA-INFRA** may be completed by **-STAND**
DYNAPOS AM (1) **DYNAPOS AT (1)** **DYNAPOS AM/AT (1)**	[6.15.5]	Pt F, Ch 11, Sec 5	**DYNAPOS AM**, **DYNAPOS AT** and **DYNAPOS AM/AT** may be completed by: either **R** or **RS**, and by **ESKI (xx ; xx)** corresponding to the two number vector for the Environmental Station Keeping Index, and by -**HWIL**. **R** and **RS** may be completed by **-EI** and **-DDPS**
DYNAPOS SAM (1)	[6.15.5]	Pt F, Ch 11, Sec 5	**DYNAPOS** notations may be completed by **-HWIL**
ECFP-1 **ECFP-2** **ECFP-3**	[6.19.2]	Pt F, Ch 13, Sec 2	**ECFP-2** and **ECFP-3** are to be complemented by the notation **(Area 1, X_1m ; ... ; Area n, X_nm)**
EFP-A **EFP-M** **EFP-C** **EFP-AMC**	[6.19.1]	Pt F, Ch 13, Sec 1	
EGCS-SCRUBBER	[6.8.12]	Part F, Chapter 9	
ELECTRIC HYBRID ( )	[6.20.1]	Pt F, Ch 14, Sec 1	between brackets, at least 1 eligible notation is to be assigned among the following ones: **PM**, **PB**, **ZE MODE**
ELECTRIC HYBRID PREPARED ( )	[6.20.2]	Pt F, Ch 14, Sec 2	between brackets, at least 1 eligible notation is to be assigned among the following ones: **PM**, **PB**, **ZE MODE**
ERS-H **ERS-M** **ERS-S** **[ERS-H]** **[ERS-M]** **[ERS-S]**	[6.13.2]	NR556	
ESA	[6.25.8]	NR592	
ETA	[6.26.3]	Pt B, Ch 12, Sec 4, [3]	
EVFP-1 **EVFP-2** **EVFP-3**	[6.19.4]	Pt F, Ch 13, Sec 4	
EVOC	[6.16.12]	Pt F, Ch 12, Sec 9	
EWCT	[6.16.10]	Pt F, Ch 12, Sec 7	

Additional class notation	Definition in	Reference in NR467 or to other Rule Notes	Remarks
EXGEM( )	[6.8.16]	Pt F, Ch 9, Sec 9	**EXGEM( )** is to be completed between brackets by one or more of the following notations: **CH4**, **CH3OH** and **HCHO**; **EXGEM( )** may be completed by **-AUX** or **-PROP**
FORS	[6.8.19]	Pt F, Ch 9, Sec 12	**FORS** may be complemented by the notation **-NS**
FSRU READY **FSRU READY ( )**	[6.25.13]	Pt F, Ch 15, Sec 7	**FSRU READY** may be complemented, between brackets, by one, more or all of the following notations: **P**, **R**, **I**
GRAB [X]	[6.18.2]	NR606 **(2)** NR522, Ch 12	on a voluntary basis for bulk carriers other than **CSR BC-A** or **CSR BC-B**
GRABLOADING	[6.18.2] b)	Pt F, Ch 15, Sec 2	
GREEN PASSPORT **GREEN PASSPORT EU**	[6.8.22]	NR528	
GWT **GWT-B**	[6.8.6]	Part F, Chapter 9	
HABITABILITY	[6.7.6]	Pt F, Ch 6, Sec 6	
HEADING CONTROL-DS **HEADING CONTROL-IS**	[6.15.2]	Pt F, Ch 11, Sec 2	
HEL	[6.25.3]	Pt F, Ch 15, Sec 5	
HEL(Y)	[6.25.4]	NR500	
HMPS	[6.20.3]	Pt F, Ch 14, Sec 3	
HMPS-PREPARED	[6.20.4]	Pt F, Ch 14, Sec 6	
HYDROGENFUEL-PREPARED	[6.25.12]	NR678	**HYDROGENFUEL-PREPARED** may be completed, between brackets, by one, more or all of following notations: **S**, **A**, **TL** or **TG**, **HL** or **HG**, **PL** or **PG**, **B**
IATP ( )	[6.16.11]	Pt F, Ch 12, Sec 8	**IATP** is to be complemented, between brackets, by one of the following notations: **dual setting**, **boil-off** or **dual setting and boil-off**.
ICE	[6.10.3]	Part F, Chapter 8	
ICE CLASS IA SUPER **ICE CLASS IA** **ICE CLASS IB** **ICE CLASS IC**	[6.10.1]		
ICE CLASS ID	[6.10.2]		
IG	[6.26.2]	Pt D, Ch 7, Sec 6 and Pt D, Ch 8, Sec 9	
INTERNAL CONNECTIVITY	[6.25.15]	NR688	
INWATERSURVEY	[6.25.1]	Pt F, Ch 15, Sec 3	
LASHING **LASHING-RSSA( )**	[6.16.6]	Pt F, Ch 12, Sec 5	**LASHING** and **LASHING-RSSA( )** may be completed by the notation **-WAF**
LI-HG **LI-S1** **LI-S2** **LI-S3** **LI-S4** **LI-HG-S1** **LI-HG-S2** **LI-HG-S3** **LI-HG-S4** **LI-LASHING**	[6.16.1]	Pt B, Ch 1, Sec 5	
LNGFUEL-PREPARED	[6.25.9]	NR529	**LNGFUEL-PREPARED** may be complemented, between brackets, by one, more or all of the following notations: **S**, **A**, **P**, **ME-DF**, **AE, B**
MANOVR	[6.15.1]	Pt F, Ch 11, Sec 1	IMO Resolution MSC 137(76)
METHANOLFUEL-PREPARED	[6.25.11]	NR670	**METHANOLFUEL-PREPARED** may be completed, between brackets, by one, more or all of the following notations: **S**, **T**, **H**, **P**, **A**, **ME-DF**, **AE**, **B**
MOB	[6.25.14]	Pt F, Ch 15, Sec 6	

Additional class notation	Definition in	Reference in NR467 or to other Rule Notes	Remarks
MON-HULL	[6.6.2]	Pt F, Ch 5, Sec 1	
MON-ICE	[6.6.4]	NR616	**MON-ICE** is to be complemented by criteria **L(i)**, where **i** is a (list of) Roman numeral(s) from **I** to **VII**, or/and **G**
MON-SHAFT	[6.6.3]	Pt F, Ch 5, Sec 2	
NDO-x days	[6.8.7]	Part F, Chapter 9	
NOX-x%	[6.8.9]	Part F, Chapter 9	
OAS **(1)**	[6.25.7]	NI629	
OCC-PREPARED	[6.8.14]	Part F, Chapter 9	
OHS **(1)**	[6.25.6]	NR595	
OPEN-HATCH	[6.16.9]	Pt F, Ch 12, Sec 6	
OPS( )	[6.20.5]	Part F, Chapter 14	**OPS( )** is to be completed, between brackets, by the design power supply voltage and frequency
OPS( )-PREPARED	[6.20.6]	Part F, Chapter 14	**OPS( )-PREPARED** is to be completed, between brackets, by the design power supply voltage and frequency, **OPS( )-PREPARED** may be completed by the notation **-C**
OWS-x ppm	[6.8.8]	Part F, Chapter 9	
PaRoll1 **PaRoll2**	[6.16.8]	NR667	may be assigned to container ships
POLAR CLASS z	[6.11]	NR527	**z** is equal to **1**, **2**, **3**, **4**, **5**, **6** or **7**
PROTECTED FO TANK	[6.8.18]	Pt F, Ch 9, Sec 11	
REALTIME ( )	[6.6.5]	Pt F, Ch 5, Sec 3	**REALTIME ( )** is to be completed, between brackets by at least one of the following notations: **CII**, **EU ETS** or **FuelEU**.
REF-CARGO **(1)**	[6.9.2]	Pt F, Ch 7, Sec 2	**REF-CARGO** may be complemented by the notations: **-AIRCONT**, **-PRECOOLING** and/or **-QUICKFREEZE**
REF-CONT **(1)**	[6.9.3]	Pt F, Ch 7, Sec 3	
REF-STORE **(1)**	[6.9.4]	Pt F, Ch 7, Sec 4	**REF-STORE** may be complemented by the notations: **-PRECOOLING** and/or **-QUICKFREEZE**
SAFE-LASHING	[6.16.7]	–	
SAS	[6.16.4]	Pt F, Ch 12, Sec 3	
SDS	[6.17.1]	Pt B, Ch 3, Sec 3	
SCRUBBER READY	[6.8.13]	Pt F, Ch 9, Sec 7	
SINGLEPASSLOADING	[6.16.2]	Pt F, Ch 12, Sec 1	**SINGLEPASSLOADING** may be complemented by the design loading rate in tons per hour, for example: **SINGLEPASSLOADING [xxxxx t/h]**
SMART( )	[6.23.1]	NR675	**SMART( )** is to be completed between brackets by at least one of the following notations: **Hx**, **Mx**, **MHx**, **Nx**, **EnEx**, **Lx** and **Xx** where **x** indicates the smart group designation (**1**, **2** or **3**). The notation **EnEx** may be complemented by one or by a combination of the following complementary notations: -**Em**, **-T**, **-LIT**, **-S**, **-W** and **-CII**.
SOX-x%	[6.8.10]	Part F, Chapter 9	as an alternative, equivalent arrangements (e.g. exhaust gas cleaning systems) may be accepted
Spectral Fatigue ( )	[6.18.3]	NI 611	the information between brackets is a short description of routes and/or areas considered for the spectral fatigue analysis and associated design fatigue life
SPM	[6.15.3]	Pt F, Ch 11, Sec 3	
STABLIFT	[6.17.2]	Pt E, Ch 8, Sec 3	
STAB-WIND	[6.17.3]	NR500	
STAR-CARGO **(1)**	[6.2.7]	Pt F, Ch 1, Sec 4	
STAR-REGAS **(1)**	[6.2.6]	Pt F, Ch 1, Sec 3	
STAR-MACH **(1)**	[6.2.4]	Pt F, Ch 1, Sec 2	
STAR-MACH SIS **(1)**	[6.2.5]	Pt F, Ch 1, Sec 2	

Additional class notation	Definition in	Reference in NR467 or to other Rule Notes	Remarks
STRENGTHBOTTOM	[6.18.1]	Pt F, Ch 15, Sec 1	
SUSTAINABLESHIP-1 **SUSTAINABLESHIP-2**	[6.22.1]	Pt F, Ch 15, Sec 8	
SYNC-COM	[6.5.6]	Pt F, Ch 4, Sec 3	**SYNC-COM** may be completed by **-R**
SYS-IBS **(1)** **SYS-IBS-1** **(1)**	[6.5.3]	Pt F, Ch 4, Sec 2	**SYS-IBS** can only be assigned to ships which are also assigned the notation **SYS-NEQ** **SYS-IBS-1** can only be assigned to ships which are also assigned the notations **SYS-NEQ-1** and **AUT-UMS** **SYS-IBS** and **SYS-IBS-1** may be complemented by **-HWIL**
SYS-NEQ **(1)** **SYS-NEQ-1** **(1)**	[6.5.2]	Pt F, Ch 4, Sec 1	
SYS-NEQ-OSV **(1)**	[6.5.5]	NR633	
ULEV	[6.8.15]	Pt F, Ch 9, Sec 8	
UNSHELTERED ANCHORING	[6.15.4]	Pt F, Ch 11, Sec 4	
URN	[6.8.21]	NR 614	
VCS	[6.8.17]	Pt F, Ch 9, Sec 10	**VCS** may be complemented by the specific notation: **-TRANSFER** (see [6.8.17])
VeriSTAR-HULL **(1)** **VeriSTAR-HULL CM** **(1)**	[6.2.2]	Pt F, Ch 1, Sec 1	these notations may be completed by the notation **FLM** these notations may be complemented by **FAT** or **FAT xx years**, with 30 ≤ xx ≤ 40 **(3)**
WhiSp1 **WhiSp2** **WhiSp3**	[6.18.4]	Pt D, Ch 2, Sec 4	
WIND PROPULSION **(1)**	[6.25.5]	NR206	**WIND PROPULSION** may be completed by **-1** or **-2**
YOUNG ICE 1 **YOUNG ICE 2**	[6.10.2]	Part F, Chapter 8	

(1) A construction mark is added to this notation.

(2) Bulk carriers and Oil Tankers assigned with the additional service feature **CSR** contracted for new construction on or after 1 July 2015 are to comply with the requirements of NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

(3) For vessels contracted for construction between 1 July 2015 and 1 July 2022, the notation **FAT xx years**, with xx having values between 25 and 40, may have been assigned.

6.2 VeriSTAR and STAR notations

6.2.1 General

VeriSTAR and **STAR** notations integrate rational analysis at design stage or after construction and possibly with data and records from ships-in-service concerning planned inspection and ship maintenance.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment of these notations are given in Part F, Chapter 1, as detailed in [6.2.2] to [6.2.7], except for **VeriSTAR-HULL SIS**, **STAR-HULL** and **STAR SIS** as detailed in [6.2.3].

6.2.2 VeriSTAR-HULL CM and VeriSTAR-HULL

The additional class notation **VeriSTAR-HULL CM** may be assigned to new ships, the structural condition of which is checked with 3D FEM calculation program at design stage, according to the requirements Pt F, Ch 1, Sec 1. The additional class notation **VeriSTAR-HULL** may be completed by the notation **CM** where, in addition to the requirements given for the assignment of the notation **VeriSTAR-HULL**:

- the ship is provided with a hot spot map made available for construction surveys
- hull surveys for new construction are carried out according to the requirements of Ch 3, Sec 7.

Note 1: Existing ships contracted for construction before the 1st July 2015 and for which the structural condition is checked with 3D FEM calculation program at design stage according to the requirements of the Society may have only been assigned the notation **VeriSTAR-HULL** which encompassed the submission of a hot spot map.

VeriSTAR-HULL CM and **VeriSTAR-HULL** encompass the fatigue assessment carried out on selected structural details as per the requirements of Part B.

The additional class notations **VeriSTAR-HULL CM** and **VeriSTAR-HULL** may be assigned to ships of less than 150 m in length, subject to special consideration by the Society.

The additional class notations **VeriSTAR-HULL CM** and **VeriSTAR-HULL** may be completed by the notation **FLM** when a complementary tridimensional structural analysis has been performed based on a full length finite elements model.

The requirements for the assignment of these notations are given in Pt F, Ch 1, Sec 1.

The additional class notations **VeriSTAR-HULL CM** and **VeriSTAR-HULL** may be completed by the notation **FAT** when a fatigue assessment has been carried on selected structural details in accordance with Pt B, Ch 10, Sec 1 and Part D or Part E when relevant.

The notation **FAT** may be completed by **xx years**, with xx having values between 30 and 40, when evaluated design fatigue life is not less than xx years.

Note 2: For vessels contracted for construction between 1st July 2015 and 1st July 2022, the notation **FAT xx years**, with xx having values between 25 and 40, may have been assigned.

6.2.3 VeriSTAR-HULL SIS, STAR-HULL and STAR SIS

These additional class notations **VeriSTAR-HULL SIS**, **STAR-HULL** and **STAR SIS** may have been assigned to ships contracted for construction before 1st July 2022 and are not applicable to ships contracted for construction on or after 1st July 2022. They were not applicable to ships assigned the additional service feature **CSR**.

The requirements for maintenance of these notations are given in Ch 5, Sec 2.

Note 1: The requirements for the assignment of these notations were given in the edition July 2021 (as amended in January 2022) of NR467 Rules for the Classification of Steel Ships, in respectively, Pt A, Ch 1, Sec 2, [6.2.3]; Pt A, Ch 1, Sec 2, [6.2.4] and Pt A, Ch 1, Sec 2 [6.2.7].

6.2.4 STAR-MACH

The additional class notation **STAR-MACH** may be assigned, after construction, to ships for which a risk analysis has been performed for ship propulsion, steering installations and associated auxiliary systems (machinery, electrical) in order to support and validate the Maintenance Plan in the operating context.

The requirements for the assignment of this notation are given in Pt F, Ch 1, Sec 2.

6.2.5 STAR-MACH SIS

The additional class notation **STAR-MACH SIS** is assigned to ships on which a Planned Maintenance Survey system for machinery (PMS) is implemented as per the requirements of Ch 2, Sec 2, [4.4] for which the Maintenance Plan of the ship propulsion, steering installations and associated auxiliary systems (machinery, electrical) is re-approved periodically based on a risk analysis update.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 1, Sec 2 and in Ch 5, Sec 2.

6.2.6 STAR-REGAS

The additional class notation **STAR-REGAS** may be assigned, after construction, to ships having both the service notation **liquefied gas carrier** and the additional service feature **REGAS** (with or without the additional service feature **STL-SPM**) and for which a risk analysis has been performed for the regasification installation and its associated systems, in order to support and validate the maintenance plan in the operating context.

The requirements for the assignment of this notation are given in Pt F, Ch 1, Sec 3.

6.2.7 STAR-CARGO

The additional class notation **STAR-CARGO** may be assigned, after construction, to ships liable to carry cargoes and for which a risk analysis has been performed for the cargo handling installation and its associated systems, in order to support and validate the maintenance plan in the operating context.

The requirements for the assignment of this notation are given in Pt F, Ch 1, Sec 4.

6.3 Availability of machinery (AVM)

6.3.1 General

The notations dealt with under this heading are relevant to systems and/or arrangements enabling the ship to carry on limited operations when single failure affects propulsion or auxiliary machinery or when an external event such as fire or flooding involving machinery spaces affects the availability of the machinery.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment and maintenance of these notations are given respectively in Part F, Chapter 2 and in Ch 5, Sec 3.

6.3.2 Alternative propulsion system (AVM-APS)

The additional class notation **AVM-APS** is assigned to ships which are fitted with systems and/or arrangements enabling them to maintain operating conditions with some limitations in speed, range and comfort, in the case of single failure of items relative to the propulsion or power generating system.

The limitations in operation and the types of single failure covered by this notation are specified in Pt F, Ch 2, Sec 1, [1.2].

6.3.3 Duplicated propulsion system (AVM-DPS)

The additional class notation **AVM-DPS** is assigned to ships which are fitted with a duplicated propulsion system enabling them to maintain operating conditions with some limitations in power (but 50% of the main power is to be maintained), speed, range and comfort, in the case of single failure of items relative to the propulsion or power generating system.

The limitations in operation and the types of failure which are covered by this notation are specified in Pt F, Ch 2, Sec 2, [1.2].

The additional suffix **P** may be added to the notation when all components as defined in Pt F, Ch 2, Sec 2, [1.2.6], item b), are included in the definition of system failure.

The additional suffix **NS** may be added to the notation when the ship is intended for normal operation with one propulsion system out of service in accordance with the provisions of Pt F, Ch 2, Sec 2, [4].

Example:

AVM-DPS/NS

AVM-DPS/P/NS

Note 1: The loss of one compartment due to fire or flooding is not considered as a single failure case.

6.3.4 Independent propulsion system (AVM-IPS)

The additional class notation **AVM-IPS** is assigned to ships which are fitted with an independent propulsion system enabling them to maintain operating conditions with some limitations in power (but 50% of the main power is to be maintained), speed, range and comfort, in the case of single failure of items relative to the propulsion or power generating system.

The limitations in operation and the types of failure which are covered by this notation are specified in Pt F, Ch 2, Sec 3, [1.2].

The additional suffix **NS** may be added to the notation when the ship is intended for normal operation with one propulsion system out of service in accordance with the provisions of Pt F, Ch 2, Sec 3, [4].

Note 1: The loss of one compartment due to fire or flooding is considered as a single failure case.

6.3.5 Fire mitigation for main diesel-generator rooms (AVM-FIRE)

The additional class notation **AVM-FIRE** is assigned to ships which are fitted with an electrical production plant distributed over minimum two main diesel-generator rooms enabling to maintain sufficient operating functionality with respect to propulsion, safety, navigation and steering, and a minimum of 50% operability for defined habitability services in case of loss of one main diesel-generator room due to fire.

The additional class notation **AVM-FIRE** is assigned alone or in addition to the additional class notation **AVM-APS** or **AVM-DPS**.

6.4 Automated machinery systems (AUT)

6.4.1 General

The notations dealt with under this heading are relevant to automated machinery systems installed on board ships.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment and maintenance of these notations are given respectively in Part F, Chapter 3 and in Ch 5, Sec 4.

6.4.2 Unattended machinery space (AUT-UMS)

The additional class notation **AUT-UMS** is assigned to ships which are fitted with automated installations enabling machinery spaces to remain periodically unattended in all sailing conditions including manoeuvring.

6.4.3 Centralised control station (AUT-CCS)

The additional class notation **AUT-CCS** is assigned to ships which are fitted with machinery installations operated and monitored from a centralised control station.

6.4.4 Automated operation in port (AUT-PORT)

The additional class notation **AUT-PORT** is assigned to ships which are fitted with automated installations enabling the ship's operation in port or at anchor without personnel specially assigned for the watch-keeping of the machinery in service.

6.4.5 Integrated machinery system (AUT-IMS)

The additional class notation **AUT-IMS** is assigned to ships which are fitted with automated installations enabling machinery spaces to remain periodically unattended in all sailing conditions including manoeuvring, and additionally provided with integrated systems enabling to handle control, safety and monitoring of machinery.

The notation **-HWIL** is added to the additional class notation **AUT-IMS** when the control system has been verified according to the requirements of NR632, Hardware-in-the-loop Testing.

6.5 Integrated and digital systems

6.5.1 General

The notations dealt with under this heading are relevant to operation of integrated systems regarding navigation, machinery, communication and specific cargo, as applicable.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment and maintenance of these additional class notations are given, as applicable, in:

- NR633 for the notation **SYS-NEQ-OSV**
- Part F, Chapter 4 and Ch 5, Sec 5, respectively, for the other notations **SYS**.

6.5.2 Centralised navigation equipment (SYS-NEQ and SYS-NEQ-1)

The additional class notation **SYS-NEQ** is assigned to ships which are fitted with a centralised navigation control system so laid out and arranged that it enables normal navigation and manoeuvring operation of the ship by two persons in cooperation.

The additional class notation **SYS-NEQ-1** is assigned when, in addition to the above, the installation is so arranged that the navigation and manoeuvring of the ship can be operated under normal conditions by one person, for periodical one man watch. This notation includes specific requirements for prevention of accidents caused by the operator's unfitness.

6.5.3 Integrated bridge system (SYS-IBS and SYS-IBS-1)

The additional class notation **SYS-IBS** is assigned to ships fitted with an integrated bridge system which allows simplified and centralised bridge operation of the main functions of navigation, manoeuvring and communication, as well as monitoring from bridge of other functions related to passage execution, route control and monitoring and control and monitoring of machinery installation according to Part C, Chapter 3.

The notation **SYS-IBS** is assigned only to ships which are also assigned the additional class notation **SYS-NEQ**.

The additional class notation **SYS-IBS-1** is assigned to ships fitted with an integrated bridge system which allows simplified and centralised bridge operation of the main functions of navigation, manoeuvring and communication, as well as monitoring from bridge of other functions related to passage execution, route control and monitoring and control and monitoring of machinery installation according to Part C, Chapter 3 and Pt F, Ch 3, Sec 1 (**AUT-UMS** notation).

In addition, the following functions may be part of the notation **SYS-IBS-1**:

- external/internal communication system
- monitoring of specific cargo operations
- pollution monitoring
- monitoring of heating, ventilation and air conditioning for passenger ships.

The notation **SYS -IBS-1** is assigned only to ships which are also assigned the additional class notation **SYS-NEQ-1**.

The notation **-HWIL** is added to the additional class notations **SYS-IBS** and **SYS-IBS-1** when the control system has been verified according to the requirements of NR632, Hardware-in-the-loop Testing.

6.5.4 Safety and security of communication system (SYS-COM)

The additional class notation **SYS-COM** may have been assigned to ships contracted for construction before 1st January 2023 and is not applicable to ships contracted for construction on or after 1st January 2023.

The requirements for maintenance of this additional class notation are given in Ch 5, Sec 5.

6.5.5 Bridge design and instrumentation (SYS-NEQ-OSV)

The additional class notation **SYS-NEQ-OSV** may be assigned to ships fulfilling specific requirements for bridge design and instrumentation, and, in addition, provided with further means for safe operation in all the waters, including areas with harsh operational and environmental conditions such as the North Sea.

The aim of the additional class notation **SYS-NEQ-OSV** is to reduce the risk, in bridge operation, of failure causing collision, contact and grounding.

The requirements for the assignment of this notation are given in Rule Note NR633.

6.5.6 Ship-Shore Communication

The additional class notation **ASYNC-COM** may be assigned to ships equipped with asynchronous communication systems which can ensure transfer of data between the ship and the shore.

When the communication systems are redundant, the additional class notation **ASYNC-COM** is complemented by the suffix **-R**.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 4, Sec 3 and Ch 5, Sec 5.

The additional class notation **SYNC-COM** may be assigned to ships equipped with synchronous communication systems which can ensure transfer of data between the ship and the shore.

When the communication systems are redundant, the additional class notation **SYNC-COM** is complemented by the suffix **-R**.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 4, Sec 3 and Ch 5, Sec 5.

6.5.7 DATA-INFRA

The additional class notation **DATA-INFRA** may be assigned to ships fitted with a data infrastructure on board, which ensure reliable data collection, transmission, storage, control, sharing and availability to multiple data consumers.

The additional class notation **DATA-INFRA** may be completed by the suffix **-STAND**, when the data infrastructure supports international standards or norms which are ensuring a higher level of interoperability with other systems.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 4, Sec 4 and Ch 5, Sec 5.

6.5.8 DATA-CENTRIC

The additional class notation **DATA-CENTRIC** may be assigned to ships equipped with digital solutions which are to collect and manage the data for regular Data-centric Evaluation.

The requirements for the assignment and maintenance of this notation are given respectively in NR690 Data-centric Evaluation and Ch 5, Sec 5.

6.6 Monitoring equipment

6.6.1 General

The notations dealt with under this heading are relevant to hull and tailshaft monitoring equipment installed on board ships.

6.6.2 Hull stress monitoring (MON-HULL)

The additional class notation **MON-HULL** is assigned to ships which are fitted with equipment continuously monitoring ship's dynamic loads through measurements of motions in waves and stresses/deformations in the hull structure.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 5, Sec 1 and in Ch 5, Sec 6.

6.6.3 Tailshaft monitoring system (MON-SHAFT)

The additional class notation **MON-SHAFT** is assigned to ships fitted with oil or water lubricated systems for tailshaft bearings and podded propulsions. The assignment of this notation allows the ship to be granted a reduced scope for complete tailshaft surveys, see Ch 2, Sec 2, [5.5.3] and Ch 5, Sec 6, [3].

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 5, Sec 2 and in Ch 5, Sec 6.

6.6.4 Ice load monitoring system (MON-ICE)

The additional class notation **MON-ICE** is assigned to ships which are fitted with equipment to continuously monitor ice loads exerted on ship's hull by ice formations.

The notation **MON-ICE** is to be completed by one of the criteria **L(i)** and **G**, as follows:

- **MON-ICE L(i)** for ships equipped with a local ice load monitoring system, where **i** is a (list of) Roman numeral(s) from **I** to **VII**, depending on the design scenario
- **MON-ICE G** for ships intended to perform ramming and required to be equipped with a hull girder ice load monitoring system.

Note 1: The above letters and numerals denote the location (i.e. areas and regions) of the sensors and the interaction scenario, and the two notations are cumulative.

Examples: **MON-ICE L(I, III, VI), MON-ICE G**

MON-ICE L(II), MON-ICE G

The requirements for the assignment and maintenance of these notations are given respectively in NR616 Ice Load Monitoring System (MON-ICE) and in Ch 5, Sec 6.

6.6.5 Real-Time emission reporting (REALTIME)

The additional class notation **REALTIME ( )** may be assigned to ships provided with digital solutions which collect data from the ship and calculate the emissions which fall in the scope of international and regional reporting schemes. The additional class notation is to be completed, between brackets, by at least on of the following notations:

- **CII** (Carbon Intensity Indicator)
- **EU ETS** (European Emission Trading System)
- **FeulEU** (European regulations on the use of renewable and low-carbon fuels).

Example:

REALTIME (CII, EU ETS)

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 5, Sec 3 and Ch 5, Sec 6.

6.7 Comfort on board ships and habitability

6.7.1 Notations COMF

The notations listed in [6.7.2] to [6.7.5] are relevant to the assessment of comfort on board ships with regard to the noise and/or vibration.

The parameters which are taken into consideration for the evaluation of the comfort, such as the level of noise, the level of vibration, may be indicated in a memorandum.

COMF notations, as defined in [6.7.2] to [6.7.5], are to be considered as design notations.

The requirements for the assignment of these notations are given in Part F, Chapter 6.

It is the responsibility of the Owner to advise the Society of modifications, alterations or repairs, including major machinery item replacements, which may lead to a significant modification of the noise and vibration levels on board compared to initial survey. In such a case, a renewal survey may be carried out following a measurement programme agreed between the Owner and the Society.

For ships intended with in-service assessment, the notations **COMF** as defined in [6.7.2] to [6.7.5] are followed by notation **-SIS**. The requirements for the maintenance of these notations are given in Ch 5, Sec 7.

6.7.2 Comfort with regard to noise (COMF-NOISE)

The additional class notation **COMF-NOISE** is assigned to ships satisfying levels of noise defined in Part F, Chapter 6. The assessment of noise levels is carried out through measurements during harbour and sea trials.

The notation is completed by a grade **1**, **2** or **3** which represents the comfort level achieved for the assignment of the notation. The lower grade (**1**) corresponds to the higher class of comfort.

Example:

COMF-NOISE 2

6.7.3 Comfort with regard to vibration (COMF-VIB)

The additional class notation **COMF-VIB** is assigned to ships satisfying levels of vibration defined in Part F, Chapter 6. The assessment of vibration is carried out through measurements during harbour and sea trials.

The notation is completed by a grade:

- **1**, **2** or **3** for an evaluation based on overall frequency criteria, or
- **1PK**, **2PK** or **3PK** for an evaluation based on single amplitude peak criteria.

The grade represents the comfort level achieved for the assignment of the notation. The lower grade (**1** or **1PK**) corresponds to the higher class of comfort.

Example:

COMF-VIB 1PK

6.7.4 High comfort level with regard to noise (COMF+)

The additional class notation **COMF+** is assigned only to ships having the service notation **yacht** or **charter yacht** satisfying levels of noise defined in Pt F, Ch 6, Sec 5.

Note 1: The additional class notation **COMF+** may also be applied to ships assigned with the service notation **Passenger ship** after special consideration.

The requirements for the assignment of this notation are given in NR500, Rules for the Classification and Certification of Yachts.

6.7.5 Comfort for passenger and crew areas

The additional class notations **COMF-NOISE-Pax**, **COMF-NOISE-Crew**, followed by grade **1**, **2** or **3** and **COMF-VIB-Pax** and **COMF-VIB-Crew**, followed by grade **1**, **2** or **3** or **1PK**, **2PK** or **3PK** are assigned to ships satisfying levels of noise / vibration defined in Part F, Chapter 6, for passenger or crew area, as applicable.

Example:

COMF-VIB-Crew 3

6.7.6 Habitability

The additional class notation **HABITABILITY** may be assigned to ships found to be in compliance with the criteria of the Maritime Labour Convention and with the provisions contained in Pt F, Ch 6, Sec 6.

The requirements for the maintenance of this notation are given in Ch 5, Sec 7.

Note 1: Ships assigned, before 1st January 2017, with the additional class notation **ACCOMMODATION** may keep this notation until the first renewal survey, time at which the former additional class notation is to be replaced by **HABITABILITY**.

6.8 Environmental protection

6.8.1 Pollution prevention (CLEANSHIP)

The additional class notation **CLEANSHIP** is assigned to ships so designed and equipped as to control and limit the emission of polluting substances in the sea and the air in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 2.

The requirements for the maintenance of this notation are given in Ch 5, Sec 8.

Note 1: The additional class notations **CLEANSHIP** may be completed by the notation **CEMS**, as defined in [6.8.11].

6.8.2 Pollution prevention (CLEANSHIP SUPER)

The additional class notation **CLEANSHIP SUPER** is assigned to ships so designed and equipped as to control and limit the emission of polluting substances in the sea and the air in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 2.

Note 1: At least 3 eligible notations are to be assigned among the following ones:

AWT-A, AWT-B, AWT-A/B, BWT, **GWT**, **GWT-B**, **OPS( )**, **NDO-x days**, **NOX-x%**, **OWS-x ppm**, **SOX-x%**

Example:

CLEANSHIP SUPER (AWT, NOX-80%, SOX-60%)

The requirements for the maintenance of this notation are given in Ch 5, Sec 8.

Note 2: The additional class notations **CLEANSHIP SUPER ( )** may be completed by the notation **CEMS**, as defined in [6.8.11].

6.8.3 Advanced wastewater treatment (AWT)

The following additional class notations are assigned to ships fitted with Advanced Wastewater Treatment plant in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 3 as relevant:

- **AWT-A** for ships complying with Alaska specific requirements
- **AWT-B** for ships complying with the specific requirements of IMO Resolution MEPC.227(64) paragraph 4.2 applicable to ships operating in special areas
- **AWT-A/B** for ships complying with the 2 above mentioned specific requirements.

Note 1: ships complying only with general requirements of IMO Resolution MEPC.227(64) are not granted with any specific notation.

The requirements for the maintenance of this notations are given in Ch 5, Sec 8.

6.8.4 Ballast water exchange (BWE)

The additional class notation **BWE** is assigned to ships intended for ballast water exchange at sea and whose design is in compliance with the technical provisions of BWM Convention (2004), Regulation D-1 and in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 4.

Note 1: the additional class notation **BWE** does not waive the ship from being in compliance with any statutory or local requirement applicable to her.

The requirements for maintenance of this notation are given in Ch 5, Sec 8.

6.8.5 Ballast water treatment (BWT)

The additional class notation **BWT** is assigned to ships fitted with a Ballast Water Treatment plant in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 4.

The requirements for the maintenance of this notation are given in Ch 5, Sec 8.

6.8.6 Grey water treatment (GWT)

The following additional class notations are assigned to ships fitted with a treatment installation for grey waters in accordance with the provisions of Pt F, Ch 9, Sec 1and Pt F, Ch 9, Sec 5:

- **GWT** for ships complying with the requirements of IMO Resolution MEPC.227(64) section 4.1
- **GWT-B** for ships complying with the requirements of IMO Resolution MEPC.227(64) sections 4.1 and 4.2.

The requirements for the maintenance of these notations are given in Ch 5, Sec 8.

6.8.7 No discharge operation (NDO-x days)

The additional class notation **NDO-x days** is assigned to ships designed for no discharge operation during x days, in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 5.

Note 1: **x days** is the number of consecutive days the ship is able to operate with the full complement of on-board people, including crew and passengers, without the need for discharging any substances into the sea. This number cannot be less than one day (24 hours).

The requirements for the maintenance of this notations are given in Ch 5, Sec 8.

6.8.8 High-performance oily water separator (OWS-x ppm)

The additional class notation **OWS-x ppm** is assigned to ships fitted with an oily water separator producing effluents having a hydrocarbon content not exceeding x ppm (parts per million) in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 5.

The requirements for the maintenance of this notations are given in Ch 5, Sec 8.

6.8.9 NOx emissions control (NOX-x%)

The additional class notation **NOX-x%** is assigned to ships for which the average NOx emissions of engines are not to exceed x% of IMO Tier II limit in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 6.

The requirements for the assignment and maintenance of this notations are given respectively in Part F, Chapter 9 and in Ch 5, Sec 8.

6.8.10 SOx emissions control (SOX-x%)

The additional class notation **SOX-x%** is assigned to ships for which the oil fuels used within and outside SECAs have a sulphur content not exceeding x% of the relevant IMO limit in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 6.

Note 1: As an alternative, equivalent arrangements (e.g. exhaust gas cleaning systems) may be accepted.

The requirements for the maintenance of this notations are given in Ch 5, Sec 8.

6.8.11 Continuous emission monitoring system (CEMS)

The additional class notations **CLEANSHIP** and **CLEANSHIP SUPER ( )** may be completed by the notation **CEMS** when the ship is fitted with a measurement, monitoring, recording and transmission equipment of air emissions in compliance with the requirements laid down in Pt F, Ch 9, Sec 6.

The requirements for the maintenance of this notation are given in Ch 5, Sec 8.

6.8.12 Exhaust gas cleaning system-SCRUBBER (EGCS-SCRUBBER)

The additional class notation **EGCS-SCRUBBER** is assigned to ships fitted with an Exhaust Gas Cleaning System using Scrubber(s) installed in accordance with the provisions of Pt F, Ch 9, Sec 1 and Pt F, Ch 9, Sec 7.

The requirements for the maintenance of this notations are given in Ch 5, Sec 8.

6.8.13 SCRUBBER READY

The additional class notation **SCRUBBER READY** is assigned to ships on which an exhaust gas cleaning system is planned to be installed in the future. This additional class notations may be granted to a new ship or a ship in service during overhaul period. The requirements for the assignment of this notation are given in Pt F, Ch 9, Sec 7

6.8.14 OCC-PREPARED

The additional class notation **OCC-PREPARED** may be assigned to ships with specific arrangements intended to accommodate an onboard carbon capture and storage system (CCS) at a later stage.

The requirements for the assignment of this notation are given in Pt F, Ch 9, Sec 14.

6.8.15 Ultra-low emission vessel (ULEV)

The additional class notation **ULEV** may be assigned to sea-going ships. The additional class notation **ULEV** may not be assigned to vessels dedicated to operations on inland waterways (including estuaries, rivers, estuary and lakes) falling into the scope of EU Regulation 2016/1628.

The additional class notation **ULEV** refers to the capacity of the internal combustion engines installed on a ship to emit gaseous pollutants and particular pollutants at a very low level at the time of assignment of the notation.

When granting the additional class notation **ULEV**, a memorandum is to be endorsed in order to record the list of engines covered, the fuel(s) with which they have been tested and their ULEV mode if any.

The requirements for the assignment and the maintenance of this notation are given respectively in Pt F, Ch 9, Sec 8 and in Ch 5, Sec 8.

6.8.16 Exhaust Gas emissions measurement (EXGEM)

The additional class notation **EXGEM( )** may be assigned to ships having one of the additional service features **CNGfuel**, **LNGfuel** or **methanolfuel**, and fitted with gas-fuelled or dualfuel internal combustion engines for which the level of methane, and/or methanol and/or formaldehyde emissions in one of the mentioned fuels operating mode has been measured.

When granting the additional class notation **EXGEM**, a memorandum is to be endorsed in order to record:

- the list of engines covered
- for each engine, the measured brake specific emissions, in g/kWh
- for each engine, the average level of measured emissions as a mass percentage, in g of specific emission considered / g of gas fuel supplied to the engine.

The additional class notation **EXGEM** may be completed by:

-AUX, when the level of specific emissions has been measured only for auxiliary gas-fuelled or dual fuel engines

-PROP, when the level of specific emissions has been measured only for propulsion gas-fuelled or dual fuel engines

-AUX and **-PROP** are not appended to **EXGEM** when the level of emissions has been measured for all gas-fuelled or dual fuel engines on board.

The requirements for the assignment of this notation are given in Pt F, Ch 9, Sec 9.

6.8.17 Vapour control system (VCS)

The additional class notation **VCS** (Vapour Control System) may be assigned to ships equipped with cargo vapour control systems. The notation **-TRANSFER** is added to the notation where, in addition, the ship is fitted with specific arrangements for transferring cargo vapours to another ship.

This notation is assigned only to ships having the service notation **oil tanker**, **combination carrier/OBO ESP**, **combination carrier/OOC ESP**, **liquefied gas carrier**, **chemical tanker** or **FLS tanker**. For the service notation **liquefied gas carrier**, the additional class notation **VCS** may be assigned only to gas carriers designed for various cargoes, especially those ones which are also covered by IBC code. This notation can not be assigned to a LNG carrier.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 9, Sec 10 and in Ch 5, Sec 8, [5].

6.8.18 Protected FO tank

The additional class notation **PROTECTED FO TANK** may be assigned to ships with an aggregate oil fuel capacity of less than 600 m^3, fitted with oil fuel tanks complying with the requirements given in Pt F, Ch 9, Sec 11.

6.8.19 Fast oil recovery system (FORS)

The additional class notation **FORS** may be assigned to ships with oil fuel tanks and cargo tanks, as applicable, fitted with two (or more) connectors allowing the recovery of the tank contents as follows:

- by injecting sea water through one connector, the tank contents being recovered through the other one, and
- by introducing a submersible pump in the tank through one of the connectors.

The requirements for the assignment of this notation are given in Pt F, Ch 9, Sec 12.

The additional class notation **FORS** may be completed by the notation **-NS** when the connectors are intended to be used during the normal service of the ship and, for that purpose, comply with the additional requirements given in Pt F, Ch 9, Sec 12, [3].

For ships not assigned with the notation **-NS**, the connectors may be used only to facilitate the recovery of the tank contents when the ship is damaged or wrecked.

6.8.20 BIOFUEL READY

The additional class notation **BIOFUEL READY** may be assigned to new and existing ships for which the use of biofuel has been technically analysed and, if applicable, tested.

When granting the additional class notation **BIOFUEL READY**, a memorandum is to be endorsed in order to record:

- the specification of the biofuel(s) intended to be used, the blend ratio(s) and type(s) of blend(s) (including fossil fuel specification)
- the list of engines covered and their main destination (auxiliary or propulsion).

The requirements for the assignment of this notation are given in Pt F, Ch 9, Sec 13.

6.8.21 Underwater radiated noise (URN)

The additional class notation **URN** may be assigned to self-propelled ships meeting the underwater radiated noise level limits complying with the requirements of NR614 Underwater Radiated Noise (URN).

According to the limits given in Rule Note NR614, the notation **URN** is to be completed as follows:

URN - controlled vessel

URN - advanced vessel

URN - specified vessel

The requirements for the assignment and maintenance of this notation are given in Rule Note NR614.

6.8.22 Green passport for ship recycling

The additional class notation **GREEN PASSPORT** or **GREEN PASSPORT EU** may be assigned to ships for which requirements intended to facilitate ship recycling have been applied, encompassing the identification, quantification and localization of materials which may cause harm to the environment and people when the fittings or equipment containing such materials are removed, or when the ship is recycled, as detailed hereafter.

GREEN PASSPORT may be assigned to ships for which such requirements have been applied in accordance with:

- the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009, and
- the European Regulation Reg (EU) N°1257/2013 on Ship Recycling, as amended, as applicable to ships flying the Flag of a non-EU member State.

GREEN PASSPORT EU may be assigned to ships for which such requirements have been applied in accordance with:

- the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009, and
- the European Regulation Reg (EU) N°1257/2013 on Ship Recycling as applicable to ships flying the Flag of a EU member State.

The requirements for the assignment and maintenance of this notation are given in NR528 Green Passport.

6.9 Refrigerating installations

6.9.1 General

The notations dealt with under this heading are relevant to refrigerating installations fitted on board ships, including machinery and storing equipment or arrangements.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment and maintenance of these notations are given respectively in Part F, Chapter 7 and in Ch 5, Sec 9.

6.9.2 Refrigerating installations for cargo (REF-CARGO)

The additional class notation **REF-CARGO** is assigned to ships fitted with refrigerating plants and holds intended to carry cargoes, with the condition that the number and the power of the refrigerating units are such that the specified temperatures can be maintained with one unit on standby.

The notation **-AIRCONT** is added when the refrigerating plant is equipped with controlled atmosphere installations.

6.9.3 Self refrigerated containers (REF-CONT)

The additional class notation **REF-CONT** is assigned to ships intended to supply electrical power to self-refrigerated containers.

6.9.4 Refrigerating installations for domestic supplies (REF-STORE)

The additional class notation **REF-STORE** is assigned to ships fitted with refrigerating plants and spaces exclusively intended for the preservation of ship's domestic supplies.

6.9.5 The additional class notations **REF-CARGO** and **REF-STORE** may also be completed by the following notations:

a) **-PRECOOLING** when the refrigerating plants are designed to cool down a complete cargo of fruit and/or vegetables to the required temperature of transportation

b) **-QUICKFREEZE** for the refrigerating plants of fishing vessels and fish factory ships where the design and equipment of such plants have been recognised suitable to permit quick-freezing of fish in specified conditions.

6.10 Navigation in cold environment

6.10.1 Notations ICE CLASS IA SUPER, ICE CLASS IA, ICE CLASS IB and ICE CLASS IC

The following notations are relevant to ships strengthened for navigation in ice in accordance with the "Finnish-Swedish Ice Class Rules 1985 as amended":

- **ICE CLASS IA SUPER** for ships with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers
- **ICE CLASS IA** for ships with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary
- **ICE CLASS IB** for ships with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary
- **ICE CLASS IC** for ships with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary.

The requirements for the assignment and maintenance of these notations are given respectively in Part F, Chapter 8 and in Ch 5, Sec 10.

These requirements reproduce the provisions of the Finnish-Swedish Ice Class Rules cited above.

Note 1: These National requirements are applicable for ships trading in the Finnish/Swedish waters and other relevant areas of the Baltic sea during the ice period.

6.10.2 Notations ICE CLASS ID and YOUNG ICE

The additional class notations **ICE CLASS ID**, **YOUNG ICE 1** and **YOUNG ICE 2** are assigned to ships whose reinforcements for navigation in ice are different from those required for the assignment of the notations defined in [6.10.1] but who comply with the specific requirements detailed in Part F, Chapter 8.

Note 1: No minimum engine output is required for these notations.

The requirements for maintenance of these notations are given respectively in Ch 5, Sec 10.

6.10.3 Notation ICE

The additional class notation **ICE** is assigned to ships whose reinforcements for navigation in ice are similar but not equivalent to those required for the assignment of the notations defined in [6.10.1] and [6.10.2], when this has been specially considered by the Society.

The requirements for maintenance of these notations are given respectively in Ch 5, Sec 10.

6.10.4 Ships operating in cold weather conditions

The additional class notations **COLD DI**, **COLD BASIC (H t_{DH} , E t_{DE})** and **COLD (H t_{DH} , E t_{DE})** are assigned to ships intended to operate in cold climate environments as specified in Note 1.

Note 1:

- sea water temperature: not below –2°C
- wind speed: not higher than 30 knots.

The additional class notation **COLD DI** is assigned to ships operating in cold climate environments for shorter periods, not necessarily including ice covered waters and fitted with systems and equipment for de-icing.

The additional class notation **COLD BASIC (H t_{DH} , E t_{DE})** is assigned to ships operating in cold weather conditions and which are built and fitted with systems and equipment for the de-icing where t_{DH} and t_{DE} are defined below respectively for the hull and equipment exposed to low air temperature.

The additional class notation **COLD (H t_{DH} , E t_{DE})** is assigned to ships operating in cold weather conditions and which are built and fitted with systems and equipment for advanced de-icing where t_{DH} and t_{DE} are defined below respectively for the hull and equipment exposed to low air temperature.

t_{DH} : design air temperature to be considered for the hull exposed to low air temperature, which is to be taken equal to the lowest mean daily average air temperature, but not more than 13°C above t_{DE}.

t_{DE} : design air temperature to be considered for the equipment exposed to low air temperature, which is to be taken 10°C below the lowest mean daily low air temperature.

The requirements for the assignment and maintenance of these notations are given respectively in Pt F, Ch 8, Sec 4 and in Ch 5, Sec 10.

6.10.5 Liquid cold cargoes (COLD CARGO)

The additional class notation **COLD CARGO** is assigned to ships assigned one of the service notation **oil tanker**, **FLS tanker**, **tanker** or **chemical tanker** intended to be loaded with liquid cargoes:

- having a cargo temperature below –10°C, in particular when loading is from cold storage tanks (winter conditions), and
- not needing to be heated in normal operating conditions.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 8, Sec 4 and in Ch 5, Sec 10.

6.11 Navigation in polar waters

6.11.1 The notations dealt with under [6.11.2] are relevant to ships intended for navigation in ice-infested polar waters, except icebreakers.

The requirements for the assignment of these notations are given in Rule Note NR527 Rules for the Classification of POLAR CLASS and ICEBREAKER Ships.

Ships complying with the requirements of Rule Note NR527 and assigned one of the additional class notations **POLAR CLASS** are also to comply with the requirements for the assignment of one of the additional class notations **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH} , E t_{DE})**.

Note 1: Icebreaker refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake independent operations in ice covered waters.

Note 2: Ships assigned the additional class notation **POLAR CLASS 6** or **POLAR CLASS 7** and not intended to operate in low air temperature may be exempted of the additional class notations **COLD BASIC (H t_{DH} , E t_{DE})** or **COLD (H t_{DH}, E t_{DE})**.

6.11.2 The following additional class notations are assigned:

- **POLAR CLASS 1** for year-round operations in all polar waters
- **POLAR CLASS 2** for year-round operations in moderate multi-year ice conditions
- **POLAR CLASS 3** for year-round operations in second-year ice which may include multi-year ice conditions
- **POLAR CLASS 4** for year-round operations in thick first-year ice which may include old ice inclusions
- **POLAR CLASS 5** for year-round operations in medium first-year ice which may include old ice inclusions
- **POLAR CLASS 6** for summer/autumn operations in medium first-year ice which may include old ice inclusions
- **POLAR CLASS 7** for summer/autumn operations in thin first-year ice which may include old ice inclusions.

6.12 Lifting appliances

6.12.1 Ships fitted with lifting appliances meeting the requirements of NR526 Rules for the Certification Lifting Appliances onboard Ships and Offshore Units may be assigned the following additional class notations:

a) **ALP** for appliances intended to be used at harbour, for loading or unloading cargoes, equipment, spare parts or consumable

b) **ALM** for appliances intended to be used in offshore conditions for various lifting operations exclusive of the appliances mentioned in item a).

Note 1: Ships fitted with lifting appliances used in harbour or in similar conditions for lifting operations other than ships loading or unloading may be assigned the additional service notation **ALP**.

6.12.2 The additional class notations **(ALP)** or **(ALM)** may be assigned by the Society in lieu of the notations **ALP** or **ALM** respectively, when the corresponding lifting appliances meet the requirements of specific National Regulations under the conditions defined in NR526.

6.12.3 The additional class notation **ALM** may be completed by:

- **-EN**, when lifting appliances are in compliance with additional specific safety requirements as defined in NR526
- **-SUBSEA**, when lifting appliances are intended to be used for lifting of subsea equipment in compliance with some specific requirements.

6.12.4 The additional class notations **ALP**, **ALM**, **ALM-EN** and **ALM-SUBSEA** may be completed by **-MR** when, in addition, lifting appliances are intended to be used for lifting of personnel.

6.12.5 The additional class notations **ALP**, **ALM**, **(ALP)**, **(ALM)**, **ALM-EN** or **ALM-SUBSEA** are optional. However, the Society may require the compliance of lifting appliances with the assigning conditions of one of the above mentioned additional class notations for the classification of ships, when one or several lifting appliances are of a primary importance for their operation, or when such appliances significantly influence their structure. As a rule, such is the case for the shear leg pontoons, crane pontoons, crane vessels and when the lifting appliances concerned have special high capacities, for example in case of ships specially equipped for handling very heavy loads.

6.12.6 In compliance with [6.1.3], these notations are assigned a construction mark as defined in [3].

6.12.7 The requirements for assignment and maintenance of these notations are given in NR526.

6.13 Emergency response service (ERS)

6.13.1 General

The notations dealt with under this Article are related to the provision of technical assistance in case of a maritime accident at sea by providing information on their remaining strength and stability in the resulting damaged condition.

The requirements for the assignment and maintenance of these notations are given in NR556 (Emergency Response Service).

6.13.2 ERS-S (Strength), ERS-H (Hydrodynamic), ERS-M (Mooring), [ERS-S] (Strength-partial), [ERS-H] (Hydrodynamic-partial) and [ERS-M] (Mooring-partial) services

ERS-S corresponds to damage longitudinal strength and damage stability analyses. It aims at providing information on the remaining hull strength and stability after the accident.

ERS-H aims at providing limits of navigation, based on direct calculations of vertical wave bending moment and vertical wave shear force for the accidental site sea-states, instead of empirical rule formulae. It is only applied in complement to **ERS-S**. It aims at providing maximum environmental conditions (Hs), heading restriction, or speed limit. These limits of navigation are given for hull girder strength only.

ERS-M corresponds to damaged mooring analyses for permanently moored units. It aims at providing information on the remaining capacities of the mooring system after the failure of one or several mooring lines and the potential failure of an additional mooring line.

[ERS-S], [ERS-H] and [ERS-M] are assigned to ships until the respective ERS service becomes fully effective. The Society will provide service in case of damage as far as possible depending on the available information.

Note 1: The notations **[ERS-S]**, **[ERS-H]** and **[ERS-M]** are replaced respectively by **ERS-S**, **ERS-H** and **ERS-M** when all necessary information has been made available to the Society allowing the service to become fully effective.

6.14 Protection against chemical, biological, radiological or nuclear risks

6.14.1 Chemical, biological, radiological or nuclear hazards

The additional class notation **CBRN** may be assigned to civilian ships intended for operations in atmospheres contaminated by chemical, biological or nuclear hazardous material for rescue or damage control purposes and equipped with a citadel with a collective protection system that effectively protects people inside from contamination thanks to its dedicated ventilating system.

The additional class notation **CBRN** may be completed by:

- **-WASHDOWN** for ships which, in addition to the above features, are provided with a wash-down system that will give increased protection during CBRN operations and will also allow immediate primary decontamination of the superstructures
- **-AIR BLAST RESISTANCE** for ships which, in addition, have their collective protection systems designed to withstand an air blast.

The requirements for the assignment and maintenance of these notations are given respectively in Part F, Chapter 10 and in Ch 5, Sec 11.

6.14.2 Biological risk control

The additional class notations **BIORISK MANAGED** and **BIORISK SECURED** may be assigned to ships where measures improving the ability to prevent and manage an infectious disease outbreak are implemented.

The additional class notation **BIORISK MANAGED** may be assigned when an outbreak management plan is established for the ship and implemented on board.

The additional class notation **BIORISK SECURED** may be assigned when, in addition to the above-mentioned outbreak management plan, systems and arrangements are provided on board in order to support the management of an infectious disease outbreak.

The requirements for the assignment and the maintenance of these additional class notations are given respectively in Pt F, Ch 10, Sec 6 and in Ch 5, Sec 11, [3].

6.15 Manoeuvring, mooring, anchoring and position keeping

6.15.1 Ship manoeuvrability

The additional class notation **MANOVR** may be assigned to ships complying with the requirements related to manoeuvring capability defined in Pt F, Ch 11, Sec 1.

Note 1: According to Resolution MSC.137(76), these provisions are to be applied to ships of all rudder and propulsion types, of 100 m in length and over, and to chemical tankers and gas carriers regardless of the length, which were constructed on or after 1 January 2004.

6.15.2 Heading control

The additional class notations **HEADING CONTROL** may be assigned to ships arranged with redundant propulsion and steering systems in order to maintain their heading to the waves in adverse weather conditions and to avoid large transversal accelerations, taking into account the windage of the deck cargo if any.

The additional class notation **HEADING CONTROL** is complemented by:

-DS for ships with duplicated propulsion systems able to maintain their heading to the waves in case of single failure on the propulsion or steering system

-IS for ships with independent propulsion systems, which in addition to the requirements applicable to **-DS** notation, comply with additional requirements covering the event of fire or flooding casualty in machinery space.

The requirements for the assignment and the maintenance of these notations are given respectively in Pt F, Ch 11, Sec 2 and Ch 5, Sec 12, [2].

6.15.3 Single point mooring

The additional class notation **SPM** (Single Point Mooring) may be assigned to ships fitted with a specific mooring installation.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 11, Sec 3 and in Ch 5, Sec 12.

These requirements reproduce the provisions of “Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings” (4th edition - May 2007), issued by OCIMF (Oil Companies International Marine Forum).

6.15.4 UNSHELTERED ANCHORING

The additional class notation **UNSHELTERED ANCHORING** is assigned to ships fitted with anchoring equipment in deep and unsheltered water complying with the requirements of Pt F, Ch 11, Sec 4, in addition to the requirements from Pt B, Ch 12, Sec 4, as applicable to equipment.

The requirements of this section apply to ships:

- with an equipment length L_E, as defined in Pt B, Ch 12, Sec 4, [1.2.2], greater than 135 m

and intended to anchor in deep and unsheltered water with:

- depth of water up to 120 m
- current speed up to 3 knots (1.54 m/s)
- wind speed up to 27 knots (14 m/s)
- waves with significant height up to 3 m.

The scope of chain cable, being the ratio between the length of chain paid out and water depth, is assumed to be to the maximum possible and not less than 3.

6.15.5 Dynamic positioning

The additional class notation **DYNAPOS** may be assigned to ships equipped with a dynamic positioning system.

In compliance with [6.1.3], this notation is assigned a construction mark, as defined in Article [3].

The scope of the additional class notation **DYNAPOS**, including the additional notations for the description of capability of the installation (**SAM**, **AM**, **AT**, **AM/AT**), and the requirements for the assignment of this notation are given in Pt F, Ch 11, Sec 5.

The requirements for the maintenance of this notation are given in Ch 5, Sec 12.

The additional class notation **DYNAPOS** may be completed by **-HWIL** when the DP control system and the power management system have been verified according to the requirements of NR632, Hardware-in-the-loop Testing.

The additional class notations **DYNAPOS AM**, **DYNAPOS AT** and **DYNAPOS AM/AT** may be completed by:

- **ESKI (xx; xx)**: corresponding to the two number vector for the Environmental Station Keeping Index

and either:

- **R**: when the dynamic positioning system is provided with redundancy achieved by using two or more systems or alternative means of performing a function, or
- **RS**: when, in addition to the symbol **R**, the redundancy is achieved by using two systems or alternative means of performing a function physically separated.

The additional class notations **R** and **RS** may be completed by:

- **-EI**: when the ship is fitted with an enhanced dynamic positioning control system and complying with the requirements of Pt F, Ch 11, Sec 5, [10]. This notation allows improving the reliability, availability and operability of a DP vessel, and
- **-DDPS**: when the ship is fitted with a system which enables the vessel to undertake digital surveys in compliance with Pt F, Ch 11, Sec 5, [11].

  The notation **-DDPS** allows the ship's crew to conduct tests, proving the ability of a DP vessel to keep position after single failures associated with the assigned equipment class and to validate the FMEA and operation manual, as a part of annual survey as laid down in Ch 5, Sec 12, [4.1.2] and only for this part, according to their own schedule within the window of the Annual Survey, with the results witnessed by the Society digitally.

Any test from the approved FMEA test programme not completed by ship's crew at the time of Surveyor's attendance for annual survey has to be carried out before completion of the survey.

A confirmatory survey, to be carried out by a Surveyor of the Society, is to be requested, when the ship is within the window for annual survey of its classed DP system.

The Surveyor carries out the annual survey as laid down in Ch 5, Sec 12, [4.1] and satisfies himself with the validation of the FMEA and operations manual, based on the reports/records provided by the ship's crew. If doubts arise, the Surveyor extend the tests as deemed necessary.

Example:

DYNAPOS AM/AT RS ESKI (99; 95) -HWIL -EI

6.16 Cargo operation, securing and safety

6.16.1 Loading instrument

The additional class notations **LI-HG**, **LI-S1**, **LI-S2**, **LI-S3**, **LI-S4**, **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** and **LI-LASHING** may be assigned to ships equipped with a loading instrument.

The requirement for the assignment of these notations are given in Pt B, Ch 1, Sec 5.

The requirements for the maintenance of the notation **LI-LASHING** are given in Ch 5, Sec 13.

Note 1: When the ship is equipped with a loading instrument performing:

- only hull girder calculations, the additional class notation **LI-HG** is assigned
- only intact stability calculations (when the ship is not required to meet damage stability requirements), the additional class notation **LI-S1** is assigned
- intact stability calculations and damage stability on a basis of a limit curve, the additional class notation **LI-S2** is assigned
- intact stability calculations and direct damage stability calculations based on pre-programmed damage cases, the additional class notation **LI-S3** is assigned
- damage stability calculations associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port (SRtP), the additional class notation **LI-S4** is assigned
- lashing calculations, the additional class notation **LI-LASHING** is assigned.

When the loading instrument performs hull girder and stability calculations, one of the additional class notations **LI-HG-S1**, **LI-HG-S2** or **LI-HG-S3**, **LI-HG-S4** is assigned, as applicable.

6.16.2 SINGLEPASSLOADING

The additional class notation **SINGLEPASSLOADING** may be assigned to ships having the service notation **ore carrier** which are specially designed for single pass loading.

Note 1: This additional class notation may be completed by the design loading rate, in tons per hour, for example:

SINGLEPASSLOADING [xxxxx t/h]

The additional class notation **SINGLEPASSLOADING** only covers the loading sequences provided to the Society, as referred to in Pt F, Ch 12, Sec 1.

The requirements for the assignment of this notation are given in Pt F, Ch 12, Sec 1.

6.16.3 Bow loading/unloading systems (BLUS) - Stern loading/unloading systems (SLUS)

The additional class notations **BLUS** or **SLUS** may be assigned to ships having the service notation **oil tanker** and fitted with bow or stern loading/unloading systems.

The requirements for the assignment of these notations are given in Pt F, Ch 12, Sec 2.

6.16.4 Supply at sea (SAS)

The additional class notation **SAS** may be assigned to ships having the service notation **supply** and operated for underway ship-to-ship supply at sea (SAS) of liquid and solid supplies.

The requirements for the assignment of this notation are given in Pt F, Ch 12, Sec 3.

Note 1: Application to other service notations may be considered on a case-by-case basis.

6.16.5 Centralised cargo control

The additional class notation **CARGOCONTROL** may be assigned to ships (carrying liquid cargo in bulk) equipped with a centralised system for handling cargo and ballast liquids.

In principle, this notation is assigned only to ships having the service notation **oil tanker**, **combination carrier/OBO**, **combination carrier/OOC**, **chemical tanker** or **FLS tanker**.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 12, Sec 4 and in Ch 5, Sec 13.

6.16.6 Container lashing equipment

The additional class notation **LASHING** may be assigned to ships initially fitted with mobile container lashing equipment which has been documented, tested and checked.

The additional class notation **LASHING-RSSA( )** may be assigned in lieu of the notation **LASHING** to ships which may be engaged in voyages on specific routes or in specific areas. The specific routes and specific areas are to be indicated between brackets (e.g.:**LASHING-RSSA(Asia-Europe through Mediterranean sea; Baltic sea)**).

The additional class notations **LASHING** and **LASHING-RSSA( )** may be completed by the notation **-WAF** when the ship is also engaged in short voyages (less than 72 hours) and provided with weather dependent lashing procedures.

These notations are assigned only to ships having the service notation **container ship** or the additional service feature **equipped for carriage of containers**.

This equipment, however, will not be verified any longer at the periodical class surveys to which the ship is submitted.

The requirements for the assignment of these notations are given in Pt F, Ch 12, Sec 5.

6.16.7 SAFE-LASHING

The additional class notation **SAFE-LASHING** may be assigned to ships having the service notation **container ship** or the additional service feature **equipped for carriage of containers** and the keel of which was laid, or which are at a similar stage of construction, on or after 1 January 2015.

The requirements for the assignment of this notation are given in IMO MSC.1/Circ.1352/Rev.1 "Amendments to the Code of Safe Practice for Cargo Stowage and Securing (CSS Code)", Annex 14 "Guidance on Providing Safe Working Conditions for Securing of Containers on Deck", paragraphs 4.3 "Cargo Safe Access Plan (CSAP)" and 6 "Design".

6.16.8 Parametric roll assessment (PaRoll)

The additional class notation **PaRoll1** or **PaRoll2** may be assigned to container ships, for which numerical simulations and operational guidance (polar plot) for evaluation of maximum dynamic roll angle (including parametric roll) in various loading conditions and sea states are developed in compliance with NR667.

- The additional class notation **PaRoll1** is granted to ships using only bilge keels as anti-rolling devices
- The additional class notation **PaRoll2** is granted to ships using anti-rolling devices such as anti-roll tank, stabilizer fins or any anti-rolling devices different from bilge keels.

The requirements for the assignment and maintenance of this notation are given respectively in NR667 and Ch 5, Sec 13.

6.16.9 Open hatch

The additional class notation **OPEN-HATCH** may be assigned to ships granted with the service notation **general cargo ship** or **container ship** and intended to undertake sea voyage with one or several hatch covers not in place, as defined in Pt F, Ch 12, Sec 6.

The requirements for the assignment and maintenance of this additional class notation are given respectively in Pt F, Ch 12, Sec 6 and in Ch 4, Sec 7.

6.16.10 Efficient washing of cargo tanks

The additional class notation **EWCT** may be assigned to ships fitted with washing arrangements complying with the requirements given in Pt F, Ch 12, Sec 7.

This notation may only be assigned to ships having the service notation **oil tanker**, **FLS tanker**, or **chemical tanker**.

6.16.11 Sealed liquefied natural gas tanks

The additional class notation **IATP** (increased admissible cargo tank pressure) may be assigned to ships or units intended to carry or store methane (LNG) whose maximum cargo tank design pressure does not exceed 70 kPa and that are designed and built so as to allow the pressure in the tanks to increase above 25 kPa.

The additional class notation **IATP** is to be complemented, between brackets, by one of the following notations:.

- **dual setting**, when a dual setting of the cargo tanks pressure relief valves is installed, or
- **boil-off**, when a boil-off handling system whose available capacity can be lower than 100% of the nominal boil-off rate of the ship during the periods referred to in Pt F, Ch 12, Sec 8, [4.3.2]is installed,
- **dual setting and boil-off**, when both systems are installed.

The requirements for the assignment of this notation are given in Pt F, Ch 12, Sec 8.

Note 1: In case of dual setting of the cargo tanks pressure relief valves, the operational conditions and limitations for both setting pressures are to be specified in a memorandum.

6.16.12 Electric vehicles onboard charging (EVOC)

The additional class notation **EVOC** may be assigned to ships having the service notation **ro-ro passenger ship**, carrying electric vehicles intended to be charged on board.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 12, Sec 9 and Ch 5, Sec 13.

6.17 Additional notations for stability

6.17.1 Ship subdivision and damage stability

The additional class notation **SDS** may be assigned to ships for which a damage buoyancy, subdivision and stability file has been examined and found to satisfy the requirements given in Pt B, Ch 3, Sec 3 or those required for granting the service notation, when applicable.

An attestation of compliance may be issued to the Interested Party, specifying the rules and criteria considered for the examination of the file.

Note 1: As a rule, class assigned to a ship does not cover requirements applicable to the assignment of the notation **SDS**.

6.17.2 STABLIFT

The additional class notation **STABLIFT** may be assigned to ships engaged in lifting operations at sea and equipped for that purpose with one or several lifting equipment, having their residual stability during lifting operations checked and complying with the stability requirements specified in Pt E, Ch 8, Sec 3.

6.17.3 STAB-WIND

The additional class notation **STAB-WIND** may be assigned, to yacht having the service notation **yacht** or **charter yacht** satisfying the intact stability and weather criterion as defined in Rule Note NR500 Rules for the Classification and the Certification of Yachts.

Note 1: The attention of the Owner and the Shipyard is drawn to the fact that the flag Administration may impose an intact stability and weather criterion calculation.

6.18 Additional notations for hull structure assessment

6.18.1 Strengthened bottom

The additional class notation **STRENGTHBOTTOM** may be assigned to ships built with specially strengthened bottom structures so as to be able to be loaded and/or unloaded when properly stranded.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 15, Sec 1 and in Ch 5, Sec 14.

6.18.2 Loading by grabs

a) Loading by grabs for bulk carriers subject to NR522 Common Structural Rules for Bulk Carriers or to NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

The additional class notation **GRAB [X]** is assigned to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to [X] tons.

The requirements for the assignment of this notation are given in NR522 Common Structural Rules for Bulk Carriers or in NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

The requirements for the maintenance of this notation are given in Ch 5, Sec 14.

Note 1: It is reminded that for bulk carriers assigned with the additional service feature **CSR**, and one of the additional service features **BC-A** or **BC-B**, **GRAB [X]** is assigned as a mandatory additional service feature.

For bulk carriers assigned with the additional service feature **CSR** others than above, **GRAB [X]** may be assigned on a voluntary basis as an additional class notation.

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

b) Loading by grabs for ships other than those subject to NR522 Common Structural Rules for Bulk Carriers or to NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

The additional class notation **GRABLOADING** may be assigned to ships with hold tank tops specially reinforced for loading/unloading cargoes by means of grabs or buckets.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 15, Sec 2 and in Ch 5, Sec 14.

Note 2: This additional class notation may only be assigned to ships with the service notation **general cargo ship** (intended to carry dry bulk cargoes), **ore carrier**, **combination carrier/OBO**, **combination carrier/OOC** or **bulk carrier** not assigned with the additional service feature **CSR**.

However, this does not preclude ships not assigned with this notation from being loaded/unloaded with grabs.

6.18.3 Spectral fatigue analysis

The additional class notation **Spectral Fatigue ( )** may be assigned when the fatigue check of structural details is performed through spectral fatigue techniques. The information between brackets is a short description of routes and areas considered for this spectral fatigue analysis and associated design fatigue life.

Example: **Spectral Fatigue (North Atlantic)**

The Guidance Note NI611, Guidelines for Fatigue Assessment of Steel Ships and Offshore units, is to be used.

Other methodology may be used, subject to approval by the Society.

6.18.4 Whipping and springing assessment

The additional class notations **WhiSp1**, **WhiSp2** or **WhiSp3** may be assigned to ships where hydro-structure calculations taking into account the springing and whipping structural responses are performed. The requirements for the assignment of these notations are given in Pt D, Ch 2, Sec 4.

6.19 Additional notations for fire protection

6.19.1 Enhanced fire protection

The additional class notation **EFP-A** or **EFP-M** or **EFP-C** or **EFP-AMC** may be assigned to ships fitted with enhanced fire safety protection in, respectively, accommodation spaces or machinery spaces or cargo areas or all these spaces and areas.

The notations **EFP-A**, **EFP-C** and **EFP-AMC** may only be assigned to ships having one of the service notations listed in [4.2] (Cargo ships), or [4.3] (Bulk, ore and combination carriers), or [4.4] (Ships carrying liquid cargo in bulk). The notation **EFP-M** may be assigned to ships having one of the service notations listed in [4.2] (Cargo ships), or [4.3] (Bulk, ore and combination carriers), or [4.4] (Ships carrying liquid cargo in bulk), or [4.5] (Ships carrying passengers).

The requirements for the assignment of these notations are given respectively in Pt F, Ch 13, Sec 1.

The requirements for the maintenance of the notations **EFP-M** and **EFP-AMC** are given in Ch 5, Sec 16, [2].

6.19.2 Enhanced cargo fire protection for container ships

The additional class notations **ECFP** may be assigned to ships fitted with equipment, systems and arrangements improving the ability to manage a container cargo fire, as follows:

- **ECFP-1**, when the ship is fitted with portable equipment and arrangements, as per Pt F, Ch 13, Sec 2, [2], that may be considered as retrofit for an existing ship
- **ECFP-2**, when, in addition to the requirements for the notation **ECFP-1**, the ship is fitted with equipment, systems and arrangements, as per Pt F, Ch 13, Sec 2, [3], which constitute an extensive set of mitigation measures which are deemed effective and available with standard technologies
- **ECFP-3**, when, in addition to the requirements for the above mentioned notations, the ship is fitted with equipment, systems and arrangements, as per Pt F, Ch 13, Sec 2, [4], which include measures that are deemed relevant using innovative technologies.

In general, the additional class notations **ECFP-1**, **ECFP-2** or **ECFP-3** may be granted to ships assigned with the service notation **container ship**. In general, the additional class notation **ECFP-1** may also be granted to ships assigned the additional service feature **- equipped for carriage of containers**.

The additional class notations **ECFP-2** and **ECFP-3** are to be completed by the following notation **(Area 1, X_1m ; ... ; Area n, X_nm)**, where:

- **Area n** indicates the cargo holds where the maximum flooding level X_n is allowed,
- **X_n**, corresponds to the maximum flooding level in area n, in meters, with respect to the bottom of the hold.

Examples:

ECFP-2(All cargo holds, 20m)

ECFP-3(Holds 1 to 4,16m; Holds 5 to 8, 20m; Holds 9 to 12, 15m)

The requirements for the assignment and the maintenance of these notations are given respectively in Pt F, Ch 13, Sec 2 and in Ch 5, Sec 16, [3].

6.19.3 Cofferdam ventilation

The additional class notation **COVENT** may be assigned to ships having cofferdams in the cargo area which can be used as ballast tanks and which may be ventilated through a fixed ventilation system.

This notation is assigned only to ships having the service notation **bulk carrier**, **ore carrier**, **oil tanker**, **combination carrier/OBO**, **combination carrier/OOC**, **liquefied gas carrier**, **chemical tanker** or **FLS tanker**.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 13, Sec 3 and in Ch 5, Sec 16.

6.19.4 Electrical Vehicle Fire Protection

The additional class notations **EVFP** may be assigned to ships fitted with equipment, systems and arrangements which enhance the ability to manage a fire in the presence of electric vehicles, as follows:

- **EVFP-1** when the ship is fitted with equipment and arrangements, as per Pt F, Ch 13, Sec 4, [2], that may be considered as retrofit for an existing ship
- **EVFP-2** when, in addition to the requirements for the notation EVFP-1, the ship is fitted with equipment, systems and arrangements, as per Pt F, Ch 13, Sec 4, [3], which constitute an extensive set of mitigation measures using standard technologies
- **EVFP-3** when, in addition to the requirements for the above-mentioned notations, the ship is fitted with equipment, systems and arrangements as per Pt F, Ch 13, Sec 4, [4], which include measures using more advanced technologies.

The additional class notations **EVFP-1**, **EVFP-2** and **EVFP-3** may be assigned only to ships having the service notation **PCTC** or **PCC**.

The requirements for the assignment and maintenance of these notations are given respectively in Pt F, Ch 13, Sec 4 and Ch 5, Sec 16, [5].

6.20 Electric propulsion or electric power supply

6.20.1 Electric hybrid

The additional class notation **ELECTRIC HYBRID ( )** may be assigned to ships provided with an energy storage system (ESS) used to supply the electric propulsion and/or the main electrical power distribution system of the vessel.

The additional class notation **ELECTRIC HYBRID ( )** is to be completed, between brackets, by at least one of the following notation:

- **PM**, when at least one of the following power management mode is available: load smoothing mode, peak shaving mode or enhanced dynamic mode
- **PB**, when power backup mode is available
- **ZE MODE**, when zero emission mode is available.

The requirements for the assignment and maintenance of this notation are given in Pt F, Ch 14, Sec 1 and Ch 5, Sec 15.

Example:

ELECTRIC HYBRID (**PM**, **ZE MODE**).

6.20.2 Electric hybrid prepared

The additional class notation **ELECTRIC HYBRID PREPARED ( )** may be assigned to new ships that are designed with specific arrangements intended to accommodate an Electric Hybrid installation in the future.

The additional class notation **ELECTRIC HYBRID PREPARED ( )** is to be completed, between brackets, by at least one of the following notation:

- **PM**, when at least one of the following power management mode is available: load smoothing mode, peak shaving mode or enhanced dynamic mode
- **PB**, when power backup mode is available
- **ZE MODE**, when zero emission mode is available.

The requirements for the assignment of this notation are given in Pt F, Ch 14, Sec 2.

Example:

ELECTRIC HYBRID PREPARED (PM, ZE MODE).

6.20.3 Hybrid mechanical propulsion (HMPS)

The additional class notation **HMPS** may be assigned to ships provided with a propulsion plant which combines a diesel mechanical system and an electric system.

The requirements for the assignment and the maintenance of this notation are given respectively in Pt F, Ch 14, Sec 3, and in Ch 5, Sec 15, [3].

6.20.4 Hybrid mechanical propulsion prepared (HMPS-PREPARED)

The additional class notation **HMPS-PREPARED** may be assigned to new ships that are designed with specific arrangements intended to accommodate a hybrid mechanical propulsion installation in the future.

The requirements for the assignment of this notation are given in Pt F, Ch 14, Sec 4.

6.20.5 Onshore Power Supply (OPS)

The additional class notation **OPS( )** may be assigned to ships fitted with shore connection systems allowing the ship to plug into an onshore power source (OPS) when berthed.

The additional class notation **OPS( )** is to be completed between brackets by one or several shore supply characteristics the ship's installation is designed to receive:

- power supply voltage the ship can connect to, completed by AC and the ship's main frequency
- power supply voltage the ship can connect to, completed by DC.

Example:

OPS(440V AC 60Hz)

OPS(440V AC 60Hz / 6,6kV AC 60Hz / 11kV DC)

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 14, Sec 5 and Ch 5, Sec 15.

6.20.6 Onshore Power Supply prepared ships (OPS-PREPARED)

The additional class notation **OPS( )-PREPARED** may be assigned to ships designed with specific arrangements to accommodate a shore connection installation at a later stage where between bracket one or several shore supply characteristics the ship's installation is considered to receive:

- power supply voltage the ship can connect to, completed by AC and the ship's main frequency
- power supply voltage the ship can connect to, completed by DC.

The additional class notation **OPS( )-PREPARED** may be completed by **-C** when the cables for connection between the shore connection receiving box and the ship switchboard and to the relevant electrical pieces of equipment are already installed on board.

Example:

OPS(440V AC 60Hz)-PREPARED-C

The requirements for the assignment of this notation are given respectively in Pt F, Ch 14, Sec 6.

6.21 Cyber security

6.21.1 The additional class notations **CYBER MANAGED**, **CYBER RESILIENT** and **CYBER SECURE** may be assigned to ships equipped with computer based systems and equipment which comply with the requirements of NR659 Rules on Cyber Security for the Classification of Marine Units.

- The additional class notation **CYBER MANAGED** covers cyber security controls which are based in particular on the management of administration, and the operator actions subject to procedures and policies.
- The additional class notation **CYBER RESILIENT** covers cyber security controls which are based in particular on the management of administration, and engineering specifications subject to the requirements for procedures, software and hardware secure design.
- The additional class notation **CYBER SECURE** covers cyber security controls which are based in particular on the engineering specifications, and hardening of software and hardware.

6.21.2 The additional class notation **CYBER MANAGED** may be assigned to ships complying with the set of requirements for critical equipment management, crew training, remote access and change management defined in NR659 Chapter 2.

The requirements for the maintenance of the notation **CYBER MANAGED** are given in Ch 5, Sec 17.

Note 1: Ships already assigned the additional class notation **CYBER MANAGED PREPARED**, as defined in NR467 Rules for the Classification of Steel Ships July 2022 edition, may be assigned the additional class notation **CYBER MANAGED** upon satisfactorily compliance with the relevant parts of NR659.

6.21.3 The additional class notation **CYBER RESILIENT** may be assigned to ships other than those defined in [4.16.14] and complying with the minimum requirements regarding ships resilience defined in NR659, Chapter 3.

In compliance with [6.1.3], the additional class notation **CYBER RESILIENT** is assigned a construction mark, as defined in Article [3].

The requirements for the maintenance of the notation **CYBER RESILIENT** are given in Ch 5, Sec 17.

6.21.4 The additional class notation **CYBER SECURE** may be assigned to ships complying with the set of requirements for cyber management, equipment hardening and overall design of the systems to guarantee a defence in depth as defined in NR659 Chapter 4.

In compliance with [6.1.3], the additional class notation **CYBER SECURE** is assigned a construction mark, as defined in Article [3].

The requirements for the maintenance of the notation **CYBER SECURE** are given in Ch 5, Sec 17.

Note 1: Ships assigned the additional class notation **CYBER SECURE** comply with the requirements of the notation **CYBER RESILIENT** and additional requirements which are made to cover a higher level of cyber security.

6.22 Sustainable ships

6.22.1 The additional class notations **SUSTAINABLESHIP-1** or **SUSTAINABLESHIP-2** may be assigned to ships that are designed, built and equipped according to the requirements laid down in Pt F, Ch 15, Sec 8, focusing on the following sustainability aspects:

- prevention of sea and air pollution
- protection of the marine environment
- reduction of greenhouse gases emissions
- preparation for ship recycling
- enhancement of people well-being on board.

The requirements for the assignment of the additional class notations **SUSTAINABLESHIP-1** and **SUSTAINABLESHIP-2** are those corresponding to a combination of notations, their applicable associated requirements and any additional requirements, covering the sustainability aspects as defined in Pt F, Ch 15, Sec 8.

The maintenance of the additional class notations **SUSTAINABLESHIP-1** and **SUSTAINABLESHIP-2** are those respectively applicable to each required notations of the combination.

6.23 Smart systems (SMART)

6.23.1 The additional class notation **SMART( )** may be assigned to ships fitted with computerized based systems that incorporate smart functions for collection, transmission, analysis and visualisation of data.

These smart functions may be related to operation or maintenance of ships and may include monitoring, decision making support, remote monitoring, maintenance from shore or remote operation of systems.

The additional class notation **SMART( )** is to be completed between brackets by at least one of the following notations indicating the scope of application of the smart function:

- **Hx** for Hull
- **Mx** for Machinery
- **MHx** for Machinery Health Monitoring
- **Nx** for Navigation
- **EnEx** for Energy Efficiency
- **Lx** for Electronic Logbook
- **Xx** for Special smart function

where **x** indicates the smart group designation and can take one of the following values:

- **1** for “Computer Based ship”, i.e. for ships equipped with at least one smart system, which is in accordance with requirements related to computer based systems and smart functions as specified in the relevant Sections of NR675
- **2** for “Connected ship”, i.e. for ships equipped with at least one smart system, which is in accordance with smart group **1** requirements and with additional requirements related to data infrastructures, ship-shore data communication and cybersecurity as specified in the relevant Sections of NR675
- **3** for “Augmented ship”, i.e. for ships equipped with at least one smart system, which is in accordance with smart group **1** requirements and with additional requirements related to Shore Digital Solutions (SDS) as specified in the relevant Sections of NR675.

Note 1: For **Lx** the attention of the Owner is drawn to the fact that the flag Administration may impose additional and/or more stringent requirements issued by the Administration of the State whose flag the ship is entitled to fly.

The notation **EnEx** may be complemented by one or by a combination of the following complementary notations: **-Em**, **-T**, **-LIT**, **-S**, **-W** and **-CII**.

Each smart system with a distinctive smart function may be assigned the smart group **1**, **2** or **3**.

Examples:

SMART(H1)

SMART(MH2, N1, EnE3-LIT)

The requirements for the assignment and maintenance of the additional class notation **SMART( )** are given respectively in NR675 and Ch 5, Sec 17.

6.24 Corrosion protection

6.24.1 Coating performance standard CPS(COT)

The additional class notation **CPS(COT)** for cargo oil tanks may be assigned to ships complying with the requirements of NR530 Coating Performance Standard.

The requirements for the maintenance of this notation are given in Ch 5, Sec 18.

Note 1: **CPS(COT)** applies to cargo oil tanks of crude oil tankers of 5 000 tonnes deadweight and above.

6.24.2 Coating performance standard CPS(MFT)

The additional class notation **CPS(MFT)** for methanol fuel tanks may be assigned to ships complying with the requirements of NR530 Coating Performance Standard.

The requirements for the maintenance of this notation are given in Ch 5, Sec 18.

6.24.3 Coating performance standard CPS(VSP)

The additional class notation **CPS(VSP)** for void spaces may be assigned to bulk carriers and oil tankers complying with the requirements of NR530 Coating Performance Standard.

The requirements for the maintenance of this notation are given in Ch 5, Sec 18.

6.24.4 Coating performance standard CPS(WBT)

The additional class notation **CPS(WBT)** for water ballast tanks may be assigned to ships complying with the requirements of NR530 Coating Performance Standard.

The requirements for the maintenance of this notation are given in Ch 5, Sec 18.

Note 1: For bulk carriers and oil tankers assigned the additional service feature **CSR** and contracted for construction on or after 8 December 2006, and for ships complying with IMO resolution MSC.215(82), as amended, and contracted for construction on or after 1 July 2008, reference is made to [4.3.2] and [4.4.2] for the mandatory assignment of the additional service feature **CPS(WBT)**.

6.25 Other additional class notations

6.25.1 In-water surveys

The additional class notation **INWATERSURVEY** may be assigned to ships provided with suitable arrangements to facilitate the in-water surveys as provided in Ch 2, Sec 2, [5.4.5].

The requirements for the assignment of this notation are given in Pt F, Ch 15, Sec 3.

6.25.2 Permanent means of access (ACCESS)

The additional class notation **ACCESS** may be assigned to ships constructed on or after 1 January 2006 and:

- assigned with service notations as specified in [4.4.2] for ships carrying oil cargo in bulk and of 500 gross tonnage and over, having integral tanks, or
- assigned with service notations as specified in [4.3] for bulk, ore and combination carrier of 20 000 gross tonnage and over.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 15, Sec 4 and in Ch 5, Sec 19.

6.25.3 Helideck (HEL)

The additional class notation **HEL** may be assigned to ships complying with chapter II-2 of SOLAS and Civil Aviation Publication (CAP) 437 when they are fitted with helicopter facilities subject to design review and construction and installation survey by the Society.

The requirements for the assignment and maintenance of this notation are given respectively in Pt F, Ch 15, Sec 5 and in Ch 5, Sec 19.

6.25.4 Helicopter facilities for yachts

The additional class notation **HEL(Y)** may be assigned to ships assigned with service notation **yacht** or **charter yacht** fitted with helicopter facilities.

The requirements for the assignment of this notation are given in NR500, Rules for the Classification and Certification of Yachts.

6.25.5 Yachts equipped with a wind propulsion system

Ships assigned the service notation **yacht** or **charter yacht**, and equipped with a wind propulsion system as defined in NR206, Sec 1, [2.1], may be assigned one of the following additional class notations:

- **WIND PROPULSION-1** when the safety rigging parts of the wind propulsion system are included in the scope of classification
- **WIND PROPULSION-2** when both the safety and the operating rigging parts of the wind propulsion system are included in the scope of classifications.

In compliance with [6.1.3], these notations are assigned a construction mark as defined in [3].

The requirements for the assignment and the maintenance of these notations are given respectively in NR206 Wind propulsion systems and in Ch 4, Sec 12.

Note 1: The safety rigging parts and operating rigging parts are defined in NR206, Sec 1, [2.2].

6.25.6 Offshore handling systems (OHS)

The additional class notation **OHS** may be assigned to ships having offshore handling systems such as winches, strand jacks, chain jacks, sheaves and their foundations used for lifting/pulling of a load.

The requirements for the assignment and maintenance of this notation are given respectively in NR595 Classification of Offshore Handling Systems and in Ch 5, Sec 19.

Note 1: Specific procedures for non-permanent equipment are not applicable for ships.

6.25.7 Offshore access system (OAS)

The additional class notation **OAS** may be assigned to ships fitted with an offshore access system, based on gangways and used for the transfer of persons from ships to offshore facilities or from ship to ship, certified in accordance with NI 629 Certification of Offshore Access Systems.

In compliance with [6.1.3], this notation is assigned a construction mark as defined in Article [3].

The requirements for the assignment and maintenance of this notation are given respectively in NI 629 Certification of Offshore Access Systems and in Ch 5, Sec 19.

6.25.8 Elastic shaft alignment (ESA)

The additional class notation **ESA** may be assigned to ships having their shaft alignment assessment, such as calculations in view of hull deflection, aft steelwork elasticity, oil film behaviour and shaft bearing stiffness, and shaft installation procedure, compliant with specific requirements and methodology.

The requirements for the assignment of this additional class notation are given in Rule Note NR592 Elastic Shaft Alignment (ESA).

6.25.9 LNGFUEL-PREPARED

The additional class notation **LNGFUEL-PREPARED** may be assigned to new ships that are designed to accommodate future installation of an LNG fuel system.

The requirements for the assignment of this notation are given in Appendix 4 of NR529 Gas fuelled ships.

The additional class notation **LNGFUEL-PREPARED** may be completed, between brackets, by one or a combination of the following additional notations:

- **S**, when specific arrangements are implemented for the ship structure
- **A**, when specific arrangements for ventilation and access to gas-related spaces are already on board
- **P**, when specific arrangements are implemented for piping
- **ME-DF**, when the main engine(s) is (are) of the dual fuel type
- **AE**, when the auxiliary engines are either of the dual fuel type, or designed for future conversion to dual-fuel operation
- **B**, when the oil-fired boilers are either of the dual fuel type, or designed for future conversion to dual fuel operation.

Examples:

- **LNGFUEL-PREPARED**
- **LNGFUEL-PREPARED (P)**
- **LNGFUEL-PREPARED (P, ME-DF)**
- **LNGFUEL-PREPARED (S, P, ME-DF)**

Note 1: When the ship is effectively converted to dualfuel operation, the additional class notation **LNGFUEL-PREPARED** will be replaced by the additional service feature **LNGfuel dualfuel**, provided that all the applicable requirements given in [4.16.4] are complied with.

6.25.10 AMMONIAFUEL-PREPARED

Ships designed to accommodate future installation of an ammonia fuel system may be granted the additional class notation **AMMONIAFUEL-PREPARED**.

The additional class notation **AMMONIAFUEL-PREPARED** may be completed between brackets by one or a combination of notations **S**, **A**, **T**, **H**, **P** and **B**:

- **S**, when specific arrangements are implemented for the ship structure at the original design stage with the aim of preventing the need for specific structural modifications at the later stage
- **A** when specific arrangements for ventilation and access to ammonia related spaces are already on board
- **T**, when at least one original LNG or LPG fuel storage tank can also be used with ammonia fuel, possibly with modifications of the operational conditions of the tank at the later stage
- **H**, when the original LNG or LPG fuel handling equipment (pumps, heat exchangers, compressors) can also be used with ammonia
- **P**, when the original LNG or LPG piping system can also be used with ammonia
- **B**, when the original LNG or LPG boil-off gas management method (other than pressure accumulation, i.e. combustion unit, boiler, scrubbing system or refrigerating system) can also be used with ammonia.

Examples:

AMMONIAFUEL-PREPARED

AMMONIAFUEL-PREPARED (T)

AMMONIAFUEL-PREPARED (S,T,H)

The requirements for the assignment of this additional class notation are given in NR671 Ammonia-fuelled ships.

6.25.11 METHANOLFUEL-PREPARED

Ships designed to accommodate future installation of a methanol fuel system may be assigned the additional class notation **METHANOLFUEL-PREPARED**.

The additional class notation **METHANOLFUEL-PREPARED** may be completed between brackets by one or a combination of notations **S**, **T**, **H**, **P**, **ME-DF**, **AE**, **B**:

- **S**, when the ship structure is designed and built with specific arrangements at new construction stage with the aim of preventing the need for specific structural modifications at a later stage
- **T**, when at least one original fuel storage tank can be used with methanol fuel, possibly with modifications of the operational conditions of the tank at a later stage
- **H**, when the original fuel handling equipment can be used with methanol
- **P**, when the original piping system can be used with methanol
- **A**, when specific arrangements for ventilation and access to methanol-related spaces are already on board
- **ME-DF**, when the main engine(s) is (are) of the dual fuel type approved for methanol
- **AE**, when the auxiliary engines either are of a dual fuel type approved for methanol, or designed for future conversion to dual fuel operation
- **B** when the oil-fired boilers are either of a dual fuel type approved for methanol, or designed for future conversion to dual fuel operation.

Examples:

METHANOLFUEL-PREPARED

METHANOLFUEL-PREPARED (T)

METHANOLFUEL-PREPARED (S,T,H).

The requirements for the assignment of this additional class notation are given in NR670.

6.25.12 HYDROGENFUEL-PREPARED

Ships designed to accommodate future installation of a hydrogen fuel system may be assigned the additional class notation **HYDROGENFUEL-PREPARED**.

The additional class notation **HYDROGENFUEL-PREPARED** may be completed between brackets by one or a combination of notations **S**, **A**, **TL** or **TG**, **HL** or **HG**, **PL** or **PG**, **B**:

- **S** when specific arrangements are implemented for the ship structure at the original design stage with the aim of preventing the need for specific structural modifications at the conversion stage
- **A** when specific arrangements for ventilation and access to hydrogen-related spaces are already on board
- **TL** or **TG** when at least one original fuel storage tank can also be used with hydrogen fuel respectively in its liquefied or gaseous form, possibly with modifications of the operational conditions of the tank at the ship conversion stage
- **HL** or **HG** when the original fuel handling equipment (pumps, heat exchangers, compressors) can also be used with hydrogen respectively in its liquefied or gaseous form
- **PL** or **PG** when the original piping system can also be used with hydrogen respectively in its liquefied or gaseous form

Note 1: The notations **PL** and **PG** are assigned for the whole piping system meaning that they are mutually exclusive.

- **B** when the original boil-off gas management method can also be used with hydrogen.

Examples:

HYDROGENFUEL-PREPARED

HYDROGENFUEL-PREPARED (TL)

HYDROGENFUEL-PREPARED (TL, HL, PL, B)

HYDROGENFUEL-PREPARED (A, PG, B)

The requirements for the assignment of this additional class notation are given in NR678.

6.25.13 FSRU READY

The additional class notation **FSRU READY** may be assigned to ships having the service notation **liquefied gas carrier** that are designed and built with specific arrangements in view of accommodating future installation of a regasification system.

The additional class notation **FSRU READY** may be completed between brackets by one, or by a combination, of the following notations:

- **P**, when specific arrangements for piping and process systems are taken into account during the initial design of the ship in order to consider additional capacity for a future conversion
- **R**, when the regasification system, or main pieces of equipment, are defined at the time of assignment of the notation
- **I**, when the ship is designed and built in order to allow on-site in-water survey without dry-docking once converted into FSRU and subject to acceptance from Authorities.

The requirements for the assignment of this notation are given in Pt F, Ch 15, Sec 7.

6.25.14 Man overboard detection (MOB)

The additional class notation **MOB** may be assigned to self-propelled ships arranged with means capable of automatically detecting a person going overboard and instantaneously alert the ship's personnel.

This notation developed for passengers ships may be assigned to cargo ships at the discretion of Society.

The requirements for the assignment of this notation are given in Pt F, Ch 15, Sec 6.

6.25.15 Internal connectivity

The additional class notation **INTERNAL CONNECTIVITY** may be assigned to ships for which the onboard network infrastructure enables internal connectivity.

The requirements for the assignment and the maintenance of this notation are given in Rule Note NR688 Internal Connectivity.

Note 1: The scope of this notation is limited to a list of Internal Connectivity Areas (ICAs) to be specified by the applicant.

This list of ICAs is to be indicated in a memorandum.

6.26 System fitted but not required by the rules

6.26.1 General

The notations dealt with in this sub-article are assigned only when a system is installed on board, although the ship does not meet the conditions under which the Rules request it to be fitted.

6.26.2 Inert gas

The additional class notation **IG** may be assigned to ships fitted with an inert gas system, as follows:

- Ships contracted for construction before 1 January 2016:

  This notation is assigned only to ships having the service notation:

  - **oil tanker** or **FLS tanker**, and of less than 20000 tonnes deadweight, or
  - **chemical tanker** for which an inert gas system is not required in pursuance of July 2014 edition of the Rules, Pt D, Ch 8, Sec 9, [1.3.1].

  The requirements for the assignment of the notation **IG** are given in July 2014 edition of the Rules:

  - Pt D, Ch 7, Sec 6, [5.1.2], for oil tankers or FLS tankers, and
  - Pt D, Ch 8, Sec 9, [2.5.3], for chemical tankers.
- Ships contracted for construction on or after 1 January 2016:

  This notation is assigned only to ships having the service notation **oil tanker**, **FLS tanker** or **chemical tanker**, and of less than 8000 tonnes deadweight.

  The requirements for the assignment of the notation **IG** are given in:

  - Pt D, Ch 7, Sec 6, [5.1.3], for oil tankers or FLS tankers, and
  - Pt D, Ch 8, Sec 9, [2.3], for chemical tankers.
- This notation may be assigned to ships having the service notation **supply**.

  The requirements for the assignment of the **IG** notation are given in Pt D, Ch 8, Sec 9, [2.3].

The requirements for the maintenance of the notation **IG** are given respectively:

- for **oil tanker** or **FLS tanker**, in Ch 4, Sec 3, [3.4]
- for **chemical tanker** or **supply**, in Ch 4, Sec 4, [3.4].

6.26.3 Emergency towing arrangement (ETA)

The additional class notation **ETA** may be assigned to ships fitted with an emergency towing arrangement.

In principle, this notation is assigned only to ships of less than 20000 tonnes deadweight having one of the service notations **oil tanker**, **combination carrier/OBO**, **combination carrier/OOC**, **liquefied gas carrier**, **chemical tanker** and **FLS tanker**.

The requirements for the assignment of this notation are given in Pt B, Ch 12, Sec 4, [3].

7 Other notations

7.1

7.1.1 The Society may also define other notations by means of provisional requirements and guidelines, which may then be published in the form of tentative rules.

8 Diving systems

8.1 General

8.1.1 The service notations related to diving systems are listed in [8.1.2]. The requirements for the assignment of these service notations are given in NR610 Rules for the Classification of Diving Systems.

8.1.2 The following service notations are to be assigned to the diving systems, as relevant:

- **diving system-integrated**, for the diving systems permanently installed on diving support units
- **diving system-portable**, for the diving systems on portable modules and installed temporarily on diving support units
- **hyperbaric reception facility**, when a decompression chamber is used to transfer the occupants of hyperbaric rescue units.

8.1.3 The service notations **diving system-integrated** and **diving system-portable** are to be completed by one of the following additional service features:

- **surface air**, for diving systems using only compressed air
- **surface mixed-gas**, for diving systems using mixed-gas
- **saturation**, for saturation diving systems
- **bounce**, for bounce systems using a closed bell.

8.1.4 The requirements for the maintenance of these notations are given in Ch 4, Sec 8, [18].

Appendix 1 Notations Assigned According to Editions of the Rules Former to June 2000 Edition

1 Application for surveys and correspondence with current notations

1.1 General

1.1.1 The current edition of the Rules uses a different system of class notations, in comparison with the one in force in the editions of the Rules former to June 2000 edition.

Sub- article [1.4] gives correspondence between the notations assigned to ships according to the editions of the Rules former to June 2000 edition and the class notations assigned according to the current edition.

1.2 Phasing out from former to current notations

1.2.1 All ships admitted or being admitted to class after the effective application date of the current Rules are to be assigned class notations in accordance with Ch 1, Sec 2.

1.2.2 Ships with notations assigned in accordance with editions of the Rules former to the June 2000 edition of the Rules keep their current notations, latest until next class renewal survey.

At the class renewal survey, notations having an equivalence with the notations given in the current edition, are replaced by the corresponding notation according to tables of subarticle [1.4].

Notations indicated as having no equivalence with any notation in the current Rules are kept for the life time of the ship.

Note 1: At Owner's request, change over from former to current notations may be performed before the next class renewal survey.

1.3 Application of scope of surveys

1.3.1 For periodicity and scope of surveys for maintenance of class of ships being still assigned class notations according to editions of the Rules former to June 2000 edition, tables given in [1.4] indicate which requirements are applicable to such notations, with reference to class notations of the current Rules.

1.4 Correspondence between former and current notations

1.4.1 Tab 1 gives correspondence between former class symbols and construction marks and the current ones.

1.4.2 Tab 2 gives correspondence between former service notations and the current ones, as well as corresponding periodicity and scope of survey for maintenance of class.

Tab 3 gives correspondence between former additional service notations and the current additional service feature.

1.4.3 Tab 4 gives correspondence between former navigation notations or operating area notations and the current ones.

1.4.4 Tab 5 gives correspondence between former additional class notations or special notations and the current ones, as well as corresponding survey requirements for maintenance of class.

Table 1 : Class symbols and construction marks

Former notation	Current notation	Remarks
I 3/3	class symbol **I**	Validity of certificate ≤ 5 years
II 5/6, II 3/3 or I 5/6	class symbol **II**	Validity of certificate ≤ 3 years
E, (E) or (–)	None. A note is entered in a memorandum for notations (E) or (–)	Surveys of anchors and chains dealt with in Part A, Chapter 3
✠, ✠ or • placed before the service notation	✠, ✠ or • **HULL**	**(1)**
✠, ✠ or • MACH	✠, ✠ or • **MACH**	**(1)**
(1) No specific periodicity or scope of survey attached to such notation.		

Table 2 : Service notations

Former notation	Current notation	Periodicity and scope of surveys
bulk carrier	**bulk carrier**	bulk carrier ESP or general cargo ship, as applicable
bulk carrier - oil tanker	**combination carrier/OBO**	combination carrier/OBO
cargoship	**general cargo ship**	general cargo ship
chemical tanker	**chemical tanker**	chemical tanker
containership	**container ship**	container ship
deck ship	**deck ship**	all ships
dredger	**dredger**	dredger
fire fighting ship 1, 2, 3, - or water spray	**fire fighting 1**, **2**, **3**, **E** or **water spraying**	fire fighting ship 1, 2, 3, E or water spraying
fishing vessel	**fishing vessel**	fishing vessel
floating dock	**floating dock (3)**	floating dock
hopper barge	**hopper unit**	hopper unit
hopper dredger	**hopper dredger**	hopper dredger
HSC (CAT A or CAT B)	**HSC** (**-CAT A** or **-CAT B**)	HSC (CAT A or CAT B)
launch, seagoing launch	**launch**, **seagoing launch**	all ships
light ship	**light ship**	light ship
liquefied gas carrier	**liquefied gas carrier**	liquefied gas carrier
livestock carrier	**livestock carrier**	livestock carrier
oil recovery ship	**oil recovery**	oil recovery ship
oil tanker	**oil tanker**	oil tanker
ore carrier	**ore carrier**	ore carrier
ore carrier - oil tanker	**combination carrier/OOC**	combination carrier/OOC
passenger ferry	**ro-ro passenger ship**	ro-ro passenger ship
passenger ship	**passenger ship**	passenger ship
pontoon	**pontoon**	pontoon
pontoon/crane or pontoon/derrick	**pontoon - crane**	pontoon - crane
product tanker	**FLS tanker**	FLS tanker
pusher	**tug**	tug
refrigerated carrier	**refrigerated cargo ship**	refrigerated cargo ship
roll on - roll off	**ro-ro cargo ship**	ro-ro cargo ship
special service / ...	**special service - ... (1)**	special service - ... **(1)**
split hopper barge	**split hopper unit**	split hopper unit
split hopper dredger	**split hopper dredger**	split hopper dredger
supply vessel	**supply**	supply vessel
tanker	**tanker**	tanker
tug	**tug**	tug
yacht	**yacht -motor-S** or **yacht -sailing-S (2)**	yacht

(1) Unless a new service notation corresponds to the specified service, such as **cable laying**.

(2) Ships assigned with the service notation **charter yacht** according to the Rule Note NR381 keep their service notation latest until next class renewal survey. At the next class renewal survey, or before it at Owner's request, the service notation is replaced by the current service notation as per Rule Note NR500 (**charter yacht-motor-S** or **charter yacht-sailing-S**).

(3) Vessels assigned the service notation **floating dock** in accordance with previous editions of these Rules, keep their service notation. For floating docks contracted after 1 July 2024, reference is made to Ch 1, Sec 2, [4.15.7] and NR612 Rules for the Classification of Harbour Equipment

Table 3 : Additional service notations - Additional service features

Former notation	Current notation (additional service feature)
/NP	**- no propulsion**
/AP	**- assisted propulsion**
/WAP	**WAP**
/EAWP	**EAWP**
ESP	**ESP**
flash point above 60°C	**flash point > 60°C**
(oil tanker) /floating storage	refer to NR445 Rules of Offshore Units, Pt D, Ch 1, Sec 1 or **oil storage service**
/F	none
/LNG	none
/LNG-LPG	none

Table 4 : Navigation notations and operating area notations

Former notation	Current notation
deep sea	**unrestricted navigation**
coastal waters	none **(1)**
sheltered waters	**sheltered area**
sea and river waters, deep sea and river waters, coastal waters and river waters, sheltered waters and river waters	none
deep sea/occasionally	**temporary unrestricted navigation**
dredging within 8 miles from shore	**dredging within 8 miles from shore**
dredging within 15 miles from shore or within 20 miles from port	**dredging within 15 miles from shore or within 20 miles from port**
dredging over 15 miles from shore	**dredging over 15 miles from shore**

(1) However, navigation notations **summer zone**, **tropical zone** and/or **coastal area** may be assigned by equivalence after review of the Society.

Table 5 : Additional class notations and special notations

Former notation	Current notation	Survey requirements
ACA	**LASHING**	**(1)**
ALP, ALM, (ALP), (ALM) ALS, (ALS)	**ALP**, **ALM**, **(ALP)**, **(ALM)** none (existing notation is kept)	see Rule Note NR526
ALT	**nonhomload** (additional service feature)	**(1)**
AUT, AUT-MS, AUT-CC	**AUT-IMS**, **AUT-UMS**, **AUT-CCS**	automated machinery systems Ch 5, Sec 4
AUT-OS	none (existing notation is kept)	automated machinery systems Ch 5, Sec 4
BRG	**STRENGTHBOTTOM**	STRENGTHBOTTOM Ch 5, Sec 14, [2]
CL	none (existing notation is kept)	**(1)**
CM1 or CM2	none (existing notation is kept)	**(1)**
CNC-E, CNC-1, -V	**SYS-NEQ**, **SYS-NEQ-1** notation -V is not retained	SYS-NEQ, SYS-NEQ-1 Ch 5, Sec 5
COMFORT - 1, 2, 3	**COMF-1, 2, 3**	
COMFORT -n1, -n2, -n3	**COMF-NOISE 1, 2, 3**	
COMFORT -v1, -v2, -v3	**COMF-VIB 1, 2, 3**	
CSA	**SDS**	**(1)**

(1) No survey requirement attached to such notation.
(2) However, **AVM-APS**, **AVM-DPS** or **AVM-IPS** may be assigned by equivalence on a case by case basis after review by the Society.

Former notation	Current notation	Survey requirements
DEP	none (existing notation is kept) **(2)**	availability of machinery Ch 5, Sec 3
ETA	**ETA** Ships of 20000 tdw and above: existing notation is kept only until next class renewal survey and will be dropped after	see survey of emergency towing arrangement as per relevant service notation
F	none (existing notation is kept)	**(1)**
Heavy cargo	**heavy cargo** (additional service feature)	**(1)**
Heavy parcels on deck	**heavy cargo** (additional service feature)	**(1)**
Ice I super, Ice I, Ice II, Ice III	none (existing notation is kept)	arrangements for navigation in ice Ch 5, Sec 10
Ice Class IA Super, Ice Class IA, Ice Class IB, Ice Class IC	**ICE CLASS IA SUPER**, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC**	arrangements for navigation in ice Ch 5, Sec 10
Ice, Ice Class ID	**ICE**, **ICE CLASS ID**	arrangements for navigation in ice Ch 5, Sec 10
IG	**IG** For chemical tankers and oil tankers/FLS tankers for which an inert gas system is required by the Rules, the existing notation is kept only until next class renewal survey and will be dropped after	see survey of inert gas installation as per relevant service notation assigned
INT	none (existing notation is kept)	**(1)**
OIL POL-ENG, OIL POL-CARG, NLS-POL	none (existing notation is kept only until next class renewal survey and will be dropped after)	**(1)**
PDY	**DYNAPOS**	DYNAPOS Ch 5, Sec 12, [4]
PFA	none (existing notation is kept only until next class renewal survey and will be dropped after)	see survey of internal platforms and ramps in Ch 4, Sec 6
PORT	**AUT-PORT**	automated machinery systems Ch 5, Sec 4
PST, LCDT	none (existing notation is kept)	**(1)**
PTR	none (existing notation is kept)	survey of thruster installation (all ships)
(RMC) -A	none (existing notation is kept)	**(1)**
(RMC) /precooling, /quick freezing plant, /CA	**-PRECOOLING**, **-QUICKFREEZE**, **-AIRCONT**	refrigerating installations Ch 5, Sec 9
RMC, RMC-C, RMC-V	**REF-CARGO**, **REF-CONT**, **REF-STORE**	refrigerating installations Ch 5, Sec 9
RMC-S	none (existing notation is kept)	refrigerating installations Ch 5, Sec 9
SPM	**SPM**	SPM Ch 5, Sec 12, [3]
TOR, TOR-F	none (existing notation is kept)	**(1)**
Veristar notations hull and machinery	**VeriSTAR-HULL**, **VeriSTAR-HULL SIS**, **STAR-MACH**, **STAR-MACH SIS**, **STAR SIS**	VeriSTAR system Ch 5, Sec 2

(1) No survey requirement attached to such notation.

(2) However, **AVM-APS**, **AVM-DPS** or **AVM-IPS** may be assigned by equivalence on a case by case basis after review by the Society.

CHAPTER 2
ASSIGNMENT, MAINTENANCE, SUSPENSION AND WITHDRAWAL OF CLASS

Section 1 Assignment of Class

Section 2 Maintenance of Class

Section 3 Suspension and Withdrawal of Class

Appendix 1 Planned Maintenance Survey System

Appendix 2 CSM and PMS Systems: Surveys Carried out by the Chief Engineer

Appendix 3 Thickness Measurements: Extent, Determination of Locations, Acceptance Criteria

Appendix 4 Condition Monitoring and Condition Based Maintenance

Appendix 5 Remote Classification Surveys

Section 1 Assignment of Class

1 General

1.1

1.1.1 Class is assigned to a ship upon a survey, with the associated operations, which is held in order to verify whether it is eligible to be classed on the basis of the Rules of the Society (see Ch 1, Sec 1, [1.3.2]). This may be achieved through:

- the completion of the new building, during which a survey has been performed
- a survey carried out according to the agreement developed by the IACS Member Societies when ships change class between members, or
- a specific admission to class survey, in cases where a ship is classed with a non-IACS Society or is not classed at all.

2 New building procedure

2.1 Ships surveyed by the Society during construction

2.1.1 When a ship is surveyed by the Society during construction, it is to comply with those requirements of the Rules which are in force and applicable depending on the class of the ship, taking into account the provisions of Ch 1, Sec 1, [2.1] and Ch 1, Sec 1, [2.2].

The hull surveys for new constructions are to be carried out in accordance with the requirements of Ch 3, Sec 7.

2.1.2 The Society:

- approves the plans and documentation submitted as required by the Rules
- proceeds, if required, with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works
- carries out surveys, attends tests and trials provided for in the Rules, or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the rule requirements in relation to the approved drawings
- assigns the construction mark ✠; refer to Ch 1, Sec 2, [3.2.1].

2.1.3 The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

2.1.4 As part of his interventions during the ship's construction and subject to the provisions of [2.1.2], the Surveyor will:

- conduct an overall examination of the parts of the ship covered by the Rules
- examine the construction methods and procedures when required by the Rules
- check selected items covered by the rule requirements
- attend tests and trials where applicable and deemed necessary.

2.1.5 Use of materials, machinery, appliances and items

As a general rule, all materials, machinery, boilers, auxiliary installations, equipment, items etc. (generally referred to as "products") which are covered by the class and used or fitted on board ships surveyed by the Society during construction are to be new and, where intended for essential services as defined in Ch 1, Sec 1, [1.2.1], tested by the Society.

Second hand materials, machinery, appliances and items may be used subject to the specific agreement of the Society and the Owner.

The requirements for the selection of materials to be used in the construction of the various parts of a ship, the characteristics of products to be used for such parts and the checks required for their acceptance are to be as stated in Part C of the Rules (NR467) and in NR216 Materials and Welding, as applicable, or in other Parts of NR467, or as specified on approved plans. In particular, the testing of products manufactured according to quality assurance procedures approved by the Society and the approval of such procedures are governed by the requirements of NR216 Materials and Welding, Ch 1, Sec 1, [3].

Attention is drawn to the provisions of the EC Regulation 391/2009, specifically Article 10.

2.1.6 Defects or deficiencies and their repair

The Society may, at any time, reject items found to be defective or contrary to rule requirements or require supplementary inspections and tests and/or modifications, notwithstanding any previous certificates issued.

All repairs are subject to the preliminary agreement of the Society. When the limits of tolerance for defects are specified in the Rules concerned or by the Manufacturer, they are to be taken into account for repairs.

It is incumbent upon the Interested Party to notify the Society of any defects noted during the construction of the ship and/or of any item not complying with the applicable requirements or in any case unsatisfactory. Proposals regarding remedial actions intended to be adopted to eliminate such defects or unsatisfactory items are to be submitted to the Society and, if accepted, carried out to the Surveyor's satisfaction.

2.1.7 Equivalence of Rule testing under certain conditions

Notwithstanding the provisions of [2.1.4], the Society may, at its discretion and subject to conditions and checks deemed appropriate, accept certain materials, appliances or machinery which have not been subjected to rule testing.

2.2 Other cases

2.2.1 When the procedure adopted does not comply with that detailed in [2.1] but the Society deems that it is acceptable for the assignment of class, the construction mark μ is assigned in accordance with Ch 1, Sec 2, [3.2.3].

2.3 Documentation

2.3.1 Documentation relevant to the class applied for is to be submitted for the approval of the Society.

2.3.2 The documentation to be submitted is listed in the relevant chapters of the Rules.

The lists of requested plans, documents and other items related to classification are not exhaustive and are intended as guidance for specifying the set of information to be submitted, rather than lists of actual titles. The Society may require that additional information be submitted if deemed necessary for the verification of rule requirements, especially in the case of non-conventional design.

2.3.3 The documentation submitted to the Society is examined in relation to the class applied for in the request for classification.

Note 1: Should the Interested Party subsequently wish to have the class, in particular the service notation or navigation notation, granted to the ship modified, plans and drawings are generally to be re-examined.

2.3.4 A copy of the submitted plans will be returned duly stamped, with remarks related to the compliance with the rule requirements should the need arise.

2.3.5 As a rule, modifications of the approved plans regarding items covered by classification are to be submitted.

2.3.6 Design data to be submitted to the Society are to incorporate all information necessary for the assessment of the design of the ship for the purpose of assignment of class. It is the responsibility of the Interested Party to ascertain that the design data are correct, complete and compatible with the use of the ship.

2.3.7 Design calculations are to be provided, when called for, as supporting documents to the submitted plans.

2.3.8 Design data and calculations are to be adequately referenced. It is the duty of the Interested Party to ascertain that the references used are correct, complete and applicable to the design of the ship.

2.3.9 The submitted plans are to contain all necessary information for checking the compliance with the requirements of the Rules.

2.3.10 In the case of conflicting information, submitted documentation will be considered in the following order of precedence: design data, plans, design calculations.

2.3.11 It is the responsibility of the Interested Party to ascertain that drawings used for the procurement, construction and other works are in accordance with the approved plans.

2.3.12 Upon specific agreement between the Society and the Interested Parties, three-dimensional models may be submitted in place of two-dimensional plans. In this case, the Society may require that additional documentation containing information that cannot be specified in three-dimensional models be submitted.

3 Ships classed after construction

3.1 General

3.1.1 When an Owner applies to the Society for a ship already in service to be admitted to class, the application will be processed differently depending on whether the ship is:

- classed with an IACS Society, or
- not classed with an IACS Society.

3.2 Ships classed with a Classification Society subject to compliance with QSCS, reported as compliant by the Losing Society

3.2.1 In this case, ships will be admitted to the Society's class upon satisfactory surveys and verification of documentation. For the extent and scope of the surveys to be carried out and the list of documentation to be submitted by the Interested Party, reference is to be made to [3.2.3], [3.2.4] and [3.2.5].

Note 1: For transfer of class at ship's delivery, specific procedures apply.

Note 2: Compliant ship means a ship classed with a Classification Society subject to verification of compliance with QSCS and in full compliance with all applicable and relevant IACS Resolutions.

3.2.2 Surveys principle

Surveys to be carried out are based on the age of the ship and the updated current class status as provided by the previous IACS Member Society. The extent of these surveys is to be at least as contained in [3.2.3] and in [3.2.4].

3.2.3 Hull surveys

a) For vessels of age less than 5 years, the survey is to take the form of an annual survey

b) For vessels between 5 and 10 years of age, in addition, the survey is to include the inspection of a representative number of ballast spaces

c) For vessels of 10 years of age and above but less than 20 years of age, in addition, the survey is to include the inspection of a representative number of cargo spaces, except for:

- For gas carriers, in lieu of internal inspection of cargo spaces, the following applies:
  - inspection of surrounding ballast tank(s), including external inspection of independent cargo tank(s) and supporting systems as far as possible
  - review of cargo log books and operational records to verify correct functioning of the cargo containment system.
- For chemical tankers of 10 years and above but less than 15 years of age, in lieu of an internal inspection of cargo tanks without internal stiffening and framing, inspections of surrounding ballast tank(s) and void spaces and deck structure, are to be applied.

d) For vessels with notation **ESP**, which are 15 years of age and above, but less than 20 years of age, the survey is to have the scope of a class renewal survey or an intermediate survey, whichever is due next

e) For all vessels which are 20 years of age and above, the survey is to have the scope of a class renewal survey (this requirement is also applicable to ships having their hull under continuous survey)

f) In lieu of the requirements in items a) through e) above, the following apply for site specific purpose-built Floating Production and/or Storage Vessels:

- for vessels of age less than 5 years, the survey is to have the scope of an annual survey
- for vessels of age between 5 and 10 years, in addition, the survey is to include the inspection of twenty percent of ballast spaces
- for vessels of age between 10 and 20 years, in addition, the survey is to include twenty percent of cargo spaces
- for vessels over 20 years of age, the survey is to have the scope of a class renewal survey.

g) For site specific Floating Production and/or Storage Vessels which have been converted from other vessels, the survey is to take form of an annual survey and also include inspection of twenty percent of ballast spaces and twenty percent of cargo spaces until 20 years have elapsed since conversion. After 20 years the survey is to have the scope of a class renewal survey.

h) In the context of applying items d) and e) above, if a dry-docking of the vessel is not due at time of transfer, consideration can be given to carrying out an underwater examination in lieu of dry-docking

i) In the context of applying items d) and e) above, as applicable, the anchors and anchor chain cables ranging and gauging for vessels over 15 years of age is not required to be carried out as part of the class entry survey unless the class entry survey is being credited as a periodical survey for maintenance of class. If the class entry survey is to be credited as a periodical survey of maintenance of class, consideration may be given by the gaining society to the acceptance of the anchors and anchor chain cables ranging and gauging carried out by the losing society provided they were carried out within the applicable survey window of the periodical survey in question

j) In the context of applying items a) to h) above, as applicable:

- if the class entry survey is to be credited as a periodical survey for maintenance of class, consideration may be given by the gaining society to the acceptance of thickness measurements taken by the losing society provided they were carried out within the applicable survey window of the periodical survey in question.
- if the class entry survey is not to be credited as a periodical survey for maintenance of class, consideration may be given by the gaining society to the acceptance of thickness measurements taken by the losing society provided they were carried out within 15 months prior to completion of class entry survey when it is in the scope of a class renewal survey, within 18 months prior to the completion of class entry survey when it is in the scope of an intermediate survey.

In both cases, the thickness measurements are to be reviewed by the gaining society for compliance with the applicable survey requirements, and confirmatory gauging are to be taken to the satisfaction of the gaining society.

k) In the context of applying c) to h) above, as applicable, tank testing for vessels over 15 years of age is not required to be carried out as part of class entry survey unless the class entry survey is being credited as a periodical survey for the maintenance of class. If the class entry survey is to be credited as a periodical survey for maintenance of class, consideration may be given by the gaining society provided they were carried out within the applicable survey window of the periodical survey in question.

l) In the context of applying a) to h) above, as applicable, compliance with IACS Unified Requirements that require compliance at the forthcoming due periodical survey (such as UR S26 and S27) are not required to be carried out /completed as part of the class entry survey unless the class entry survey is credited as a periodical survey for maintenance of class.

3.2.4 Machinery surveys

A general examination of all essential machinery is to be held including at least the following:

a) Examination under working condition of oil fuel burning equipment, boilers, economizers and steam/steam generators. The adjustment of safety valves of this equipment is to be verified by checking the records on board ship

b) All pressure vessels are to be examined

c) Insulation resistance, generator circuit breakers, preference tripping relays and generator prime mover governors are to be tested and paralleling and load sharing to be proved

d) In all cases, navigating lights and indicators are to be examined and their working and alternative sources of power verified

e) Bilge pumps, emergency fire pumps and remote controls for oil valves, oil fuel pumps, lubricating oil pumps and forced draught fans are to be examined under working condition

f) Recirculating and ice clearing arrangements, if any

g) The main and all auxiliary machinery necessary for operation of the ship at sea together with essential controls and steering gear is to be tested under working conditions. Alternative means of steering are to be tested

h) A short sea trial is to be held, at the Surveyor's discretion, if the ship has been laid up for a long period

i) Initial start arrangements are to be verified

j) In the case of oil tankers, the cargo oil system and electrical installations in way of hazardous spaces are to be checked for compliance with rule requirements. Where intrinsically safe equipment is installed, the Surveyors are to satisfy themselves that such equipment has been approved by a recognised authority. The safety devices, alarms and essential instruments of the inert gas system are to be verified and the plant generally examined to ensure that it does not constitute a hazard to the ship.

Note 1: For the transfer of class or adding class at ship's delivery, items c) and j) may be verified by reviewing the ship's record.

3.2.5 Documentation

As a rule, the documentation to be supplied is the following.

a) Main plans:
- General arrangement
- Capacity plan
- Hydrostatic curves
- Loading manual, where required
- Damage stability calculation, where required.

b) Hull structure plans:
- Midship section
- Scantling plan
- Decks
- Shell expansion
- Transverse bulkheads
- Rudder and rudder stock
- Hatch covers
- For ship assigned with the additional service feature **CSR**, plans showing, for each structural element, both as-built and renewal thicknesses and any thickness for "voluntary addition".

c) Machinery plans:
- Machinery arrangement
- Intermediate, thrust and screw shafts
- Propeller
- Main engines, propulsion gears and clutch systems (or Manufacturer's make, model and rating information)
- For steam turbine ships, main boilers, superheaters and economisers (or Manufacturer's make, model and rating information) and steam piping
- Bilge and ballast piping diagram
- Wiring diagram
- Steering gear system piping and arrangements and steering gear Manufacturer's make and model information
- Torsion vibration calculations, for ships less than two years old
- Plans for flexible couplings and/or torque limiting shafting devices in the propulsion line shafting (or Manufacturer's make, model and rating information), for ships assigned with one of the ice class additional class notations described in Ch 1, Sec 2, [6.10.1]
- Pumping arrangements at the forward and after ends, drainage of cofferdams and pump rooms and general arrangements of cargo piping in tanks and on decks, for oil tankers.

d) Plans required for ships assigned one of the additional class notations for Automated Machinery Systems:
- Instrument list
- Fire alarm system
- Plans for systematic maintenance and functioning tests.

e) Additional documents required for approval of alternative design and arrangements.

f) Document(s) of approval of alternative design and arrangements are to be submitted, if any.

g) Structural fire protection and fire control plan.

Alternative technical data may be accepted by the Society in lieu of specific items of the listed documentation not available at the time of the transfer of class.

3.2.6 For ships of less than 100 gross tonnage, special consideration will be given to the scope of surveys and documentation to be supplied.

3.3 Non-compliant ships

3.3.1 In this case, the class of the ship will be assigned upon a preliminary review of the documentation listed in [3.3.3] and subsequent satisfactory completion of the surveys, the extent and scope of which are given below.

Note 1: Non-compliant ship means a ship either not classed with a Classification Society subject to verification of compliance with QSCS or not in full compliance with all applicable and relevant IACS Resolutions.

3.3.2 Surveys

The extent and scope of the admission to class survey are to be not less than those required at the class renewal survey of a ship of the same age and type; in addition all other periodical surveys should be performed together with those inspections which are linked to specific service notations and/or additional class notations and/or special installations the ship is provided with.

3.3.3 Documentation

As a general rule, the documentation to be supplied to the Society is not to be less than the following.

a) Main plans:
- General arrangement
- Capacity plan
- Loading cases, calculations of still water bending moments, and relevant documents, particulars of loading calculator and instruction booklet as per Society's requirements, according to the case
- Stability documents, if applicable (refer to Part B, Chapter 3).

b) Hull structure plans:
- Midship section
- Profile and deck plan
- Watertight bulkheads
- Rudder and rudder stock
- Shell expansion
- Hatch covers
- Stern frame.

c) Machinery plans:
- Engine room general arrangement
- Diagram of fuel- (transfer, service), bilge-, ballast-, lubricating oil-, cooling-, steam- and feed-, general service and starting compressed air piping
- Diagram of fire-fighting systems
- Drawings of boilers and air receivers
- Drawings of shaft line, reduction gear and propeller
- Drawings of steering gear
- Torsion vibration calculations as per conditions laid down in Pt C, Ch 1, Sec 9. Such documents are required only for ships less than 2 years old or for older ships the propelling system of which has been modified during the two years preceding the classification.

d) Electrical installation plans:
- Master plan of power distribution, lighting and emergency power circuits
- Single line diagram of networks and switchboards
- Location and arrangement of electrical equipment in hazardous areas.

e) Structural fire protection and fire control plan.

Alternative technical data may be accepted by the Society in lieu of specific items of the listed documentation not available at the time of the transfer of class.

3.3.4 Where appropriate within reasonable limits, a proven service record of satisfactory performance during a period of adequate length may be used as a criterion of equivalence. Special consideration will be given to ships of recent construction.

3.3.5 For installations or equipment covered by additional service and/or class notations, the Society will determine the documentation to be submitted.

3.3.6 In addition, the Society may base its judgement upon documentation such as certificates issued or accepted by the former Classification Society, if any, and statutory certificates issued by the flag Administration or by a recognised organisation on its behalf; moreover, other documents and/or plans may be specifically required to be supplied to the Society in individual cases.

4 Date of initial classification

4.1 Definitions

4.1.1 Date of build

For a new building the date of build is the year and month at which the new construction survey process is completed. Where there is a substantial delay between the completion of the construction survey process and the ship commencing active service, the date of commissioning may be also specified.

If modifications are carried out, the date of build remains assigned to the ship. Where a complete replacement or addition of a major portion of the ship is involved, the following applies:

- the date of build associated with each major portion of the ship is to be indicated on the Classification Certificate and in the Register, where it has been agreed that the newer structure shall be on a different survey cycle
- survey requirements are to be based on the date of build associated with each major portion of the ship
- survey due dates may be aligned at the discretion of the Society.

Note 1: For example, a major portion of the ship may include a complete forward or after section, a complete main cargo section (which may include a complete hold / tank of a cargo ship), a complete block of deck structure of a passenger ship or a structural modification of a single hull to a double hull ship.

4.1.2 Date of initial classification for new buildings

As a general rule, for new buildings the date of initial classification coincides with the date of build.

4.1.3 Date of initial classification for existing ships

In principle, for existing ships the date of initial classification is the date of completion of the admission to class survey.

5 Reassignment of class

5.1

5.1.1 At the request of the Owner, a ship which was previously classed with the Society, subsequently withdrawn from class and has not been classed since may have the class reassigned subject to an admission to class survey. If applicable and appropriate, account may be taken of any periodical surveys held in the former period of class with the Society.

Section 2 Maintenance of Class

1 General principles of surveys

1.1 Survey types

1.1.1 Classed ships are submitted to surveys for the maintenance of class. These surveys include the class renewal survey, intermediate and annual survey, bottom survey (either survey in dry condition or in-water survey), tailshaft survey, boiler survey, and surveys for the maintenance of additional class notations, where applicable. Such surveys are carried out at the intervals and under the conditions laid down in this Section. In addition to the above periodical surveys, ships are to be submitted to occasional surveys whenever the circumstances so require; refer to [6], also when the Owner requires a specific survey in case of sales; refer to Article [7].

1.1.2 The different types of periodical surveys are summarised in Tab 1. The intervals at which the periodical surveys are carried out are given in the items referred to in the second column of Tab 1. The relevant extent and scope are given in Part A, Chapter 3 and Part A, Chapter 4 for all ships and for service notations, respectively, while surveys related to additional class notations are given in Part A, Chapter 5.

Where there are no specific survey requirements for additional class notations assigned to a ship, equipment and/or arrangements related to these additional class notations are to be examined, as applicable, to the Surveyor's satisfaction at each class renewal survey for the class.

The surveys are to be carried out in accordance with the relevant requirements in order to confirm that the hull, machinery, equipment and appliances comply with the applicable Rules and will remain in satisfactory condition based on the understanding and assumptions mentioned in Ch 1, Sec 1, [3.3].

Where the conditions for the maintenance of the class, service notations and additional class notations are not complied with, the class and/or the service notation and/or the additional class notations as appropriate will be suspended and/or withdrawn in accordance with the applicable Rules given in Ch 2, Sec 3.

Note 1: It is understood that requirements for surveys apply to those items that are required according to the Rules or, even if not required, are fitted on board.

1.1.3 Unless specified otherwise, any survey other than bottom survey and tailshaft survey may be effected by carrying out partial surveys at different times to be agreed upon with the Society, provided that each partial survey is adequately extensive. The splitting of a survey into partial surveys is to be such as not to impair its effectiveness.

1.1.4 Special consideration may be given in application of Ch 3, Sec 1 to Ch 3, Sec 6 to commercial ships owned or chartered by Administrations, which are utilized in support of military operations or service.

Table 1 : List of periodical surveys

Type of survey	Reference in this Section	Reference to scope of survey
Class renewal - hull	[4]	Ch 3, Sec 3 and Part A, Chapter 4 **(1)**
Class renewal - machinery	[4]	Ch 3, Sec 3 and Part A, Chapter 4 **(1)**
Class renewal - additional class notations	[1.1]	Part A, Chapter 5 **(2)**
Annual - hull	[5.2]	Ch 3, Sec 1 and Part A, Chapter 4 **(1)**
Annual - machinery	[5.2]	Ch 3, Sec 1 and Part A, Chapter 4 **(1)**
Annual - additional class notations	[1.1]	Part A, Chapter 5 **(2)**
Intermediate - hull	[5.3]	Ch 3, Sec 2 and Part A, Chapter 4 **(1)**
Intermediate - machinery	[5.3]	Ch 3, Sec 2 and Part A, Chapter 4 **(1)**
Bottom - dry condition	[5.4]	Ch 3, Sec 4
Bottom - in water	[5.4]	Ch 3, Sec 4
Tailshaft - complete	[5.5]	Ch 3, Sec 5
Tailshaft - modified	[5.5]	Ch 3, Sec 5
Boiler - complete	[5.6]	Ch 3, Sec 6

(1) As applicable, according to the service notation assigned to the ship.
(2) As applicable, according to the additional class notations assigned to the ship.

1.2 Change of periodicity, postponement or advance of surveys

1.2.1 The Society reserves the right, after due consideration, to change the periodicity, postpone or advance surveys, taking into account particular circumstances.

1.2.2 When a survey becomes overdue during a voyage, the following applies:

a) In the case of a class renewal survey, the Society may grant an extension to allow for completion of the class renewal survey, provided there is documented agreement to such an extension prior to the expiry date of the Certificate of Classification, adequate arrangements have been made for attendance of the Surveyor at the first port of call and the Society is satisfied that there is technical justification for such an extension. Such an extension will be granted only until arrival at the first port of call after the expiry date of the Certificate of Classification.

   However, if owing to "exceptional circumstances" as defined in [2.1.8], the class renewal survey cannot be completed at the first port of call, the Society may grant an extension according to [4.1.1], but the total period of extension shall in no case be longer than three months after the original limit date of the class renewal survey.

b) In the case of annual and intermediate surveys, no postponement is granted. Such surveys are to be completed within their prescribed windows; see [2.1.3].

c) In the case of all other periodical surveys and conditions of class, extension of class may be granted until the arrival of the ship at the port of destination.

1.3 Extension of scope of survey

1.3.1 The Society and/or its Surveyors may extend the scope of the provisions in Part A, Chapter 3 to Part A, Chapter 5, which set forth the technical requirements for surveys, whenever and so far as considered necessary, or modify them in the case of special ships or systems.

1.3.2 The extent of any survey also depends upon the condition of the ship and its equipment. Should the Surveyor have any doubt as to the maintenance or condition of the ship or its equipment, or be advised of any deficiency or damage which may affect the class, then further examination and testing may be conducted as considered necessary.

1.4 General procedure of survey

1.4.1 The general procedure of survey consists in:

- an overall examination of the parts of the ship covered by the rule requirements
- checking selected items covered by the rule requirements
- attending tests and trials where applicable and deemed necessary by the Surveyor.

1.4.2 When a survey results in the identification of significant corrosion, structural defects or damage to hull, machinery and/or any piece of its equipment which, in the opinion of the Surveyor, affect the ship's class, remedial measures are to be implemented before the ship continues in service (see also [2.11]).

Note 1: The Society's survey requirements cannot be considered as a substitute for specification and acceptance of repairs and maintenance, which remain the responsibility of the Owner.

Note 2: In accordance with the provisions of Ch 1, Sec 1, [4.1.3], the Society will, at the request of the Owner, apply the regulations of Administrations concerning the scope and periodicity of surveys when they differ from those laid down in [4] and [5].

Note 3: During the surveys, the Surveyor does not check that the spare parts are kept on board, maintained in working order and suitably protected and lashed.

1.5 Appointment of another Surveyor

1.5.1 In compliance with the provisions of Ch 1, Sec 1, [2.4.1], should a disagreement arise between the Owner and the Surveyor during a survey, the Society may, at the request of the Owner, designate another Surveyor.

1.6 Alterations or additions to approved systems

1.6.1 When an alteration or addition to an approved system is proposed, documentation is to be submitted and approved by the Society before the work on the alteration or addition is commenced.

1.6.2 Where the modifications may affect compliance with the Rules, they are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

2 Definitions and procedures related to surveys

2.1 General

2.1.1 Period of class

Period of class means the period starting either from the date of the initial classification, see Ch 2, Sec 1, [4], or from the credited date of the last class renewal survey, and expiring at the limit date assigned for the next class renewal survey.

2.1.2 Anniversary date

Anniversary date means the day of the month of each year in the period of class which corresponds to the expiry date of the period of class.

2.1.3 Survey time window

Survey time window, or more simply window, mean the fixed period during which annual and intermediate surveys are to be carried out.

2.1.4 Overdue surveys

Each periodical survey is assigned a limit date specified by the relevant requirements of the Rules (end of survey interval or end date of window) by which it is to be completed.

A survey becomes overdue when it has not been completed by its limit date.

Examples:

- Anniversary date: 15th April

  The 2000 annual survey can be validly carried out from 16th January 2000 to 15th July 2000. If not completed by 15th July 2000, the annual survey becomes overdue.

- Last bottom survey 20th October 2000:

  If not completed by 20th October 2003 or end of the class period, whichever comes first, the bottom survey becomes overdue.

2.1.5 Condition of class

A defect and/or deficiency to be dealt with in order to maintain class, within a specific period of time, is indicated as a condition of class. A condition of class is pending until it is cleared, through a survey by the attending Surveyor or upon evidence that requirements have been completed, to the satisfaction of the Society. Where it is not cleared by its limit date, the condition of class is overdue.

Condition of class may be imposed in other cases, which, in the Society's opinion, require specific consideration.

2.1.6 Classification memoranda

Those defects and/or deficiencies which do not affect the maintenance of class and which may therefore be cleared at the Owner's convenience and any other information deemed noteworthy for the Society's convenience are indicated as classification memoranda.

Classification memoranda are not to be regarded as condition of class.

2.1.7 Statutory memoranda

Those defects and/or deficiencies which do not affect the statutory certification and which may therefore be cleared at the Owner's convenience and any other information noteworthy for the Society's convenience are indicated as statutory memoranda.

Statutory memoranda are not to be regarded as statutory recommendations

2.1.8 Exceptional circumstances

"Exceptional circumstances" means:

- unavailability of dry-docking facilities, or
- unavailability of repair facilities, or
- unavailability of essential materials, equipment or spare parts, or
- delays incurred by action taken to avoid severe weather conditions.

2.2 Terminology related to hull survey

2.2.1 Ballast tank

A ballast tank is a tank that is being used primarily for salt water ballast.

For single skin and double skin bulk carriers subject to the requirements of Ch 4, Sec 2, a ballast tank is a tank which is used primarily for salt water ballast, or, where applicable, a space which is used for both cargo and salt water ballast will be treated as a ballast tank when substantial corrosion has been found in that space, see [2.2.7]. For double skin bulk carriers, a double side tank is to be considered as a separate tank even if it is in connection to either the topside tank or the hopper side tank.

For oil tankers subject to the requirements of Ch 4, Sec 3 and chemical tankers subject to the requirements of Ch 4, Sec 4, a ballast tank is a tank which is used primarily for the carriage of salt water ballast. A combined cargo/ballast tank is a tank which is used for the carriage of cargo or ballast water as a routine part of the vessel's operation and will be treated as a ballast tank. Cargo tanks in which water ballast might be carried only in exceptional cases per MARPOL I/18(3) are to be treated as cargo tanks.

2.2.2 Spaces

Spaces are separate compartments including holds and tanks.

For ships subject to Ch 4, Sec 2, spaces are separate compartments including holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

2.2.3 Overall survey

An overall survey is a survey intended to report on the overall condition of the hull structure and determine the extent of additional close-up surveys.

2.2.4 Close-up survey

A close-up survey is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e. normally within reach of hand.

2.2.5 Transverse section

A transverse section includes all longitudinal members contributing to longitudinal hull girder strength, such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom, longitudinal bulkheads and, as applicable for the different ship types, relevant longitudinals, hopper sides, bottom in top wing tanks, inner sides. For a transversely framed ship, a transverse section includes adjacent frames and their end connections in way of transverse sections.

2.2.6 Representative tanks or spaces

Representative tanks or spaces are those which are expected to reflect the condition of other tanks or spaces of similar type and service and with similar corrosion prevention systems. When selecting representative tanks or spaces, account is to be taken of the service and repair history on board and identifiable critical structural areas and/or suspect areas.

2.2.7 Substantial corrosion

Substantial corrosion is an extent of corrosion such that assessment of the corrosion pattern indicates a wastage in excess of 75% of allowable margins, but within the acceptable limits.

For the following ships:

- ships assigned the service notation **liquefied gas carrier** contracted for construction on or after 1st July 2022,
- oil tankers built under Common Structural Rules for Double Hull Oil Tankers (NR523),
- bulk carriers built under Common Structural Rules for Bulk Carriers (NR522),
- bulk carriers or oil tankers built under Common Structural Rules for Bulk Carriers and Oil Tankers (NR606),
- cargo ships, other than container ships, with a length greater than 65m and contracted for construction on or after 1st July 2022,
- container ships with a length greater than 65 m and contracted for construction on or after 1st July 2016,
- ships having alternate light or heavy cargo loading conditions, irrespective of their length and contracted for construction on or after 1st July 2022,
- non-cargo ships with a length greater than 90 m and contracted for construction on or after 1st July 2022,

substantial corrosion is an extent of corrosion such that the assessment of the corrosion pattern indicates a measured thickness between ($t_{renewal}$ + 0,5 mm) and $t_{renewal}$.

Note 1: $t_{renewal}$ is the minimum allowable thickness, in mm, below which renewal of structural members is to be carried out.

Note 2: For the definition of cargo ships and non-cargo ships, reference is to be made to NR600, Ch 1, Sec 1.

2.2.8 Pitting corrosion

Pitting corrosion is defined as scattered corrosion spots/ areas with local material reductions which are greater than the general corrosion in the surrounding area. Pitting intensity is defined in Ch 2, App 3, Fig 22.

2.2.9 Edge corrosion

Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings, as shown in Ch 2, App 3, Fig 15.

2.2.10 Grooving corrosion

Grooving corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffeners or plate butts or seams, as shown in Ch 2, App 3, Fig 16.

2.2.11 Suspect areas

Suspect areas are locations showing substantial corrosion and/or considered by the Surveyor to be prone to rapid wastage.

2.2.12 Critical structural areas

Critical structural areas are locations which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar ships or sister ships (if available), to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship.

2.2.13 Corrosion prevention system

A corrosion prevention system is normally considered a full hard protective coating.

Hard protective coating is usually to be epoxy coating or equivalent. Other coating systems, which are neither soft nor semi-hard coatings, may be considered acceptable as alternatives, provided that they are applied and maintained in compliance with the Manufacturer's specifications.

2.2.14 Coating condition

Coating condition is defined as follows:

- good: condition with only minor spot rusting
- fair: condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for poor condition
- poor: condition with general breakdown of coating over 20% or more or hard scale at 10% or more, of areas under consideration.

2.2.15 Cargo area (ships carrying liquid cargo in bulk)

The cargo area is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump rooms, compressor rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above-mentioned spaces.

2.2.16 Cargo length area (dry cargo ships)

The cargo length area is that part of the ship which includes cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces.

2.2.17 Prompt and thorough repair

A “Prompt and thorough repair” is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of class. See also [2.11].

2.2.18 Special consideration

Special consideration or specially considered (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

2.2.19 Air pipe head

Air pipe heads installed on the exposed decks are those extending above the freeboard deck or superstructure decks.

2.2.20 Remote inspection techniques (RIT)

Remote inspection techniques is a means of survey that enables examination of any part of the structure without the need for direct physical access of the Surveyor (refer to IACS Recommendation 42, “Guidelines for use of remote inspection techniques for surveys”).

2.2.21 Remote Survey

A “Remote Survey” is a process of verifying that a ship and its equipment are in compliance with the Rules where the verification is undertaken, or partially undertaken, without attendance on board by a Surveyor.

2.3 Procedures for thickness measurements

2.3.1 When required as per the scope of surveys defined below, thickness measurements are normally to be carried out under the responsibility of the Owner, and in the presence of the Surveyor, by a service supplier independent from the Owner.

2.3.2 For all ships, the following applies:

- thickness measurements required in the context of surveys of hull structure is to be witnessed by a Surveyor. This requires the Surveyor to be on board while the gaugings are taken, enabling him at any time to intervene and to control the process.
- prior to commencement of the intermediate or class renewal survey, a meeting is to be held between the attending Surveyor(s), the master of the ship or an appropriately qualified representative appointed by the master or Company, the Owner’s representative(s) in attendance and the thickness measurement firm’s representative(s) so as to ensure the safe and efficient execution of the surveys and thickness measurements to be carried out onboard.

2.3.3 In any kind of survey, i.e. class renewal, intermediate, annual or other surveys having the same scope, thickness measurements of structures in areas where close-up surveys are required, are to be carried out simultaneously with close-up surveys.

2.3.4 Consideration may be given by the attending Surveyor to allow the use of Remote Inspection Techniques (RIT) as an alternative to close-up survey. Surveys conducted using a RIT are to be completed to the satisfaction of the attending Surveyor. When RIT is used for a close-up survey, temporary means of access for the corresponding thickness measurements is to be provided unless such RIT is also able to carry out the required thickness measurements.

Note 1: Use of RIT as an alternative to close-up survey is normally not allowed for ships assigned the service notation **bulk carrier ESP** or **bulk carrier BC-A ESP** or **bulk carrier BC-B ESP** or **bulk carrier BC-C ESP** or **self-unloading bulk carrier ESP** or **ore carrier ESP** or **combination carrier/ OBO ESP** or **combination carrier/OOC ESP** or **oil tanker ESP**, unless written agreement of the ship's Flag is obtained.

2.3.5 For structure built with a material other than steel, alternative thickness measurement requirements may be developed and applied as deemed necessary by the Society.

2.3.6 Thickness measurement is normally to be carried out by means of ultrasonic test equipment. The accuracy of the equipment is to be proven to the Surveyor as required. The thickness measurements are to be carried out by a company authorised by the Society.

The Society reserves the right to limit the scope of authorisation of the Company.

Note 1: Rule Note NR533 Approval of Service Suppliers gives details about the authorisation.

2.3.7 A thickness measurement report is to be prepared. The report is to give the location of measurements, the thickness measured and the corresponding original thickness. Furthermore, the report is to include the date when the measurements were carried out, the type of measuring equipment, the names and the qualification of the operators and their signatures.

The Surveyor is to review the final thickness measurement report and countersign the cover page.

2.3.8 For acceptance criteria applicable to structural corrosion diminution levels, reference is to be made to Ch 2, App 3.

2.4 Agreement of firms for in-water survey

2.4.1 The in-water surveys referred to in the Rules are to be carried out by a certified company accepted by the Society.

Note 1: Rule Note NR533 Approval of Service Suppliers gives details about the certification.

2.5 Preparations and conditions for surveys

2.5.1 The Owner is to provide the necessary facilities for the safe execution of the surveys, as per Ch 1, Sec 1, [3.2.2].

2.5.2 Cargo holds, tanks and spaces are to be safe for access. Cargo holds, tanks and spaces are to be gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in the tank or space is free from hazardous gas and contains sufficient oxygen.

In preparation for survey and thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc. to reveal corrosion, deformation, fractures, damages or other structural deterioration as well as the condition of the coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of the areas to be renewed.

Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration as well as condition of the coating.

Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

Casings, ceilings or linings, and loose insulation, where fitted, are to be removed, as required by the Surveyor, for examination of plating and framing. Compositions on plating are to be examined and sounded, but need not be disturbed if found adhering satisfactorily to the plating.

In refrigerated cargo spaces the condition of the coating behind the insulation is to be examined at representative locations. The examination may be limited to verification that the protective coating remains effective and that there are no visible structural defects. Where POOR coating condition is found, the examination is to be extended as deemed necessary by the Surveyor. The condition of the coating is to be reported. If indents, scratches, etc., are detected during surveys of shell plating from the outside, insulations in way are to be removed as required by the Surveyor, for further examination of the plating and adjacent frames.

2.5.3 A communication system is to be arranged between the survey party in the cargo hold, tank or space being examined, the responsible officer on deck and, as the case may be, the navigation bridge. The communication arrangements are to be maintained throughout the survey. This system is also to include the personnel in charge of ballast pump handling if boats or rafts are used.

2.5.4 Explosimeter, oxygen-meter, breathing apparatus, lifelines, riding belts with rope and hook and whistles together with instructions and guidance on their use are to be made available during the survey. A safety check-list is to be provided.

2.5.5 Adequate and safe lighting is to be provided for the safe and efficient conduct of the survey.

2.5.6 Adequate protective clothing is to be made available and used (e.g. safety helmet, gloves, safety shoes, etc.) during the survey.

2.5.7 Surveys of tanks or applicable holds by means of boats or rafts may only be undertaken with the agreement of the Surveyor, who is to take into account the safety arrangements provided, including weather forecasting and ship response under foreseeable conditions and provided the expected rise of water within the tank does not exceed 0,25m.

2.5.8 When rafts or boats will be used for close-up survey the following conditions are to be observed:

a) only rough duty, inflatable rafts or boats, having satisfactory residual buoyancy and stability even if one chamber is ruptured, are to be used

b) the boat or raft is to be tethered to the access ladder and an additional person is to be stationed down the access ladder with a clear view of the boat or raft

c) appropriate lifejackets are to be available for all participants

d) the surface of water in the tank or hold is to be calm (under all foreseeable conditions the expected rise of water within the tank is not to exceed 0,25 m) and the water level stationary. On no account is the level of the water to be rising while the boat or raft is in use

e) the tank, hold or space must contain clean ballast water only. Even a thin sheen of oil on the water is not acceptable, and

f) at no time is the water level to be allowed to be within 1 m of the deepest under deck web face flat so that the survey team is not isolated from a direct escape route to the tank hatch. Filling to levels above the deck transverses is only to be contemplated if a deck access manhole is fitted and open in the bay being examined, so that an escape route for the survey party is available at all times. Other effective means of escape to the deck may be considered.

g) if the tanks (or spaces) are connected by a common venting system, or Inert Gas system, the tank in which the boat or raft is to be used is to be isolated to prevent a transfer of gas from other tanks (or spaces).

2.5.9 Rafts or boats alone may be allowed for inspection of the under deck areas for tanks or spaces, if the depth of the webs is 1,5 m or less.

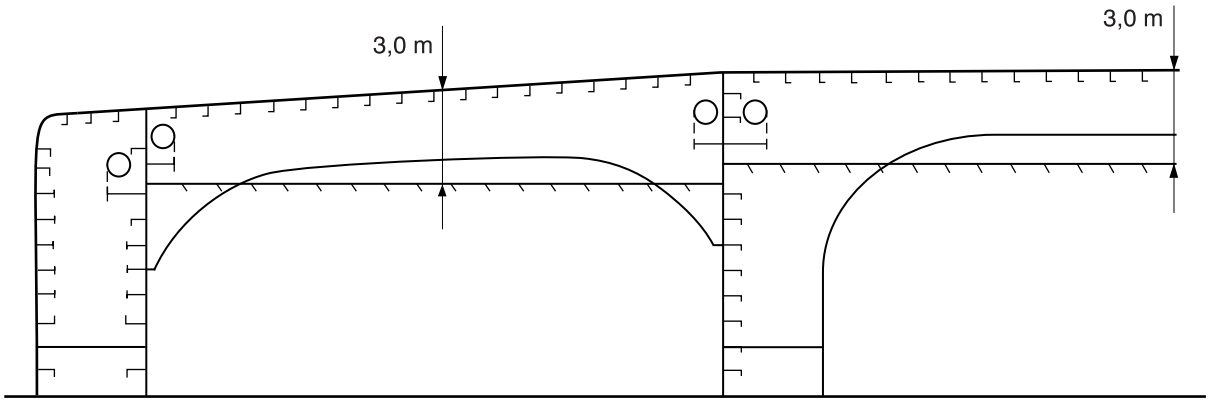
If the depth of the webs is more than 1,5 m, rafts or boats alone may be allowed only:

- when the coating of the under deck structure is in GOOD condition and there is no evidence of wastage; or
- if a permanent means of access is provided in each bay to allow safe entry and exit. This means:
  - access direct from the deck via a vertical ladder and a small platform fitted approximately 2 m below the deck in each bay; or
  - access to deck from a longitudinal permanent platform having ladders to deck in each end of the tank. The platform shall, for the full length of the tank, be arranged in level with, or above, the maximum water level needed for rafting of under deck structure. For this purpose, the ullage corresponding to the maximum water level is to be assumed not more than 3 m from the deck plate measured at the midspan of deck transverses and in the middle length of the tank (see Fig 1).

If neither of the above conditions are met, then staging or an other equivalent means is to be provided for the survey of the under deck areas.

The use of rafts or boats as mentioned above does not preclude the use of boats or rafts to move about within a tank during a survey.

Figure 1 : Platform position and ullage corresponding to the maximum water level for oil tankers and chemical tankers



2.5.10 When examination of associated structure is required, the following applies:

- ceilings in holds and floors in the engine room are to be lifted to the necessary extent for examination of the structure
- cement or other protective sheathing is to be removed when there is any doubt as to the condition of the plating underneath or when adherence to plating is not tight
- in the case of solid ballast spaces, the solid ballast is to be partially removed for examination of the condition of the structure in way. Should doubts arise, the Surveyor may require more extensive removal of the solid ballast
- insulation of compartments intended for refrigerated cargoes is to be removed over the necessary extent for examination by the Surveyor of the condition of the structure, unless constructional arrangements make such inspections possible without removing the insulation.

2.6 Access to structures

2.6.1 For overall survey, means are to be provided to enable the Surveyor to examine the hull structure in a safe and practical way.

2.6.2 For survey in cargo holds and ballast tanks, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

- permanent staging and passages through structures
- temporary staging and passages through structures
- hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
- boats or rafts
- other equivalent means.

2.6.3 For surveys conducted by use of a remote inspection technique, one or more of the following means of access, acceptable to the Surveyor, is to be provided:

- unmanned robot arm
- remotely operated vehicles (ROV)
- unmanned aerial vehicles/drones
- other means acceptable to the Society.

Note 1: Use of RIT as an alternative to close-up survey is normally not allowed for ships assigned the service notation **bulk carrier ESP** or **bulk carrier BC-A ESP** or **bulk carrier BC-B ESP** or **bulk carrier BC-C ESP** or **self-unloading bulk carrier ESP** or **ore carrier ESP** or **combination carrier/ OBO ESP** or **combination carrier/OOC ESP** or **oil tanker ESP**, unless written agreement of the ship's Flag is obtained.

2.7 Equipment for surveys

2.7.1 One or more of the following fracture detection procedures may be required if deemed necessary by the Surveyor:

- radiographic equipment
- ultrasonic equipment
- magnetic particle equipment
- dye penetrant.

2.8 Rescue and emergency response equipment

2.8.1 If breathing apparatus and/or other equipment is used as 'Rescue and emergency response equipment' then it is recommended that the equipment should be suitable for the configuration of the space being surveyed.

2.9 Surveys at sea and anchorage

2.9.1 Surveys at sea or at anchorage may be accepted provided the Surveyor is given the necessary assistance by the personnel on board. Precautions and procedures for carrying out the survey are to be in accordance with [2.5] to [2.7].

2.10 Repairs and maintenance during voyage

2.10.1 Where repairs to hull, machinery or other equipment, which affect or may affect the class, are to be carried out by a riding crew during a voyage, they are to be planned in advance. A complete repair procedure including the extent of proposed repair and the need for the Surveyor's attendance during the voyage is to be submitted to the Society for approval sufficiently in advance. Failure to notify the Society in advance of the repairs may result in the suspension of class of the ship.

Where in any emergency circumstance, emergency repairs are to be effected immediately, the repairs should be documented in the ship's log and submitted thereafter to the Society for use in determining further survey requirements.

2.10.2 The above is not intended to include maintenance to and overhaul of the hull, machinery and equipment in accordance with the Manufacturer's recommended procedures and established marine practice, which does not require the Society's agreement. However, any repair resulting from such maintenance and overhauls which affects or may affect the class is to be noted in the ship's log and submitted to the attending Surveyor for use in determining further survey requirements.

2.11 Repairs

2.11.1 Any damage in association with wastage over the allowable limits (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly (see [2.2.17]) repaired.

Areas to be considered include, as applicable for the different ship types:

- side structure and side plating; side shell frames, their end attachments and adjacent shell plating; inner side structure and inner side plating
- deck structure and deck plating
- bottom structure and bottom plating; inner bottom structure and inner bottom plating
- longitudinal bulkheads structure and longitudinal bulkheads plating, where fitted
- watertight or oiltight bulkheads structure and plating
- hatch covers or hatch coamings, where fitted
- weld connection between air pipes and deck plating
- air pipe heads installed on the exposed decks
- ventilators, including closing devices, if any; bunker and vent piping systems.

2.11.2 For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

2.11.3 Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the vessel's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

2.11.4 Where the damage found on structure mentioned in [2.11.1] is isolated and of a localised nature which does not affect the ship's structural integrity, consideration may be given by the Surveyor to allow an appropriate temporary repair to restore watertight or weathertight integrity and impose a condition of class in accordance with the Rules, with a specific time limit.

2.12 Remote Inspection Techniques (RIT)

2.12.1 The RIT is to provide the information normally obtained from a close-up survey (except on ESP ships). RIT surveys are to be carried out in accordance with the requirements given here-in and the requirements of IACS Recommendation 42, "Guidelines for use of remote inspection techniques for surveys". These considerations are to be included in the proposals for use of a RIT which are to be submitted in advance of the survey so that satisfactory arrangements can be agreed with the Society.

Note 1: Use of RIT as an alternative to close-up survey is normally not allowed for ships assigned the service notation **bulk carrier ESP** or **bulk carrier BC-A ESP** or **bulk carrier BC-B ESP** or **bulk carrier BC-C ESP** or **self-unloading bulk carrier ESP** or **ore carrier ESP** or **combination carrier/ OBO ESP** or **combination carrier/OOC ESP** or **oil tanker ESP**, unless written agreement of the ship's Flag is obtained.

2.12.2 The equipment and procedure for observing and reporting the survey using a RIT are to be discussed and agreed with the parties involved prior to the RIT survey, and suitable time is to be allowed to set-up, calibrate and test all equipment beforehand.

2.12.3 When using a RIT as an alternative to close-up survey, if not carried out by the Society itself, it is to be conducted by a firm approved as a service supplier and is to be witnessed by an attending Surveyor of the Society.

Note 1: NR533, Approval of Service Suppliers, gives details about the certification.

2.12.4 The structure to be examined using a RIT is to be sufficiently clean to permit meaningful examination. Visibility is to be sufficient to allow for a meaningful examination. The Society is to be satisfied with the methods of orientation on the structure.

2.12.5 The Surveyor is to be satisfied with the method of data presentation including pictorial representation, and a good two-way communication between the Surveyor and RIT operator is to be provided.

2.12.6 If the RIT reveals damage or deterioration that requires attention, the Surveyor may require traditional survey to be undertaken without the use of a RIT.

2.13 Remote survey

2.13.1 For the planning and execution of remote surveys, the requirements given in Ch 2, App 5 are to be applied.

3 Certificate of Classification: issue, validity, endorsement and renewal

3.1 Issue of Certificate of Classification

3.1.1 A Certificate of Classification, bearing the class notations assigned to the ship and an expiry date, is issued to any classed ship.

3.1.2 A Provisional Certificate of Classification may serve as a Certificate of Classification in some cases, such as after an admission to class survey, after a class renewal survey, or when the Society deems it necessary.

The period of validity for the Provisional Certificate of Classification is not to exceed 6 months from the date of issuance.

3.1.3 The Certificate of Classification is to be made available to the Society's Surveyors upon request.

3.2 Validity of Certificate of Classification, maintenance of class

3.2.1 According to Ch 1, Sec 1, [2.4], the Society alone is qualified to confirm the class of the ship and the validity of its Certificate of Classification.

3.2.2 During the class period, a Certificate of Classification is valid when it is not expired.

The class is maintained during a certain period or at a given date, when during the said period or at such date the conditions for suspension or withdrawal of class are not met.

Refer also to Ch 1, Sec 1, [1.3.4].

3.2.3 At the request of the Owner, a statement confirming the maintenance of class may be issued by the Society based on the information in its records for that ship at the time.

This statement is issued on the assumption that the Owner has complied with the Rules, in particular with [6].

Should any information which would have prevented the Society from issuing the statement and which was not available at the time subsequently come to light, the statement may be cancelled.

Attention is drawn to Ch 2, Sec 3, [1.2], whereby the Society, upon becoming aware of a breach of the Rules, is empowered to suspend class from the date of the breach, which may be prior to the date of the statement.

3.2.4 According to the same conditions as in [3.2.3], a statement declaring that the class is maintained "clean and free from condition of class" may be issued by the Society when there is no pending condition of class at that date.

3.2.5 Classification-related documents and information are liable to be invalidated by the Society whenever their object is found to differ from that on which they were based or to be contrary to the applicable requirements. The Owner is liable for any damage which may be caused to any third party from improper use of such documents and information.

3.3 Endorsement of Certificate of Classification

3.3.1 Text of endorsement

When surveys are satisfactorily carried out, the Certificate of Classification is generally endorsed accordingly, with the relevant entries.

3.3.2 Possible modifications to endorsements

The Society reserves the right to modify the endorsements made by Surveyors.

3.4 Status of surveys and conditions of class

3.4.1 Information given in the Certificate of Classification, ship survey status, Rules and other ship specific documents made available to the Owner, enables the Owner to identify the status of surveys and conditions of class.

3.4.2 The omission of such information does not absolve the Owner from ensuring that surveys are held by the limit dates and pending conditions of class are cleared to avoid any inconvenience which is liable to result from the suspension or withdrawal of class; see Ch 2, Sec 3.

4 Class renewal survey

4.1 General principles

4.1.1 Class renewal surveys are to be carried out at five-year (class symbol **I**) or three-year (class symbol **II**) intervals. However, consideration may be given by the Society to granting an extension for a maximum of three months after the limit date, in exceptional circumstances. In such cases the next period of class will start from the limit date for the previous class renewal survey before the extension was granted.

4.1.2 For surveys completed within three months before the limit date of the class renewal survey, the next period of class will start from this limit date. For surveys completed more than three months before the limit date, the period of class will start from the survey completion date.

In cases where the vessel has been laid up or has been out of service for a considerable period because of a major repair or modification and the Owner elects to carry out only the overdue surveys, the next period of class will start from the expiry date of the renewal survey. If the Owner elects to carry out the next due renewal survey, the period of class will start from the survey completion date.

4.1.3 A new period of class is assigned to the ship after the satisfactory completion of the class renewal survey, and a new Certificate of Classification is issued for the new period of class.

4.1.4 Concurrent crediting to both Intermediate Survey and Class Renewal Survey for surveys and thickness measurements of spaces are not acceptable.

4.2 Normal survey system (SS)

4.2.1 When the normal survey system is applied to ships with a 5 years period of class, the class renewal survey may be commenced at the fourth annual survey and continued during the following year with a view to completion by its due date. In this case the survey may be carried out by partial surveys at different times. The number of checks to be performed at each partial survey and the interval between partial surveys are to be agreed by the Society.

4.2.2 A class renewal survey may be commenced before the fourth annual survey at the request of the Owner. In this case, the survey is to be completed within fifteen months. The conditions for the execution of partial surveys are the same as those referred to in [4.2.1].

4.3 Continuous survey system (CS)

4.3.1 The request by the Owner for admission to the continuous survey system will be considered by the Society and agreement depends on the type and age of hull and machinery. This system may apply to the class renewal survey of hull (CSH), machinery (CSM) or other installations such as refrigerating installations (CSR) covered by an additional class notation.

4.3.2 The continuous survey system is not applicable to the class renewal survey of the hull of those ships subject to the Enhanced Survey Program (**ESP**), i.e. ships with the service notation **oil tanker**, **combination carrier**, **bulk carrier**, **ore carrier** or **chemical tanker**, nor to ships subject to the requirements of Ch 4, Sec 7, nor to ships with the class symbol **II**.

4.3.3 For ships other than those referred to in [4.3.2], the continuous survey system is not applicable to the class renewal survey of the hull of ships over 20 years old. However, consideration may be given, at the discretion of the Society, to the applicability of the continuous survey system to the class renewal survey of the hull of ships over 20 years old.

4.3.4 When the continuous survey system is applied, appropriate notations as indicated in [4.3.1] are entered in the Register of Ships.

4.3.5 Ships subject to the continuous survey system are provided with lists of items to be surveyed under this system.

4.3.6 For items surveyed under the continuous survey system, the following requirements generally apply:

a) the interval between two consecutive surveys of each item is not to exceed five years

b) the items are to be surveyed in rotation, so far as practicable ensuring that approximately equivalent portions are examined each year

c) the Society may credit for continuous survey results of surveys carried out before the admission to the continuous survey scheme

d) each item is to be surveyed at one time, as far as practicable; the Society may, however, allow possible repair work to be carried out within a certain period.

e) main or auxiliary engine crankshaft journal and associated bearings may be surveyed within intervals specified in item a) or in accordance with engine manufacturers recommended replacement schedule subject to satisfactory verification of survey items listed in item f)

f) The Surveyor shall check within the 5 year CSM cycle:
   - at least 1 crank journal bearing for medium and high speed engines (> 300 rpm), with the selected bearing to be presented for survey chosen from 1 of the 3 aftermost bearings and alternate to the last CSM cycle
   - at least 2 crank journal bearings for slow speed engines (< 300 rpm), with the selected bearings to be presented for survey chosen from 1 of the 3 aftermost bearings (alternate to last CSM cycle) and the highest loaded bearing as determined by the engine manufacturer.

   The remainder of the bearings may be permitted for verification by C/E followed by confirmatory surveys, i.e. checking bearing clearances, oil analysis, photos of non-invasive bearing and bearing edge checks performed, crankcase inspection and verification of deflections.

4.3.7 For ships more than ten years of age, the ballast tanks are to be internally examined twice in each five-year class period, i.e. once within the scope of the intermediate survey and once within the scope of the continuous survey system for the class renewal survey.

4.3.8 For ships under continuous survey, items not included in the continuous survey cycle are to be inspected according to the provisions given in [4.2]. Bottom surveys are to be carried out according to the requirements of [5.4]. In addition, the bottom survey which is to be carried out in conjunction with the end of class period is to be performed within 15 months before the end of this class period.

4.3.9 Upon application by the Owner, the Society may agree, subject to certain conditions, that some items of machinery which are included in the continuous survey cycle are examined by the Chief Engineer where the Society is not represented. The Chief Engineer's inspection is to be followed by a confirmatory survey carried out by a Surveyor. The conditions for the application of this procedure are given in Ch 2, App 2.

4.3.10 The continuous survey system does not supersede the annual surveys and other periodical and occasional surveys.

4.3.11 A general examination of the ship, as detailed in Ch 3, Sec 1 for annual surveys, is to be carried out at the end of the period of class.

4.3.12 For laid-up ships, specific requirements given in [8.1] apply.

4.3.13 The continuous survey system may be discontinued at any time at the discretion of the Society, or at the request of the Owner, and a specific arrangement devised.

4.4 Planned maintenance survey system for machinery (PMS)

4.4.1 A planned maintenance survey system may be considered as an alternative to the continuous survey system for machinery and is limited to components and systems covered by it. When such a system is implemented, a survey system other than those normally adopted and with intervals different from those of the continuous survey system as detailed in [4.3] may be accepted.

4.4.2 The conditions for review of the planned maintenance survey system, the determination of survey item intervals and the general scope of surveys are detailed in Ch 2, App 1.

4.4.3 The conditions related to Chief Engineer's inspections within the scope of PMS are given in Ch 2, App 2.

4.4.4 The planned maintenance survey system does not supersede the annual surveys and other periodical and occasional surveys.

4.4.5 A general examination of the machinery, as detailed in Ch 3, Sec 1 for annual surveys, is to be carried out.

4.4.6 The planned maintenance survey system may be discontinued at any time at the discretion of the Society, or at the request of the Owner, and a specific arrangement devised.

4.4.7 Surveys of machinery may be carried out on a condition based maintenance (CBM) scheme basis on vessels operating on approved PMS survey system.

4.4.8 The conditions for approval of the condition monitoring and condition based maintenance survey schemes and the general scope of surveys are detailed in Ch 2, App 4.

5 Other periodical surveys

5.1 General

5.1.1 The different types of periodical surveys are summarised in Tab 1.

5.2 Annual surveys

5.2.1 Annual surveys are to be carried out within three months before or after each anniversary date.

5.3 Intermediate surveys

5.3.1 An intermediate survey, where applicable, is to be carried out within the window from three months before the second to three months after the third anniversary date.

5.3.2 The intermediate survey is applicable at any period of class to ships with the following service notations:

- **oil tanker**, **chemical tanker**, **FLS tanker**, **liquefied gas carrier**, **combination carrier/OBO**, **combination carrier/OOC**
- **yacht** of less than 24 meters in length, as defined in NR500, Rules for the Classification and Certification of Yachts.

5.3.3 The intermediate survey is applicable at any period of class to ships other than those indicated in [5.3.2] which are five years old and over.

5.3.4 The intermediate survey is not applicable to ships with class symbol **II**.

5.3.5 Concurrent crediting to both Intermediate Survey and Class Renewal Survey for surveys and thickness measurements of spaces are not acceptable.

5.4 Bottom survey

5.4.1 Bottom survey means the examination of the outside of the ship's bottom and related items. This examination may be carried out with the ship either in dry dock (or on a slipway) or afloat: in the former case the survey will be referred to as dry-docking survey, while in the latter case as in-water survey.

5.4.2 The Owner is to notify the Society whenever the outside of the ship's bottom and related items can be examined in dry dock or on a slipway.

5.4.3 For ships classed with the class symbol **I**, there are to be two examinations of the outside of the ship's bottom and related items in each period of class of five years

In all cases, the interval between any two such examinations is not to exceed 36 months.

Note 1: Compliance with the above does not absolve the Owner from compliance with the requirements of SOLAS as amended, especially when shorter intervals between examination of the ship's bottom for certain types of ships are required. Attention is also drawn to the relevant requirements of Ch 1, Sec 1, [3.1], concerning application of national and international regulations.

An extension of examination of the ship's bottom of three months beyond the due date can be granted in exceptional circumstances, as defined in [2.1.8].

5.4.4 For ships under the normal survey system (SS), one of the bottom surveys to be performed in each period of class is to be carried out in conjunction with the class renewal survey and is to be a dry-docking survey.

The Society may allow the bottom survey carried out between class renewal surveys to be replaced by an in-water survey, subject to the provisions of Ch 3, Sec 4. Special consideration is to be given to ships of 15 years of age and over before being permitted to have such in-water examinations.

For ships with additional service feature **ESP** and over 15 years of age, it is however reminded that a bottom survey in dry dock is to be carried out concurrently with the intermediate survey.

5.4.5 For ships under the continuous survey system of hull (CSH), one of the bottom surveys to be performed in each period of class is to be carried out in conjunction with the end of class period.

This bottom survey may be an in-water survey, subject to the provisions of Ch 3, Sec 4 and provided that the previous bottom survey performed in the period of class was a dry-docking survey. Special consideration is to be given to ships of 15 years of age and over before being permitted to have such in-water examinations.

5.4.6 Ships with service notation **HSC**, **HSC-CAT A**, **HSC-CAT B** are to be submitted to a bottom survey in dry condition at each annual survey and each class renewal survey.

5.4.7 The interval between examinations of the outside of the ship's bottom and related items for ships operating in fresh water and for certain harbour or non-self-propelled craft may be greater than that given above, as approved by the Society.

5.5 Tailshaft survey

5.5.1 Definition

Tailshaft survey means survey of propeller shafts and tube shafts (hereafter referred to as tailshafts) as well as survey of other propulsion systems.

5.5.2 Tailshaft complete survey

Tailshafts are to be submitted to complete examination at the periodicity specified below and summarised in Fig 2, based on the type of shaft and its design.

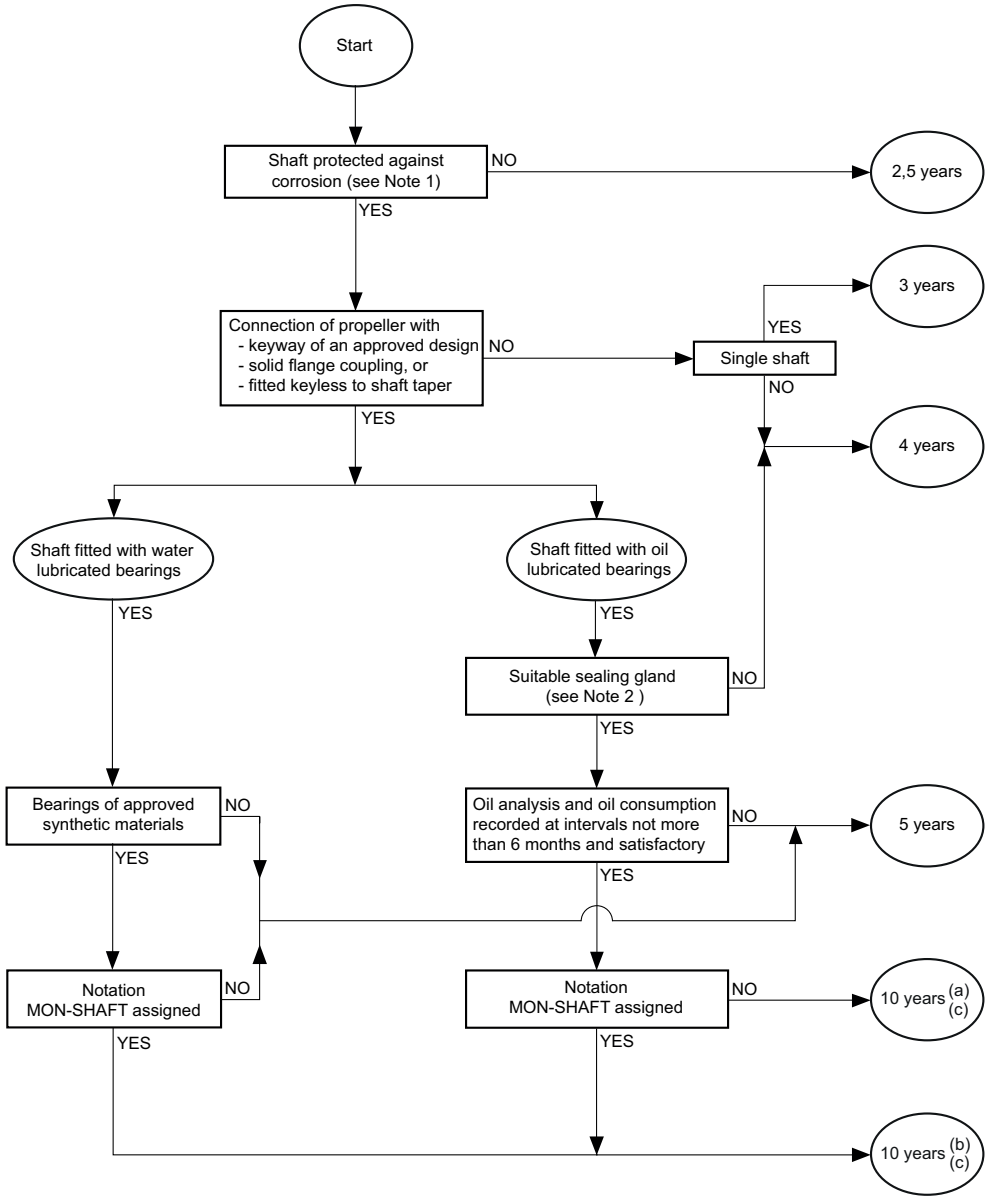
a) Where the tailshaft is fitted with continuous liners, or approved oil sealing glands, or made of corrosion-resistant material, the periodicity of complete surveys is:
   - 3 years for single shafting arrangements
   - 4 years for multi-shafting arrangements.

b) These periodicities may be increased to 5 years in the following cases:
   - where the propeller is fitted keyless to the shaft taper, the shaft is protected from sea water, the design details are approved, and a non-destructive examination of the forward part of the aft shaft taper is performed at each survey by an approved crack-detection method

- where the propeller is fitted to a keyed shaft taper the design details of which comply with the applicable requirements in Pt C, Ch 1, Sec 7, and a non-destructive examination of the after end of the cylindrical part of the shaft (from the after end of the liner, if any), and of about one third of the length of the taper from the large end is performed at each survey by an approved crack-detection method
- where the propeller is fitted to a solid flange coupling at the aft end of the shaft, the shaft and its fittings are not exposed to corrosion, the design details are approved. Non-destructive examination of the fillet radius of the aft propeller shaft flange may be required if the visual examination of the area is not satisfactory.

c) In all other cases the periodicity of complete surveys is two years and six months (2,5 years).

Figure 2 : Periodicity of complete survey of tailshaft



(a) : with shaft withdrawn, subject to modified survey at 5 years plus or minus 6 months

(b) : with shaft in place, subject to modified survey at 5 years plus or minus 6 months

(c) : the periodicity cannot exceed the maximum recommended by the designer and manufacturer of the tailshaft and bearing system.

Note 1: Shafts protected against corrosion are those:

- made of corrosion resistant material, or
- fitted with continuous liners or systems considered as equivalent, or
- fitted with oil lubricated bearings and oil sealing glands.

Note 2: Suitable sealing glands are glands which are type-approved by the Society with regard to protection of the sterntube against ingress of water.

5.5.3 Tailshaft modified survey

A modified survey of the tailshaft is an alternate way of examination the scope of which is given in Ch 3, Sec 5. It may be accepted for tailshafts described in [5.5.2] and for water lubricated tailshafts, provided that the design criteria for **MON-SHAFT** notation as per Pt F, Ch 5, Sec 2, [3] are fulfilled and that, accordingly:

- For ships fitted with oil lubricated tailshaft bearings:
  - the tailshafts are fitted with approved oil sealing glands
  - the shaft and its fittings are not exposed to corrosion
  - the design details are approved
  - the clearances of the aft bearing are found to be within acceptable limits
  - the oil and the oil sealing arrangements prove effective
  - lubricating oil analyses are carried out regularly at intervals not exceeding six months and oil consumption is recorded at the same intervals.
- For ships fitted with water lubricated tailshaft bearings:
  - the clearances of the aft bearing are found to be within acceptable limits
  - the results of the endoscopic examination are found satisfactory

Note 1: Note 1: The purpose of the endoscopic examination is to check visually the condition of the shaft in particular in way of bearings and at junction with sleeves (where provided)

  - in case of forced lubrication system, satisfactory operation of water pumping and filtering system has been checked
  - if applicable, water analyses have been carried out and recorded, at regular intervals not exceeding six months.

The modified survey is to be carried out five years after the last complete survey, with a window period of plus or minus six months.

The next complete survey is to be carried out ten years after the last complete survey.

5.5.4 Survey of propeller shafts and tube shafts - Applicable requirements from 1 January 2016

Reference is to be made to Ch 3, Sec 5, [3] for revised requirements applicable to all ships with conventional shafting fitted with a propeller, unless alternative means are provided to assure the condition of the propeller shaft assembly.

Such requirements are applicable:

- from 1 January 2016, for ships delivered on or after 1 January 2016
- after the first shaft survey scheduled on or after 1 January 2016, for ships delivered before 1 January 2016.

5.5.5 Other propulsion systems

Driving components serving the same purpose as the tailshaft in other propulsion systems, such as directional propellers, vertical axis propellers, water jet units, dynamic positioning systems and thruster assisted mooring systems, are to be submitted to periodical surveys at intervals not exceeding five years.

5.5.6 Pod propulsion systems

Shafting system (including tightness system and connection of the propeller to the shaft) of pod propulsion systems are to be submitted to complete or modified surveys, the periodicity of which is determined in the same principle as for tailshafts described in [5.5.2], [5.5.3] and Fig 2.

Propulsion motors, orientating devices and other arrangement, are to be surveyed at each class renewal survey, see Ch 3, Sec 3, [3.2.7].

5.6 Boiler survey

5.6.1 There are to be two internal examinations of boilers in each period of class of five years.

In all cases, the interval between any two such examinations is not to exceed 36 months.

5.6.2 The internal examination of thermal oil heaters is to be carried out once during each 5-year period in conjunction with the renewal survey.

5.6.3 An extension of examination of the boiler up to three months beyond the due date can be granted in exceptional circumstances, as defined in [2.1.8]. The extension may be granted by the Society after the following is satisfactorily carried out:

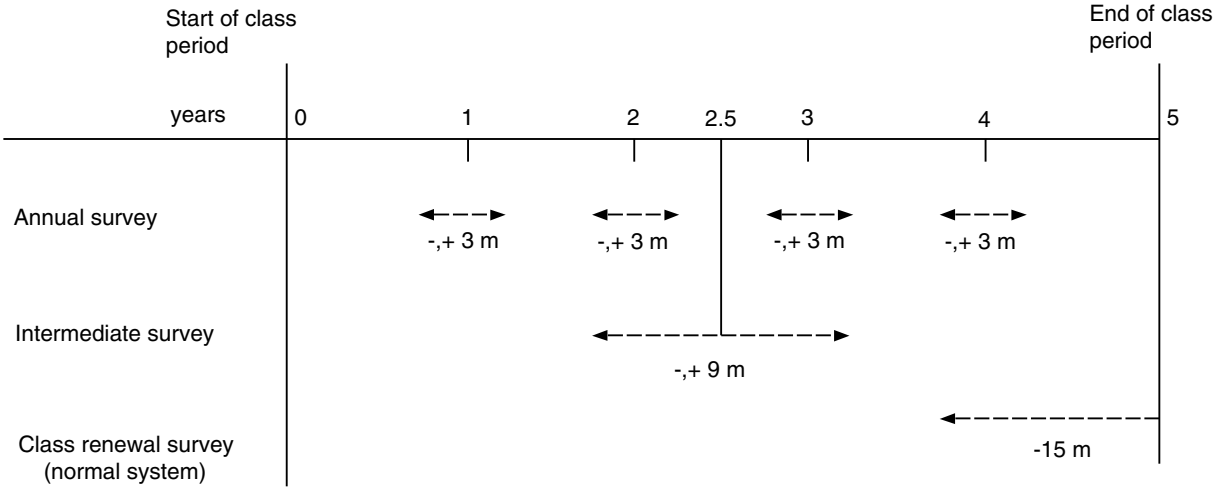
- external examination of the boiler
- examination and operational test of boiler safety valve relieving gear (easing gear)
- operational test of boiler protective devices
- review of the following records since the last boiler survey: operation, maintenance, repair history, feedwater chemistry.

5.6.4 Boilers are also submitted to an external examination as a part of the annual survey of machinery.

5.7 Links between anniversary dates and annual surveys, intermediate surveys and class renewal surveys

5.7.1 The link between the anniversary dates, the class renewal survey (when carried out according to the normal system), and the annual and intermediate surveys is given in Fig 3.

Figure 3 : Links between anniversary dates and annual, intermediate and class renewal surveys



6 Occasional surveys

6.1 General

6.1.1 An occasional survey is any survey which is not a periodical survey. The survey may be defined as an occasional survey of hull, machinery, boilers, refrigerating plants, etc., depending on the part of the ship concerned.

Where defects are found, the Surveyor may extend the scope of the survey as deemed necessary.

6.1.2 Occasional surveys are carried out at the time of, for example:

- updating of classification documents (e.g. change of the Owner, name of the ship, flag)
- damage or suspected damage
- repair or renewal work
- Port State Control inspections
- alterations or conversion
- quality system audits
- postponement of surveys or conditions of class.

6.2 Damage and repair surveys

6.2.1 In the event of damage which affects or may affect the class of the ship, the Owner is to apply to the Society for a survey. Such application is to be made as soon as possible to enable the Surveyor to ascertain the extent of the damage and necessary repairs, if any.

Note 1: Whenever a ship is fitted with an helicopter platform which is made in aluminium or other low melting metal construction which is not made equivalent to steel, and a fire occurred on the said platform or in close proximity, the platform is to be subject to a structural survey to determine its suitability for further use.

6.2.2 If, after sustaining damage, the ship calls at a port where the Society is not represented, the Owner is to notify the Society forthwith, supply all available information regarding the damage and make arrangements for the ship to be surveyed in the nearest port where the Society is represented.

6.2.3 All repairs to hull, machinery and equipment which may be required in order for a ship to retain its class are to be to the satisfaction of the Surveyor.

During repairs or maintenance work, the Owner is to arrange so that any damage, defects or non-compliance with the rule requirements are reported to the Surveyor during his survey.

6.2.4 Damages and partial or temporary repairs considered acceptable by the Surveyor for a limited period of time are the subject of an appropriate condition of class.

6.2.5 Damages or repairs required by the Surveyor to be re-examined after a certain period of time are the subject of an appropriate condition of class.

6.3 Port State Control survey

6.3.1 An occasional survey is to be requested by the Owner wherever a ship is detained as a result of a Port State Control inspection, as described in Ch 1, Sec 1, [3.4].

6.4 Conversions, alterations and repairs

6.4.1 Conversions, alterations or repairs of/to structures and arrangements affecting the class are to be carried out in accordance with the requirements of the Society and to its satisfaction. Where necessary, documentation is to be submitted to the Society and/or made available to the attending Surveyor.

6.4.2 Materials and equipment used for conversions, alterations or repairs are generally to meet the requirements of the Rules for new ships built under survey; see Ch 2, Sec 1, [2.1.5].

6.5 Quality System audits

6.5.1 The Society reserves the right to carry out occasional surveys in order to conduct audits either as deemed necessary in pursuance of its internal Quality System or as required by external organisations (e.g. IACS, flag Administrations).

6.5.2 These surveys may also be attended by auditors external to the Society.

6.5.3 The scope of these surveys is determined by the Society.

6.6 Unscheduled surveys

6.6.1 The Society reserves the right to carry out unscheduled surveys as deemed necessary and whose scope is determined by the Society, based on PSC (Port State Control) history of the ship.

7 Change of ownership

7.1

7.1.1 In the case of change of ownership, the ship retains its current class with the Society provided that:

- the Society is informed of the change sufficiently in advance to carry out any specific survey required by the Owner in view of the sale; refer to [1.1.1], and
- the new Owner signs the appropriate request, involving acceptance of the Society's general conditions and Rules. This request covers inter alia the condition of the ship when changing ownership.

Note 1: The ship's class is maintained without prejudice to those provisions in the Rules which are to be enforced in cases likely to cause suspension or withdrawal of the class such as particular damages or repairs to the ship of which the Society has not been advised by the former or, as the case may be, new Owner.

Note 2: No information whatsoever related to the class of the ship will be provided or confirmed to any third party, unless the appropriate request for information is duly completed and signed by the party making the request and the authorisation of the current Owner is obtained.

8 Lay-up and re-commissioning

8.1 General principles

8.1.1 A ship put out of commission may be subject to specific requirements for maintenance of class, as specified below, provided that the Owner notifies the Society of the fact.

If the Owner does not notify the Society of the laying-up of the ship or does not implement the lay-up maintenance program, the ship's class may be suspended and/or withdrawn when the due surveys are not carried out by their limit dates in accordance with the applicable requirements given in Ch 2, Sec 3.

8.1.2 The lay-up maintenance program provides for a "laying-up survey" to be performed at the beginning of lay-up and subsequent "annual lay-up condition surveys" to be performed in lieu of the normal annual surveys which are no longer required to be carried out as long as the ship remains laid-up. The minimum content of the lay-up maintenance program as well as the scope of these surveys are given in Ch 3, App 1. The other periodical surveys which become overdue during the lay-up period may be postponed until the re-commissioning of the ship.

8.1.3 Where the ship has an approved lay-up maintenance program and its period of class expires, the period of class is extended until it is re-commissioned, subject to the satisfactory completion of the annual lay-up condition surveys as described in [8.1.2].

8.1.4 The periodical surveys carried out during the lay-up period may be credited, either wholly or in part, at the discretion of the Society, having particular regard to their extent and dates. These surveys will be taken into account for the determination of the extent of surveys required for the re-commissioning of the ship and/or the expiry dates of the next periodical surveys of the same type.

8.1.5 When a ship is re-commissioned, the Owner is to notify the Society and make provisions for the ship to be submitted to the following surveys:

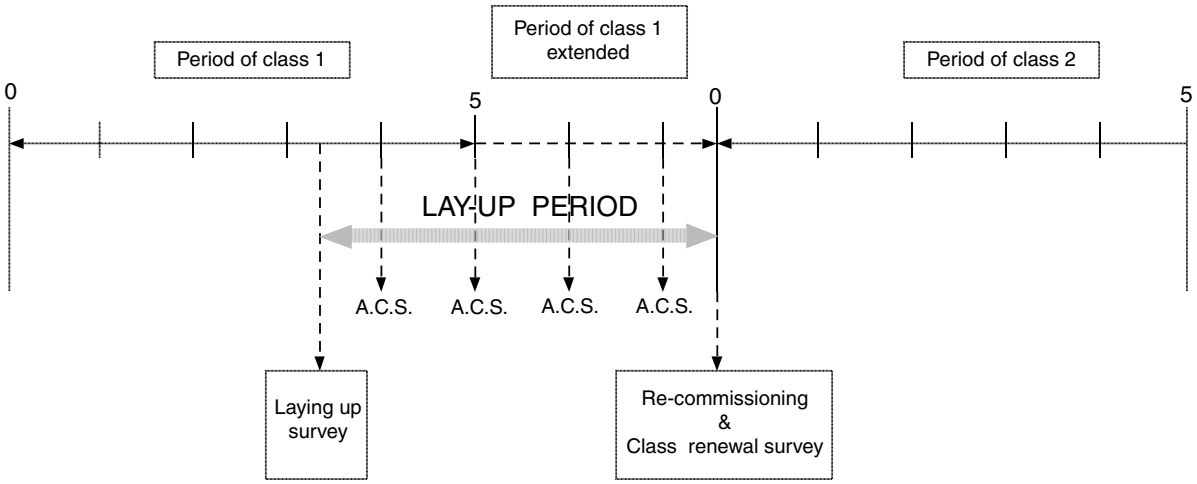
- an occasional survey prior to re-commissioning, the scope of which depends on the duration of the lay-up period
- all periodical surveys which have been postponed in accordance with [8.1.2], taking into account the provisions of [8.1.4].

8.1.6 Where the previous period of class expired before the re-commissioning and was extended as stated in [8.1.3], in addition to the provisions of [8.1.5] a complete class renewal survey is to be carried out prior to re-commissioning. Those items which have been surveyed in compliance with the class renewal survey requirements during the 15 months preceding the re-commissioning may be credited. A new period of class is assigned from the completion of this class renewal survey.

8.1.7 The principles of intervals or limit dates for surveys to be carried out during the lay-up period, as stated in [8.1.1] to [8.1.6], are summarised in Fig 4.

8.1.8 The scope of the laying-up survey and annual lay-up condition surveys are described in detail in Ch 3, App 1.

Figure 4 : Survey scheme of a case of a lay-up going beyond the expiry date of the period of class



Note 1: A. C. S. means annual lay-up condition survey.

9 Safety Management System

9.1

9.1.1 For all ships to which the ISM Code applies, the Society may have to report possible safety management system shortcomings, on the occasion of the Annual Survey or Intermediate Survey or Class Renewal Survey or Occasional Surveys or Statutory Surveys, to the Organisation that has issued the Safety Management Certificate.

Section 3 Suspension and Withdrawal of Class

1 General

1.1 Discontinuance of class

1.1.1 The class may be discontinued either temporarily or permanently. In the former case it is referred to as “suspension” of class, in the latter case as “withdrawal” of class. In both these cases, the class is invalidated in all respects. In the case of withdrawal, the name of the ship is deleted from the Register of Ships. The current version of the Register can be consulted on the Society website.

1.2 Suspension of class

1.2.1 The class may be suspended either automatically or following the decision of the Society. In any event, the ship will be considered as not retaining its class from the date of suspension until the date when class is reinstated.

1.2.2 The class may be automatically suspended when one or more of the following circumstances occur:

- when a ship is not operated in compliance with the rule requirements, such as in cases of services or conditions not covered by the service notation, or trade outside the navigation restrictions for which the class was assigned
- when a ship proceeds to sea with less freeboard than that assigned, or has the freeboard marks placed on the sides in a position higher than that assigned, or, in cases of ships where freeboards are not assigned, the draught is greater than that assigned
- when the Owner fails to inform the Society in order to submit the ship to a survey after defects or damages affecting the class have been detected
- when repairs, alterations or conversions affecting the class are carried out either without requesting the attendance of the Society or not to the satisfaction of the Surveyor. For voyage repairs, reference is to be made to Ch 2, Sec 2, [2.10].

Suspension of class with respect to the above cases will remain in effect until such time as the cause giving rise to suspension has been removed. Moreover, the Society may require any additional surveys deemed necessary taking into account the condition of the ship and the cause of the suspension.

1.2.3 In addition, the class is automatically suspended:

- when the class renewal survey has not been completed by its limit date or within the time granted for the completion of the survey, unless the ship is under attendance by the Society’s Surveyors with a view to completion prior to resuming trading
- when the annual or intermediate surveys have not been completed by the end of the corresponding survey time window (see Ch 2, Sec 2, [2.1.3]) unless the ship is under attendance for completion of the survey.

  Continuous survey item(s) due or overdue at the time of annual surveys is (are) to be dealt with. The ship's class will be subject to a suspension procedure if the item(s) is (are) not surveyed or postponed by agreement with the Society.

Suspension of class with respect to the above cases will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

1.2.4 In addition to the circumstances for which automatic suspension may apply, the class of a ship may also be suspended following the decision of the Society:

- when a condition of class is not dealt with within the time limit specified, unless it is postponed before the limit date by agreement with the Society
- when one or more surveys are not held by their limit dates (see Ch 2, Sec 2, [2.1.4]) or the dates stipulated by the Society also taking into account any extensions granted in accordance with the provisions of Part A
- when, due to reported defects, the Society considers that a ship is not entitled to retain its class even on a temporary basis (pending necessary repairs or renewals, etc.)
- when the ship has not been maintained in proper condition, as set forth in Ch 1, Sec 1, [3.3.2]
- in other circumstances which the Society will consider on their merits (e.g. in the event of non-payment of fees or where the Owner fails to render the ship available for the occasional surveys as listed in Ch 2, Sec 2, [6.1.2].

Suspension of class decided by the Society takes effect from the date when the conditions for suspension of class are met and will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

1.3 Withdrawal of class

1.3.1 The Society will withdraw the class of a ship in the following cases:

- at the request of the Owner
- as a rule, when the causes that have given rise to a suspension currently in effect have not been removed within six months after due notification of suspension to the Owner
- when the ship is reported as a constructive total loss
- when the ship is lost
- when the ship is reported scrapped.

Withdrawal of class may take effect from the date on which the circumstances causing such withdrawal occur.

The contract for the classification of the ship is terminated as of right in the above cases.

The class is also withdrawn according to the provisions of article 9 of the Marine & Offshore General Conditions in case of contract termination.

1.3.2 When the withdrawal of class of a ship comes into effect, the Society will:

- forward the Owner written notice
- delete the ship from the Register of Ships
- notify the flag Administration
- make the information available to the Underwriters, at their request.

1.4 Suspension/withdrawal of additional class notations

1.4.1 If the survey requirements related to maintenance of additional class notations are not complied with, the suspension or withdrawal may be limited to the notations concerned.

The same procedure may apply to service notations of ships which are assigned with more than one service notation.

1.4.2 The suspension or withdrawal of an additional class notation or a service notation (where a ship is assigned with more than one service notation) generally does not affect the class.

Appendix 1 Planned Maintenance Survey System

1 General

1.1

1.1.1 A Planned Maintenance Survey system (hereafter referred to as PMS) is a survey system for machinery items which may be considered as an alternative to the Continuous Survey for Machinery system (hereafter referred to as CSM), as described in Ch 2, Sec 2, [4.4].

1.1.2 This survey scheme is to be approved by the Society before being implemented. When the PMS system is applied, the scope and periodicity of the class renewal survey are tailored for each individual item of machinery and determined on the basis of recommended overhauls stipulated by the manufacturers, documented experience of the operators and, where applicable and fitted, condition monitoring. For instance, within the scope of a PMS system the following cases may occur:

- switchboard A is surveyed based on the regular expiry date of the class renewal survey
- lubricating oil pump B is surveyed based on CSM scope and periodicity
- diesel engine C is surveyed based on running hours
- turbo pump D is surveyed based on condition monitoring.

1.1.3 In general, the survey intervals for items surveyed under the PMS system should not exceed those specified for the CSM. However, for components where the maintenance is based on running hours, longer intervals may be accepted as long as the intervals are based on the manufacturer's recommendations.

1.1.4 The Chief Engineer shall be the responsible person on board in charge of the PMS.

The conditions related to Chief Engineer's inspections within the scope of PMS are given in Ch 2, App 2.

Items surveyed by this authorised Chief Engineer will be subject to the confirmatory survey as detailed in Ch 2, App 2.

Documentation on overhauls of items covered by the PMS are to be reported and signed by the Chief Engineer.

1.1.5 The conditions and procedures for the review of a PMS are indicated in Article [2].

1.1.6 For machinery undergoing maintenance based on condition monitoring, reference is made to Ch 2, App 4.

2 Conditions and procedures for the review of the system

2.1 General

2.1.1 The PMS documentation is to be subject to a consistency check. To this end the Owner is to make a formal request to the Society and provide the documentation and information specified in [2.2], combined in a manual describing the proposed scheme and including sample copies of the different documents to be used during the implementation of the scheme. The PMS is to be programmed and maintained by a computerized system. However, this may not be applied to the current already reviewed schemes.

2.1.2 When using computerised systems, access for updating of the maintenance documentation and the maintenance programmes is only granted to the person responsible for the PMS or another person authorised by him.

The computerised systems are to include a back-up procedure, which is to be activated at regular intervals.

The Owner himself is to confirm to the Society, by written declaration, that the required functionalities of the system are met. Or, alternatively, the Society may approve the software upon specific request.

2.2 Documentation

2.2.1 The documentation to be submitted is the manual mentioned above, which is to include:

a) a description of the scheme and its application on board as well as the proposed organisation chart identifying the areas of responsibility and the people responsible for the PMS on board

b) the document flow and pertinent filing procedure

c) the list of items of machinery and components to be considered for classification in the PMS, distinguishing for each the principle of survey periodicity used as indicated in [1.1.2]

d) the procedure for the identification of the items listed in c), which is to be compatible with the identification system adopted by the Society

e) the scope and time schedule of the maintenance procedures for each item listed in c), including acceptable limit conditions of the parameters to be monitored based on the manufacturers' recommendations or recognised standards and laid down in appropriate preventive maintenance sheets.

2.3 Information on board

2.3.1 The following information is to be available on board:

a) all the documentation listed in [2.2], duly updated

b) the maintenance instructions including routine tests and inspections for each item of machinery, as applicable (supplied by the manufacturer or by the shipyard)

c) reference documentation (trend investigation procedures etc.)

d) the records of maintenance performed, including conditions found, repairs carried out, spare parts fitted

e) the list of personnel on board in charge of the PMS management.

2.4 List of items

2.4.1 Ships subject to the planned maintenance survey system are provided with lists of items to be surveyed under this system, as indicated in [5.2.9].

3 Implementation of the system

3.1

3.1.1 When the documentation submitted has been checked for consistency and the PMS system has been implemented on board and used for a sufficient period (which is not to exceed one year) so that all personnel become familiar with it, a survey is to be carried out in order to start the system and make it officially operational. The scope of this survey, referred to as Implementation Survey, is given in [5.1.1].

3.1.2 Upon the successful outcome of the Implementation Survey, the PMS is considered approved.

4 Retention and withdrawal of the system

4.1

4.1.1 The PMS system is retained throughout the class period provided that:

- an annual report covering the year's service is supplied to the Society in accordance with [5.2.8]
- an annual audit in accordance with [5.2] is satisfactorily completed
- any change to the approved PMS is submitted to the Society for agreement.

4.1.2 The survey arrangement for machinery according to the PMS may be withdrawn by the Society if the PMS is not satisfactorily operated on account of either the maintenance records or the general condition of the machinery or the failure to observe the agreed intervals between overhauls.

4.1.3 The Owner may discontinue the PMS at any time by informing the Society in writing. In this case, the items which have been inspected under the PMS since the last annual audit will be credited for class at the discretion of the attending Surveyor.

4.1.4 In the case of sale or change of management of the ship or classification after construction, the assignment of the PMS will be reconsidered.

5 Surveys

5.1 Implementation survey

5.1.1 The implementation survey is to be carried out by a Surveyor of the Society, as stated in [3.1.1], within one year from the date of approval of the PMS.

5.1.2 The scope of this survey is to verify that:

- the PMS is implemented in accordance with the documentation which has been checked and is suitable for the type and complexity of the components and systems on board
- the documentation required for the annual audit is produced by the PMS
- the requirements of surveys and testing for retention of class are complied with
- the shipboard personnel are familiar with the PMS procedures.

Upon the successful outcome of the survey confirming the proper implementation of the PMS, the system is considered operational subject to the submission to the Society of a report describing the PMS.

5.2 Annual audit and confirmatory surveys

5.2.1 Once the PMS system is implemented, the continued compliance with the requirements for checks, overhauls and repairs, where needed, indicated in [2] is to be verified by means of annual audits and confirmatory surveys in order to confirm the validity of the approved survey scheme system.

5.2.2 The annual audit and confirmatory surveys are to be carried out in conjunction with the annual class surveys.

5.2.3 The purpose of this audit is to verify that the scheme is being correctly operated, in particular that all items (to be surveyed in the relevant period) have actually been surveyed in due time. A general examination of the items concerned is carried out.

5.2.4 The maintenance and performance records are examined to verify that the machinery has been functioning satisfactorily since the previous survey or audit or, if necessary, that the necessary measures have been taken in response to machinery operating parameters exceeding acceptable tolerances, and that the overhaul intervals have been observed.

5.2.5 Written reports of breakdown or malfunction are to be made available.

5.2.6 The description of the repairs, if any, carried out is to be examined. Any machinery part or component which has been replaced by a spare due to damage is to be retained on board, where possible. On this occasion such replaced parts are to be submitted to the examination of the Surveyor.

5.2.7 The Surveyor also checks that the personnel on board in charge of the PMS have the appropriate authorisation (see Ch 2, App 2).

5.2.8 An annual report covering the year's service is to be supplied to the Society. It is to include the information as required by items c) and e) of [2.2.1] above, as well as the information on changes to other requirements in [2.2.1].

The Surveyor is to review this annual report or verify that it has been reviewed by the Society.

5.2.9 The Surveyor carries out a confirmatory survey of the items which have been surveyed by the Chief Engineer and decides which items can be confirmed for classification, on the PMS list of items.

5.3 Damage and repairs

5.3.1 Damage to components or items of machinery covered by the PMS which may affect the class is to be reported to the Society. Where applicable, a Surveyor will attend on board, survey the damaged items and, on the basis of the survey results, decide whether conditions of class are to be imposed.

5.3.2 All parts of machinery or components which need to undergo substantial repairs are to be surveyed before, during and after the repairs, as deemed appropriate by the Surveyor. Any repair and corrective action regarding machinery under PMS system shall be recorded in the PMS logbook and repairs verified by the Surveyor at the annual audit.

5.3.3 In the case of overdue condition of class or records of unrepaired damage which may affect the PMS, the relevant items are to be taken out of the PMS until the conditions of class have been fulfilled or the repairs carried out.

Appendix 2 CSM and PMS Systems: Surveys Carried out by the Chief Engineer

1 Conditions

1.1

1.1.1 The basic conditions for the acknowledgment of surveys carried out by Chief Engineers are specified hereafter. Consideration may be given to other conditions on a case by case basis.

1.1.2 An Owner's attestation, confirming that the Chief Engineer is duly qualified to carry out the inspection of the machinery items when the CSM system or PMS system, as applicable, is implemented on-board ships in accordance with the requirements in [2.1.1] and [2.1.2], is to be made available to the Surveyor on-board.

2 Limits of the interventions

2.1

2.1.1 For ships where the CSM system is implemented, the following items of the class renewal survey for machinery cannot be inspected by the Chief Engineer:

- pressure vessels
- main and auxiliary turbines
- main reduction gears
- turbochargers of main propulsion internal combustion engines
- intermediate shafting and associated bearings.

2.1.2 For ships where the PMS system is implemented, all items covered by the system can be surveyed by the Chief Engineer, with the exception of pressure vessels.

2.1.3 In no case may the surveys of tailshafts and boilers, which are items not included in the scope of the class renewal survey, be carried out by the Chief Engineer.

3 Procedure for carrying out surveys

3.1 General

3.1.1 As regards the procedure for carrying out surveys, the Owner is to inform the Chief Engineer that surveys are to be conducted in accordance with the Rules of the Society and, specifically, the requirements for class renewal surveys related to machinery and systems contained in Ch 3, Sec 3, [3].

It is the responsibility of the ship's Captain and Chief Engineer to decide the date and place for the survey of each component in order to avoid possible accidents (fire included) in the event of damage to the unit(s) remaining in service.

Some guidelines for the Chief Engineer relevant to the dismantling and inspections of main components of the machinery installation are given below.

The items and/or machinery which, as a result of the surveys, are replaced due to wear, damage or defects, are to be kept on board until they are inspected by a Surveyor of the Society.

3.2 Main diesel engines

3.2.1 The following items are to be surveyed as indicated:

- the top and bottom halves of the main bearings are to be removed and inspected, and the clearances are to be taken, recorded and compared with the limits recommended by the engine builder
- the top and bottom halves of bottom end connecting rod bearings are to be examined, and the clearances are to be taken, recorded and compared with the limits recommended by the engine builder
- crankpins, journals and webs are to be examined for crack detection, mainly at the fillets and in the vicinity of the lubricating oil holes
- crankshaft deflections are to be taken and recorded at regulars intervals, enabling verification of the trend when they are taken in the presence of the Society's Surveyor. This operation is to be effected bearing in mind that during the readings the journals are to be steady on their bearings

- other parts exposed to wear or operating incidents are to be carefully examined and the results recorded. In particular, the wear of liners is to be measured and recorded.

3.3 Auxiliary diesel engines

3.3.1 The survey generally consists of the complete dismantling of the engine and a careful examination of those items most liable to be exposed to wear or operating incidents. In particular:

- crankshaft deflections and wear of cylinder liners are to be measured
- the crankshaft is to be checked by means of dye penetrant in way of fillets and lubricating oil holes
- all top halves of the main bearings together with at least two bottom halves are to be dismantled
- crankcase explosion relief valves, if fitted, are to be checked.

3.4 Reciprocating compressors

3.4.1 The survey is to include:

- the dismantling of pistons and valves for inspection
- the examination and testing of the nest of cooler tubes
- the verification of safety relief valves after reassembling.

3.5 Coolers, condensers, heaters

3.5.1 The survey is to include:

- the dismantling of the covers
- the examination of the nest of tubes
- the testing of the nest of tubes, if necessary.

3.6 Electrical switchboard

3.6.1 The survey is to include:

- the cleaning of the switchboard
- the verification of the connection assemblies, locking device tightening and busbar tightening
- the examination of the condition of the circuit-breakers, switches and fuses
- the verification of the contacts and screens
- the checking of the measuring instruments, which are to be re-calibrated or replaced, if inaccurate
- the insulation resistance test.

3.7 a.c. and d.c. generators

3.7.1 The survey is to include:

- the removal of protection plates and brush carriers
- the cleaning of field coils and armature windings
- the verification of proper contact of brushes, which are to be renewed if excessively worn
- the verification of commutators and sliprings
- the measurement of air gap clearances
- the checking of journals and bearings
- the insulation resistance test.

3.8 Other items (pumps, electric motors, etc.)

3.8.1 The survey is generally to include the complete dismantling for inspection of the main parts exposed to wear or operating incidents, such as bearings, casings, impellers and rotors.

4 Records of surveys carried out

4.1

4.1.1 The surveys carried out by the Chief Engineer are to be recorded in the engine/machinery log-book and a survey report is to be prepared for each item surveyed.

The report is generally to be drawn up in English; however, for ships trading in specific restricted areas the use of the language of the country concerned will be accepted.

The report may be provided in hard copy or using a computerised recording system.

4.1.2 The report is to indicate the following information:

- identification data:
  - name of ship and register number
  - name of Chief Engineer and Owner's attestation
  - date and place (port or voyage leg) of the survey
  - reference of the item in the CSM or PMS list, and description of the item
- inspection conducted:
  - the type of inspection carried out: visual external examination, internal examination after dismantling, overhaul
  - readings performed, when applicable: clearances, measurements, working pressure, or other working parameters of the equipment
  - inspection findings: corrosion, fractures, pieces of equipment worn out, broken or missing
- maintenance and repairs carried out and parts replaced
- results of tests performed after the inspection, such as working test, pressure test.

For sake of completeness, other documentation such as sketches, photos, measurement reports may be attached to the report.

The report is to be signed by the Chief Engineer.

5 Confirmatory survey

5.1

5.1.1 A confirmatory survey, to be carried out by a Surveyor of the Society, is to be requested according to the following principle:

- for ships under the CSM system, within a reasonably short time from the date of the surveys carried out by the Chief Engineer, and, in any case, in the first port which is under the jurisdiction of an Office of the Society
- for ships under the PMS system, at the next annual audit (see Ch 2, App 1, [5.2]).

5.1.2 The Surveyor is to be supplied with a copy of this survey report and also shown the engine log-book.

5.1.3 The Surveyor carries out an external examination of the relevant items and parts replaced and, if applicable, attends running tests. If doubts arise, the Surveyor may request dismantling as deemed necessary.

5.1.4 For confirmatory survey of the main engine crankshaft and bearings, the Surveyor performs the following:

- check of condition monitoring records
- check of crankshaft deflection readings
- check of bearing clearances (where possible)
- checks for signs of wiped or broken white metal in the crankcase or filters
- check of the witness marks of shrink fits of crankshafts
- check of the bedplate structure (inside and outside)
- check that the condition of crankpins, journals and associated bearings is duly recorded.

5.1.5 Where the confirmatory survey is performed with an abnormal delay, the inspection is to be more extensive and, if necessary, the due surveys are to be completely repeated.

5.1.6 The date of the execution of the surveys will be assumed to be the date of the confirmatory survey.

6 Suspension of the Chief Engineer's authorization

6.1

6.1.1 Where the condition of the items surveyed by the Chief Engineer as specified in his or her reports does not correspond to the findings of the attending Surveyor, or in case of doubt on the general maintenance of the machinery installation, the Society may request the Owner to withdraw the Chief Engineer qualification attestation until further training and re-assessment of his/her qualification.

Appendix 3 Thickness Measurements: Extent, Determination of Locations, Acceptance Criteria

1 General

1.1 Aim of the Appendix

1.1.1 Thickness measurements are a major part of surveys to be carried out for the maintenance of class, and the analysis of these measurements is a prominent factor in the determination and extent of the repairs and renewals of the ship's structure.

1.1.2 The Appendix is intended to provide Owners, companies performing thickness measurements and the Society's Surveyors with a uniform means with a view to fulfilling Rule requirements for thickness measurements. In particular, it will enable all the above-mentioned parties to carry out:

- the planning and preparation
- the determination of extent and location, and
- the analysis

of the thickness measurements in cooperation.

1.1.3 It is to be noted that this Appendix also takes into account specific requirements for thickness measurements relevant to close-up surveys of ships which are subject to the Enhanced Survey Program (ESP).

1.2 Scope of the Appendix

1.2.1 Separate Articles below provide the following information:

- references to rule requirements and some additional information on the extent of the thickness measurements to be performed during surveys according to types of ships and related surveys (see [2])
- locations of the measurements for the main parts of the ship (see [3])
- how to analyse the results of thickness measurements (see [4]).

Tables and sketches are also given to detail the above points according to the types of ships.

2 Rule requirements for the extent of measurements

2.1 General

2.1.1 For the maintenance of class, thickness measurements may be required during annual, intermediate and class renewal surveys.

Tab 1 gives the references to the requirements for minimum thickness measurements indicated in Part A, Chapter 3 and Part A, Chapter 4 for each service notation and related to the different types of surveys.

Some additional explanations are also given about the wording used in the Rules as well as the general principles of the required thickness measurements during class renewal surveys.

2.2 Class renewal survey: all ships except those submitted to ESP or equivalent

2.2.1 The thickness measurements required by the Rules consist of:

- systematic thickness measurements, i.e. measurements of different parts of the structure, in order to assess the overall and local strength of the ship
- measurements of suspect areas as defined in Ch 2, Sec 2, [2.2.11]
- additional measurements on areas determined as affected by substantial corrosion as defined in Ch 2, Sec 2, [2.2.7].

Table 1 : References to rule requirements related to thickness measurements

SERVICE NOTATION	TYPE OF SURVEY		
	CLASS RENEWAL	INTERMEDIATE	ANNUAL
all service notations except those in other rows	Ch 3, Sec 3, [2.6] and Ch 3, Sec 3, Tab 3: systematic measurements and suspect areas Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 4 as guidance	Ch 3, Sec 2, Tab 1: thickness measurements to be taken if deemed necessary by the Surveyor Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 4 as guidance	Ch 3, Sec 1, [2.1.2]: areas of substantial corrosion identified at previous surveys Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 4 as guidance
bulk carrier ESP **bulk carrier BC-A ESP** **bulk carrier BC-B ESP** **bulk carrier BC-C ESP** **ore carrier ESP** **combination carrier/ OBO ESP** **combination carrier/ OOC ESP**	Ch 4, Sec 2, [4.1] and Ch 4, Sec 2, [4.6]: planning and general requirements Ch 4, Sec 2, Tab 8 and Ch 4, Sec 2, Tab 9: measurements of elements subjected to close-up survey Ch 4, Sec 2, Tab 11: extent of systematic thickness measurements Ch 4, Sec 2, Tab 12 to Ch 4, Sec 2, Tab 20, according to the different locations, where substantial corrosion is found	• Ships 10 years of age or less: Ch 4, Sec 2, Tab 3 and Ch 4, Sec 2, Tab 5 for cargo holds Ch 4, Sec 2, Tab 4 and Ch 4, Sec 2, Tab 6 for salt water ballast tanks Ch 4, Sec 2, Tab 12 to Ch 4, Sec 2, Tab 20, according to the different locations, where substantial corrosion is found • Ships over 10 years of age: see references given for class renewal survey	Ch 4, Sec 2, Tab 1 and Ch 4, Sec 2, Tab 2 for cargo holds and when deemed necessary by the Surveyor Ch 4, Sec 2, [2.4] for salt ballast tanks and when deemed necessary by the Surveyor Ch 4, Sec 2, Tab 12 to Ch 4, Sec 2, Tab 20, according to the different locations, where substantial corrosion is found
oil tanker ESP **combination carrier/ OBO ESP** **combination carrier/ OOC ESP**	Ch 4, Sec 3, [6.1] and Ch 4, Sec 3, [6.5]: planning and general requirements Ch 4, Sec 3, Tab 1 and Ch 4, Sec 3, Tab 2: measurements of elements subjected to close-up survey Ch 4, Sec 3, Tab 3: extent of systematic thickness measurements Ch 4, Sec 3, Tab 4 and Ch 4, Sec 3, Tab 5, according to the different locations, where substantial corrosion is found	• Ships 10 years of age or less: Ch 4, Sec 3, [4.2] for salt ballast tanks Ch 4, Sec 3, Tab 4 and Ch 4, Sec 3, Tab 5, according to the different locations, where substantial corrosion is found • Ships over 10 years of age: see references given for class renewal survey	Ch 4, Sec 3, [2.4] limited to salt ballast tanks and when deemed necessary by the Surveyor Ch 4, Sec 3, Tab 4 and Ch 4, Sec 3, Tab 5, according to the different locations, where substantial corrosion is found
chemical tanker ESP	Ch 4, Sec 4, [6.1] and Ch 4, Sec 4, [6.5]: planning and general requirements Ch 4, Sec 4, Tab 1: measurements of elements subjected to close-up survey Ch 4, Sec 4, Tab 3: extent of systematic thickness measurements Ch 4, Sec 4, Tab 4: according to the different locations, where substantial corrosion is found	• Ships 10 years of age or less: Ch 4, Sec 4, [4.2] for salt ballast tanks Ch 4, Sec 4, Tab 4: according to the different locations, where substantial corrosion is found • Ships over 10 years of age: see references given for class renewal survey	Ch 4, Sec 4, [2.4] limited to salt ballast tanks and when deemed necessary by the Surveyor Ch 4, Sec 4, Tab 4: according to the different locations, where substantial corrosion is found
liquefied gas carrier	Ch 4, Sec 5, [6.2], Ch 4, Sec 5, [6.3.2] and Ch 4, Sec 5, [6.5]: planning and general requirements Ch 4, Sec 5, Tab 2: measurements of elements subjected to close-up survey Ch 4, Sec 5, Tab 3: extent of systematic thickness measurements Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 4 as guidance	Ch 4, Sec 5, Tab 1: thickness measurements to be taken if deemed necessary by the Surveyor Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 4 as guidance	Ch 4, Sec 5, [2.5.2] limited to ballast tanks and when deemed necessary by the Surveyor Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 4 as guidance

SERVICE NOTATION	TYPE OF SURVEY		
	CLASS RENEWAL	INTERMEDIATE	ANNUAL
general cargo ship	Ch 4, Sec 7, [4.1], Ch 4, Sec 7, [4.2] and Ch 4, Sec 7, [4.5]: planning and general requirements Ch 4, Sec 7, Tab 4: measurements of elements subjected to close-up survey Ch 4, Sec 7, Tab 5: extent of systematic thickness measurements Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 4, Sec 7, Tab 6 as guidance	• Ships 15 years of age or less: Ch 4, Sec 7, Tab 2 for cargo holds Ch 4, Sec 7, Tab 3 for ballast tanks Ch 4, Sec 7, Tab 6, where substantial corrosion is found • Ships over 15 years of age: see references given for class renewal survey	Ch 4, Sec 7, Tab 1 for cargo holds when deemed necessary by the Surveyor or where extensive corrosion exists Ch 4, Sec 7, [2.4] for ballast tanks when deemed necessary by the Surveyor or where extensive corrosion exists Ch 4, Sec 7, Tab 6 where substantial corrosion is found

2.3 Class renewal survey: ships submitted to ESP or equivalent

2.3.1 The thickness measurements required by the Rules consist of:

- systematic thickness measurements in order to assess the overall and local strength of the ship
- thickness measurements as indicated in the program of close-up survey
- measurements of elements considered as suspect areas as defined in Ch 2, Sec 2, [2.2.11]
- additional measurements on areas determined as affected by substantial corrosion as defined in Ch 2, Sec 2, [2.2.7].

2.3.2 For the determination of close-up surveys and relevant thickness measurements as well as the areas considered as suspect areas, reference is to be made to the relevant Sections of Part A, Chapter 4 according to the different service notations of the ships.

3 Number and locations of measurements

3.1 General

3.1.1 Considering the extent of thickness measurements as required by the Rules and indicated in [2], the locations of the points to be measured are given here for the most important items of the structure. Thus the number of points can be estimated.

Note 1: This Article applies to ships built under the Common Structural Rules as well as ships not built under the Common Structural Rules, as specified.

3.2 Locations of points

3.2.1 Tab 2 provides explanations and/or interpretations for the application of those requirements indicated in the Rules which refer to both systematic thickness measurements related to the calculation of global hull girder strength and specific measurements connected to close-up surveys.

Figures are also given to facilitate the explanations and/or interpretations given in the table. These figures show typical arrangements of cargo ships, bulk carriers and oil tankers. Due to the various designs of the other ship types, figures are not given to cover all the different cases. However, the figures provided here may be used as guidance for ships other than those illustrated.

Table 2 : Interpretations of rule requirements for the locations and number of points to be measured

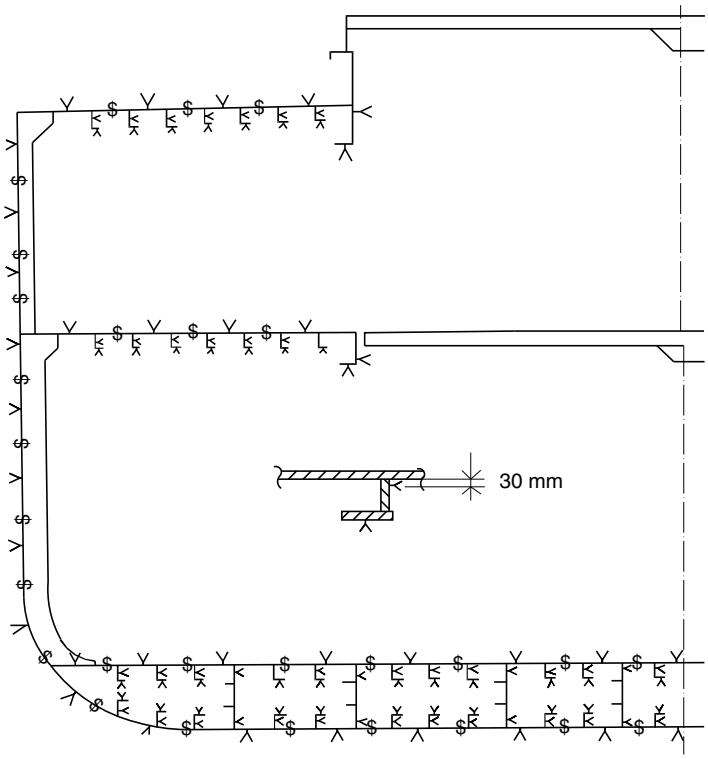
A) SYSTEMATIC MEASUREMENTS		
ITEM	INTERPRETATION	FIGURE
Selected plates on deck, tank top, bottom, double bottom and wind-and-water (for all ship types including CSR ships)	"Selected" means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	No figure
All deck, tank top and bottom plates and wind-and-water strakes (for all ship types including CSR ships)	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	No figure

Transverse section (for all ship types including CSR ships)	Refer to the definition given in Ch 2, Sec 2, [2.2.5] One point to be taken on each plate. Both web and flange to be measured on longitudinals, if applicable (for CSR oil tankers) For tankers older than 10 years of age: within 0,1D (where D is the ship's moulded depth) of the deck and bottom at each transverse section to be measured, every longitudinal and girder is to be measured on the web and face plate, and every plate is to be measured at one point between longitudinals (for CSR oil tankers)	Fig 1 for general cargo ships Fig 2 for bulk carriers including CSR bulk carriers Fig 3 for oil tankers Fig 15 for CSR oil tankers For other ship types, see [3.2.1]
All cargo hold hatch covers and coamings (for all ship types except CSR oil tankers)	Including plates and stiffeners (for CSR single skin and double skin bulk carriers)	Fig 4 for ships fitted with hold hatch covers and coamings
Bulkheads on ships other than bulk carriers, oil tankers, chemical tankers, liquefied gas carriers and CSR ships (for these ships refer to B) and C): CLOSE-UP SURVEYS AND RELATED MEASUREMENTS)	"Selected bulkheads" means at least 50% of the bulkheads	Fig 5 for general cargo ships. It may also apply to other ship types (see [3.2.1])
Selected internal structure such as floors and longitudinals, transverse frames, web frames, deck beams, 'tweendecks, girders (for all ship types other than CSR ships)	The internal structural items to be measured in each space internally surveyed are to be at least 20% within the cargo area and 10% outside the cargo area	Fig 6 for general cargo ships. It may also apply to other ship types (see [3.2.1])
Transverse section of deck plating outside line of cargo hatch openings (for bulk carriers, ore carriers, combination carriers and CSR single skin and double skin bulk carriers)	Two single points on each deck plate (to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion) between the ship sides and hatch coamings in the transverse section concerned	No figure
Transverse rings **(1)** in cargo and ballast tanks (for CSR oil tankers)	At least two points on each plate in a staggered pattern and two points on the corresponding flange where applicable. Minimum 4 points on the first plate below deck. Additional points in way of curved parts. At least one point on each of two stiffeners between stringers / longitudinal girders	Fig 16 for CSR oil tankers
One section of deck plating for the full beam of the ship within the cargo area (for oil tankers, chemical tankers and liquefied gas carriers, other than CSR ships)	Two single points on each deck plate (to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion) in the transverse section concerned	No figure
All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches (for CSR single skin and double skin bulk carriers)	«All deck plating» means at least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion. "Under deck structure": at each short longitudinal girder: three points for web plating (fwd/middle/aft), single point for face plate, one point for web plating and one point for face plating of transverse beam in way. At each ends of transverse beams, one point for web plating and one point for face plating	Fig 10 for CSR single skin and double skin bulk carriers Extent of areas is shown in Ch 4, Sec 2, Fig 1 and Ch 4, Sec 2, Fig 4
B) CLOSE-UP SURVEYS AND RELATED MEASUREMENTS (oil tankers, chemical tankers, liquefied gas carriers and combination carriers)		
ITEM	INTERPRETATION	FIGURE
Web frame ring (for oil tankers and combination carriers other than CSR ships)	Refer to the definition given in Ch 4, Sec 3, Tab 1 "Adjacent structural members" means plating and stiffeners of deck, bottom, double bottom, sides and longitudinal bulkheads in the vicinity of the web frame ring	Extent of areas is shown as ① in Ch 4, Sec 3, Fig 1 Locations of points are given in Fig 13
Transverse section (for chemical tankers and liquefied gas carriers)	Refer to the definitions given in Ch 4, Sec 4, Tab 1 and Ch 4, Sec 5, Tab 2 "Adjacent structural members" means plating and stiffeners of deck, bottom, double bottom, sides and longitudinal bulkheads in the vicinity of the web frame ring	No figure

Deck transverse (for all ships other than CSR ships)	This is the upper part of the web frame ring including the adjacent structural members (see meaning given above). For chemical tankers it may be fitted on deck, i.e. outside the tank	Extent of areas is shown as ② in Ch 4, Sec 3, Fig 1 Locations of points are given in Fig 13
Deck and bottom transverses (for oil tankers other than CSR ships)	Refer to the definition given in Ch 4, Sec 3, Tab 1	Extent of areas is shown as ② and ⑤ in Ch 4, Sec 3, Fig 1 Locations of points are given in Fig 13
Transverse bulkheads (for all ships other than CSR ships)	"Complete" means the whole bulkhead including stringers and stiffeners and adjacent structural members as defined above	Extent of areas is shown as ③ in Ch 4, Sec 3, Fig 1 Locations of points are given in Fig 14
	"Lower part" means lower part of bulkhead up to 1/4 of ship's depth or 2 metres above the lower stringer, whichever is the greater (stringers, stiffeners and adjacent structural members included)	Extent of areas is shown as ④ in Ch 4, Sec 3, Fig 1 Locations of points are given in Fig 14
Transverse bulkheads in cargo tanks (for CSR oil tankers)	At least two points on each plate. Minimum 4 points on the first plate below main deck At least one point on every third stiffener to be taken between each stringer At least two points on each plate of stringers and girders, and two points on the corresponding flange. Additional points in way of curved part Two points of each diaphragm plate of stools, if fitted.	Fig 17 for CSR oil tankers
Transverse bulkheads in ballast tanks (for CSR oil tankers)	At least 4 points on plates between stringers / longitudinal girders, or per plate if stringers/girders not fitted At least two points on each plate of stringers and girders, and two points on the corresponding flange. Additional points in way of curved part At least one point on two stiffeners between each stringer / longitudinal girder	Fig 18 for CSR oil tankers
Adjacent structural members (for CSR oil tankers)	On adjacent structural members one point per plate and one point on every third stiffener/longitudinal	No figure
All plating and internal structures (for chemical tankers and liquefied gas carriers)	Refer to the definitions given in Ch 4, Sec 4, Tab 1 and Ch 4, Sec 5, Tab 2	No figure
C) CLOSE-UP SURVEYS AND RELATED MEASUREMENTS (bulk carriers and ore carriers)		
ITEM	INTERPRETATION	FIGURE
Frames in cargo holds (for bulk carriers and ore carriers other than CSR ships)	25% of frames: one out of four frames should preferably be chosen throughout the cargo hold length on each side "Selected frames" means at least 3 frames on each side of cargo holds	Extent of areas is shown as ① in Ch 4, Sec 2, Fig 1 Locations of points are given in Fig 7
Selected side shell frames in cargo holds (for CSR single skin bulk carriers)	Includes side shell frame, upper and lower end attachments and adjacent shell plating 25% of frames: one out of four frames should preferably be chosen throughout the cargo hold length on each side 50% of frames: one out of two frames should preferably be chosen throughout the cargo hold length on each side «Selected frames» means at least 3 frames on each side of cargo holds	Fig 11 for CSR single skin bulk carriers Extent of areas is shown in Ch 4, Sec 2, Fig 1
Transverse frame in double skin tank (for CSR double skin bulk carriers)		Fig 2
Transverse bulkheads in cargo holds (for bulk carriers, ore carriers and CSR single skin and double skin bulk carriers)	Refer to the definition given in Ch 4, Sec 2, Tab 8 footnote **(3)** Two selected bulkheads: one is to be the bulkhead between the two foremost cargo holds and the second may be chosen in other positions (for CSR single skin and double skin bulk carriers)	Areas of measurements are shown in Ch 4, Sec 2, Fig 1 and Ch 4, Sec 2, Fig 4 Locations of points are given in Fig 8

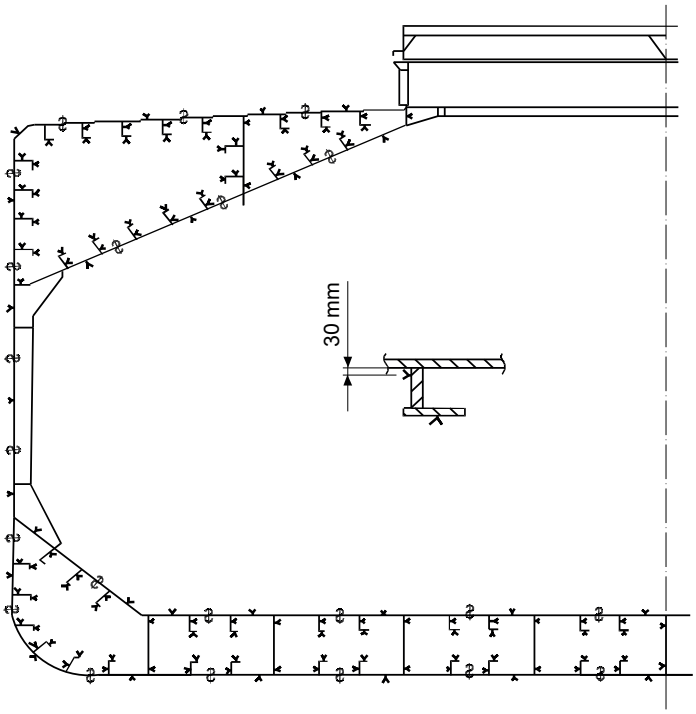
One transverse bulkhead in each cargo hold (for bulk carriers, ore carriers and CSR single skin and double skin bulk carriers)	This means that the close-up survey and related thickness measurements are to be performed on one side of the bulkhead; the side is to be chosen based on the outcome of the overall survey of both sides. In the event of doubt, the Surveyor may also require (possibly partial) close-up survey on the other side	Areas of measurements are shown in Ch 4, Sec 2, Fig 1 and Ch 4, Sec 2, Fig 4 Locations of points are given in Fig 8
Transverse bulkheads in one topside/side, hopper and double bottom ballast tank (for bulk carriers, ore carriers and CSR single skin and double skin bulk carriers)	Includes bulkhead and stiffening systems (for CSR single skin and double skin bulk carriers) The ballast tank is to be chosen based on the history of ballasting among those prone to have the most severe conditions	Locations of points are given in Ch 2, App 3
Transverse webs in ballast tanks (for bulk carriers, ore carriers and CSR single skin and double skin bulk carriers)	Either one of the representative tanks of each type (i.e. topside or hopper or side tank) is to be chosen in the forward part Includes web plating, face plates, stiffeners and associated plating and longitudinals (for CSR single skin and double skin bulk carriers) "Associated plating and longitudinals" means adjacent plating and longitudinals of deck, bottom, side shell, slope, hopper and longitudinal bulkhead, as applicable	Extent of areas is shown as ② in Ch 4, Sec 2, Fig 1 and Ch 4, Sec 2, Fig 4 Locations of points are given in Fig 7 Locations of points are given in Fig 11 for CSR single skin bulk carriers and in Fig 12 for CSR double skin bulk carriers
Areas of deck plating inside line of hatch openings (for bulk carriers and ore carriers other than CSR ships)	"Selected" means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion "All deck plating" means at least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	Extent of areas is shown as ⑤ in Ch 4, Sec 2, Fig 1
(1) Transverse rings means all transverse material appearing in a cross-section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse (definition from the Common Structural Rules).		

Figure 1 : Transverse section of a general cargo ship

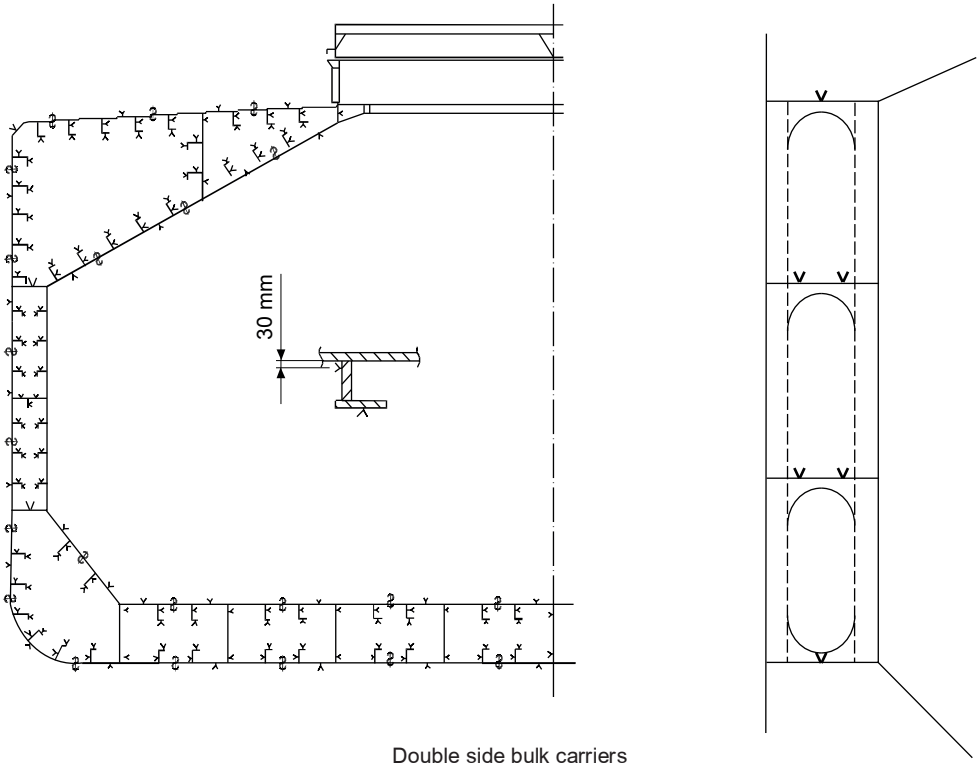


Measurements are to be taken on both port and starboard sides of the selected transverse section

Figure 2 : Transverse section of bulk carriers



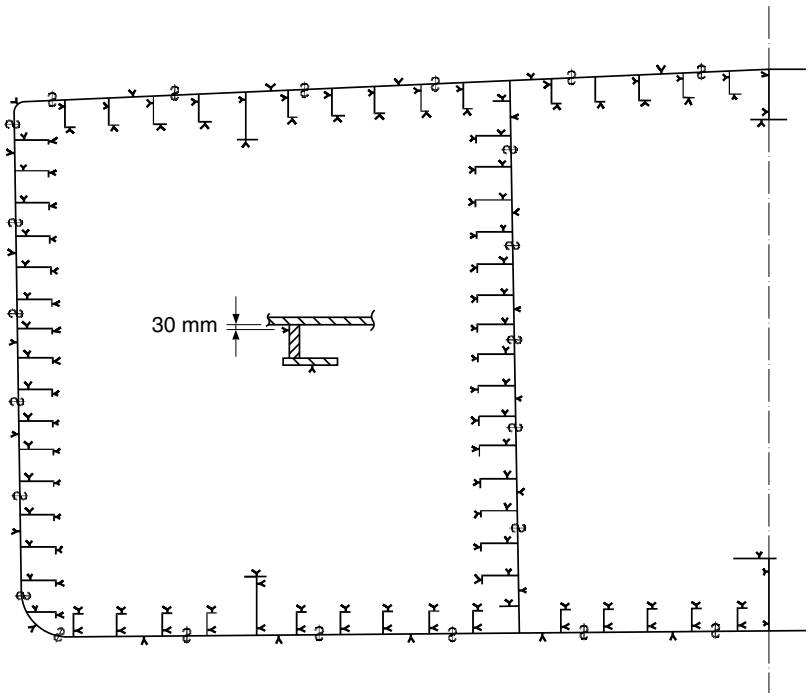
Single side bulk carriers



Double side bulk carriers

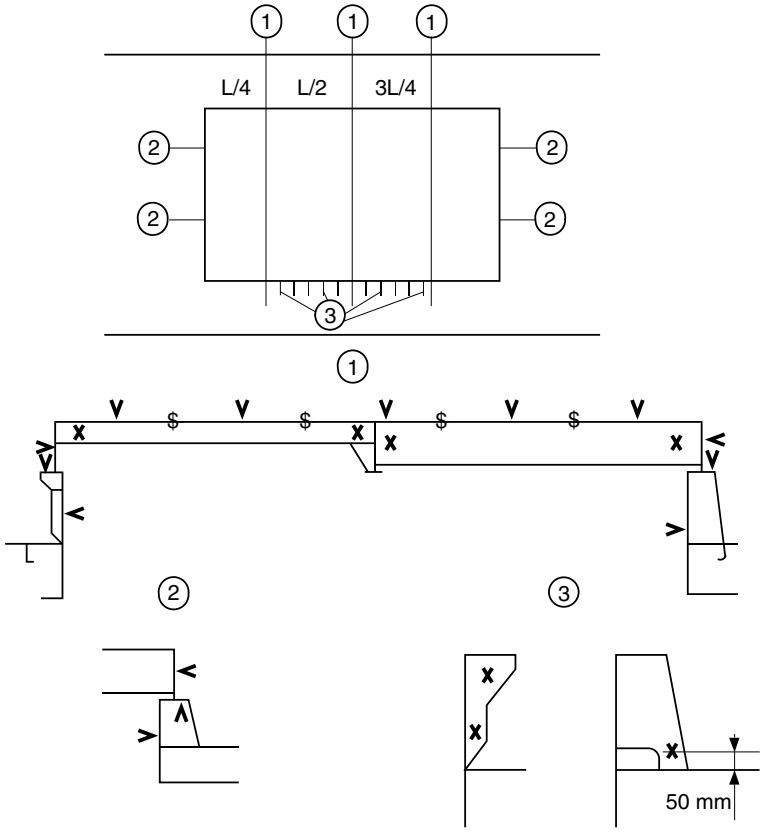
Measurements are to be taken on both port and starboard sides of the selected transverse section

Figure 3 : Transverse section of an oil tanker



Measurements are to be taken on both port and starboard sides of the selected transverse section

Figure 4 : Locations of measurements on hatch covers and coamings (valid for all ships fitted with hatch covers and coamings)



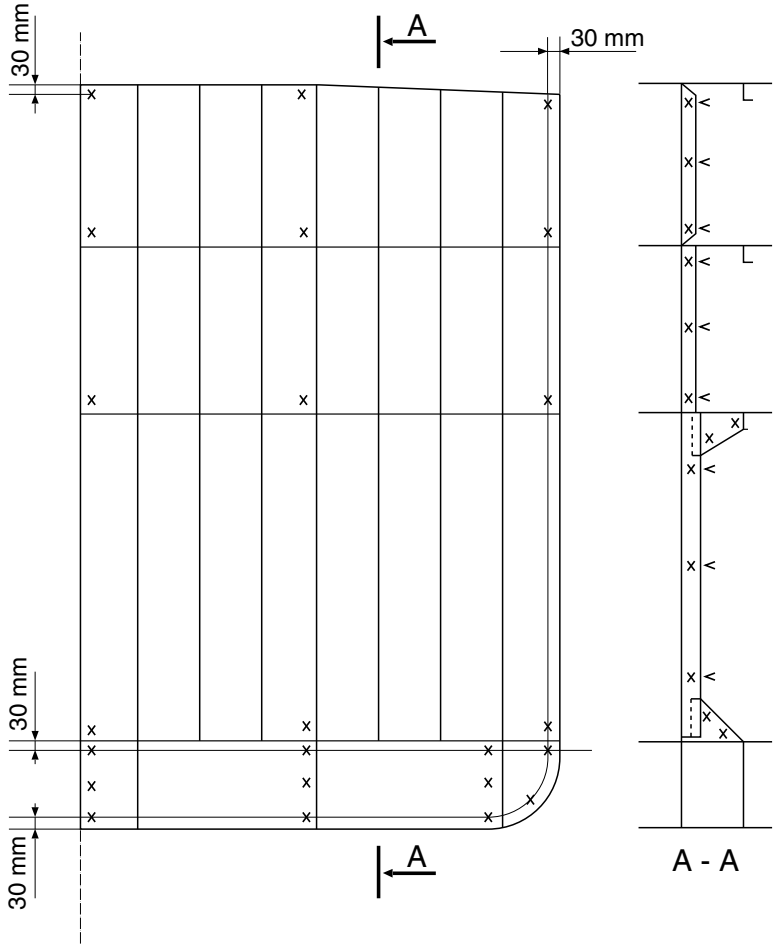
(1) Three sections at L/4, L/2, 3L/4 of hatch cover length, including:

- one measurement of each hatch cover plate and skirt plate
- measurements of adjacent beams and stiffeners
- one measurement of coaming plates and coaming flange, each side

(2) Measurements of both ends of hatch cover skirt plate, coaming plate and coaming flange

(3) One measurement of one out of three hatch coaming brackets and bars, on both sides and both ends

Figure 5 : Locations of measurements on bulkheads of general cargo ships



Cargo hold bulkhead/watertight floor plating to be measured as per main view

One stiffener out of three to be measured as per view A - A

Figure 6 : Locations of measurements on selected internal structural elements of general cargo ships

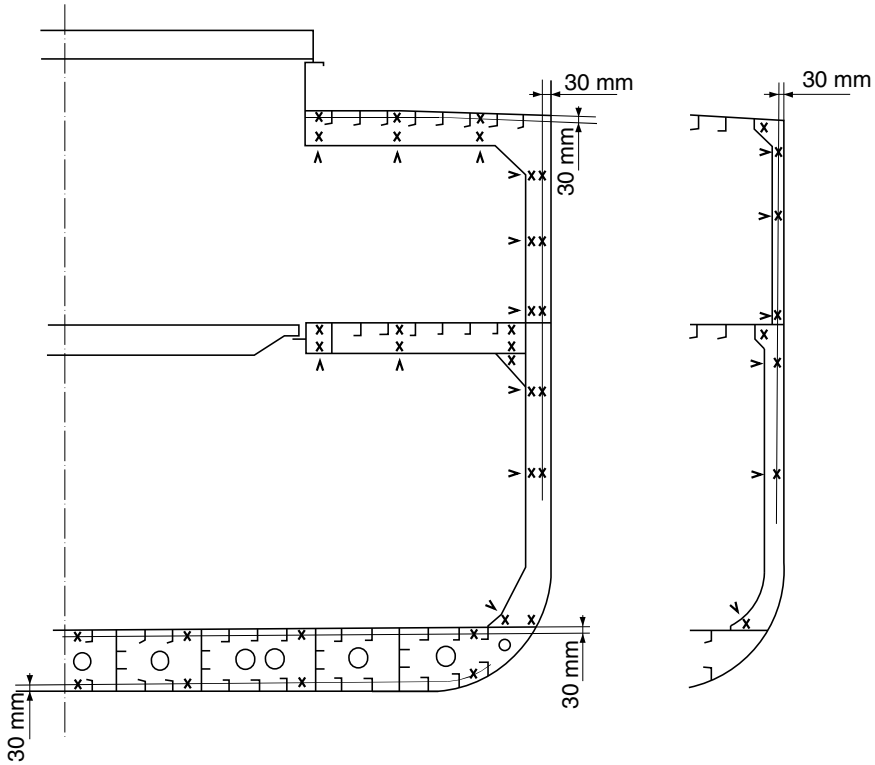


Figure 7 : Locations of measurements on structural members in cargo holds and ballast tanks of bulk carriers

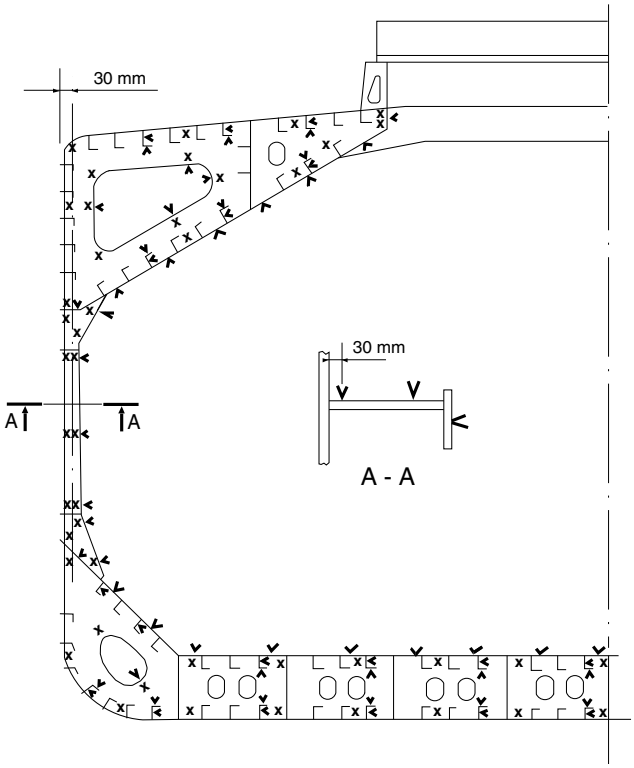
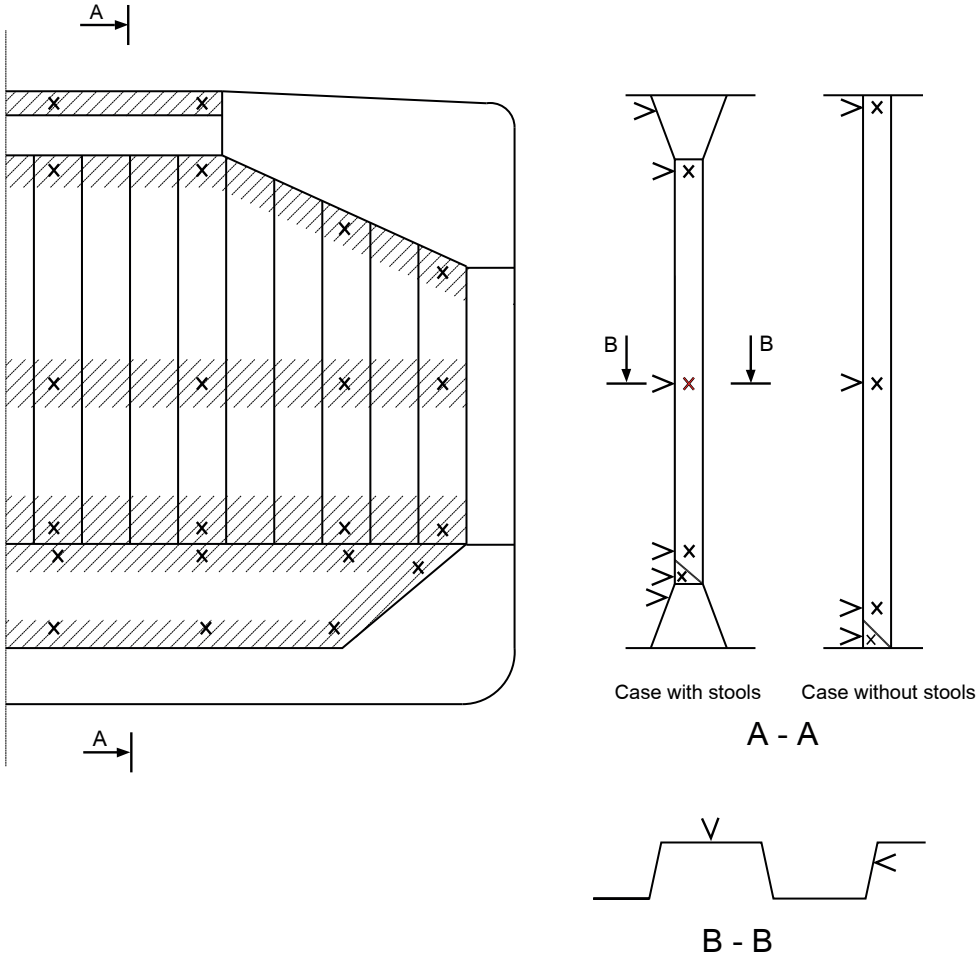
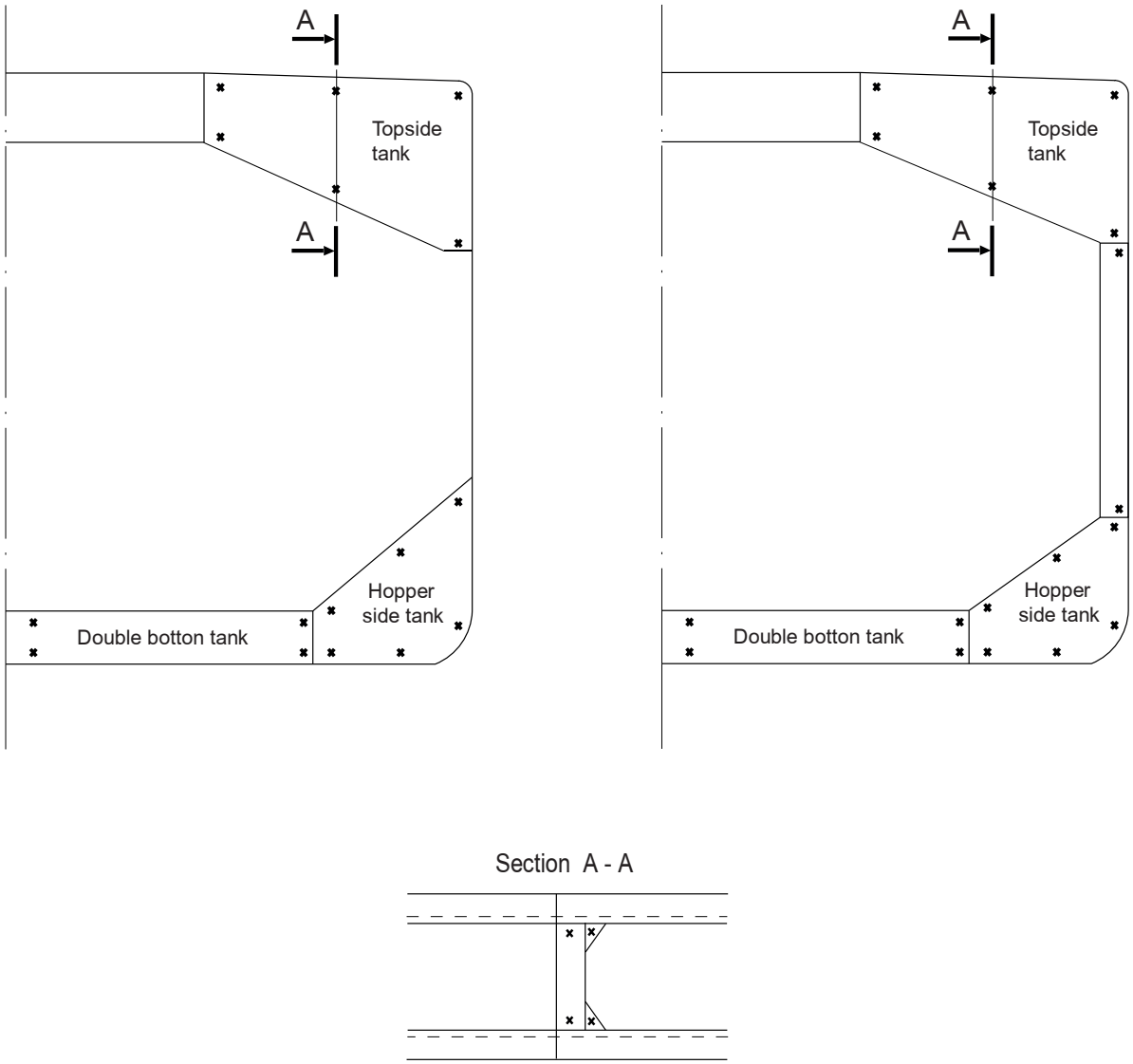


Figure 8 : Locations of measurements on cargo hold transverse bulkheads of bulk carriers (additional measurements to internal structure of upper and lower stools to be added, e.g. two points in the upper and two points in the lower stools to be indicated in section A-A)



Measurements to be taken in each shaded area as per views A - A and B - B

Figure 9 : Locations of measurements on transverse bulkheads of topside, hopper and double bottom tanks of bulk carriers (two additional measurements to internal structure of double bottom tank to be added at midspan)



Measurements to be taken in each vertical section as per view A - A

Figure 10 : Location of measurements on underdeck structure of CSR single skin and double skin bulk carriers

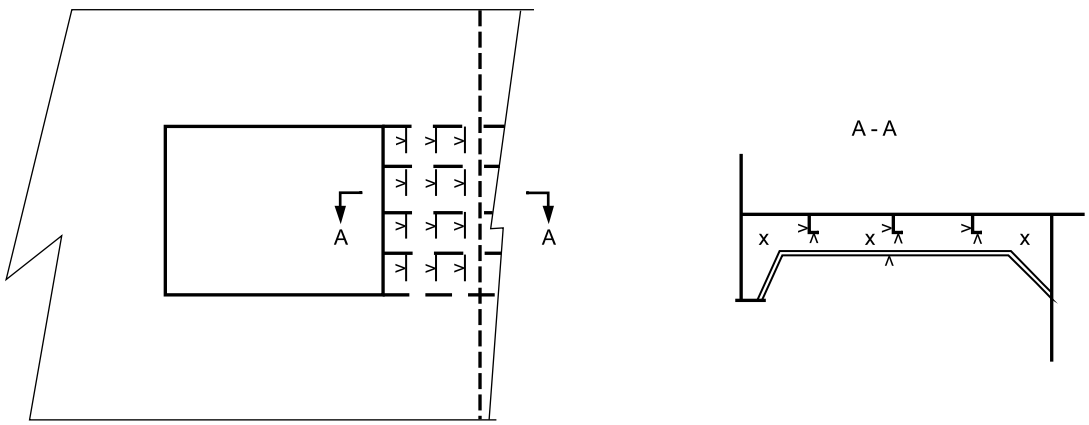
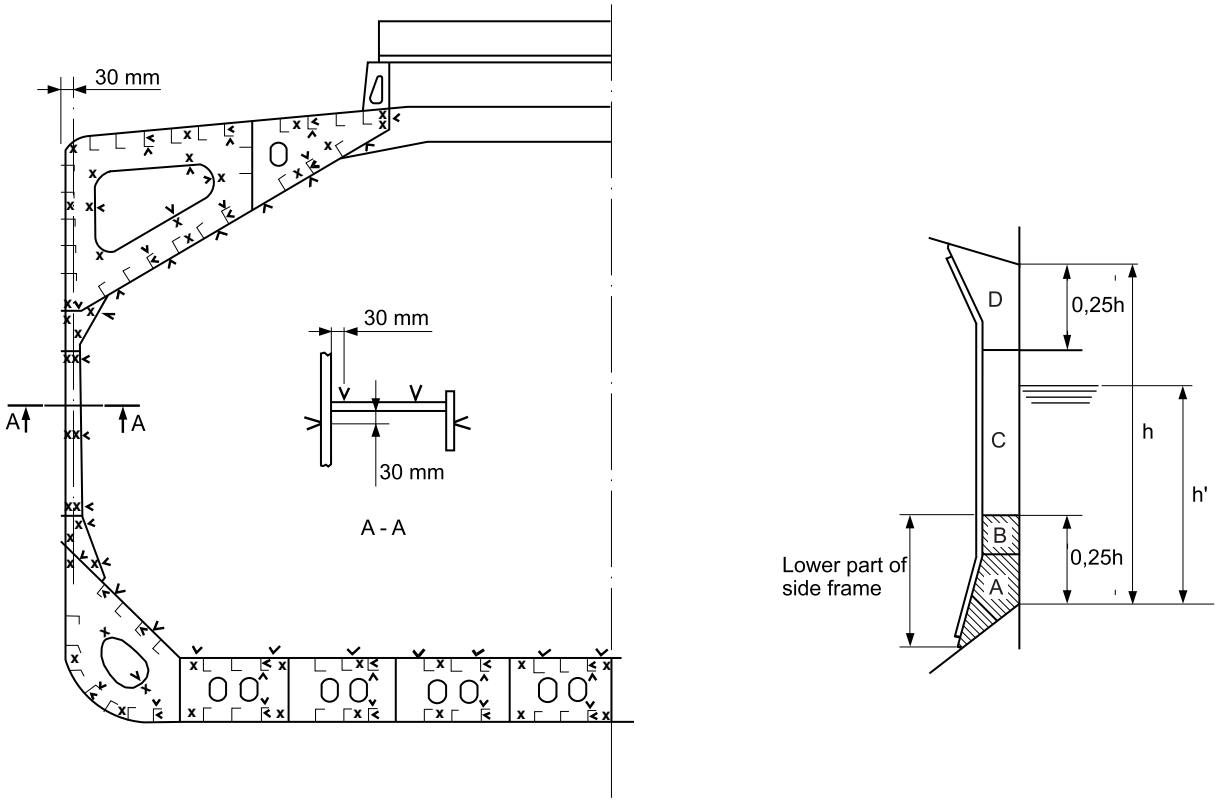


Figure 11 : Location of measurements on structural members in cargo holds and ballast tanks of CSR single skin bulk carriers



The gauging pattern for web plating is to be a three-point pattern for zones A, C and D, and a two-point pattern for zone B (see Figure). The gauging report is to reflect the average reading. The average reading is to be compared with the allowable thickness.

If the web plating has general corrosion, then this pattern is to be expanded to a five-point pattern.

Figure 12 : Location of measurements on structural members in ballast tanks of CSR double skin bulk carriers (topside or hopper or side tank)

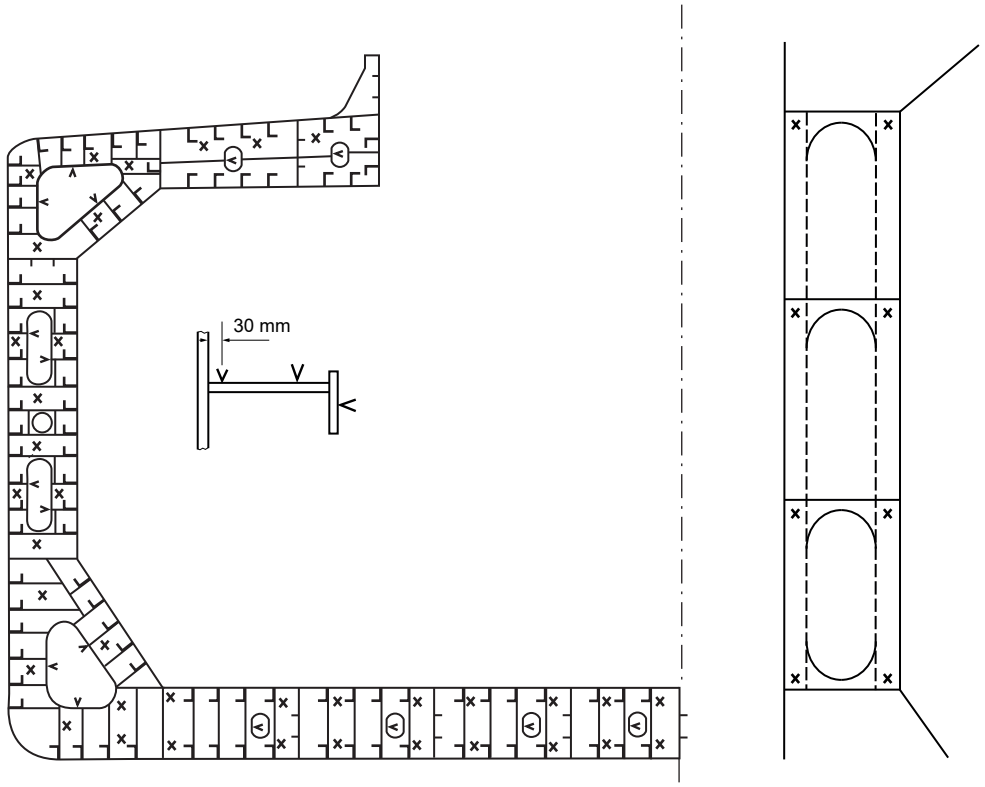


Figure 13 : Locations of measurements on web frame rings and longitudinal elements of oil tankers

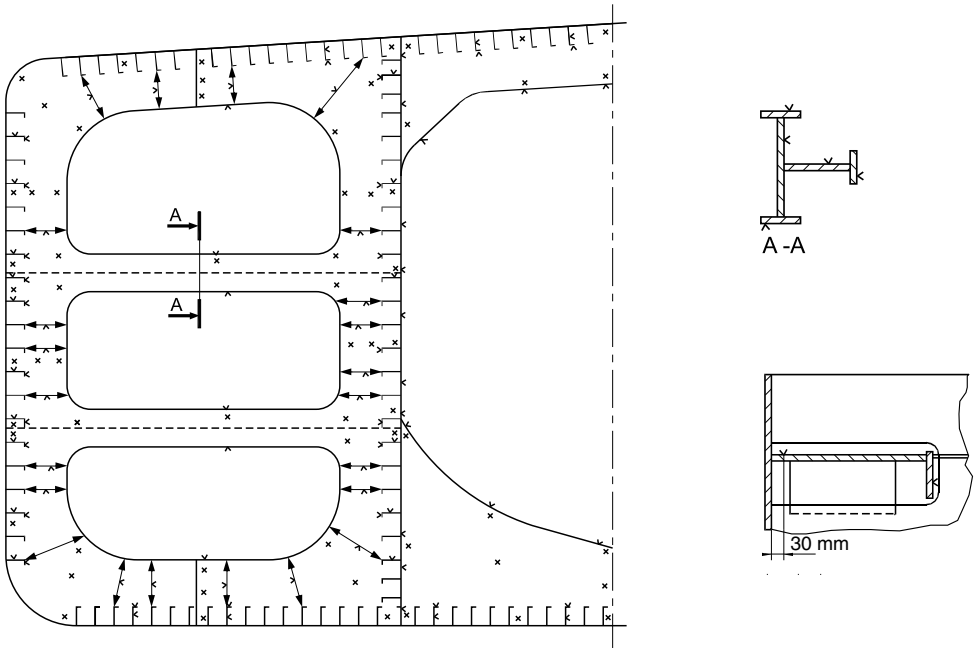
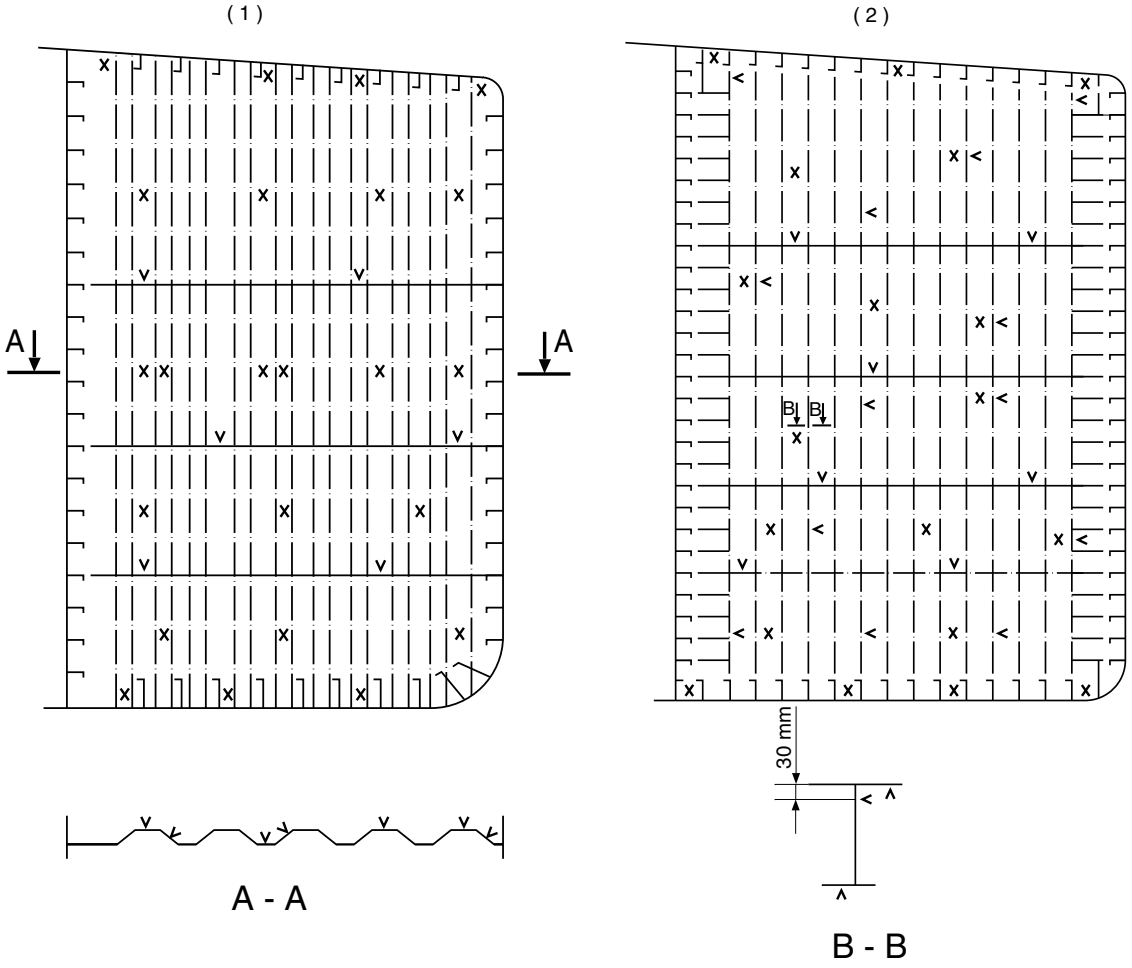


Figure 14 : Locations of measurements on transverse bulkheads of oil tankers



(1) : Corrugated bulkhead

(2) : Plane bulkhead

Measurements are to be taken in a similar way on the centre tank bulkheads

Measurements are to cover the different thicknesses of strakes over the height of the bulkhead

Measurements are to be taken of the adjacent structural members

Figure 15 : Location of measurements ontransverse section of CSR oil tankers

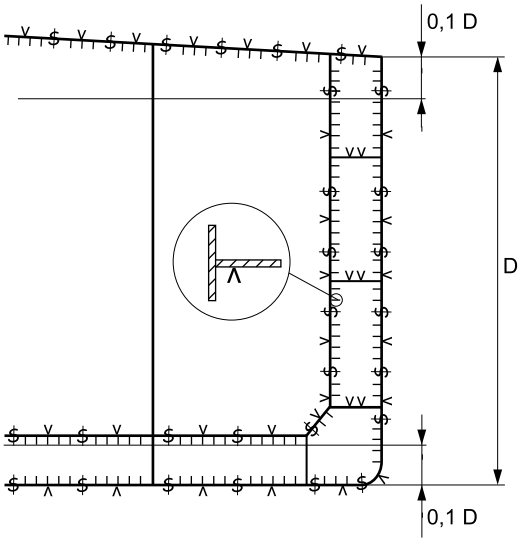


Figure 16 : Location of measurements on transverse rings in cargo and ballast tanks of CSR oil tankers

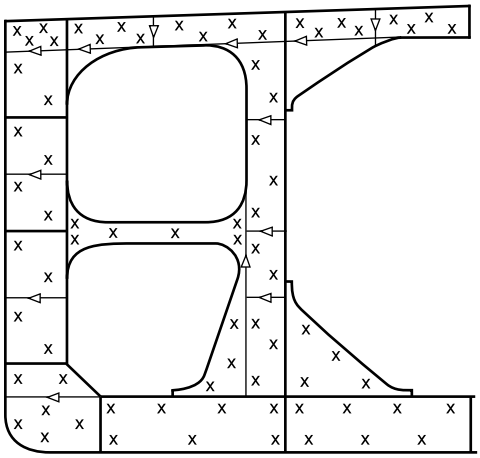


Figure 17 : Location of measurements on transverse bulkheads in cargo tanks of CSR oil tankers

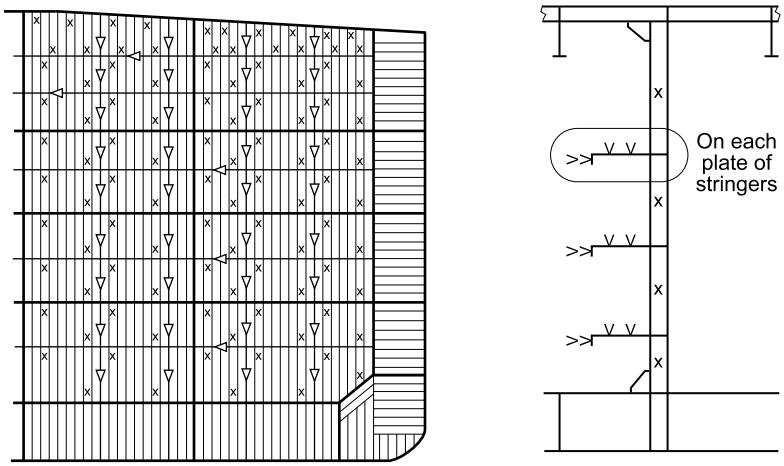
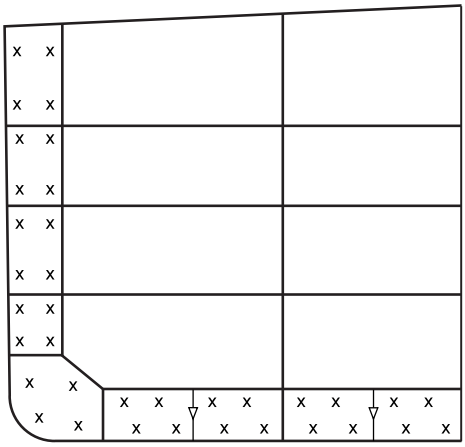


Figure 18 : Location of measurements on transverse bulkheads in ballast tanks of CSR oil tankers



4 Acceptance criteria for thickness measurements

4.1 General

4.1.1 Acceptance criteria stipulate limits of wastage which are to be taken into account for reinforcements, repairs or renewals of steel structure.

Note 1: In any case, at the request of the Owner, the Society may perform a direct calculation based on the current measurements.

4.1.2 In cases where the ship has some structural elements with reduced wear margins (e.g. due to ship conversion, increase of draught), the minimum acceptable thickness for these elements is to be calculated with reference to the rule scantlings without taking account of any reduction originally agreed.

4.1.3 Decisions on steel renewals are taken by the attending Surveyor applying the criteria given in this Article and based on his judgment and the actual condition of the ship. Should advice be needed to support his decision, the Surveyor may refer to the relevant technical office of the Society.

4.2 Criteria

4.2.1 The acceptance criteria for the minimum thicknesses are divided into:

- criteria given in Tab 3 for ships not assigned the additional service feature **CSR**
- criteria given in [4.7] for ships assigned the additional service feature **CSR**
- criteria on hull supporting structure of shipboard fittings associated with towing and mooring, given in [4.8]
- criteria on ice strengthened structures for ships assigned additional class notation for navigation in polar waters, given in [4.9]

4.2.2 Each measured structural item is to be checked against criteria given in [4.2.1], as far as applicable. When the criteria are not met, reinforcements, repairs and renewals are to be carried out as appropriate.

Table 3 : Criteria for ships not assigned the additional service feature CSR

<table>
<tr><td></td><td>Ships contracted for construction before 1st July 2016</td><td colspan="2">Ships contracted for construction on or after 1st July 2016 and before 1st July 2022</td><td>Ships contracted for construction on or after 1st July 2022</td></tr>
<tr><td></td><td>All ships (1)</td><td>Ships assigned the service notation containership</td><td>Other ships (1)</td><td>All ships (1)</td></tr>
<tr><td>Cargo ships with L < 65m (2)
Non-cargo ships with L < 90m</td><td rowspan="2">see [4.3], [4.4] and [4.6]</td><td>see [4.3]and [4.6]</td><td rowspan="2">see [4.3], [4.4] and [4.6]</td><td>see [4.3] and [4.6]</td></tr>
<tr><td>Cargo ships with L ≥ 65m
Non-cargo ships with L ≥ 90m</td><td>see [4.5] and [4.6]</td><td>see [4.5] and [4.6]</td></tr>
<tr><td colspan="5">Note 1: For the definition of cargo ships and non-cargo ships, reference is to be made to NR600, Ch 1, Sec 1 [2.1.3]
Note 2: For the definition of L, reference is made to Pt B, Ch 1, Sec 3, [2.1.1]
(1) Ships having alternate light and heavy cargo loading conditions, or ships assigned the service notation liquefied gas carrier, are to comply with the requirements applicable to cargo ships with L ≥ 65m, irrespective of their length.
(2) Except ships having alternate light and heavy cargo loading conditions, or ships assigned the service notation liquefied gas carrier.</td></tr>
</table>

4.3 Local and global strength criteria based on percentage of acceptable wastage

4.3.1 Local and global strength criteria are given for the following ship types:

- general cargo ships
- bulk carriers
- oil tankers.

These criteria are generally expressed for each structural item as a maximum percentage of acceptable wastage (W). When the maximum percentage of wastage is indicated, the minimum acceptable thickness (t_{min}) is that resulting from applying this percentage to the rule thickness (t_{rule}), according to the following formula:

$$t_{min} = \left(1 - \frac{W}{100}\right) t_{rule} - t_{wc}$$

Where t_{wc} is to be taken equal to:

- 0 in general
- 1,5 mm for the inner bottom plating when not protected by any continuous wooden ceiling, for ships contracted for construction on or after January 1st 2001 and assigned one of the following service notations:
  - **bulk carrier**
  - **bulk carrier ESP,** not assigned the additional service feature **CSR**
  - **ore carrier ESP**
  - **combination carrier/OBO ESP**
  - **combination carrier/OOC ESP**

However, when the rule thickness is not available, the as-built thickness can be used.

Only for criteria related to an item (see [4.3.4], item b), the Society may establish a list of renewal thicknesses tailored to the different structural items. In such a case these thicknesses are used in lieu of the minimum thicknesses calculated from the percentage of wastage.

These criteria may also be used for other ship types taking into consideration the equivalence or similarity of structural elements and their contribution to local and/or global strength.

4.3.2 For the evaluation of the ship longitudinal strength, it is a prerequisite that fillet welding between longitudinal members and deck, side and bottom plating is maintained effective so as to keep continuity of hull structures.

4.3.3 Each structural item to be assessed is illustrated in a typical transverse section (see Fig 19 for general cargo ships, Fig 20 for bulk carriers, Fig 21 for oil tankers).

These structural items are also listed in a table (Tab 4 for general cargo ships, Tab 5 for bulk carriers, Tab 6 for oil tankers) grouped according to their position and contribution to the local or global strength of the ship.

4.3.4 Each structural item is to be assessed according to four different criteria which vary with regard to the domain under which it is considered, namely:

a) an isolated area, which is meant as a part of a single structural item. This criterion takes into consideration very local aspects such as grooving of a plate or web, or local severe corrosion; however, it is not to be used for pitting for which separate criteria are considered (see [4.6])

b) an item, which is meant as an individual element such as a plate, a stiffener, a web, etc. This criterion takes into consideration the average condition of the item, which is assessed by determining its average thickness using the various measurements taken on the same item

c) a group of items, which is meant as a set of elements of the same nature (plates, longitudinals, girders) contributing either to the longitudinal global strength of the ship in a given zone or to the global strength of other primary transverse elements not contributing to the ship longitudinal strength, e. g. bulkheads, hatch covers, web frames

d) a zone, which is meant as all and only longitudinal elements contributing to the longitudinal strength of the ship; in this regard, the three main zones are defined as deck zone, neutral axis zone and bottom zone. This criterion takes into consideration the average condition of all groups of items belonging to the same zone.

4.3.5 The assessment of the thickness measurements is to be performed using the values given in the tables for each structural element with regard to the four criteria defined above, in the following order:

a) assessment of isolated areas (column 1 in the tables). If the criterion is not met, the wasted part of the item is to be dealt with as necessary.

b) assessment of items (column 2 in the tables). If the criterion is not met, the item is to be dealt with as necessary in the measured areas as far as the average condition of the item concerned is satisfactory. In cases where some items are renewed, the average thicknesses of these items to be considered in the next step are the new thicknesses.

c) assessment of groups of items (column 3 in the tables). If the criterion is not met, a sufficient number of elements are to be renewed in order to obtain an increased average thickness satisfying the considered criterion of the group (generally the elements to be renewed are those most wasted). As an example, for the assessment of the group “deck plates” all deck plates are measured and an average thickness of each of them is estimated. Then the average of all these values is to satisfy the criteria given for this group.

d) assessment of zones (column 4 in the tables). In principle, the criterion of the zone is met when all groups of items belonging to the zone meet their own criteria (see c) above). However, a greater diminution than those given in column 3 may be accepted for one group of items if, considering the other groups of items belonging to the same zone, the overall diminution of the zone does not exceed the criterion given for it in column 4.

Example: The deck zone consists of two groups of items:

- deck plating, which has an average diminution of 12% (criterion 10%)
- deck longitudinals, which has an average diminution of 4% (criterion 10%).

Even though the deck plating group exceeds its acceptance criterion, the average diminution of the zone, which can be very roughly estimated at 8%, is acceptable and thus the deck plating group can be accepted as it is.

Note 1: This criterion applicable to the zones is based on the general rule that the current hull girder section modulus is not to be less than 90% of the rule section modulus within 0,4L amidships. When the zone criterion is used, the assessment is made on the basis of the original modulus instead of the rule modulus. At the request of the Owner, a direct calculation using the ship’s current thicknesses may be performed by the Society in order to accept greater diminutions than those given for this criterion.

4.3.6 These criteria take into consideration two main aspects:

- the overall strength of the hull girder
- the local strength and integrity of the hull structure, such as hatch covers, bulkheads, etc.

As a rule, they are applicable to the structure within the cargo area of ships having a length greater than 90 metres. However, they may also be used for smaller ships and for structure outside the cargo area according to the following principles:

- for ships having a length less than 90 metres, the percentages of acceptable wastage given in the tables can be increased by 5 (%) (e.g. 15% instead of 10%, etc.), except for those of deck and bottom zones
- for structure outside the cargo area, the same 5 (%) increase can be applied,

on the understanding, however, that both conditions cannot be applied at the same time.

Figure 19 : General cargo ship: layout of items to be assessed

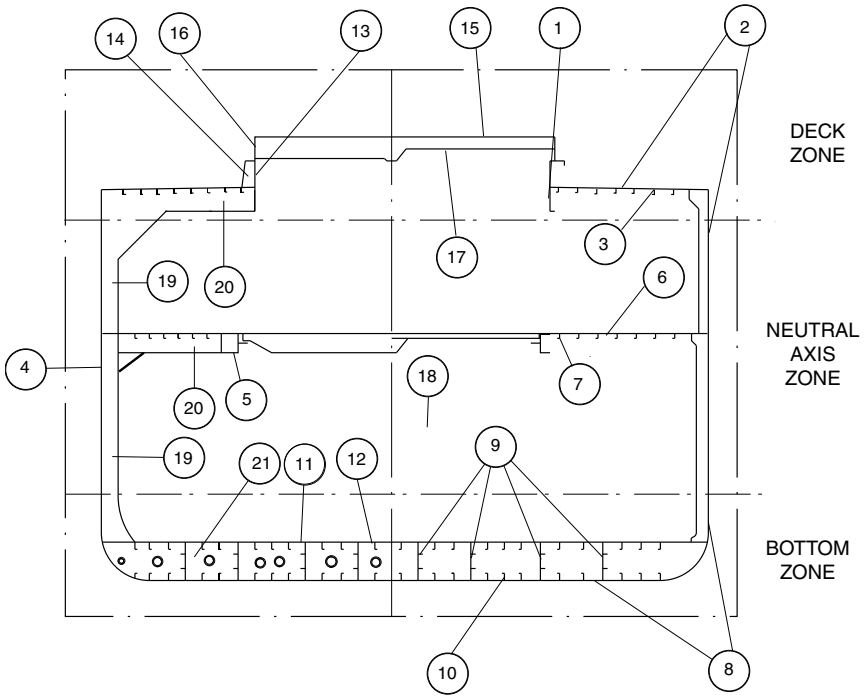


Table 4 : Local and global acceptance criteria for general cargo ships (given in % of wastage)

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
	ITEMS CONTRIBUTING TO THE LONGITUDINAL STRENGTH (TRANSVERSE SECTION)				
	DECK ZONE **(1)**	–	–	–	10
1	Hatch coaming underdeck girder web underdeck girder flange	– 25 20	– 20 15	10 – –	– – –
2	Upperdeck plating, deck stringer plates and sheer strakes	30	20	10	–
3	Deck longitudinals web flange	– 30 25	– 20 15	10 – –	– – –
	NEUTRAL AXIS ZONE **(1)**	–	–	–	15
4	Side shell plating	25	20	15	–
5	'Tweendeck hatch girder web flange	– 25 20	– 20 15	15 – –	– – –
6	'Tweendeck plating	30	20	15	-
7	'Tweendeck longitudinals web flange	– 30 25	– 20 15	15 – –	– – –
	BOTTOM ZONE **(1)**	–	–	–	10
8	Bilge and bottom strakes and keel plate	25	20	10	–
9	Bottom girders	25	20	10	–
10	Bilge and bottom longitudinals web flange	– 30 25	– 20 15	10 – –	– – –
11	Inner bottom plating	30	20	10	–
12	Inner bottom longitudinals web flange	– 30 25	– 20 15	10 – –	– – –
	OTHER ITEMS				
13	Hatch coaming plating **(2)**	25	20	–	–
14	Hatch coaming brackets	30	25	–	–
15	Hatch cover top plating **(4)**	25	20	15	–
16	Hatch cover skirt plating **(4)**	30	20	–	–
17	Hatch cover stiffeners **(4)**	30	20	–	–
18	Transverse bulkheads **(3) (5)** plating stringer web stringer flange stiffener web stiffener flange brackets	 30 30 25 30 25 30	 20 20 15 20 15 20	 15 – – – – –	 – – – – – –
19	Side frames web flange brackets	 30 25 30	 20 15 20	 – – –	 – – –
20	Deck/'tweendeck beams web flange	 30 25	 20 15	 – –	 – –
21	Floors plating	 30	 20	 –	 –

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
22	Forward and aft peak bulkheads				
	plating	30	20	15	–
	stiffener web	30	20	–	–
	stiffener flange	25	15	–	–

(1) Each zone is to be evaluated separately.

(2) If continuous, to be included in item 1.

(3) For deep tank bulkheads, the values "average of item" and "average of group" are to be increased by 5 (%).

(4) For cargo ships constructed (i.e. keel laid) from 1st January 2012:

- steel renewal is required where the gauged thickness is less than (t_{net} + 0,5) mm for: single skin hatch covers, plating of double skin hatch covers, and coaming structures the corrosion additions t_C of which are provided in Pt B, Ch 8, Sec 7, Tab 1 of the July 2021 edition of the Rules (for ships contracted for construction on or after 1st July 2016).
- where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,0) mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition. If t_{net} is not available, the as-built thickness minus the total corrosion addition can be used.
- for the internal structures of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when this is deemed necessary, at the discretion of the Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required when the gauged thickness is less than t_{net}. If t_{net} is not available, the as-built thickness minus the total corrosion addition can be used.
- for corrosion addition t_C = 1,0 mm the thickness for steel renewal is t_{net} and the thickness for coating or annual gauging is when gauged thickness is between t_{net} and (t_{net} + 0,5) mm.
- for coaming structures, the corrosion addition t_C of which are not provided in Pt B, Ch 8, Sec 7, Tab 1 of the July 2021 edition of the Rules, steel renewal and coating or annual gauging are to be in accordance with the requirements of the Society (for ships contracted for construction on or after 1st July 2016).

For cargo ships constructed (i.e. keel laid) from 1st January 2005:

- for hatch covers in way of cellular cargo holds intended for containers (plating, stiffeners and internals), steel renewal is required where the gauged thickness is less than t_{net}. Where the gauged thickness is within the range t_{net} and (t_{net} + 0,5) mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in good condition. If t_{net} is not available, the as-built thickness minus the total corrosion addition can be used.

(5) For ships contracted for construction on or after 1 July 2006, with transverse vertically corrugated watertight bulkheads, of length greater than or equal to 150 m, intended for the carriage of bulk cargoes having dry bulk cargo density 1,0 t/m3 or above where the unloading system maintains the watertightness during seagoing operations: the vertically corrugated transverse bulkheads are to be repaired by steel renewal where the gauged thickness is less than (t_{net} + 0,5) mm, where t_{net} is the thickness obtained by applying the strength criteria given in Pt D, Ch 4, Sec 3, [6.1] of the July 2021 edition of the Rules. However, where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,0) mm, coating (applied in accordance with the coating Manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

Figure 20 : Bulk carrier: layout of items to be assessed

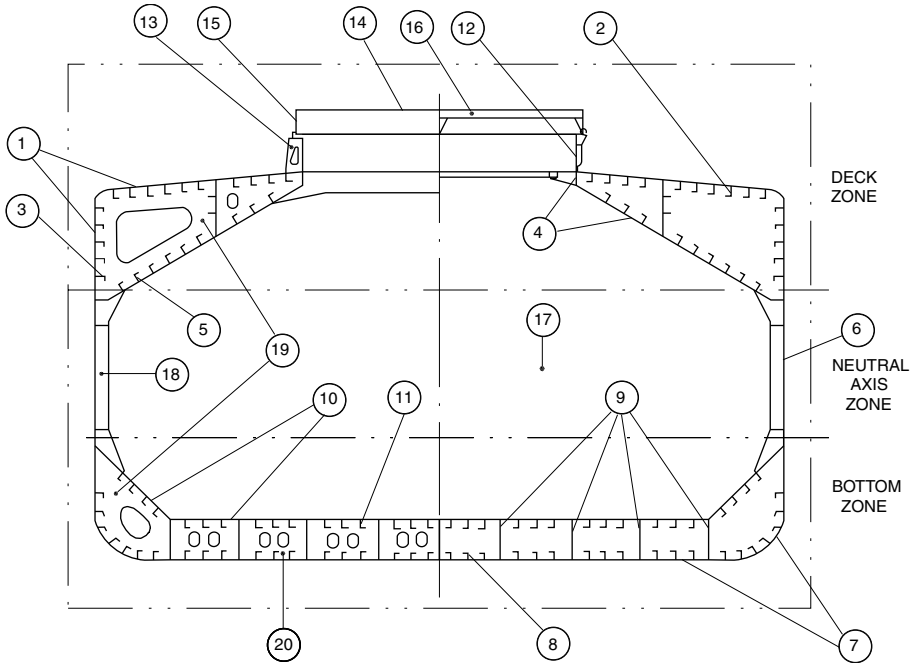


Table 5 : Local and global acceptance criteria for bulk carriers (given in % of wastage)

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
ITEMS CONTRIBUTING TO THE LONGITUDINAL STRENGTH (TRANSVERSE SECTION)					
	DECK ZONE **(1)**	–	–	–	10
1	Strength deck plating, deck stringer, sheer strake and part of side shell plating in way of top side tanks	25	20	10	–
2	Deck longitudinals web flange	– 25 20	– 20 15	10 – –	– – –
3	Side shell longitudinals in way of top side tanks web flange	– 25 20	– 20 15	10 – –	– – –
4	Top side tank sloped plating, including horizontal and vertical strakes	25	20	10	–
5	Longitudinals connected to top side tank sloped plating web flange	– 25 20	– 20 15	10 – –	– – –
	NEUTRAL AXIS ZONE **(1)**	–	–	–	15
6	Side shell plating	25	20	15	–
	BOTTOM ZONE **(1)**	–	–	–	10
7	Bilge and bottom plating and keel plate	25	20	10	–
8	Bilge and bottom longitudinals web flange	– 25 20	– 20 15	10 – –	– – –
9	Bottom girders	25	15	10	–
10	Inner bottom plating and hopper tank sloped plating	25	20	10	–
11	Longitudinals connected to inner bottom and hopper tank sloped plating web flange	– 25 20	– 20 15	10 – –	– – –
OTHER ITEMS					
12	Hatch coaming plating **(2)** **(6)**	25	20	–	–
13	Hatch coaming brackets **(6)**	30	25	–	–
14	Hatch cover top plating **(5)** **(6)**	25	20	15	–
15	Hatch cover skirt plating **(5)** **(6)**	25	20	–	–
16	Hatch cover stiffeners **(5)** **(6)**	25	20	–	–
17	Transverse bulkheads **(3)** plating stiffener web stiffener flange	 25 25 20	 20 20 15	 15 – –	 – – –
18	Side shell frames **(4)** web flange brackets	 25 20 20	 20 15 15	 – – –	 – – –
19	Topside and hopper tank web frames web flange	 25 20	 20 15	 – –	 – –

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
20	Floors plating	 25	 15	 –	 –
21	Forward and aft peak bulkheads plating stiffener web stiffener flange	 25 25 20	 20 20 15	 15 – –	 – – –

(1) Each zone is to be evaluated separately.

(2) If continuous, to be included in item 1.

(3) For vertically corrugated transverse bulkheads in cargo holds:

- For ships indicated in Ch 6, Sec 2, [1.1] which are to comply with the retroactive requirements according to the schedule given in Ch 6, Sec 2, [1.2], the bulkhead between the two foremost cargo holds is to be assessed based on the criteria given in Ch 6, Sec 2, [1.3].
- For ships assigned with the notation bulk carrier or self-unloading bulk carrier, contracted for construction on or after 1 July 1998, with transverse vertically corrugated watertight bulkheads, of length greater than or equal to 150 m, intended for the carriage of bulk cargoes having dry bulk cargo density 1,0 t/m3 or above where the unloading system maintains the watertightness during seagoing operations: all bulkheads are to be repaired by steel renewal where the gauged thickness is less than (t_{net} + 0,5) mm, where t_{net} is the thickness obtained by applying the strength criteria given in Pt D, Ch 4, Sec 3, [6.1] of the July 2021 edition of the Rules. However, where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,0) mm, coating (applied in accordance with the coating Manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

(4) Steel renewal criteria or other measures (reinforcement or coating) to be taken for the side shell frames and brackets in single side skin ships with service notation **bulk carrier ESP** not built in accordance with Part II, Chapter 08, Section 8-03 of the 1st April 1998 edition of the Rules or subsequent editions are given in Ch 6, Sec 2, [5] and Ch 6, App 1, [5]. However, for such ships which are to comply with Ch 6, Sec 2, [5], the thickness measurements of flanges and side shell plating not covered in Ch 6, Sec 2, [5.3], as well as the thickness measurements of additional intermediate frames fitted for reinforcement in order to comply with an ice class notation (ice strengthening structure), are to be carried out in accordance with Article [3] and the measured thicknesses assessed against the criteria indicated in Article [4] and the present Table.

(5) For ships which are assigned one of the service notations **bulk carrier ESP**, **bulk carrier BC-A ESP**, **bulk carrier BC-B ESP** or **bulk carrier BC-C ESP**, contracted for construction on or after the 1st July 1998 and for hatch covers on exposed decks:

- for single skin hatch covers and for the plating of double skin hatch covers, steel renewal is required where the gauged thickness is less than (t_{net} + 0,5) mm. Where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,0) mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. If t_{net} is not available, the as-built thickness, minus the total corrosion addition, can be used.
- for the internal structures of double skin hatch covers, thickness gauging is required when plating renewal is to be carried out or when this is deemed necessary, at the discretion of the Society's Surveyor, on the basis of the plating corrosion or deformation condition.In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}. If t_{net} is not available, the as-built thickness, minus the total corrosion addition, can be used.

(6) For ships which are assigned one of the service notations **bulk carrier BC-A ESP**, **bulk carrier BC-B ESP**, **bulk carrier BC-C ESP**, **ore carrier ESP**, **combination carrier/OBO ESP** or **combination carrier/OOC ESP**, contracted for construction on or after 1 January 2004 and for all cargo hatch covers and hatch forward and side coamings on exposed decks in position 1 as defined in ILLC:

- for single skin hatch covers and for the plating of double skin hatch covers, steel renewal is required where the gauged thickness is less than (t_{net} + 0,5) mm. Where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,0) mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in good condition. If t_{net} is not available, the as-built thickness, minus the total corrosion addition, can be used.
- for the internal structures of double skin hatch covers, thickness gauging is required when plating renewal is to be carried out or when this is deemed necessary, at the discretion of the Society's Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}. If t_{net} is not available, the as-built thickness, minus the total corrosion addition, can be used.
- for hatch coamings, steel renewal is required where the gauged thickness is less than (t_{net} + 0,5) mm. Where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,00) mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in good condition. If t_{net} is not available, the as-built thickness, minus the total corrosion addition, can be used.

Figure 21 : Oil tanker: layout of items to be assessed

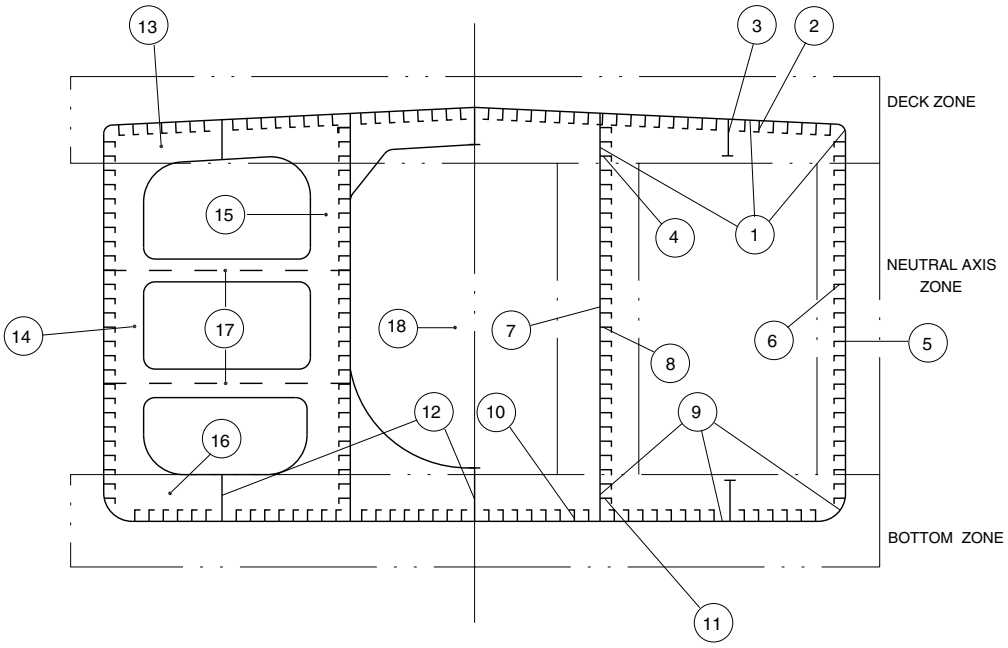


Table 6 : Local and global acceptance criteria for oil tankers (given in % of wastage)

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
ITEMS CONTRIBUTING TO THE LONGITUDINAL STRENGTH (TRANSVERSE SECTION)					
	DECK ZONE **(1)**	–	–	–	10
1	Deck plating, deck stringer, sheer strake and longitudinal bulkhead upper strake **(2)**	25	20	10	–
2	Deck and sheer strake longitudinals web flange	– 25 20	– 20 15	10 – –	– – –
3	Deck longitudinal girders web flange	– 25 20	– 20 15	10 – –	– – –
4	Longitudinals connected to longitudinal bulkhead upper strake **(2)** web flange	– 25 20	– 20 15	10 – –	– – –
	NEUTRAL AXIS ZONE **(1)**	–	–	–	15
5	Side shell plating **(2)**	25	20	15	–
6	Side shell longitudinals and stringers **(2)** web flange	– 25 20	– 20 15	15 – –	– – –
7	Longitudinal bulkhead plating	25	20	15	–
8	Longitudinal bulkhead longitudinals and stringers web flange	– 25 20	– 20 15	15 – –	– – –
	BOTTOM ZONE **(1)**	–	–	–	10
9	Bilge and bottom strakes, longitudinal bulkhead lower strake and keel plate **(2)**	25	20	10	–
10	Bilge and bottom longitudinals **(2)** web flange	– 25 20	– 20 15	10 – –	– – –
11	Longitudinals connected to longitudinal bulkhead lower strake web flange	– 25 20	– 20 15	10 – –	– – –

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
12	Bottom girders	–	–	10	–
	web	25	20	–	–
	flange	20	15	–	–
	OTHER ITEMS				
13	Deck transverse web frame				
	web	25	20	–	–
	flange	20	15	–	–
	brackets / stiffeners	25	20	–	–
14	Side shell web frame				
	web	25	20	–	–
	flange	20	15	–	–
	brackets / stiffeners	25	20	–	–
15	Longitudinal bulkhead web frame				
	web	25	20	–	–
	flange	20	15	–	–
	brackets / stiffeners	25	20	–	–
16	Bottom transverse web frame				
	web	25	20	–	–
	flange	20	15	–	–
	brackets / stiffeners	25	20	–	–
17	Cross tie				
	web	25	15	–	–
	flange	20	15	–	–
	brackets / stiffeners	20	15	–	–
18	Transverse bulkheads **(3)**				
	plating	25	20	15	–
	stringer web	25	20	–	–
	stringer flange	20	15	–	–
	stiffener web	30	20	–	–
	stiffener flange	25	15	–	–

(1) Each zone is to be evaluated separately.

(2) For double hull oil tankers, the structural elements of the inner skin (plating, longitudinals, girders, bulkheads) are to be included in the corresponding elements of the outer skin.

(3) Including swash bulkheads, forward and aft peak bulkheads.

4.4 Buckling strength criterion

4.4.1 This criterion is applicable to ships having a length greater than 120 metres.

The structural items contributing to the longitudinal strength of the ship, such as deck and bottom plating, deck and bottom girders, etc., are to be assessed with regard to their buckling strength, as deemed necessary by the Surveyor. In such a case, the values shown in Tab 7 are not to be exceeded.

Note 1: The minimum thickness will be specially considered for ships built with excess hull girder section modulus.

Table 7 : Buckling strength criterion

Items		Ratio	Material (R_{eH})		
			235	315	355 and 390
Bottom and deck plates		s / t	56,0	51,0	49,0
Longitudinals	flat bar web	h_w / t_w	20,0	18,0	17,5
Flanged longitudinals / girders	web	h_w / t_w	56,0	51,0	49,0
	symmetrical flange	b_f / t_f	34,0	30,0	29,0
	asymmetrical flange	b_f / t_f	17,0	15,0	14,5

Note 1: Symbols:

R_{eH} : Minimum yield stress of the material, in N/mm^2;

s : Longitudinal spacing, in mm;

t : Actual plate thickness, in mm;

h_w : Web height, in mm;

t_w : Web thickness, in mm;

b_f : Flange breadth, in mm;

t_f : Flange thickness, in mm.

4.5 Acceptance criteria based on net scantling approach

4.5.1 General

The acceptance criteria for allowable thickness diminution of ship hull structure are given here after.

Symbols:

$t_{as\text{-}built}$: As built thickness, in mm.

t_c : Corrosion addition, in mm, as defined in Pt B, Ch 4, Sec 2.

t_{res} : Reserve thickness, taken equal to 0,5 mm.

$t_{vol\text{-}add}$: Thickness for voluntary addition, in mm.

t_m : Measured thickness, in mm, on one item, i.e. average thickness on one item using the various measurements taken on this same item during periodical ship's in service surveys.

4.5.2 Definitions

a) Deck zone

The deck zone includes all the following items contributing to the hull girder strength:

- strength deck plating
- longitudinal hatch coaming
- sheer strake
- side shell plating
- inner hull and other plane longitudinal bulkhead plating, if any
- topside tank sloped plating, including horizontal and vertical strakes, if any
- longitudinal upper stool, if any
- longitudinal stiffeners, girders and stringers connected to the above mentioned plating.

b) Bottom zone

The bottom zone includes all the following items contributing to the hull girder strength:

- keel plate
- bottom plating
- bilge plating
- bottom girders
- inner bottom plating
- side shell plating
- plane longitudinal bulkheads lower strake
- hopper tank sloping plating, and horizontal plating, if any
- longitudinal lower stool, if any
- longitudinal stiffeners connected to the above mentioned plating.

c) Neutral axis zone

The neutral axis zone includes the following items between the deck zone and the bottom zone, as for example:

- side shell plating
- inner hull plating and longitudinal bulkhead, if any
- double hull girder.

4.5.3 Local corrosion

a) Renewal thickness of local structural elements

Local structural elements include local supporting members and primary supporting members.

Steel renewal is required if the measured thickness, t_m in mm, is less than the renewal thickness, t_{ren} defined as:

$$t_{ren} = t_{as\text{-}built} - t_c - t_{vol_add}$$

When there is a substantial corrosion as defined in Ch 2, Sec 2, [2.2.7], steel renewal is required unless coating is applied in accordance with the coating manufacturer's requirements or annual gauging is adopted. The coating is to be maintained in good condition.

b) Renewal area

Areas which need to be renewed based on the renewal criteria in [4.5.3]a) are to be repaired with inserted material which is to have the same or greater grade and yield stress as the original, and to have a thickness, t_{repair} in mm, not less than:

$$t_{repair} = t_{as\text{-}built} - t_{vol_add}$$

4.5.4 Global corrosion

a) Application

The longitudinal strength of the ship is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during Class Renewal Surveys, for ships over 10 years of age.

b) Renewal criteria

Hull girder strength criteria are given as detailed below:

- For deck and bottom zones:

  The current hull girder section modulus at deck and bottom determined with the thickness measurements are not to be less than the section modulus calculated according to Pt B, Ch 6, Sec 1 with the gross offered thickness minus 0,5 t_c.

  Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the measured item areas of the considered zones are not to be less than the sectional area of the corresponding zones determined with the gross offered thickness minus 0,5 t_c.

- For neutral axis zone:

  The current sectional area of the neutral axis zone, which is the sum of the measured plating areas of this zone, is not to be less than the sectional area of the neutral axis zone calculated with the gross offered thickness minus 0,5 t_c.

If the actual reduction of the gross offered thickness of all items, of a given transverse section which contribute to the hull girder strength is less than 0,5 t_c for the deck, bottom and neutral axis zones, the hull girder strength criteria of this transverse section is satisfied and there is no need to perform calculation of the zone areas with measured thicknesses.

The gross offered thickness is defined in Pt B, Ch 4, Sec 2.

4.6 Pitting

4.6.1 The maximum acceptable depth for isolated pits is 35% of the as-built thickness.

4.6.2 For areas with different pitting intensity, the intensity diagrams shown in Fig 22 are to be used to identify the percentage of affected areas.

For areas having a pitting intensity of 50% or more, the maximum average depth of pits is 20% of the as-built thickness. For intermediate values between isolated pits and 50% of affected area, the interpolation between 35% and 20% is made according to Tab 8.

4.6.3 In addition, for ships contracted for construction before 1st July 2022, the thickness outside the pits in the area considered is to be assessed according to [4.3] and [4.4].

Note 1: Application of filler material (plastic or epoxy compounds) is recommended as a means to stop or reduce the corrosion process, but it is not considered an acceptable repair for pitting exceeding the maximum allowable wastage limits. Welding repairs may be accepted when performed in accordance with procedures agreed with the society.

Table 8 : Pitting intensity and corresponding maximum average depth of pitting

Pitting Intensity, (%)	Maximum average pitting depth, (% of the as-built thickness)
Isolated	35,0
5	33,5
10	32,0
15	30,5
20	29,0
25	27,5
30	26,0
40	23,0
50	20,0

4.7 Acceptance criteria for CSR ships

4.7.1 General

For ships built under the Common Structural Rules, the acceptance criteria are according to the following rules:

- Chapter 13, “Ships in Operation, Renewal Criteria”, of NR522 CSR for Bulk Carriers
- Section 12, “Ship in Operation Renewal Criteria”, of NR523 CSR for Double Hull Oil Tankers,

and as specified in [4.7.2], [4.7.3], [4.7.4] and [4.7.5].

For ships built under the Common Structural Rules and complying with the requirements of Rule Note NR606 Common Structural Rules for Bulk Carriers and Oil Tankers, the acceptance criteria are to be in accordance with Part 1, Chapter 13, “Ship in Operation - Renewal Criteria”, of this NR606.

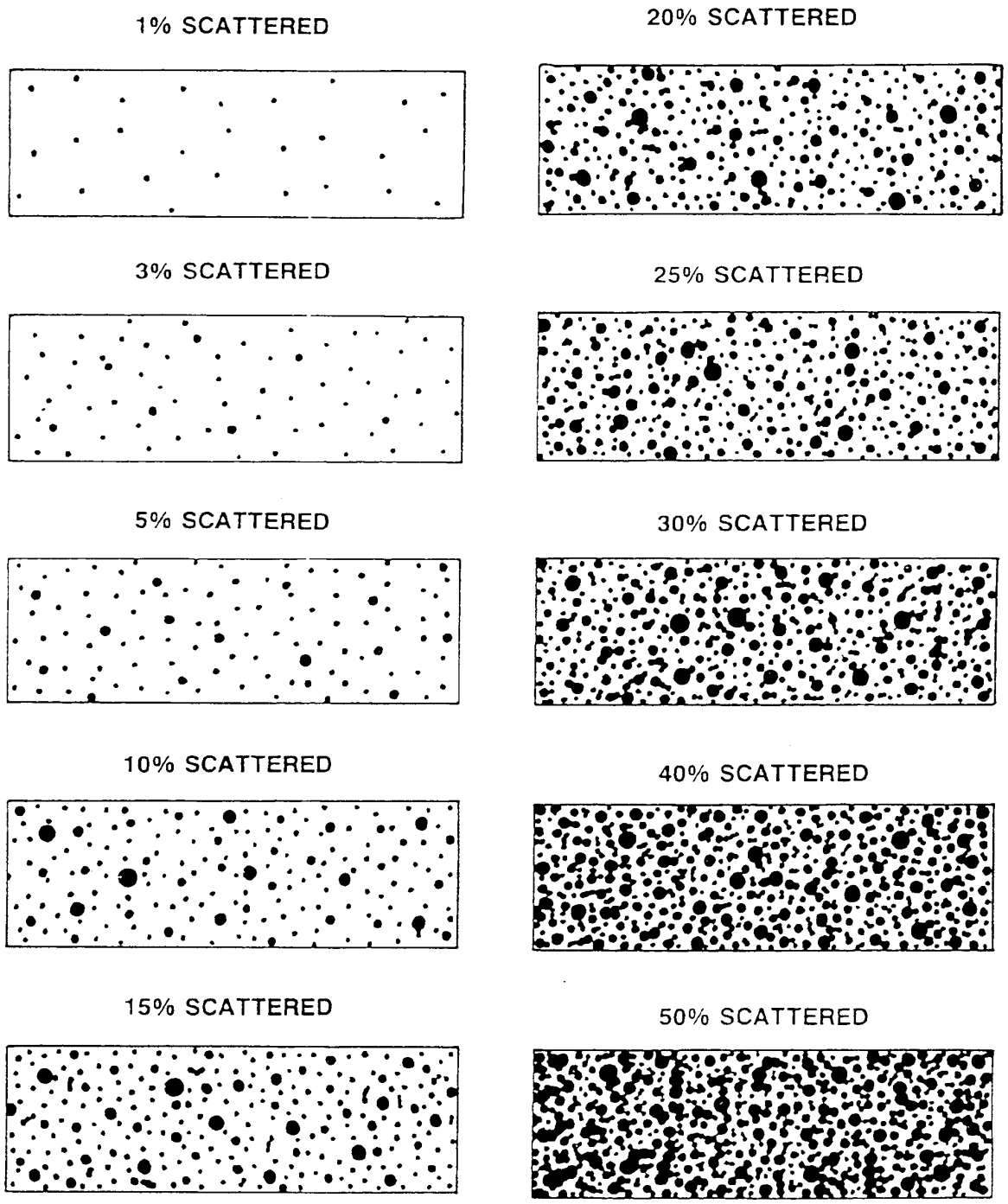
4.7.2 Pitching corrosion: side structures (CSR bulk carriers)

If pitting intensity, in an area where coating is required according to NR522 CSR for Bulk Carriers Ch 3, Sec 5, or NR606 CSR for Bulk Carriers and Oil Tankers Part 1, Ch 3, Sec 4, as applicable, is higher than 15% (see Fig 22), thickness measurements are to be performed to check the extent of pitting corrosion. The 15% is based on pitting or grooving on only one side of a plate. In cases where pitting is exceeding 15%, as defined above, an area of 300 mm or more, at the most pitted part of the plate, is to be cleaned to bare metal and the thickness is to be measured in way of the five deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded. The minimum remaining thickness in pits, grooves or other local areas is to be greater than the following values:

- for CSR single and double skin bulk carriers: 70% of the as-built thickness, in the side shell, hopper tank and topside tank plating attached to the each side frame, over a width up to 30 mm on either side of it
- for CSR single skin bulk carriers: 75% of the as-built thickness, in the frame and end bracket webs and flanges,

without being greater than the renewal thickness t_{ren} as defined in [4.7.3].

Figure 22 : Pitting intensity diagrams (from 1% to 50% intensity)



4.7.3 Pitting corrosion: other structures (CSR bulk carriers and CSR oil tankers)

For plates with pitting intensity less than 20% (see Fig 22), the measured thickness t_m, in mm, of any individual measurement is to meet the lesser of the following criteria:

$t_m \geq 0,7\ (t_{as\text{-}built} - t_{vol\ add})$

$t_m \geq t_{ren} - 1,0$

where:

$t_{as\text{-}built}$: As-built thickness of the member, in mm

$t_{vol\ add}$: Voluntary thickness addition, namely thickness, in mm, voluntarily added as the Owner's extra margin for corrosion wastage in addition to t_C

t_{ren} : Renewal thickness, namely minimum allowable thickness, in mm, below which renewal of structural members is to be carried out (see also NR523 CSR for Double Hull Oil Tankers, Section 12) or NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable)

t_C : Total corrosion addition, in mm, defined in NR522 CSR for Bulk Carriers, Ch 3, Sec 3 or in NR606 CSR for Bulk Carriers and Oil Tankers, Pt 1, Ch 3, Sec 3, as applicable

t_m : Measured thickness, in mm, on one item, i.e. average thickness on one item using the various measurements taken on this same item during periodical ship's in service surveys.

The average thickness across any cross-section in the plating is not to be less than the renewal thickness for general corrosion given in NR522 CSR for Bulk Carriers, Chapter 13 or in NR523 CSR for Double Hull Oil Tankers, Section 12 or in NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable.

4.7.4 Edge corrosion of CSR ships

Provided that the overall corroded height of the edge corrosion of the flange, or web in the case of flat bar stiffeners, is less than 25% of the stiffener flange breadth or web height, as applicable (see Fig 23), the measured thickness t_m, in mm, is to meet the lesser of the following criteria:

$t_m \geq 0,7\ (t_{as\text{-}built} - t_{vol\ add})$

$t_m \geq t_{ren} - 1,0$

where:

$t_{as\text{-}built}$, $t_{vol\ add}$, t_{ren}: As defined in [4.7.3].

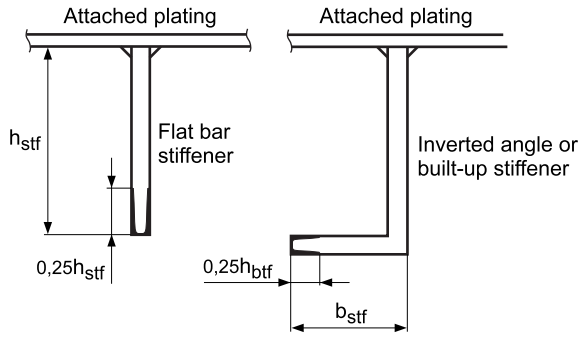
The average measured thickness t_m across the breadth or height of the stiffener is not to be less than the one defined in NR522 CSR for Bulk Carriers, Chapter 13 or in NR523 CSR for Double Hull Oil Tankers, Section 12 or in NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable.

Plate edges at openings for manholes, lightening holes, etc... may be below the minimum thickness given in NR522 CSR for Bulk Carriers, Chapter 13 or in NR523 CSR for Double Hull Oil Tankers, Section 12, or in NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable, provided that:

a) The maximum extent of the reduced plate thickness, below the minimum given in NR522 CSR for Bulk Carriers, Chapter 13 or in NR523 CSR for Double Hull Oil Tankers, Section 12 or in NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable, from the opening edge is not more than 20% of the smallest dimension of the opening and does not exceed 100 mm.

b) rough or uneven edges may be cropped-back provided that the maximum dimension of the opening is not increased by more than 10% and the remaining thickness of the new edge is not less than t_{ren} - 1 mm.

Figure 23 : Edge corrosion



4.7.5 Acceptance criteria for grooving corrosion of CSR ships

a) Where the groove breadth is a maximum of 15% of the web height but not more than 30 mm (see Fig 24), the measured thickness t_m, in mm, in the grooved area is to meet the lesser of the following criteria:

$t_m \geq 0,75\ (t_{as\text{-}built} - t_{vol\ add})$

$t_m \geq t_{ren} - 0,5$

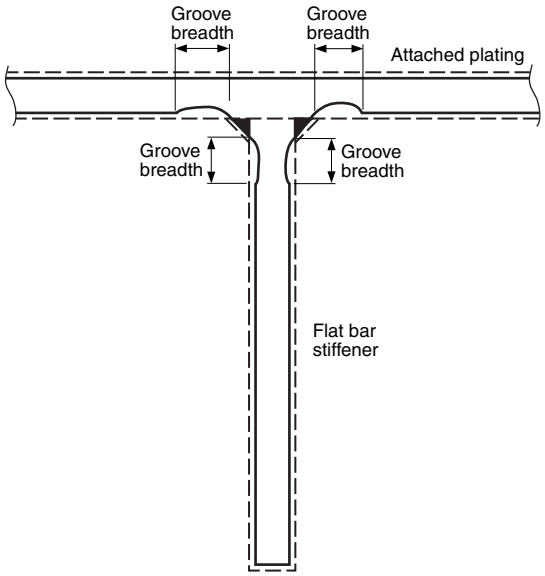
but is not to be less than: $t_m = 6$ mm,

where:

$t_{as\text{-}built}$, $t_{vol\ add}$, t_{ren}: As defined in [4.7.3].

b) Structural members with areas of grooving greater than those in item a) are to be assessed, based on the criteria for general corrosion as defined in NR522 CSR for Bulk Carriers, Chapter 13 or in NR523 CSR for Double Hull Oil Tankers, Section 12 or in NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable, using the average measured thickness across the plating/stiffener.

Figure 24 : Grooving corrosion



4.8 Hull supporting structure of shipboard fittings associated with towing and mooring

4.8.1 For ships contracted for construction on or after the 1st January 2007, the allowable wastage of the hull supporting structure of shipboard fittings associated with towing and mooring is not to exceed:

- the total corrosion addition defined in NR522 or NR523 for ships covered by the Common Structural Rules for Bulk Carriers or the Common Structural Rules for Double Hull Oil Tankers, or
- 2,0 mm for other ships.

4.9 Ice strengthened structures for ships assigned with additional class notation for navigation in polar waters

4.9.1 For ships assigned with one of the additional class notations **POLAR CLASS** as defined in Ch 1, Sec 2, [6.11], steel renewal for ice strengthened structures as defined in NR527 is required when the gauged thickness is less than t_{net} + 0,5 mm.

Appendix 4 Condition Monitoring and Condition Based Maintenance

1 General

1.1 Application

1.1.1 These requirements apply to the approved Condition Monitoring and Condition Based Maintenance schemes where the condition monitoring results are used to influence the scope and/or frequency of Class survey.

1.1.2 This scheme may be applied to components and systems covered by continuous survey system for machinery (CSM), and other components and systems as requested by the owner. The extent of Condition Based Maintenance and associated monitoring equipment to be included in the maintenance scheme is decided by the Owner.

1.1.3 These requirements can be applied only to vessels operating on approved PMS survey scheme.

1.1.4 The scheme may be applied to any individual items and systems. Any items not covered by the scheme are to be surveyed and credited in accordance with the requirements of Part A, Chapter 3, Part A, Chapter 4 and Part A, Chapter 5 as applicable.

1.1.5 Ships complying with the requirements of this Appendix are granted one of the notations **CBM**, **[CBM]**, **CBM-P** or **[CBM-P]** as defined in Ch 1, Sec 2, [4.16.16].

Note 1: See NI684 "Guideline for Condition Based Maintenance" for further details on requirements and class workflow.

1.2 Definitions

1.2.1 The following standard terms are defined in ISO 13372:2012.

1.2.2 Condition monitoring

Acquisition and processing of information and data that indicate the state of a machine over time. The machine state deteriorates if faults or failures occur.

1.2.3 Diagnostic

Examination of symptoms and syndromes to determine the nature of faults or failures.

1.2.4 Condition based maintenance

Maintenance performed as governed by condition monitoring programmes.

1.3 Condition monitoring (CM)

1.3.1 Where an approved condition monitoring system is fitted, credit for survey may be based on acceptable condition monitoring results. The condition monitoring results are to be reviewed during the annual audit.

1.3.2 Limiting parameters are to be based on the Original Equipment Manufacturers guidelines (OEM), or a recognised international standard.

1.3.3 The condition monitoring system is to provide an equivalent or greater degree of confidence in the condition of the machinery to traditional survey techniques.

1.3.4 The condition monitoring system is to be approved in accordance with the Society's procedures.

1.3.5 A condition monitoring system may be used to provide a greater understanding of equipment condition, and a condition based maintenance scheme may be used to obtain maintenance efficiency. Class approval is required where owners wish to change the survey cycle based on CM/CBM.

1.3.6 Software systems can use complex algorithms, machine learning and knowledge of global equipment populations/defect data in order to identify acceptability for continued service or the requirement for maintenance. These systems may be independent of the OEM recommended maintenance and condition monitoring suggested limits. Approval of this type of software is to be based on OEM recommendations, industry standards and Society experience.

1.3.7 The Society retains the right to test or open-up the machinery, irrespective of the CM results, if deemed necessary by Surveyor during annual and renewal audits.

1.4 Condition based maintenance (CBM)

1.4.1 Where an owner wishes to base their equipment maintenance on a CBM approach, this is to meet the requirements of the ISM Code.

1.4.2 Where an approved planned maintenance and CBM scheme is in operation, the CSM and other survey intervals may be extended based on OEM maintenance recommendations and acceptable condition monitoring results.

1.4.3 Limiting parameters (alarms and warnings) are to be based on the OEM guidelines, or a recognised international standard.

1.4.4 The CBM scheme is to provide an equivalent or greater degree of confidence in the condition of the machinery to traditional maintenance techniques.

1.4.5 The scheme is to be approved in accordance with the Society's procedures.

1.4.6 Software systems can use complex algorithms, machine learning and knowledge of global equipment populations/defect data in order to identify acceptability for continued service or the requirement for maintenance. These systems may be independent of the OEM recommended maintenance and condition monitoring suggested limits. Approval of this type of software is to be based on OEM recommendations, industry standards and Society experience. In that case, written agreement from the OEM is to be provided to the Society.

2 Procedures and conditions for approval of CM and CBM

2.1 Onboard responsibility

2.1.1 The Chief Engineer is to be the responsible person on board in charge of the CM and CBM.

2.1.2 Documentation on the overhaul of items covered by CM and CBM schemes are to be reported by the Chief Engineer.

2.1.3 Access to computerized systems for updating of the maintenance documentation and maintenance program is only to be permitted by the Chief Engineer or other authorized person.

2.1.4 All personnel involved in CM and CBM is to be appropriately qualified.

Note 1: CM does not replace routine surveillance or the Chief Engineer's responsibility for taking decisions in accordance with his judgement.

2.2 Equipment and systems requirements

2.2.1 CM equipment and systems are to be approved in accordance with the Rule Note NR674 Condition Monitoring Systems.

2.2.2 The CM/CBM scheme and its extent, are to be approved by the Society.

2.2.3 The CBM scheme is to be capable of producing a condition report, and maintenance recommendations.

2.2.4 A system is to be provided to identify where limiting parameters (alarms and warnings) are modified during the operation of the scheme.

2.2.5 Where CM and CBM schemes use remote monitoring and diagnosis (i.e. data is transferred from the vessel and analysed remotely), the system is to meet the applicable standards related to the assignment of the additional class notation **CYBER SECURE** from Rule Note NR659, Rules on Cyber Security for the Classification of Marine Units. The system is to be capable of continued onboard operation in the event of loss of the communication function.

2.2.6 CBM schemes are to identify defects and unexpected failures that were not prevented by the CM system.

2.2.7 Systems are to include a method of backing up data at regular intervals.

2.3 Documentation and information

2.3.1 The following documentation is to be made available to the Society for the approval of the scheme:

a) procedure for changes to software system and CM parameters

b) listing of equipment to be included in the scheme

c) listing of acceptable condition monitoring parameters

d) description of CBM scheme

e) listing, specifications and maintenance procedures for condition monitoring equipment

f) baseline data for equipment with condition monitoring

g) qualification of authorized personnel and company responsible for analysing CM results.

2.3.2 In addition to the above documentation the following information is to be available on board:

a) all the documentation in [2.3.1], duly updated

b) maintenance instructions (manufacturer's and shipyard's)

c) condition monitoring data including all data since last opening of the machine and the original base line data

d) reference documentation (trend investigation procedures etc.)

e) records of maintenance including repairs and renewals carried out

f) records of changes to software systems and parameters

g) sensors calibration records / certification / status.

2.4 Approval validity

2.4.1 An annual audit is to be carried out to maintain the validity of the CM/CBM scheme.

2.4.2 The survey arrangement for machinery under CM/CBM can be cancelled by the Society if the scheme is not being satisfactorily carried out either from the maintenance records or the general condition of the machinery.

2.4.3 Items under CM/CBM scheme can be cancelled from CM/CBM scheme and moved to CSM scheme by the Society if the scheme is not found to be satisfactorily maintained either from maintenance records or the general condition of the machinery, during annual and renewal audits.

2.4.4 In the case of sale or change of management of the ship or transfer of class, the approval of CM/CBM is to be reconsidered.

2.4.5 The ship owner may, at any time, cancel the CM/CBM scheme by informing the Society in writing. In this case the items which have been inspected under this scheme since the last annual audit may be credited for class at the discretion of the attending surveyor.

3 Surveys

3.1 Installation survey

3.1.1 Condition monitoring equipment is to be installed and surveyed in accordance with the Society's rules, and a set of base line readings is to be taken.

3.2 Implementation survey

3.2.1 The implementation survey is to be carried out by the Surveyor no earlier than 6 months after installation survey and no later than the first class annual survey.

3.2.2 During the implementation survey the following is to be verified by the surveyor:

a) the CM/CBM scheme is implemented according to the approval documentation, including a comparison with baseline data

b) the scheme is producing the documentation required for the annual audit and the requirements of surveys and testing for the maintenance of class are complied with

c) the onboard personnel are familiar with operating the scheme

d) records of any limiting parameters (alarms and warnings) that have been modified during the operation of the scheme

e) records of any failures of monitored equipment are to be reviewed to ensure that the condition monitoring scheme is effective / sufficient.

3.2.3 When this survey is carried out and the implementation is found in order, a report describing the scheme is to be submitted to the Society and the scheme may be put into service.

3.3 Annual audit

3.3.1 An annual audit of the CM and CBM scheme is to be carried out by a Surveyor concurrently with the class annual survey.

3.3.2 The purpose of this audit is to be to verify that the scheme is being correctly operated and that the machinery has been functioning satisfactorily since the previous audit. This is to include any limiting parameters (alarms and warnings) that have been modified since the last audit. A general examination of the concerned items is to be carried out.

3.3.3 The performance, condition monitoring and maintenance records are to be examined to verify that the machinery has functioned satisfactorily since the previous survey, or action has been taken in response to machinery operating parameters exceeding acceptable tolerances.

3.3.4 Written details of breakdown or malfunction are to be made available.

3.3.5 At the discretion of the surveyor, function tests, confirmatory surveys and random check readings, where Condition Monitoring / Condition Based Maintenance equipment is in use, are to be carried out as far as practicable and reasonable.

3.3.6 The familiarisation of the Chief Engineer and other authorized personnel involved with the CM/CBM system is to be verified.

3.3.7 Calibration status of sensors and equipment is to be verified.

3.3.8 Verification that the suitability of the CM/CBM scheme has been reviewed following defects and failures is to be carried out.

3.3.9 An annual report covering the year's service is to be supplied to the Society. It is to include the following information:

- the list of items of machinery and components and the procedures for their identification
- the preventive maintenance sheets
- the condition monitoring data, including all data since the last dismantling and the original reference data of the machinery checked through condition monitoring
- any change to the documentation listed in [2.3]
- full trend analysis (including spectrum analysis for vibrations) of machinery displaying operating parameters exceeding acceptable tolerances.

3.4 Damage and repairs

3.4.1 Damage to components or items of machinery is to be reported to the Society. The repairs of such damaged components or items of machinery are to be carried out to the satisfaction of the Surveyor.

3.4.2 Details of repairs and maintenance carried out are to be examined. Any machinery part, which has been replaced by a spare one, due to damage, is to be retained on board where possible until examined by the Surveyor.

3.4.3 Defect and failure data is to be reviewed in order to ensure the system output is appropriate. Where necessary, following review of the failure data, there is to be a method of amending the CM and CBM scheme.

3.4.4 For bearings surveyed under the continuous survey system, when a certified monitoring system is in place such a condition based monitoring or manufacturers approved bearing wear monitoring, then there is no need to turn out the bearings unless the monitoring systems are not working properly, suggest there may have been bearings problems or the monitoring data is not available and verifiable over a period covering the CSM cycle.

Appendix 5 Remote Classification Surveys

1 General

1.1 Scope

1.1.1 The surveys of ships may utilize different methods and concepts. This Section contains principles and minimum requirements for carrying out remote surveys.

Remote survey will only be appropriate provided the level of assurance is not compromised, and the survey is carried out with the same effectiveness as and is equivalent to a survey carried out with attendance on board by a Surveyor.

Note 1: Attendance on board by a surveyor means physical attendance on board the ship by a surveyor.

Note 2: Remote classification activities not requiring a survey, such as some administrative tasks, are not to be considered as remote surveys.

Note 3: An administrative task is a task where a survey decision is not being made, for example reissue of a certificate or record following a correction, or an update to the ship's records held by the Society or a document review.

1.2 Application

1.2.1 These requirements apply to all vessels, self-propelled or not.

1.3 Definitions

1.3.1 Remote survey

A “Remote Survey” is a process of verifying that a ship and its equipment are in compliance with the Rules where the verification is undertaken, or partially undertaken, without attendance on board by a Surveyor.

1.3.2 Information and communication technology (ICT)

Information and Communication Technology (ICT) are the technologies used in the scope of remote surveys for gathering, storing, retrieving, processing, analysing, and transmitting information which includes both software and hardware.

2 Requirements for equivalency

2.1 General

2.1.1 The requirements for equivalency of a remote survey to a survey attended on board by a Surveyor include:

- eligibility of the remote survey
- qualification of Surveyors
- planning of the remote survey
- performance of the remote survey
- assessment of the remote survey
- reporting.

Equivalency is obtained when, with the use of available ICT, a Surveyor can perform a survey remotely being able to:

- obtain the supporting and technical evidence required according to the applicable rules
- verify applicable survey items and relevant tests

and the results of the remote survey provide the same level of assurance obtained with attendance on board by a Surveyor.

2.2 Eligibility of the remote survey

2.2.1 Eligibility of the remote survey is to be decided based on type and scope of the requested survey, in accordance with [3.1] and, if applicable, flag State Administration acceptance and possible instructions, when the classification survey is also related to a statutory item, and the Society is carrying out the statutory survey on behalf of the flag State Administration.

A remote survey is deemed eligible when it provides the same level of assurance, according to the requirements for equivalency, as if it was conducted with attendance on board by a Surveyor.

Remote surveys are generally to be carried out with internet connection allowing a live streaming visual examination, although, at the discretion of the Surveyor, a combination of remote survey methods (see [2.4]) may be used. For simple/limited verifications, other types of ICT may be accepted by the Surveyor.

2.3 Planning of the remote survey

2.3.1 Planning of the remote survey is required to ensure that the remote survey is carried out in accordance with the applicable requirements. The content of the planning is to be based on the scope of the remote survey.

To ensure that the Surveyor can properly plan the remote survey and communicate with personnel/crew, so that the survey is carried out according to the applicable rules, adequate means are to be available enabling the Surveyor and allowing the Society to:

- properly interact with personnel/crew involved in the remote survey, before and during the survey process
- agree on ICT means to be used
- verify that personnel/crew involved in the remote survey are suitably skilled to use the electronic devices and/or software used by the Society to perform the remote survey
- acquire as deemed necessary information on identity and ranking of personnel/crew involved in the remote survey
- provide the survey item/scope to the personnel/crew involved in facilitating the remote surveys, including the tests that will be performed
- communicate, during the remote survey, additional actions depending on the evidence to be collected.

One or more of the following means is to be provided for planning the remote survey:

- live-streaming video and audio connection
- exchange of data / electronic documents
- other means acceptable to the Society.

The Owner is to provide the necessary facilities for the safe execution of the survey.

2.4 Performance of the remote survey

2.4.1 To ensure that the Surveyor can properly perform the remote survey according to the applicable rules, the available evidence must allow the attending surveyor to:

- examine and assess a survey item and/or a group of items and/or supporting documents
- verify and assess applicable tests and/or services.

The evidence provided to the Surveyor is subject to the technical evaluation and final acceptance by the Surveyor with respect to the completeness and accuracy, necessary to perform the requested survey according to the applicable requirements.

One or more of the following evidence is to be provided for performing the remote survey:

- live-streaming video and audio
- recorded videos provided by the Owner's representative
- photos provided by the Owner's representative
- other data and/or supporting documents acceptable to the Society.

2.5 Assessment of the remote survey

2.5.1 The Surveyor is to evaluate all evidence received and accept them before crediting the remote survey.

The means used for the remote survey must allow the Surveyor to collect the necessary evidence that will be examined according to the Surveyor's professional judgement in order to satisfactorily complete and credit the relevant survey items.

In case the Surveyor, according to their professional judgement, deems that the remote survey does not provide the same level of assurance as a survey with attendance on board by a Surveyor, the Surveyor may decide not to credit the relevant survey items.

3 Scope and procedures

3.1 Scope - eligible survey items

3.1.1 A remote survey may be proposed as an alternative to a survey attended on board by a Surveyor for the surveys listed in Tab 1.

When the classification survey is also related to a statutory item, and the Society is carrying out the statutory survey on behalf of the flag State Administration, then the flag State Administration acceptance is required, and possible additional requirements are to be complied with.

The Surveyor may require to confirm the results of the remote survey, by a survey attended on board by a Surveyor, to credit the relevant survey items, in case the remote survey is not carried out to the Surveyor's satisfaction or it is required by the Society.

Table 1 : Eligible remote survey items

No.	Surveys and related items eligible to remote survey	Live streaming required
1	Postponement, issuance, deletion of Condition of Class	X **(1)**
2	Postponement of Class surveys	X **(1)**
3	Items of Continuous Survey for Machinery (see Ch 2, Sec 2, [4.3]) or Planned Maintenance Scheme (see Ch 2, Sec 2, [4.4])	X **(1)**
4	Occasional survey for change of ship's name	X **(1)**
5	Occasional survey for loss of anchor	X **(1)**
6	Occasional survey for minor **(2)** machinery or equipment damage	X **(1)**
7	Occasional survey for minor **(2)** hull damage	X **(1)**
8	Occasional survey for minor **(2)** deficiencies/defects not subject to a Condition of Class	X **(1)**
9	In-water bottom survey	X
10	Specified items of a class periodical survey (excluding additional specific items of initial or renewal surveys), including completion of remaining items of a part held class periodical survey	X **(1) (3)**
11	Non-propelled / un-manned barges/pontoon – annual surveys when no survey of hull compartments is due	X **(1)**
12	Minor **(2)** retrofit / installation / upgrade of equipment	X **(1)**
13	Documentary or data based initial / periodical / renewal / occasional verifications and surveys	**(4)**

(1) Live streaming may not be required for minor survey scope or that a combination remote survey method, as listed in [2.4], may be used at the sole discretion of the Society

(2) "Minor" in the items 6, 7, 8 and 12 means that the item can be surveyed remotely according to requirements for equivalency given in [2]

(3) Pure documentary verifications are eligible in accordance with item 13

(4) Live streaming may be required for surveys not marked X in the Table, depending on the survey scope at the sole discretion of the Society

3.2 Procedures

3.2.1 Eligibility

Refer to [2.2].

3.2.2 Digital information quality, completeness, and accuracy

Final appraisal of the quality of digital information is at the discretion of the Surveyor, who is to be satisfied with the content and the quality of digital information collected, and the survey carried out, allowing the Surveyor to confirm its completion.

The Owner is responsible for the completeness and accuracy of digital information provided. The digital information submitted by the Owner to the Surveyor is to reflect the real situation of the surveyed item. The date and time, when a photo or video was taken are to be made available to the Surveyor or identifiable from its metadata.

The Society is to collect and store digital information as evidence of the survey. It is not necessary to store all of digital information received; the exact digital information stored is to support the survey decision and is to be decided by the Surveyor crediting the survey.

The remote survey is carried out under the supervision and upon instructions of the Surveyor, who is in charge of crediting the remote surveys. A surveyor attendance on board may be required to complete the survey, upon the Surveyor's request and at their discretion.

3.2.3 Requirements for a remote survey when live streaming is not used

When live streaming is not used, communication and digital information collection are to be performed through an ICT channels (such as emails, data streams and clouds), which is to be accepted by the Society prior to the survey.

The Owner's representative is to confirm the identity of the ship at the commencement of the survey.

3.2.4 Requirements for a remote survey when live streaming is used

The Owner's is to ensure that:

- the Owner's representative is attending on board and has access to the areas intended to be surveyed
- the Owner's representative has at his disposal a 2-ways visual and audible communication means complying with the requirements in [4]
- ICT solution is available on the communication means and meets the requirement described in [4].

In the case these requirements cannot be fulfilled, the remote survey may be rejected. The Surveyor is to verify the identity of the ship at the commencement of the survey by live streaming.

3.3 Hardware and ICT solution

3.3.1 Refer to [4.2].

3.4 Requirements for connectivity

3.4.1 The Owner's representative is to ensure that internet connectivity tests are carried out before the survey and that proper connectivity is available and maintained during the survey.

When remote survey by live streaming is being undertaken, a connection that enables live streaming between the Surveyor and the Owner's representative attending on board is required. The quality of the live streaming connection (audio and video) is to ensure proper communication and to allow the Surveyor to carry out the survey remotely, to the Surveyor's satisfaction. In the case where a live streaming connection with the Surveyor is not possible or is not continuous at the place of the survey (e.g., Engine Room), partly online sequences (where the Owner is able to capture pictures and videos offline of those items not covered by live streaming) may be accepted by the Surveyor.

4 Information and Communication Technology (ICT)

4.1 General

4.1.1 This Article outlines the minimum requirements for the use of ICT that can capture images, record video and/or live stream video or other data from a ship as considered acceptable to the Society.

4.2 Hardware

4.2.1 The Owner is responsible for ensuring that all hardware installations on board used for the remote survey comply with the applicable requirements relevant for use and location on board, including hazardous areas. The ICT is to typically consist of:

- A host computer device, to receive the streaming of images/data/video. This is usually a laptop or desktop computer compatible with the software application used for the remote survey.
- Onboard standalone device which may include digital cameras capable of capturing videos/photos/data.
- Onboard smart device compatible with the applicable software/technology.
- Communication accessories like headphones and microphone for the noisy environment as applicable and as deemed necessary.

Note 1: The smart device may be a smartphone, tablet, computer, wearable device, smart glass, digital camera, or any other device which can be connected to the network and capable of transmitting the necessary data/images to shore.

The communication equipment used for the live streaming is to have the following minimum functionality:

- both ends are to simultaneously see the same image/videos in near real-time (i.e., live streaming)
- two-way direct voice communication
- possibility to take screenshots.

When using a portable device on board for live streaming, the movement of the handheld device may affect the stability of the video and the image, leading to lower quality outputs. When necessary, a suitable anti-shake device is to be used to provide proper stability.

Note 2: The host computer screen is to be able to present an image quality that is sufficient to enable a survey decision to be made.

Note 3: Portable equipment on board is to be equipped with a power capacity suitable for the intended scope and time of the survey.

4.3 Internet connectivity (coverage and speed)

4.3.1 For internet connectivity requirements on board, refer to [3.4].

The onboard smart devices are to have the capability of transmitting the images/video/data over a Cellular, Wi-Fi or Satellite Connection to the remote Surveyor.

When live streaming communication is applied, the internet connection is to have sufficient and stable bandwidth capacity to ensure quality (such as resolution and frame rate) of the direct colour image/video and voice communication to the remote survey location to the satisfaction of the Surveyor.

4.4 Software and data security

4.4.1 The software used for the remote survey is to be acceptable to the Society. The overall function and ability of the software used to ensure the security of data are to be evaluated prior to use as per the below requirements.

The Surveyor is to normally control the live video call, providing instructions to the on-site personnel/crew and supervising survey activities for capturing relevant information. The onboard device is to have the capability of transmitting the data over a Cellular, Wi-Fi, or Satellite Connection to the Surveyor.

The software used to perform the remote survey may also be provided with technologies that support the Surveyor in the process of making a decision, such as:

- Artificial Intelligence (AI) for the recognition and the classification of defects.
- Internet of things (IoT) for collecting parameters and evaluating acceptability/working condition of machinery and equipment.
- Data driven verification or other means considered acceptable by the Society.

The above software and technologies are to be evaluated and accepted by the Society in each case.

When considering the use of software/applications and other technologies, data protection are to be considered in accordance with applicable requirements of the Society before the remote survey is commenced. The software/application used to perform the remote survey is to be compatible with the technical requirements detailed in this paragraph; in addition, the software used is to comply with the Society's applicable requirements for:

- cybersecurity
- data protection and confidentiality for the transmitted data.

When not provided by the Society itself, the audio/video software or application used to perform the remote survey is to be accepted by the Society.

During the survey preparation, it is the Owner's responsibility to ensure that their data security policies are implemented as per the Company's Safety Management System.

Note 1: The Company's SMS may take into account IMO resolution MSC.428(98), MSCFAL.1/Circ.3 and IACS Rec.166.

5 Recording of evidence and reporting of survey

5.1 Recording of evidence

5.1.1 Required evidence

Refer to [2.4].

In principle, live streaming video and audio are to be applied to remote surveys as a primary means (refer to Tab 1).

Additionally, and/or alternatively, one or more of the following evidence may be submitted or verified as requested by the Surveyor during remote survey so that the Surveyor is able to verify conditions of survey items:

- Recorded video and audio.
- Photos.
- Master's/chief engineer's statement.
- Ship's logbook.
- Owner's confirmation.

a) Live streaming video and audio:

Live streaming video and audio using ICT are to be in accordance with the requirements in [4].

b) Recorded videos/photos:

For the recorded videos/photos, the following information is to be available:

- confirmation that they were actually taken on the ship by the Owner's representative
- date and time when they were taken
- identity of the personnel/crew responsible for taking evidence.

c) Master's/chief engineer's statement:

Recorded videos/photos provided by the Owner's representative may be supplemented with a statement signed by the master and/or the chief engineer confirming the condition of the items shown in the evidence. The final evaluation of the remote survey by the Surveyor is to be based on all of the provided evidence, and it does not delegate the responsibility to the master/chief engineer's statement only.

d) Ship's logbook:

The Master is to make entries into ship's logbook on the following occasions and submit copies of the relevant pages when requested by the Surveyor:

- when a remote survey is carried out by the Surveyor
- when videos/photos are taken and submitted to the Surveyor with the master's/chief engineer's statement and additional documents as applicable.

e) Owner's confirmation:

The Owner's representative or the master is to confirm the correctness and completeness of the provided information and evidence (if any) relevant to the condition of the items requested to be surveyed. This confirmation may be included in the survey application.

5.1.2 Retaining/filing evidence

The evidence submitted by the Owner's representative or master is to be retained/filed in accordance with the Society's procedures which are to include:

- type of evidence to be retained/filed
- duration/location to be retained/filed.

It is not required for the Society to record and save live streaming video and audio as evidence unless the Surveyor considers it necessary.

5.1.3 Other supporting documents

The Surveyor may request the Owner's representative or master to submit supplementary documents such as ship's maintenance reports and record for the operation of machinery and equipment and service reports issued by manufacturers, service suppliers or service providers.

While the Surveyor is to verify that the documents are duly prepared and issued to the ship, they may not be required to be retained/filed by the Society as evidence.

5.2 Reporting of remote survey

5.2.1 The report of a remote survey is to be issued in accordance with the Society's procedure. The survey report is also to include the following additional information:

- indication that the survey was carried out remotely
- description of the means used during the remote survey
- indication of the provided evidence
- confirmation of the Flag State Administration's authorization, when applicable.

CHAPTER 3
SCOPE OF SURVEYS (ALL SHIPS)

Section 1 Annual Survey
Section 2 Intermediate Survey
Section 3 Class Renewal Survey
Section 4 Bottom Survey
Section 5 Tailshaft Survey
Section 6 Boiler Survey
Section 7 Hull Survey for New Construction
Section 8 Survey of Watertight Cable Transits
Appendix 1 Class Requirements and Surveys of Laid-up Ships

Section 1 Annual Survey

1 General

1.1

1.1.1 The requirements of this Section apply to annual surveys of all ships. The specific requirements for annual surveys related to service notations and additional class notations assigned to ships are addressed in Part A, Chapter 4 and Part A, Chapter 5, respectively.

Note 1: Ships assigned with the service notation **yacht** and having a length less than 24 m are not submitted to annual surveys for hull and machinery, as described in NR500.

1.1.2 At the time of annual surveys, the ship is to be generally examined. The survey is to include a visual inspection of the hull, equipment and machinery of the ship and some tests thereof, so far as necessary and practicable in order to verify that the ship is in a acceptable general condition and is properly maintained.

1.1.3 Owners are reminded that, in compliance with the requirements in Ch 2, Sec 2, [6.4], any modification to the ship's hull, equipment and machinery affecting its classification is to be made known to the Society.

2 Hull

2.1 Hull and hull equipment

2.1.1 The survey is to include a general external examination and testing, where appropriate, of the following items, as applicable:

- outer shell plating above the waterline, relevant shell doors and accessible parts of the rudder(s)
- plating of freeboard deck and exposed decks, superstructures, with their openings and means of closure
- means of closing and securing the weathertightness of miscellaneous openings in freeboard, superstructure and exposed decks (cargo hatchways, other hatchways and other openings) (for details see [2.3])
- sidescuttles and deadlights, chutes and other openings with their means of closure
- bulwarks and, if applicable, the provision of freeing ports, special attention being paid to freeing ports with shutters
- guardrails, gangways, walkways, ladders and any other means provided for the protection of the crew and means for safe passage for crew
- inlets, scuppers and sanitary discharges, valves on discharge lines and their controls
- ventilators, air pipes, overflow pipes and gas vent pipes, with their coamings, means of closure and flame screens, where required
- flame screens on vents to all bunker tanks
- all air pipe heads installed on the exposed decks (i.e. those extending above the freeboard deck or superstructure decks)
- weld connection between air pipes and deck plating
- fittings and appliances for timber deck cargoes, where applicable
- verification of the position of the deck line (or reference line) and load lines and timber marks, if any, which, if necessary, are to be re-marked and re-painted
- deck equipment such as lifeboat davit foundations, bollards, fairleads, hawse pipes, etc., masts and associated rigging, including lightning conductors
- anchoring and mooring equipment, as far as practicable
- towing and mooring equipment properly marked with any restriction associated with its safe operation (only for ships built after 1st January 2007).
- watertight bulkheads, their watertight doors and associated local and remote controls, and their watertight penetrations
- main and auxiliary steering arrangements, including their associated equipment and control systems, and manoeuvring gear
- fire divisions and fire doors, dampers in ventilation ducts, means of closure of skylights and other openings
- confirmation, as far as practicable, that no significant changes have been made to the arrangement of the structural fire protection, including cargo spaces intended for the carriage of dangerous goods
- confirmation that emergency escape routes from accommodation and service spaces are satisfactory
- accessible cargo holds, in particular in areas likely to be damaged by cargo handling
- confirmation that the drainage from enclosed cargo spaces situated on the freeboard deck is satisfactory
- engine room
- where fitted, helicopter deck and its supporting structure, safety net and arrangements for the prevention of sliding

- availability of loading manual
- availability of electronic loading instrument, where required, and verification with standard test
- availability of approved stability documentation
- checking, in general, that there has been no deterioration in the strength of the hull
- verification that no alterations have been made to the hull or superstructures that would affect the position of the load lines
- superstructure end bulkheads and openings therein
- watertight integrity of the closures to any openings in the ship's side shell below the freeboard deck (particularly, cargo ports and other similar openings)
- garbage chutes, as far as practicable
- spurling pipes and cable lockers for verification that permanent devices are fitted to minimize water ingress
- if applicable, special requirements for ships permitted to sail with type “A” or type “B-minus” freeboard (machinery casing, gangway and access, hatchways and freeing arrangements)
- hull and its closing appliances, in general and as far as can be seen
- for ships fitted with independent cargo tanks, confirmation that cargo piping and tanks are electrically bonded to the hull, as applicable.

Note 1: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested where doubts arise.

2.1.2 Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine areas of substantial corrosion, in accordance with the requirements of Ch 3, Sec 3, Tab 4. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

Note 1: These requirements are not applicable to cargo tanks of oil tankers, chemical tankers and double hull oil tankers surveyed in accordance with the requirements of Ch 4, Sec 3 and Ch 4, Sec 4.

2.1.3 Examination of ballast tanks when required as a consequence of the results of the class renewal survey and intermediate survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that Substantial Corrosion is found, then the extent of thickness measurements is to be increased to determine areas of substantial corrosion, in accordance with the requirements of Ch 3, Sec 3, Tab 4. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

2.2 Survey of watertight cable transits

2.2.1 The Cable Transit Seal Systems Register, as detailed in Ch 3, Sec 8, is to be reviewed to confirm it is being maintained and, as far as practicable, the transits are to be examined to confirm their satisfactory condition.

2.2.2 Where there are records entered since the last annual survey of any disruption to the cable transits or installation of new cable transits, the satisfactory condition of those transits is to be confirmed by review of records and, if deemed necessary, by examination. The results are to be recorded in the Cable Transit Seal Systems Register against the specific cable transit.

2.3 Hatch covers and coamings

2.3.1 The Owner or his representative is to declare to the attending Surveyor that no significant changes have been made to the hatch covers, hatch coamings and their securing and sealing devices without prior approval of the Society.

The survey of hatch covers and coamings is to include:

a) when fitted with portable covers, or wooden or steel pontoons, checking of the satisfactory condition, where applicable, of:
   - wooden covers and portable beams, carriers or sockets for the portable beams, and their securing devices
   - steel pontoons
   - tarpaulins
   - cleats, battens and wedges
   - hatch securing bars and their securing devices
   - loading pads/bars and the side plate edge
   - guide plates and chocks
   - compression bars, drainage channels and drain pipes (if any)

b) when fitted with mechanically operated steel covers, checking of the satisfactory condition, as applicable, of:
   - hatch covers
   - tightness devices of longitudinal, transverse and intermediate cross junctions (gaskets, gasket lips, compression bars, drainage channels and, if any, drain pipes)
   - clamping devices, retaining bars, cleating
   - chain or rope pulleys
   - guides

- guide rails and track wheels
- stoppers, etc.
- wires, chains, gypsies, tensioning devices
- hydraulic system essential to closing and securing
- safety locks and retaining devices
- the operation of hatch covers, by means of random examination: stowage and securing in open condition, proper fit, locking and efficiency of sealing in closed position, operational testing of hydraulic and power components, wires, chains and link drives

c) checking of the satisfactory condition of hatch coaming plating and its stiffeners, where applicable.

3 Machinery and systems

3.1 General machinery installations

3.1.1 The survey of general machinery installations is to cover the following items:

- confirmation that the machinery, boilers and other pressure vessels, associated piping systems and fittings are maintained so as to reduce to a minimum any danger to persons on board, due regard being given to moving parts, hot surfaces and other hazards
- confirmation that the normal operation of the propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative
- confirmation that provisions are made so as to bring the machinery into operation from the dead ship condition without external aid
- confirmation that the means of escape from accommodation, machinery and other spaces are satisfactory
- general examination of the machinery, boilers, all steam, hydraulic, pneumatic and other systems and their associated fittings, for confirmation of their proper maintenance
- examination of the means for the operation of the main and auxiliary machineries essential for the safety of the ship (including the control, monitoring, reporting, alert and safety action)
- test of the means of remotely controlling the propulsion machinery from the navigation bridge, where applicable
- examination of the arrangements to operate the main and other machineries from a machinery control room, where applicable
- confirmation that the ventilation system for the machinery spaces works correctly
- confirmation that the engine-room telegraph, the second means of communication between the navigation bridge and the machinery, and the means of communication with any other position, from where the engines can be controlled, operates satisfactorily
- confirmation that the engineer's alarm is clearly audible in the engineers' accommodation
- confirmation that the means of communication between the navigation bridge and the steering compartment are satisfactorily operating
- confirmation that the means of indicating the angular position of the rudder are satisfactorily operating
- for ships having emergency steering positions, confirmation that means of relaying heading information (telephone or other means of communication) are provided; confirmation that means to supply visual compass readings to the emergency steering position are provided if necessary
- confirmation that the various alarms required for hydraulic power-operated, electric- and electro-hydraulic steering gears work satisfactorily
- confirmation that the re-charging arrangements for hydraulically operated steering gears are maintained
- examination, as far as practicable, of the bilge pumping systems and bilge wells, including operation of the pumps, remote reach rods and level alarms, where fitted
- visual examination of the condition of all the non-metallic expansion joints in piping systems as appropriate, located below the deepest load waterline, and checking the relevant service record
- examination of the arrangements for periodically unattended machinery spaces and, in particular, the random testing of alarms, automatic and shut-down functions
- external examination of pressure vessels other than boilers and their appurtenances, including safety devices, foundations, controls, relieving gear, high pressure piping, insulation and gauges
- examination, where applicable, of the alternative design and arrangements for machinery or electrical installations, or fire safety, in accordance with the test, inspection and maintenance requirements, if any, specified in the approved documentation
- confirmation that the ballasting arrangements are satisfactory.

3.1.2 When the ship is equipped with a refrigerating plant (whether or not covered by an additional class notation), the annual survey is to include the external examination of:

- pressure vessels of the installation to the same extent as indicated in [3.1.1]
- refrigerant piping, as far as practicable
- for refrigerating machinery spaces using ammonia as refrigerant:
  - ventilation system including functional test
  - water-spraying fire-extinguishing system; see [3.4.2] item d)
  - bilge system including functional test
  - electrical equipment, confirming its proper maintenance
  - gas detection system
  - breathing apparatus and protective clothing.

3.1.3 When the ship is equipped with thruster installations, the annual survey is to include:

- an external examination of the machinery installation
- an operating test of the complete installation.

3.1.4 For ships subject to compliance with the requirements laid down in Ch 6, Sec 2, [6], or in Ch 6, Sec 4, [2], or in Pt B, Ch 2, Sec 1, [2.2], the annual survey is to include an examination and a test of the water ingress detection systems and of their alarms at random.

3.1.5 For ships subject to compliance with the requirements laid down in Ch 6, Sec 2, [7], or in Pt C, Ch 1, Sec 10, [6.6.3], item e), the annual survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

3.1.6 For ships fitted with an exhaust gas cleaning system (scrubber), the annual survey is to include an examination of the distance pieces on the overboard discharge system of the scrubber and a confirmation that there is no reduction of thickness of these distance pieces.

3.1.7 When the ship is equipped with a ballast water treatment system using an inert gas generator and where this inert gas generator is used solely for the purpose of ballast water treatment, the annual survey is to include the relevant items of Ch 4, Sec 3, [3.4].

3.2 Boilers

3.2.1 For main and auxiliary steam boilers, the annual survey consists of an external examination of boilers and their appurtenances, including safety devices, foundations, controls, relieving, high pressure and steam escape piping, insulation and gauges.

The annual survey is to include test of safety and protective devices and test of safety valve using its relieving gear.

For exhaust gas heated economizers, the safety valves are to be tested by the Chief Engineer at sea within the annual survey window. This test is to be recorded in the log book for review by the attending Surveyor prior to crediting the Annual Survey of Machinery.

3.2.2 For thermal oil heaters, a functional test while in operation is to be carried out, during which the following items are checked:

- the heater for detection of leakages
- the condition of the insulation
- the operation of indication, control and safety devices
- the condition of remote controls for shut-off and discharge valves.

A satisfactory analysis of the quality of oil is to be made available to the Surveyor.

3.2.3 For exhaust gas thermal oil heaters, in addition to the requirements of [3.2.2], a visual examination and a tightness testing to the working pressure of the heater tubes are to be carried out.

3.2.4 For electrical steam generators, a functional test while in operation is to be carried out, during which the following items are checked:

- the heater system for detection of leakages
- the operation of indication, control, alarm and safety devices.

3.3 Electrical machinery and equipment

3.3.1 The survey of electrical machinery and equipment is to cover the following items:

- general examination, visually and in operation, as feasible, of the electrical installations for power and lighting, in particular main and emergency generators, electric motors, switchboards, switchgears, cables and circuit protective devices, indicators of electrical insulation and automatic starting, where provided, of emergency sources of power
- checking, as far as practicable, the operation of emergency sources of power and, where they are automatic, also including the automatic mode
- verification that the precautions provided against shock, fire and other hazards of electrical origin are maintained.

3.3.2 The survey is also to cover the bridge control of propulsion machinery, and related arrangements (alarms and safety devices), when fitted.

The survey of an automated installation covered by an additional class notation is detailed in Part A, Chapter 5.

3.3.3 The survey is also to cover the computerized systems. This survey includes:

- the verification by the Surveyor regarding the management of change in operation. Procedures for management of change and relevant change records (see Pt C, Ch 3, Sec 3, [6]) are to be made available at the time of the survey

Note 1: In the cases where the change requires approval from the Society up front, the relevant procedures and documentation for the change in question may be verified at that time.

- checking that revision of software mentioned in the records corresponds with revision effectively used for at least one computerized system chosen at the satisfaction of the Surveyor.

3.3.4 For ships where the electrical distribution system includes harmonic filters, the survey is to include:

- Annual measurement, as a minimum, of the harmonic distortion levels of main busbars under seagoing conditions as close to the periodical machinery survey as possible so as to give a clear representation of the condition of the entire plant to the Surveyor. Harmonic distortion readings are to be carried out when the greatest amount of distortion is indicated by the measuring equipment. An entry showing which equipment was running and/or filters in service is to be recorded in the log so this can be replicated for the next periodical survey. Harmonic distortion levels are also to be measured following any modification to the ship's electrical distribution system or associated consumers by suitably trained ship's personnel or by a qualified outside source.
- Verification that records of all above measurements are made available to the Surveyor at each periodical survey.

Note 1: Those requirements apply at any scheduled machinery periodical survey having a due date on or after 1st July 2017 for ships contracted for construction before 1st July 2017.

- For ships contracted for construction on or after 1st July 2017, verification that the facilities used for continuous monitoring of the levels of harmonic distortion experienced on the main busbars as well as alerting the crew when the level of harmonic distortion exceeds the acceptable limits are working properly and review of corresponding records.

3.3.5 For Li-Ion batteries of a capacity above 20kWh or used as emergency source or transitional source, the survey is to include:

- general examination of the battery pack(s)
- general examination of the battery monitoring system
- general examination of the battery support system
- general examination of the battery room, including visual check of the safety measures and functions related to battery rooms, i.e. battery installation, ventilation, fire safety measures and alarms
- check of the electrolyte level and pH level
- check of State of health (SOH) of battery system according to the Manufacturer's specification and verification that the battery capacity has been regularly recorded and complies with the parameters specified by the Manufacturer
- test of sensor and alarm associated to the battery at random
- undertaking of measurement of insulation of battery packs
- additional checks when some specific part of the battery is or has been replaced (e.g. battery cells, BMS) according to the Manufacturer specification and to the satisfaction of the Surveyor.

3.3.6 For batteries used for electrical supply of pods, the survey is to include:

- verification of proper working of monitoring systems
- verification of proper working of alarms and defaults and related functions and/or interfacing to the other ship systems
- disconnection of the electrical storage system (ESS) in different operating modes, and automatic start of stand-by source, as necessary
- test of the fire detection of the battery room
- test of the gas detection system of the battery room
- examination of the fire-extinguishing system of the battery room as applicable in accordance with the relevant requirements given in [3.4]
- verification that accessibility for common maintenance and devices for battery overhaul, if any, are maintained.

3.4 Fire protection, detection and extinction

3.4.1 The survey of fire prevention and other general arrangements is to cover the following items:

- checking that fire control plans are properly posted
- examination and testing, as feasible, of the operation of manual and/or automatic fire doors, where fitted
- checking, as far as practicable, that, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in working order
- examination of the fire-extinguishing and special arrangements in the machinery spaces and confirmation, as far as practicable and as appropriate, of the operation of the remote means of control provided for the opening and closing of the skylights, the release of smoke, the closure of funnel and ventilation openings, the closure of power operated and other doors, the stopping of ventilation and boiler forced and induced draft fans and the stopping of oil fuel and other pumps that discharge flammable liquids
- examination of the arrangements for remote closing of valves for oil fuel, lubricating oil and other flammable oils and confirmation, as far as practicable and as appropriate, of the operation of the remote means of closing valves on the tanks that contain oil fuel, lubricating oil and other flammable oils
- test of the means of stopping power ventilation systems from outside the spaces served
- examination and testing of the closing arrangements of ventilators, funnel annular spaces, skylights, doorways, tunnel or other closing means for various openings, where applicable
- examination, as far as practicable, and testing, as feasible and at random, of the fire and/or smoke detection systems
- examination, where applicable, of the alternative design and arrangements for fire safety or life-saving appliances and arrangements, in accordance with the test, inspection and maintenance requirements, if any, specified in the approved documentation.

3.4.2 The operational readiness and maintenance of fire-fighting systems is to be checked. Confirmation that its means of operation is clearly marked. The survey requirements for all types of fire-fighting systems that are usually found on board ships related either to machinery spaces or cargo spaces or vehicle spaces or special category spaces or ro-ro spaces or accommodation spaces, irrespective of the service notation assigned, are the following:

a) water fire system
   - examination of the fire main system and confirmation that each fire pump including the emergency fire pump can be operated separately so that the two required powerful jets of water can be produced simultaneously from different hydrants, at any part of the ship whilst the required pressure is maintained in the fire main
   - checking that fire hoses, nozzles, applicators, spanners and international shore connection (where fitted) are in satisfactory working condition and situated at their respective locations

b) fixed gas fire-extinguishing system
   - external examination of receivers of CO_2 (or other gas) fixed fire-extinguishing systems and their accessories, including the removal of insulation for insulated low pressure CO_2 containers
   - examination of fixed fire-fighting system controls, piping, instructions and marking; checking for evidence of proper maintenance and servicing, including date of last system tests
   - checking that fixed CO_2 fire-extinguishing systems for the protection of machinery spaces and cargo pump-rooms, where applicable, are provided with two separate controls, one for opening of the gas piping and one for discharging the gas from the storage container, each of them located in a release box clearly identified for the particular space
   - test of the alarm triggered before the CO_2 is released

c) sprinkler system
   - examination of the system, including piping, valves, sprinklers and header tank
   - test of the automatic starting of the pump activated by a pressure drop
   - check of the alarm system while the above test is carried out

d) water-spraying system
   - examination of the system, including piping, nozzles, distribution valves and header tank
   - test of the starting of the pump activated by a pressure drop (applicable only for machinery spaces)

e) fixed foam systems (low or high expansion)
   - examination of the foam system
   - test to confirm that the minimum number of jets of water at the required pressure in the fire main is obtained when the system is in operation
   - checking the supplies of foam concentrate and receiving confirmation that it is periodically tested (not later than three years after manufacture and annually thereafter) by the manufacturer or an agent

f) dry powder system
   - examination of the dry powder system, including the powder release control devices
   - checking the supplies of powder contained in the receivers and that it has maintained its original smoothness
   - checking that the pressure of propelling inert gas contained in the relevant bottles is satisfactory.

3.4.3 As far as other fire-fighting equipment is concerned, it is to be checked that:

- semi-portable and portable fire extinguishers and foam applicators are in their stowed positions, with evidence of proper maintenance and servicing, and detection of any discharged containers
- the fire fighter's outfits including its self-contained compressed air breathing apparatus and emergency escape breathing devices (EEBDs) are complete and in satisfactory condition and provision of two-way portable radiotelephone apparatus of an explosion-proof type or intrinsically safe; where more than one fire-fighter's outfit is carried, confirmation that they are stored in separated positions
- the cylinders, including the spare cylinders, of any self-contained breathing apparatus are suitably charged, and that onboard means of recharging breathing apparatus cylinders used during drills or a suitable number of spare cylinders to replace those used are provided.

3.4.4 The fire-extinguishing systems for spaces containing paint and/or flammable liquids and deep-fat cooking equipment in accommodation and service spaces are to be examined.

3.4.5 Where a helideck is fitted, the helicopter facilities are to be checked, as far as appropriate:

- drainage arrangements around the landing area
- fire fighting appliances and arrangements (to be surveyed as per [3.4.2], according to the equipment installed
- overall examination of refuelling systems and hangar facilities for cleanliness and absence of leaks, condition of gutters and drainage arrangement
- availability of an operations manual, including a description and a checklist of safety precautions, procedures and equipment requirements.

3.4.6 When appropriate, the examination of the special arrangements for carrying dangerous goods is to be carried out, including checking of the electrical equipment and wiring, the ventilation, the provision of protective clothing and portable appliances, testing any fire detection and alarm system and any sample extraction smoke detection system and testing as far as practical, the water supply, bilge pumping and any water-spray system.

3.4.7 For ships designed to carry containers on or above the weather deck, as applicable, examination of the water-mist lance, and as appropriate, the mobile water monitors and all necessary hoses, fittings and required fixing hardware.

3.5 General emergency alarm system

3.5.1 The general emergency alarm system is to be examined and tested.

Section 2 Intermediate Survey

1 General

1.1

1.1.1 The requirements of this Section apply to intermediate surveys of all ships. The specific requirements for intermediate surveys related to service notations and additional class notations assigned to ships are addressed in Part A, Chapter 4 and Part A, Chapter 5, respectively.

1.1.2 A survey planning meeting is to be held prior to the commencement of the survey.

1.1.3 Concurrent crediting to both Intermediate Survey and Class Renewal Survey for surveys and thickness measurements of spaces are not acceptable.

1.1.4 The intermediate survey is to include examination and checks on a sufficiently extensive part of the structure to show that the structures of the ship are in satisfactory condition so that the ship is expected to operate until the end of the current period of class, provided that the ship is properly maintained and other surveys for maintenance of class are duly carried out during this period.

2 Hull

2.1

2.1.1 The requirements given in Tab 1 for the survey and testing of ballast tanks, cargo holds (for dry cargo ships to which the additional requirements in Ch 4, Sec 2 and Ch 4, Sec 7 do not apply) and cargo tanks (for non-ESP tankers) are to be complied with.

2.1.2 For ships fitted with independent cargo tanks, external examination of cargo tanks, as far as practicable, including tank supports, chocks and keys. The internal examination may be required if deemed necessary by the Surveyor.

For ships fitted with independent cargo tanks, confirmation that cargo piping and tanks are electrically bonded to the hull, as applicable.

Table 1 : Intermediate survey of hull (all ships)

ITEM	Age of ship (in years at time of intermediate survey)		
	5 < age ≤ 10	10 < age ≤ 15	age > 15
BALLAST TANKS	Representative ballast tanks internally examined Thickness measurements, if considered necessary by the Surveyor See **(1) (2) (3)**	All ballast tanks internally examined Thickness measurements, if considered necessary by the Surveyor See **(1) (3)**	All ballast tanks internally examined Thickness measurements, if considered necessary by the Surveyor Tightness of inner bottom plating of cargo holds in way of double bottom ballast tanks checked, if considered necessary by the Surveyor See **(1) (3)**
CARGO HOLDS (dry cargo ships to which the additional requirements in Ch 4, Sec 2 and Ch 4, Sec 7 do not apply)			Selected cargo holds internally examined

(1) If such examinations reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains effective.

(2) If there is no hard protective coating, soft or semi-hard coating, or POOR coating condition, the examination is to be extended to other ballast tanks of the same type.

(3) For ballast tanks, excluding double bottom ballast tanks, if there is no hard protective coating, soft or semi-hard coating, or POOR coating condition and it is not renewed, the tanks in question are to be internally examined at annual intervals.

When such conditions are found in double bottom ballast tanks, the tanks in question may be examined at annual intervals.

Note 1: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested should doubts arise.

ITEM	Age of ship (in years at time of intermediate survey)		
	5 < age ≤ 10	10 < age ≤ 15	age > 15
CARGO SPACES (for ships other than ships engaged in the carriage of dry cargoes only or ships subject to Ch 4, Sec 3, Ch 4, Sec 4 or Ch 4, Sec 5)		Selected cargo spaces internally examined	Selected cargo spaces internally examined
CARGO TANKS (non-ESP tankers)		Selected cargo tanks internally examined	Selected cargo tanks internally examined

(1) If such examinations reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains effective.

(2) If there is no hard protective coating, soft or semi-hard coating, or POOR coating condition, the examination is to be extended to other ballast tanks of the same type.

(3) For ballast tanks, excluding double bottom ballast tanks, if there is no hard protective coating, soft or semi-hard coating, or POOR coating condition and it is not renewed, the tanks in question are to be internally examined at annual intervals.

When such conditions are found in double bottom ballast tanks, the tanks in question may be examined at annual intervals.

Note 1: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested should doubts arise.

Section 3 Class Renewal Survey

1 General

1.1

1.1.1 The requirements of this Section apply to class renewal surveys of all ships. The specific requirements for class renewal surveys related to service notations and additional class notations assigned to ships are addressed in Part A, Chapter 4 and Part A, Chapter 5, respectively.

1.1.2 A survey planning meeting is to be held prior to the commencement of the survey.

1.1.3 Concurrent crediting to both Intermediate Survey and Class Renewal Survey for surveys and thickness measurements of spaces are not acceptable.

1.1.4 In addition to the requirements of the annual survey, the class renewal survey is to include sufficiently extensive examination and checks to show that the structures, main and auxiliary machinery, systems, equipment and various arrangements of the ship are in satisfactory condition or restored to such condition as to allow the ship to operate for the new period of class of five years to be assigned, provided that the ship is properly maintained and operated and other surveys for maintenance of class are duly carried out during this period.

The examinations of the hull are to be supplemented by testing and thickness measurements as required in [2.5] and [2.6], to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deformation that may be present.

1.1.5 The Owner is to provide the necessary facilities to enable this class renewal survey. The conditions for survey as detailed in Ch 2, Sec 2, [2.5] to Ch 2, Sec 2, [2.7] are to be met.

1.1.6 When the ship is under the continuous survey system for hull or machinery, the scope of the class renewal survey as described in this Section is carried out on a continuous basis over the period of class according to the procedure laid down in Ch 2, Sec 2, [4.3].

When the machinery installation is surveyed under the Planned Maintenance System, a specific program of survey replaces the scope of the class renewal survey of machinery and systems as laid down in [3], according to the procedure laid down in Ch 2, Sec 2, [4.4].

1.1.7 Upon completion of the class renewal survey, or at the end of the period of class (if the relevant part of the ship is surveyed under the continuous survey system), a general examination of the ship having the same scope as that of an annual survey, as detailed in Ch 3, Sec 1, is to be carried out for class renewal.

2 Hull and hull equipment

2.1 Bottom survey in dry condition

2.1.1 A bottom survey in dry condition is to be carried out, as detailed in Ch 3, Sec 4, [2], and in addition the requirements given in [2.1.3] to [2.1.5] are to be complied with.

2.1.2 For ships of unusual characteristics or engaged on special services, means of underwater inspection equivalent to the bottom survey in dry condition may be considered as an alternative by the Society, particularly when a suitable high resistance paint is applied to the underwater portion of the hull or an approved system of impressed current for external cathodic protection is fitted.

2.1.3 Anchors, windlass(es) and chain cables are to be ranged and examined, and the required complement and condition are to be checked. When the ship is more than 5 years old, chain cables are to be gauged.

Any length of chain cable which is found to be damaged or excessively worn is to be renewed.

2.1.4 Sea valves and cocks are to be opened up for internal examination.

2.1.5 Thickness measurements of the outer shell plating, as and if required within the scope of the related class renewal survey, are to be carried out (refer to [2.6]), if not already done within 15 months before the end of class period.

2.2 Decks, hatch covers and equipment

2.2.1 Decks are to be examined, particular attention being given to the areas where stress concentration or increased corrosion are likely to develop, such as hatch corners and other discontinuities of structure.

Deck erections such as hatch coamings, deckhouses and superstructures are to be examined.

The sheathing of wood-sheathed steel decks may be removed, at the Surveyor's discretion, in the case of doubt as to the condition of plating underneath.

Due attention is to be given to the examination in way of end and side openings and related shell and inner doors.

2.2.2 The hatch covers and coamings are to be surveyed as follows:

- a thorough survey of the items listed in Ch 3, Sec 1, [2.3] including close-up survey of hatch cover plating and hatch coaming plating, is to be carried out. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey is to be done of the accessible parts of hatch cover structures
- checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including stowage and securing in open condition, proper fit, locking and efficiency of sealing in closed position, operational testing of hydraulic and power components, wires, chains and link drives
- checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent is to be carried out
- thickness measurements of coaming and attached stiffeners, hatch cover plating and stiffeners (see Tab 3).

2.2.3 The survey of hull equipment is to cover the following points:

- windlass and chain stoppers, with disassembly as deemed necessary to verify the condition of the equipment and control and safety devices, holdfasts, hawse pipes
- steering arrangements, including steering gear, control and indication devices, operational tests and disassembly as deemed necessary; in the case of chain and rod gears, chains, rods, sheaves, pins and rollers are to be examined for wear
- connection of masts and standing rigging to the hull structure as well as condition of structure underneath.

2.2.4 All bilge and ballast piping systems are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory; see also [3.5].

2.2.5 For all ships, except ships having the service notation **passenger ship** or **ro-ro passenger ship**, automatic air pipe heads installed on the exposed decks (i.e. those extending above the freeboard deck or superstructure decks) are to be completely examined, both externally and internally, in accordance with the requirements given in Tab 1.

Table 1 : Requirements for internal and external examination of automatic air pipe heads at class renewal survey of all ships, except ships with service notation passenger ship or ro-ro passenger ship

Age of ship (in years at time of class renewal survey)		
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 and subsequent age > 10
Two air pipe heads, one port and one starboard, located on the exposed decks in the forward 0,25 L, preferably air pipes serving ballast tanks. See **(1)** and **(2)**	All air pipe heads located on the exposed decks in the forward 0,25 L. See **(1)** and **(2)**	All air pipe heads located on the exposed decks. See **(3)**
Two air pipe heads, one port and one starboard, on the exposed decks, serving spaces aft of 0,25 L, preferably air pipes serving ballast tanks. See **(1)** and **(2)**	At least 20% of air pipe heads on the exposed decks serving spaces aft of 0,25 L, preferably air pipes serving ballast tanks. See **(1)** and **(2)**	

(1) The selection of air pipe heads to be examined is left to the attending Surveyor.

(2) According to the results of this examination, the Surveyor may require the examination of other air pipe heads located on the exposed decks.

(3) Exemption may be considered for air pipe heads where there is substantial evidence of replacement after the last renewal survey.

Note 1: For designs where the inner parts cannot be properly examined from outside, the examination is to include removal of the head from the air pipe.

Note 2: Particular attention is to be paid to the condition of the zinc coating in heads constructed from galvanised steel.

2.3 Survey of watertight cable transits

2.3.1 The requirements for class renewal survey of watertight cable transits may be undertaken by the attending Surveyor or by a certified firm accepted by the Society.

Note 1: Rule Note NR533, Approval of Service Suppliers gives details about the certification.

2.3.2 All transits are to be examined to confirm their satisfactory condition and the Cable Transit Seal Systems Register is to be reviewed to confirm it is being maintained. The class renewal survey is to be recorded in the Cable Transit Seal Systems Register, in which a single record entry will be sufficient to record the survey of all transits.

2.3.3 From review of the Cable Transit Seal Systems Register, where there are records entered since the last class renewal survey of any disruption to the cable transits or installation of new cable transits (except which are reviewed and examined at previous annual surveys), the satisfactory condition of those transits is to be confirmed by the attending Surveyor by review of records and examination of the transits; the results are to be recorded in the Cable Transit Seal Systems Register against each of those cable transits.

2.3.4 In case the cable transits have been examined by an approved service supplier, the attending surveyor is to review the Cable Transit Seal Systems Register in order to ascertain that it has been properly maintained by the owner and correctly endorsed by the service supplier.

2.4 Holds and other dry compartments

2.4.1 Holds, 'tweendecks, cofferdams, pipe tunnels and duct keels, void spaces and other dry compartments which are integral to the hull structure are to be internally examined, ascertaining the condition of the structure, bilges and drain wells, sounding, venting, pumping and drainage arrangements.

At class renewal survey No.3 and subsequent class renewal surveys, structural down flooding ducts and structural ventilation ducts are to be internally examined.

2.4.2 Machinery and boiler spaces, pump rooms and other spaces containing machinery are to be internally examined, ascertaining the condition of the structure. Particular attention is to be given to tank tops, shell plating in way of tank tops, brackets connecting side shell frames and tank tops, and bulkheads in way of tank tops and bilge wells. Particular attention is to be given to the sea suctions, sea water cooling pipes and overboard discharge valves and their connections to the shell plating. Where wastage is evident or suspected, thickness measurements are to be carried out, and renewals or repairs effected when wastage exceeds allowable limits.

Piping systems inside these spaces are to be dealt with according to [3.5].

2.4.3 Chain lockers are to be internally examined, while the anchor chains are ranged as required for the bottom survey in dry condition (see [2.1.3]). The pumping arrangement of the chain lockers is to be tested.

2.5 Tanks

2.5.1 The type and number of tanks to be internally examined at each class renewal survey are detailed in Tab 2, according to the age of the ship.

This internal examination is to ascertain the condition of the structure, bilges and drain wells, sounding, venting, pumping and drainage arrangements, including piping systems and their fittings. Due attention is to be given to plating or double plates below the lower end of sounding and suction pipes.

Where the inner surface of the tanks is covered with cement or other compositions, the removal of coverings may be waived provided they are examined, found sound and adhering satisfactorily to the steel structures.

Note 1: For examination of independent (non-structural) tanks, refer to [3.5.9].

Note 2: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested when the ship is more than 10 years old.

Note 3: For examination of independent (non-structural) storage tanks for fuel for auxiliary vehicles covered by Pt C, Ch 4, Sec 11, refer to [2.5.6].

2.5.2 Where provided, the condition of corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a hard protective coating is found in poor condition and it is not renewed, where soft or semi-hard coating has been applied or where a hard protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the surveyor.

When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi hard coating has been applied, or where a hard protective was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

Table 2 : Requirements for internal examination of integral (structural) tanks at class renewal survey

Tank	Age of ship (in years at time of class renewal survey)			
	Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤15	Class renewal survey No.4 and subsequent age > 15
Peaks (all use)	all	all	all	all
Ballast tanks (all types)	all	all	all	all
Fresh water	none	one	all	all
Fuel oil bunkertanks:				
• Engine room	none	none	one	one
• Cargo length area	none	one	two **(1)**	half, minimum 2 **(1)**
• If no tanks in cargo length area, additional fuel tank(s) outside of Engine room (if fitted)	none	one	one	two
Lubricating oil tanks	none	none	none	one
Cargo tanks	all	all	all	all
Storage tanks for fuel for auxiliary vehicles covered by Pt C, Ch 4, Sec 11.	none	none	one	one

(1) One deep tank is to be included, if fitted.

Note 1: Independent non-structural tanks are to be surveyed according to [3.5.9].

Note 2: The extent of the survey of tanks dedicated to liquids other than those indicated in this table will be considered by the Society on a case by case basis according to the nature of the liquids.

Note 3: If a selection of tanks is accepted to be examined, then different tanks are to be examined at each class renewal survey, on a rotational basis. Tanks not internally examined may be examined externally from accessible boundaries.

2.5.3 Boundaries of double bottom, deep, ballast, peak and other tanks, both integral and independent tanks, including holds adapted for the carriage of salt water ballast, are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds.

2.5.4 Boundaries of fuel oil, lube oil and fresh water tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil, lube oil and fresh water tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results. The surveyor may extend the testing as deemed necessary.

2.5.5 For integral tanks which are intended to contain liquid cargoes such as edible oil, the Surveyor may waive the requirement specified in [2.5.4] subject to a satisfactory internal examination.

2.5.6 Non-structural storage tanks for fuel for auxiliary vehicles covered by Pt C, Ch 4, Sec 11, are to be externally examined; the relevant fittings, with particular regard to the remote-control shut-off valves under hydrostatic head, are to be externally examined and operationally tested to check that they are working properly and to verify the absence of cracks or leakage.

2.6 Thickness measurements

2.6.1 Thickness measurements are to be carried out according to the procedure detailed in Ch 2, Sec 2, [2.3].

The extent of thickness measurements is detailed in Tab 3, according to the age of the ship. The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine areas of substantial corrosion in accordance with the requirements of Tab 4. These extended thickness measurements are to be carried out before the survey is credited as completed.

Thickness measurements locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.

Thickness measurements of internals may be specially considered by the Surveyor if the hard protective coating is in good condition.

Table 3 : Requirements for thickness measurements at class renewal survey

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤15	Class renewal survey No.4 and subsequent age > 15
Suspect areas throughout the vessel	Suspect areas throughout the vessel	Suspect areas throughout the vessel	Suspect areas throughout the vessel
	One transverse section of deck plating within the amidships 0,5 L (in way of a cargo space, if applicable)	Two transverse sections within the amidships 0,5L (in way of two cargo spaces, if applicable) **(2)**	A minimum of three transverse sections within the amidships 0,5L (in way of cargo spaces, if applicable) **(2)**
		All cargo hold hatch covers and coamings **(1)**	
		Internals in fore peak and after peak ballast tanks	
			All exposed main deck plating full length.
			Representative exposed superstructure deck plating (poop, bridge, and forecastle deck).
			Lowest strake and strakes in way of 'tween decks of all transverse bulkheads in cargo spaces together with internals in way.
			All wind – and water strakes, port and starboard, full length.
			All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space, and aft end of tanks.
			Plating of sea chests. Shell plating in way of overboard discharges as considered necessary by the attending surveyor

(1) Including plates and stiffeners.

(2) For ships less than 100 m in length, the number of transverse sections required when the ship's age is between 10 and 15 years may be reduced to one and the number of transverse sections required at subsequent class renewal surveys may be reduced to two. For ships more than 100 m in length, when the ship's age is between 10 and 15 years, thickness measurements of exposed deck plating within amidship 0,5 L may be required.

Note 1: Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, thickness measurement is to be done of the accessible parts of hatch cover structures.

Table 4 : Guidance for additional thickness measurements in way of substantial corrosion areas

Structural member	Extent of measurements	Pattern of measurements
Plating	Suspect area and adjacent plates	5 point pattern over 1 square metre
Stiffeners	Suspect area	3 measurements each in line across web and flange

2.7 Independent cargo tanks

2.7.1 All independent cargo tanks are to be cleaned and examined internally, as well as their liquid-level indicators.

2.7.2 When accessible, the outer surface of uninsulated cargo tanks or the outer surface of cargo tank insulation is to be examined.

Special attention is to be given to the tank and insulation in way of chocks, supports, keys, anti-rolling/pitching systems.

Removal of insulation, in part or entirely, may be required in order to verify the condition of the tank or the insulation itself if deemed necessary by the Surveyor.

2.7.3 Thickness measurements may be required if deemed necessary by the Surveyor.

2.7.4 The tightness of all cargo tanks is to be verified by an appropriate procedure.

2.7.5 The pressure relief valves for the cargo tanks are to be opened for examination, adjusted, function tested and sealed. Where a proper record of continuous overhaul and re-testing of individually identifiable relief valves is maintained, consideration may be given to acceptance on the basis of opening, internal examination and testing of a representative sample of valves, including each size and type of relief valves in use, provided there is evidence in the log-book that the remaining valves have been overhauled and tested since crediting of the previous class renewal survey.

2.7.6 The cargo containment venting system is to be examined.

2.7.7 All piping, equipment and machinery for loading, venting, heating or otherwise handling the cargo are to be examined. Insulation is to be removed as deemed necessary to ascertain the condition of the pipes.

If the visual examination raises doubts as to the integrity of the pipelines, a pressure test at 1,25 times the MARVS for the pipeline is to be carried out. After reassembly the complete piping systems are to be tested for leaks.

2.7.8 All emergency shutdown and quick-closing valves in the cargo piping systems are to be examined and proven operable. A random selection of valves is to be opened up for examination.

2.7.9 Holds around cargo tanks are to be internally examined. In case of ships built without longitudinal bulkhead in the centre line of the ship, and fitted with long deck beams, the welded connections between the deck beams and the plating of the double hull spaces are to be thoroughly examined.

3 Machinery and systems

3.1 General

3.1.1 The survey items listed below are to be covered to the satisfaction of the Surveyor. However, other survey alternatives deemed equivalent by the Surveyor in relation to the characteristics and general condition of the ship concerned may also be accepted.

As part of the Class Renewal Survey of Machinery, a dock trial is to be carried out, to the satisfaction of the attending Surveyor, to confirm satisfactory operation of main and auxiliary machinery. If significant repairs are carried out to main or auxiliary machinery or steering gear, consideration is to be given to a sea trial, to the satisfaction of the attending Surveyor.

If the significant repairs as stated above, is considered by the Society to have any impact on response characteristics of the propulsion systems, then the scope of sea trial shall also include a test plan for astern response characteristics based on those required for such an equipment or system when fitted to the new ship. Refer to Pt C, Ch 1, Sec 18, [3.3.2] for astern testing requirements.

The tests are to demonstrate the satisfactory operation of the equipment or system under realistic service conditions at least over the manoeuvring range of the propulsion plant, for both ahead and astern directions.

Depending on the actual extent of the repair, the Society may accept a reduction of the test plan.

Note 1: Attention is drawn to the requirement Ch 2, Sec 2, [2.5.1] regarding safe execution of surveys, in particular as regards health hazards related to asbestos.

3.2 Main and auxiliary engines and turbines

3.2.1 General

Depending on the type of machinery, the following parts are to be opened up as necessary for inspection, unless surveyed in accordance with Ch 2, Sec 2, [4.3.6], items e) and f). Parts and components are to be pressure tested as appropriate or as deemed necessary by the Surveyor. A working test is also to be carried out, including testing of alarms and safety devices.

3.2.2 Internal combustion engines

a) Columns and entablature

b) Cylinders with their liners, cylinder covers (together with valves and valve gear), pistons with their rods, crossheads, slippers and guides (or gudgeon pins), connecting rods (with their top and bottom end bearings), control gear, driven scavenge pumps, driven air compressors, driven fuel pumps, supercharging blowers, fuel injection pumps, turning gear, etc.

c) Crankshafts (together with their main bearings)

d) Reverse gear, reduction gear and clutches, if fitted.

3.2.3 Steam turbines

a) Condensers and their cooling water and condensate extraction pumps

b) Casings and rotors (including their blading), impulse wheels (including guide blading and diaphragms), nozzles and nozzle boxes, journals and bearings, dummy pistons, labyrinths, external glands, etc.

c) Shafts, including their flexible couplings.

Where the propulsion steam turbines are of a well-known type, and fitted with rotor position indicators and vibration indicators of an approved type, as well as measuring equipment of steam pressure at proper locations along the steam flow, and the arrangements for change-over in the event of emergency operation of the plant are readily operable, the first class renewal survey may be limited to the examination of rotor bearings, thrust bearings and flexible couplings, provided the Surveyor is satisfied from operation service records and power trials subsequent to the survey, that the turbine plant is in good working condition.

3.2.4 Gas turbines

a) Casings, rotors and disks, impellers and blading of all turbines and compressors, combustion chambers, burners, heat exchangers, gas piping, compressed air piping with fittings, starting and reverse arrangements

b) Shafts and their flexible couplings.

3.2.5 Electric propulsion

Where the propulsion machinery consists of an electrical system, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined and the insulation resistance to earth tested. Due attention is to be given to windings, commutations and sliprings. The operation of protective gear and alarm devices is to be checked, as far as practicable. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly.

3.2.6 Thruster installations

When the ship is equipped with thruster installations, the class renewal survey is also to include:

- an examination of the machinery and electrical installation, as applicable
- an external examination of the propulsive part of the installation to be carried out at the dry dock survey due as part of the class renewal survey. During this examination other checks such as clearance readings, tightness of hub and blade sealing for controllable pitch propellers are to be verified. Locking arrangements for bolts, if fitted, are to be checked. Results of lubricating oil analysis to detect possible deterioration of internal gears and bearings or the presence of water are to be confirmed as acceptable. The Manufacturer's requirements may be taken into account. Dismantling of the assembly for the examination of internal parts may be required if the foregoing checks are not satisfactory
- a running test of the system under operating conditions.

3.2.7 Pod propulsion systems

When the ship is equipped with pod propulsion systems, the class renewal survey is to include the examination of:

- electric propulsion motors and associated equipment, see [3.2.5]
- pod orientation device (gears and wheels, hydraulic/ electric system, sealing arrangements)
- oil lubricating system of shaft bearings
- bilge system inside pod
- ventilation and cooling system
- rotating commutator
- alarm system.

3.3 Reduction gears, main thrust and intermediate shaft(s)

3.3.1 Reduction gears complete with all wheels, pinions, shafts, couplings, bearings and gear teeth, including incorporated clutch arrangements, are to be opened up, as deemed necessary by the Surveyor, for visual inspection. For complicated assemblies, gears and roller bearings may be surveyed without dismantling.

3.3.2 All shafts, thrust blocks and bearings are to be examined.

3.4 Pumps and other machinery items

3.4.1 General

The items listed in [3.4.2] are to be opened up, as deemed necessary by the Surveyor, for visual inspection. Their parts and components are to be pressure tested as appropriate and considered necessary by the Surveyor. A working test is also to be carried out, including testing of alarms and safety devices if deemed necessary by the Surveyor.

3.4.2 Items to be surveyed

a) Air compressors with their intercoolers, filters and/or oil separators and safety devices

b) Heat exchangers, ventilation fans for boilers and other equipment used for essential services

c) Piston pumps and centrifugal pumps for sea water, bilge and salt water ballast

d) Screw pumps, gear pumps and centrifugal pumps other than those listed in c) above (opening up is not required).

3.5 Systems in machinery spaces

3.5.1 Valves, cocks and strainers of the bilge and ballast systems are to be opened up, as deemed necessary by the Surveyor, for visual inspection, and, together with the piping and safety devices, examined and tested under working conditions.

3.5.2 The fuel oil, lubricating oil, hydraulic oil, thermal oil, and feed and cooling water systems, together with pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. Safety devices for the foregoing items are to be examined.

3.5.3 The compressed air system together with its valves, fittings and safety devices is to be examined, as considered necessary by the Surveyor.

3.5.4 Compressed air receivers and other pressure vessels for essential services are to be cleaned internally and examined internally and externally. Their fittings, valves and safety devices are to be opened up, as deemed necessary by the Surveyor, for visual inspection and pressure tested as appropriate.

3.5.5 Steel pipes for superheated steam having a temperature of the steam at the superheater outlet exceeding 450°C are to be examined and tested in accordance with [3.5.7] to [3.5.8] at each class renewal survey.

3.5.6 Steel pipes for saturated steam or superheated steam having a temperature of the steam at the superheater outlet not exceeding 450°C are to be examined and tested in accordance with [3.5.7] to [3.5.8] at each class renewal survey for ships over 5 years of age. When the ship is 5 years of age or less, the inspection may be limited to a check of the satisfactory general condition of pipes.

3.5.7 The examination and hydrostatic test of steel pipes for main steam machinery, and steel pipes for auxiliary steam machinery having internal diameter 75 mm and over, are to be carried out on a number of pipes selected by the Surveyor after the lagging in way is removed.

3.5.8 Representative pipe lengths connected with bolted flanges are to be internally and externally examined, and hydrostatically tested to 1,1 times the working pressure at ambient temperature. Bolts and butt-welded joints between flanges and pipes are to be submitted to a non-destructive test for crack detection.

3.5.9 Non-structural tanks located in machinery spaces are to be externally examined; the relevant fittings, with particular regard to the remote control shut-off valves under hydrostatic head, are to be externally examined and operationally tested to check that they are working properly and to verify the absence of cracks or leakage.

3.5.10 When the ship is equipped with a refrigerating plant (whether or not covered by an additional class notation), the class renewal survey is to include:

- examination and test at the design pressure of the parts of the plant under pressure
- for refrigerating machinery spaces using ammonia as refrigerant:
  - examination and test of the water-spraying fire-extinguishing system to the same extent as indicated in [3.8.3], item d)
  - examination of valves and pumps of the bilge system to the same extent as indicated in [3.4]
  - examination and test of the electrical equipment to the same extent as indicated in [3.6.11]
  - test of the gas detection system.

3.5.11 When the ship is equipped with a ballast water treatment system using an inert gas generator and where this inert gas generator is used solely for the purpose of ballast water treatment, the class renewal survey is to include the relevant items of Ch 4, Sec 3, [7.3].

3.6 Electrical equipment and installations

3.6.1 An electrical insulation resistance test is to be performed on the electrical equipment and cables. If needed, for the purpose of this test, the installation may be subdivided or equipment which may be damaged disconnected.

3.6.2 The following minimum values, when performing the insulation test, are to be considered:

- for main and emergency switchboards, feeder circuit breakers being open, busbar circuit closed, measuring and monitoring instruments disconnected, the resistance of insulation measured across each insulated busbar and the hull, and across insulated busbars, should not be less than 1 megohm
- for generators, the equipment and circuits normally connected between the generator and the first circuit breaker being connected, the resistance of insulation (preferably at working temperature whenever possible), in ohms, is to be greater than 1 000 times the rated voltage, in volts. If appropriate, the Surveyor checks also that the insulation resistance of generators separate exciter gear is not less than 1 megohm
- the insulation resistance of the entire electrical system is to be checked with all circuit breakers and protective devices closed, except for generators; in general, the resistance should not be less than 100 000 ohms. However, the variation of the resistance with time is to be checked, comparing the current figure with previous readings. If the insulation resistance was to drop suddenly or be insufficient, the defective circuits are to be traced, disconnecting the circuits as much as necessary.

3.6.3 The prime movers of generators are to be surveyed in accordance with [3.2] and their governors tested. All generators are to be presented for inspection, clean and with covers opened and examined under working conditions.

3.6.4 Main and emergency switchboards, section boards and distribution boards are to be cleaned and doors or covers opened for examination of their fittings. The condition of overcurrent protective devices and fuses is to be checked. Circuit-breakers of generators are to be tested, as far as practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily. It is to be verified that there are no loose connections on busbar.

3.6.5 Electrical cables and cable runs are to be examined at random, in particular in places where deterioration is likely to occur; terminal boxes of essential services are also to be subjected to a random check.

3.6.6 The motors and starters concerning essential services together with associated control and switchgear are to be examined and, if considered necessary by the Surveyor, checked, as far as practicable, under working conditions.

3.6.7 Navigation light indicators are to be tested under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

3.6.8 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

3.6.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

3.6.10 The visible condition of electrical equipment and installations is also to be checked as regards precautions against shock, fire and other hazards of electrical origin.

3.6.11 A general examination of the electrical equipment in areas where there may be flammable gas or vapour and/or combustible dust is to be carried out to ensure that the integrity of the electrical equipment of a safety type has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust-protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in satisfactory condition. The proper condition of bonding straps for the control of static electricity is to be checked. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation.

Note 1: Owners are reminded that maintenance, repairs or renewal of certified electrical equipment of a safe type remains their responsibility or that of their representatives.

3.6.12 The survey is also to cover the computerized systems. This survey includes checking that revision of software mentioned in the records corresponds with revision effectively used for all computerized systems.

For ships assigned the additional service feature **SW-Registry**, this survey is also to include:

- checking of modification of Software Registry, in particular the reporting of security checks during software modification inside the Software Registry
- checking that Software Registry has been updated according to the last ship relevant modifications.

3.6.13 For ships where the electrical distribution system includes harmonic filters, the survey is to include:

- annual measurement, as a minimum, of the harmonic distortion levels of main busbars under seagoing conditions as close to the periodical machinery survey as possible so as to give a clear representation of the condition of the entire plant to the surveyor. Harmonic distortion readings are to be carried out when the greatest amount of distortion is indicated by the measuring equipment. An entry showing which equipment was running and/or filters in service is to be recorded in the log so this can be replicated for the next periodical survey. Harmonic distortion levels are also to be measured following any modification to the ship's electrical distribution system or associated consumers by suitably trained ship's personnel or by a qualified outside source.
- verification that records of all above measurements are made available to the surveyor at each periodical survey.

Note 1: Those requirements apply at any scheduled machinery periodical survey having a due date on or after 1st July 2017 for ships contracted for construction before 1st July 2017.

- for ships contracted for construction on or after 1st July 2017, verification that the facilities used for continuous monitoring of the levels of harmonic distortion experienced on the main busbars as well as alerting the crew when the level of harmonic distortion exceeds the acceptable limits are working properly and review of corresponding records.

3.6.14 For Li-Ion batteries of a capacity above 20kWh or used as emergency source or transitional source, the requirements given in Ch 3, Sec 1, [3.3.5] for annual survey are to be complied with.

In addition:

- a comprehensive test of indication and alarms is to be carried out
- the traceability of cells replacement is to be checked
- the traceability of software modification is to be checked
- a battery capacity (State of Health - SOH) test is to be witnessed when:
  - release of flammable or toxic gases during battery operation was identified
  - loss of battery might jeopardize the manoeuvrability of the ship.

3.6.15 For batteries used for electrical supply of pods, the requirements given in Ch 3, Sec 1, [3.3.6] for annual survey are to be complied with.

In addition the class renewal survey is to include:

- verification of the quality of the power supply
- examination of the fire-extinguishing system as applicable in accordance with the relevant requirements given in [3.8].

3.7 Controls

3.7.1 Where remote and/or automatic controls, not covered by an additional class notation related to automated installation, are fitted for essential machinery, they are to be tested to demonstrate that they are in satisfactory condition.

3.8 Fire protection, detection and extinction

3.8.1 The Owner or his representative is to declare to the attending Surveyor that no significant changes have been made to the arrangement of structural fire protection.

Note 1: Attention is drawn to the provisions of Ch 1, Sec 1, [3.1.1] regarding compliance with any additional and/or more stringent requirements issued by the Administration of the State whose flag the ship is entitled to fly.

3.8.2 The class renewal survey of fire prevention arrangements is to cover the following items.

a) Visible parts of items forming part of structural fire protection arrangements in accommodation spaces and in machinery spaces such as bulkheads, decks, doors, stairways, crew and service lift trunks, and light and air trunks are to be examined, due attention being given to their integrity and that of the insulating material.

b) The operation of manual/automatic fire doors, where fitted, is to be checked.

c) Remote controls for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, remote controls for stopping fans in accommodation spaces and means of automatically shutting off the electrical power of the deep-fat cooking equipment upon activation of the fire-extinguishing system are to be tested.

d) Closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnels, where applicable, are to be tested.

e) Fire and/or smoke detection and alarm systems are to be tested.

3.8.3 The survey requirements for all types of fire-fighting systems that are usually found on board ships related either to machinery spaces or to cargo areas and/or spaces or to accommodation spaces, irrespective of the service notation assigned, are the following:

a) water fire system
   - the associated pumps are to be opened up and examined at the Surveyor's discretion
   - the fire main is to be hydrostatically tested to the working pressure at the Surveyor's discretion

b) fixed gas fire-extinguishing system

   Receivers of CO_2 (or other gas) fixed fire-extinguishing systems are to be externally examined together with all stationary fittings and devices. In addition, the following applies:
   - the total loss of CO_2 is not to exceed 10% of the installed quantity (5% for Halon)
   - after being repaired or discharged, containers are to be subjected to a hydrostatic test
   - hydrostatic testing of high pressure CO_2 containers is to be carried out at intervals not exceeding 10 years; the number of the tested containers is to be not less than 10% of the total number. If one or more cylinders fail, a total of 50% of the onboard cylinders are to be tested. If further cylinders fail, all cylinders are to be tested. Before the 20-year anniversary and every 10-year anniversary thereafter, all cylinders are to be subjected to a hydrostatic test.
   - low pressure CO_2 containers are to be internally surveyed if the content has been released and the container is older than five years; depending upon the result of the internal examination, the Surveyor may require the container to be hydrostatically tested.

   It is to be checked that the distribution pipework is proved clear.

c) sprinkler system
   - the associated pumps are to be opened up and examined at the Surveyor's discretion

d) water-spraying system
   - the associated pumps are to be opened up and examined at the Surveyor's discretion
   - a working test is to be carried out as far as reasonable and appropriate

e) fixed foam systems (low or high expansion)
   - the associated pumps are to be opened up and examined at the Surveyor's discretion

f) dry powder system
   - it is to be verified that the propelling inert gas bottles have been hydrostatically tested. The same applies to bottles disembarked for refilling or embarked for replacement.

3.8.4 As far as other fire-fighting equipment is concerned, the following items are to be hydrostatically tested, at intervals not exceeding 10 years:

- any CO_2 bottles of extinguishers
- shells of foam extinguishers
- shells of powder extinguishers
- air or gas bottles associated with fire extinguishers whose shells are not kept under pressure (if internally examined, the test need not be performed).

3.8.5 Where a helideck is fitted, the following is to be checked, as far as appropriate:

- drainage arrangements around the landing area
- fire fighting appliances and arrangements (to be surveyed as per [3.8.3] and [3.8.4], according to the equipment installed)
- other arrangements for helicopter refuelling and hangar facilities (fuel system, ventilation, fire protection and detection).

3.9 Hold, ballast and dry spaces water level detectors

3.9.1 For ships subject to compliance with the requirements laid down in Ch 6, Sec 2, [6], or in Ch 6, Sec 4, [2], or in Pt B, Ch 2, Sec 1, [2.2], the class renewal survey is to include an examination and a test of the water ingress detection systems and of their alarms.

3.10 Availability of pumping systems

3.10.1 For ships subject to compliance with the requirements laid down in Ch 6, Sec 2, [7], or in Pt C, Ch 1, Sec 10, [6.6.3], item e), the class renewal survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

Section 4 Bottom Survey

1 General

1.1

1.1.1 Examinations of the outside of ship's bottom and related items of ships is normally to be carried out with the ship in dry-dock or on a slipway. However, consideration may be given to alternate examination while the ship is afloat as an in-water survey, subject to provisions of Ch 2, Sec 2, [5.4] and [3] of this Section.

Note 1: for ships assigned with the service notation **yacht** or **charter yacht**, reference is made to the Rule Note NR500, Rules for the Classification and Certification of Yachts.

2 Bottom survey in dry condition

2.1 General requirements

2.1.1 When a ship is in dry-dock or on a slipway, it is to be placed on blocks of sufficient height and with the necessary staging to permit the examination of elements such as shell plating including bottom and bow plating, stern frame and rudder, sea chests and valves, propeller.

2.1.2 The shell plating is to be examined for excessive corrosion, or deterioration due to chafing or contact with the ground or for any undue unfairness or buckling. Special attention is to be paid to the connection between the bilge strakes and the bilge keels and to the plating of end structures (stem and sternframes). Important plate unfairness or other deterioration which do not necessitate immediate repairs are to be recorded.

2.1.3 Sea chests and their gratings, sea connections and overboard discharge valves and cocks and their fastenings to the hull or sea chests are to be examined. Sea valves and cocks need not be opened up more than once in a period of class unless considered necessary by the Surveyor.

For ships fitted with box coolers (chest coolers), the connection between the box cooler and the sea chest top plate are to be specifically examined from both sea side and inside (dry side) at bottom survey in drydock only.

2.1.4 Visible parts of the propeller(s), stern bush(es), propeller shaft boss, brackets and tightness system(s) are to be examined. The clearances of the propeller shaft(s) (or wear gauge) are to be checked and recorded. For controllable pitch propellers, the Surveyor is to be satisfied with the fastenings and tightness of hub and blade sealing.

Visible parts of side thrusters are to be examined. Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units) are to be examined externally with focus on the condition of gear housing, propeller blades, bolt locking and other fastening arrangements. Sealing arrangement of propeller blades, propeller shaft and steering column shall be verified.

Note 1: For the survey of propeller shafts, refer to Ch 3, Sec 5.

Dismantling is to be carried out, if considered necessary, notably where leakages are detected.

2.1.5 Visible parts of the rudder(s), rudder pintles, rudder stock and couplings as well as the sternframe are to be examined. If considered necessary by the Surveyor, the rudder(s) is (are) to be lifted or the inspection plates removed for the examination of pintles.

The clearances in the rudder bearings and the rudder lowering are to be checked and recorded.

Where applicable, pressure test of the rudder may be required as deemed necessary by the Surveyor.

2.2 Bottom survey held within the scope of class renewal survey

2.2.1 The examination and checks detailed in Ch 3, Sec 3, [2.1] are to be carried out as part of the class renewal survey. They are usually carried out during the bottom survey held concurrently with the class renewal survey.

3 Bottom in-water survey

3.1 General

3.1.1 An in-water survey may normally be carried out if the ship has been granted the additional class notation **INWATERSURVEY** as defined in Ch 1, Sec 2, [6.25.1]. Upon application by the Owner, the Society may also authorise, on a case-by-case basis, such bottom in-water survey for ships not assigned with the additional class notation **INWATERSURVEY**.

3.1.2 In principle, no outstanding conditions of class are to exist requiring repair work to be carried out to the underwater part of the shell plating, the rudder, the propeller or the propeller shaft, unless the Society is satisfied that such repairs may be carried out while the ship is afloat.

3.1.3 Proposals for in-water survey are to be submitted in advance of the survey by the Owner so that satisfactory arrangements can be agreed with the Society.

The in-water survey is to be carried out with the ship in sheltered water and preferably with weak tidal streams and currents. The in-water visibility and the cleanliness of the hull below the waterline are to be clear enough to permit a meaningful examination allowing the Surveyor and the in-water survey firm to determine the condition of the plating, the appendages and the welding.

The equipment, procedure for observing and reporting the survey are to be discussed with the parties involved prior to the in-water survey, and suitable time is to be allowed to permit the in-water survey firm to test all equipment beforehand.

3.1.4 The in-water survey is to be carried out under the surveillance of a Surveyor by an in-water survey firm approved as a service supplier by the Society according to Ch 2, Sec 2, [2.4].

The Surveyor is to be satisfied with the methods of orientation of the diver(s) or remotely operated vehicle (ROV) on the plating, which should make use where necessary of permanent markings on the plating at selected points and with the method of pictorial representation. An efficient two-way communication between the Surveyor and the diver(s) is to be provided.

3.1.5 The in-water survey is to provide the information normally obtained from a bottom survey in dry condition. Special consideration shall be given to ascertaining rudder bearing clearances and stern bush clearances of oil stern bearings based on a review of the operating history, on board testing and stern oil sample reports. These considerations are to be included in the proposals for in-water survey as required in [3.1.3].

Upon completion of the survey, the approved diving firm is to submit to the attending Society Surveyor a detailed report including video tapes, as well as a photographic documentation of the main parts inspected.

3.1.6 If the in-water survey reveals damage or deterioration that requires immediate attention, the Surveyor may require that the ship be drydocked in order that a detailed survey can be undertaken and the necessary repairs carried out.

Section 5 Tailshaft Survey

1 Survey of tailshafts

1.1 General

1.1.1 The different types of surveys to which tailshafts may be subjected and the intervals at which they are to be carried out are given in Ch 2, Sec 2, [5.5]. These surveys are:

- complete survey
- modified survey.

The requirements to be complied with at each survey are listed in [1.2] and [1.3].

1.2 Complete survey

1.2.1 The complete survey of tailshafts consists of the following, as applicable:

a) removal of propeller and key, where fitted, and their examination

Note 1: Where the propeller is fitted keyless to the shaft taper and where the additional class notation **MON-SHAFT** has been assigned, refer to item c), Note 3.

b) complete withdrawal of shaft to permit the examination of sterntube bearings (outboard or inboard depending on the type of shaft)

c) examination by an appropriate crack detection method of the after end of the cylindrical part of the shaft and forward one third of shaft cone, or the fillet of the flange in the case of a flanged coupling

Note 2: Refer also to Ch 2, Sec 2, [5.5.2], item b) where the crack detection test of the aft flange fillet area may be dispensed with for the solid flange couplings fitted at the end of the shaft.

Note 3: Refer also to Ch 2, Sec 2, [5.5.2], item b) where the propeller is fitted keyless to the shaft taper, and, where the additional class notation **MON-SHAF**T has been assigned, the non-destructive examination is carried out at intervals not exceeding 15 years.

d) examination of shaft bearing surfaces, liners, joints, threaded end and nut

e) examination of oil sealing glands with the necessary dismantling

f) measurements of clearances and/or wear (prior to and after the survey) and their recording

g) opening-up of controllable pitch propellers and examination of their working parts and control gear, if considered necessary.

1.2.2 Where the notation **MON-SHAFT** has been assigned as specified in Ch 1, Sec 2, [6.6.3], the tailshaft need not be withdrawn at the complete survey and items b) and d) of [1.2.1] need not be covered provided that all condition monitoring data (aft bearing temperature, consumption and analysis of lubricating oil) is found to be within permissible limits and the remaining requirements for the complete survey are complied with.

Where the Surveyor considers that the data presented is not entirely to his satisfaction, the shaft is to be withdrawn.

1.3 Modified survey

1.3.1 A modified survey may be carried out for those tailshafts which fulfil the conditions described in Ch 2, Sec 2, [5.5.3], where the periodicity of this type of survey is also shown.

The modified survey of water lubricated systems is eligible under the condition that the additional class notation **MON-SHAFT** has been assigned as specified in Ch 1, Sec 2, [6.6.3].

1.3.2 General

For the different types of shafts, the following is required:

a) for shafts with keyed propeller coupling:
   - removal of propeller and key, and their examination in way of the connection area
   - examination by an appropriate crack detection method of the after end of the cylindrical part of shaft and forward one third of shaft cone

b) for shafts with keyless type propeller coupling:
   - check of the tightness of the propeller hub (propeller hood, fore gland)

c) for shafts with a solid flange coupling at the aft end and variable pitch propeller:
   - check of tightness in way of blade glands and distribution box
   - check of analysis of hydraulic oil
   - working test, as far as practicable, of the blade manoeuvring.

1.3.3 See also Ch 2, Sec 2, [5.5.3] and Ch 5, Sec 6, [3], as relevant.

1.3.4 Where the Surveyor considers that the data presented is not entirely to his satisfaction, further dismantling may be required, including withdrawal of the tailshaft.

2 Periodical survey of other propulsion systems

2.1 Rotating and azimuth thrusters

2.1.1 The periodical survey of rotating and azimuth thrusters consists of:

a) removing the propeller(s) in order to examine the following items, as applicable:
   - exposed parts
   - cone and keyway to be checked by an appropriate crack detection method
   - sealing glands
   - threaded end and nut

b) examining the results of a lubricating oil analysis (water content and presence of material particles) to detect possible deterioration of internal gears and bearings

c) examining the orientation device.

If the foregoing checks are not satisfactory, dismantling of the internal parts may be required.

2.2 Vertical axis propellers

2.2.1 The periodical survey of vertical axis propeller systems consists of:

- checking the tightness of the oil glands and the backlash of the gears from outside by action on the blades
- checking the condition of gears and couplings from inside the ship
- examining the results of a lubricating oil analysis (water content and presence of material particles) to detect possible deterioration of internal gears and bearings.

If the foregoing checks are not satisfactory, dismantling of the internal parts may be required.

2.3 Pump jet systems

2.3.1 The periodical survey of pump jet systems consists of examining the following parts:

- impeller, shaft and clearances of bearings
- tightness of gland
- water duct
- steering nozzle
- reversing arrangements and control gear.

If the foregoing checks are not satisfactory, further dismantling may be required.

2.4 Pod propulsion systems

2.4.1 The scope of complete and - where applicable- modified survey of the pod propulsion system shafting arrangement is the one detailed in [1.2] and [1.3] for tailshafts.

2.4.2 Where the system is fitted with:

- a vibration monitoring of roll bearings
- a temperature monitoring of bearings, and
- a monitoring of automatic bilge pumping system,

the shaft need not be withdrawn at the complete survey and items b) and d) of [1.2.1] need not be covered provided that all condition monitoring data (vibrations and temperatures in way of bearings, consumption and analysis of lubricating oil, running rate of bilge system) are found to be within permissible limits and the remaining requirements for the complete survey are complied with.

Where the Surveyor considers that the data presented is not to his satisfaction, further dismantling are to be required.

3 Survey of propeller shafts and tube shafts

3.1 General

3.1.1 Application

Unless alternative means are provided to assure the condition of the propeller shaft assembly, these requirements apply to all ships with conventional shafting fitted with a propeller, as follows:

- from 1 January 2016, for ships delivered on or after 1 January 2016
- after the first shaft survey scheduled on or after 1 January 2016, for ships delivered before 1 January 2016.

Note 1: Note 1: Upon the completion of the first shaft survey scheduled on or after 1 January 2016, the designation of dates for the next shaft survey is to be made based upon the requirements of this Article.

3.1.2 Definitions

See also Fig 1.

a) Shaft

For the purpose of this Article, shaft is a general definition that includes:

- propeller shaft
- tube shaft.

The definition does not include the intermediate shafts which are considered as part of the propulsion shafting inside the ship.

b) Propeller shaft

Propeller shaft is the part of the propulsion shaft to which the propeller is fitted. It may also be called screwshaft or tailshaft.

c) Tube shaft

Tube shaft is a shaft placed between the intermediate shaft and the propeller shaft, normally arranged within a stern tube or running in open water. It may also be called sterntube shaft.

d) Sterntube

Tube or pipe fitted in the shell of a ship at the stern (or rear part of the ship), below the waterline, through which passes the tube shaft or the aftermost section of the propeller shaft.

Sterntube is the housing of the shaft bearings, generally two (one aft and one fore), that sustain the shaft and allow its rotation with less frictional resistance. The sterntube also accommodates the shaft sealing arrangement.

e) Closed loop (system) oil lubricated bearing

Closed loop oil lubricating systems use oil to lubricate the bearings and are sealed against the environment (seawater) by adequate sealing/gland devices.

f) Water lubricated bearing

Water lubricated bearings are bearings cooled/lubricated by water (fresh or salt).

g) Closed loop (system) fresh water lubricated bearing

Closed loop water lubricating systems use fresh water to lubricate the bearings and are sealed against the environment (such as seawater) by adequate sealing/gland devices.

h) Open systems (water)

Open water lubricating systems use water to lubricate the bearings and are exposed to the environment.

i) Adequate means for protection against corrosion

An adequate means for protection against corrosion is an approved means for full protection of the core shaft against sea water intrusion and subsequent corrosion attack. Such means are used for the protection of common steel material against corrosion, particularly in combination with water lubricated bearings.

Typical means are, for example:

- continuous metallic, corrosion resistant liners
- continuous cladding
- multiple layer synthetic coating
- multiple layer of fibreglass
- combinations of above mentioned
- rubber/elastomer covering coating.

The means for protection against corrosion are installed/ applied according to class approved procedures.

j) Corrosion resistant shaft

Corrosion resistant shaft is made in approved corrosion resistant steel as core material for the shaft.

k) Sterntube sealing system

Sterntube sealing system is the equipment installed on the inboard extremity and, for closed systems, at outboard extremity of the sterntube.

Inboard seal is the device fitted on the fore part of the sterntube that achieves the sealing against the possible leakage of the lubricant media into the ship internal.

Outboard seal is the device fitted on the aft part of the sterntube that achieves the sealing against the possible sea water ingress and the leakage of the lubricant media.

l) Service records

Service records are regularly recorded data showing in-service conditions of the shaft(s) and may include, as applicable: lubricating oil temperature, bearing temperature and oil consumption records (for oil lubricated bearings) or water flow, water temperature, salinity, pH, make-up water and water pressure (for closed loop fresh water lubricated bearings, depending on the design).

m) Oil sample examination

Oil sample examination is a visual examination of the sterntube lubricating oil taken in the presence of the Surveyor, with a focus on water contamination.

n) Lubricating oil analysis

Lubricating oil analysis is to be carried out at regular intervals not exceeding 6 months.

The documentation on lubricating oil analysis is to be available on board.

Oil samples, to be submitted for the analysis, should be taken under service conditions.

o) Fresh water sample test

Fresh water sample test should be carried out at regular intervals not exceeding 6 months

Samples are to be taken under service conditions and are to be representative of the water circulating within the sterntube.

Analysis results are to be retained on board and made available to the Surveyor.

At time of survey, the sample for the test is to be taken in the presence of the Surveyor.

Fresh water sample test shall include the following parameters:

- chlorides content
- pH value
- presence of bearing particles or other particles (only for laboratory analysis, not required for tests carried out in the presence of the Surveyor).

p) Keyless connection

Keyless connection is the forced coupling methodology, between the shaft and the propeller without a key, achieved through the interference fit of the propeller boss on the shaft tapered end.

q) Keyed connection

Keyed connection is the forced coupling methodology, between the shaft and the propeller with a key and a keyway, achieved through the interference fit of the propeller boss on the shaft tapered end.

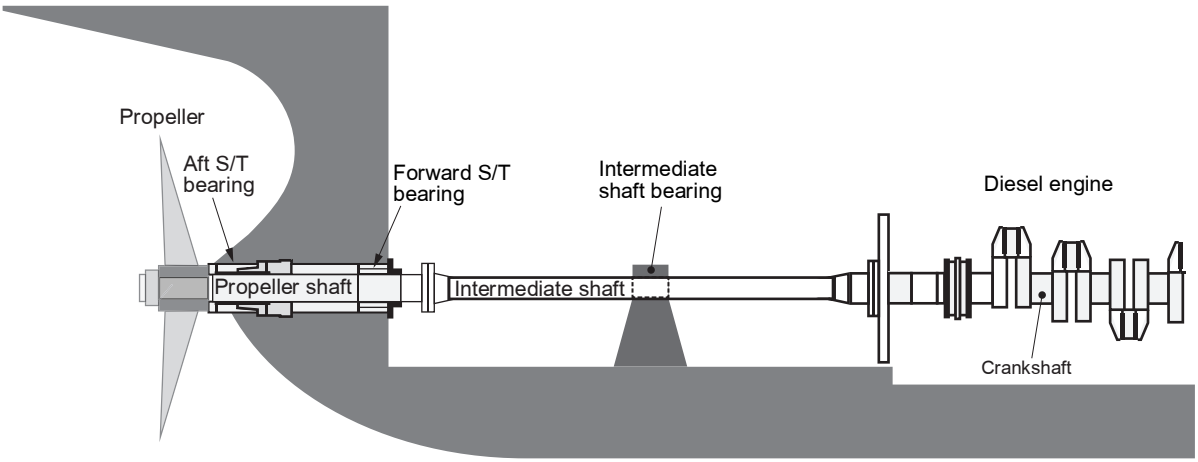
r) Flanged connection

Flanged connection is the coupling methodology, between the shaft and the propeller, achieved by a flange built-in at the shaft aft end and bolted to the propeller boss.

s) Alternative means

Shafting arrangements such as, but not limited to, an approved Condition Monitoring Scheme an/or other reliable approved means for assessing and monitoring the condition of the tail shaft, bearings, sealing devices and the sterntube lubricant system capable to assure the condition of the propeller shaft assembly with an equivalent level of safety as obtained by survey methods as applicable in [3.2] or [3.3].

Figure 1 : Typical shafting arrangement



3.2 Oil lubricated shafts or closed loop system fresh water lubricated shafts (closed system)

3.2.1 Shaft survey - Method 1

The survey is to consist in:

- Drawing the shaft and examining the entire shaft, seals system and bearings
- For keyed and keyless connections:
  - removing the propeller to expose the forward end of the taper
  - performing a non-destructive examination (NDE) by an approved surface crack detection method all around the shaft in way of the forward portion of the taper section, including the keyway (if fitted). For shaft provided with liners, the NDE shall be extended to the after edge of the liner
- For flanged connection:

  Whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs, or when deemed necessary by the Surveyor, the coupling bolts and the flange radius are to be examined by means of an approved surface crack detection method
- Checking and recording the bearing clearances
- Verifying that the propeller is free of damages which may cause the propeller to be out of balance
- Verifying the satisfactory conditions of inboard and outboard seals during reinstallation of the shaft and the propeller
- Recording the bearing wear measurements (after reinstallation).

3.2.2 Shaft survey - Method 2

The survey is to consist of:

- For keyed and keyless connections:
  - removing the propeller to expose the forward end of the taper
  - performing a non-destructive examination (NDE) by an approved surface crack detection method all around the shaft in way of the forward portion of the taper section, including the keyway (if fitted)
- For flanged connection:

  Whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs, or when deemed necessary by the Surveyor, the coupling bolts and the flange radius are to be examined by means of an approved surface crack detection method
- Checking and recording of the bearing wear measurements
- Visual inspection of all the accessible parts of the shafting system
- Verification that the propeller is free of damages which may cause the propeller to be out of balance
- Seal liner found to be or placed in a satisfactory condition
- Verification of the satisfactory reinstallation of the propeller, including verification of the satisfactory conditions of inboard and outboard seals.

Prerequisites, to satisfactorily verify in order to apply method 2, are the following ones:

- Review of service records
- Review of test records of:
  - lubricating oil analysis (for oil lubricated shafts), or
  - fresh water sample test (for closed system fresh water lubricated shafts)
- Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated shafts)
- Verification of no reported repairs by grinding or welding of shaft and/or propeller.

3.2.3 Shaft survey - Method 3

The survey is to consist of:

- Checking and recording of the bearing wear measurements
- Visual inspection of all the accessible parts of the shafting system
- Verification that the propeller is free of damages which may cause the propeller to be out of balance
- Seal liner found to be or placed in a satisfactory condition
- Verification of the satisfactory conditions of inboard and outboard seals.

Prerequisites, to satisfactorily verify in order to apply method 3, are the following ones:

- Review of service records
- Review of test records of:
  - lubricating oil analysis (for oil lubricated shafts), or
  - fresh water sample test (for closed system fresh water lubricated shafts)
- Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated shafts)
- Verification of no reported repairs by grinding or welding of shaft and/or propeller.

3.2.4 Shaft extension surveys - Extension types

a) Extension up to 2,5 years

The survey is to consist of:

- Checking and recording of the bearing wear measurements, as far as practicable
- Visual inspection of all the accessible parts of the shafting system
- Verification that the propeller is free of damages which may cause the propeller to be out of balance
- Verification of the effectiveness of the inboard seal and outboard seals.

Prerequisites, to satisfactorily verify in order to apply extension up to 2,5 years, are the following ones:

- Review of service records
- Review of test records of:
  - lubricating oil analysis (for oil lubricated shafts), or
  - fresh water sample test (for closed system fresh water lubricated shafts)
- Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated shafts)
- Verification of no reported repairs by grinding or welding of shaft and/or propeller
- Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

b) Extension up to 1 year

The survey is to consist of:

- Visual inspection of all the accessible parts of the shafting system
- Verification that the propeller is free of damages which may cause the propeller to be out of balance
- Verification of the effectiveness of the inboard seal and outboard seals.

Prerequisites, to satisfactorily verify in order to apply extension up to 1 year, are the following ones:

- Review of the previous wear and/or clearance recordings
- Review of service records
- Review of test records of:
  - lubricating oil analysis (for oil lubricated shafts), or
  - fresh water sample test (for closed system fresh water lubricated shafts)
- Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated shafts)
- Verification of no reported repairs by grinding or welding of shaft and/or propeller
- Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

c) Extension up to 3 months

The survey is to consist of:

- Visual inspection of all the accessible parts of the shafting system
- Verification of the effectiveness of the inboard seal.

Prerequisites, to satisfactorily verify in order to apply extension up to 3 month, are the following ones:

- Review of the previous wear and/or clearance recordings
- Review of service records
- Review of test records of:
  - lubricating oil analysis (for oil lubricated shafts), or
  - fresh water sample test (for closed system fresh water lubricated shafts)
- Oil sample examination (for oil lubricated shafts), or fresh water sample test (for closed system fresh water lubricated shafts)
- Verification of no reported repairs by grinding or welding of shaft and/or propeller
- Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

3.2.5 Oil lubricated shafts

a) Survey intervals (see Tab 1)

For surveys completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

1) Flanged propeller connection

The following methods are applicable:

- method 1 every 5 years, or
- method 2 every 5 years (prerequisites have to be fulfilled), or
- method 3 every 5 years (prerequisites have to be fulfilled).

2) Keyless propeller connection

The following methods are applicable:

- method 1 every 5 years, or
- method 2 every 5 years (prerequisites have to be fulfilled), or
- method 3 every 5 years (prerequisites have to be fulfilled).

The maximum interval between two surveys carried out according to method 1 or method 2 shall not exceed 15 years, except in the case when one extension for no more than three months is granted.

3) Keyed propeller connection

The following methods are applicable:

- method 1 every 5 years, or
- method 2 every 5 years (prerequisites have to be fulfilled).

b) Survey extensions (see Tab 1)

For all types of propeller connections, the interval between two consecutive surveys may be extended after execution of the extension survey, as follows:

- Extension up to a maximum of 2,5 years

  No more than one "2,5 year extension" can be granted. No further extension, of other type, can be granted.
- Extension up to a maximum of 1 year

  No more than two consecutive "one year extension" can be granted. In the event an additional extension is requested, the requirements of the "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.
- Extension up to a maximum of 3 months

  No more than one "three month extension" can be granted. In the event an additional extension is requested, the requirements of the "one year extension" or "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or 2,5 years.

The extension survey should normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date.

If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date the extension survey was completed.

Table 1 : Survey intervals for oil lubricated shafts (closed systems)

	Flanged propeller coupling	Keyless propeller coupling	Keyed propeller coupling **(2)**
Every five years **(1)**	method 1 or method 2 or method 3	method 1 or method 2 or method 3 **(3)**	method 1 or method 2
Extension 2,5 Y	yes **(4)**	yes **(4)**	yes **(4)**
Extension 1 Y	yes **(5)**	yes **(5)**	yes **(5)**
Extension 3 M	yes **(6)**	yes **(6)**	yes **(6)**

Note 1: For surveys (method 1, or method 2, or method 3) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

The extension survey should normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date the extension survey was completed.

(1) Unless an extension type (extension 2,5 Y, or extension 1 Y, or extension 3 M) is applied in between.

(2) Method 3 is not allowed.

(3) The maximum interval between two surveys carried out according to method 1 or method 2 shall not exceed 15 years, except in the case when one extension for no more than three months is granted (i.e. a sequence of surveys carried out according to method 3 cannot exceed a 15-years time interval, plus possibly one extension not exceeding three months).

(4) No more than one "2,5 year extension" can be granted. No further extension, of other type, can be granted.

(5) No more than two consecutive "one year extension" can be granted. In the event an additional extension is requested, the requirements of the "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.

(6) No more than one "three month extension" can be granted. In the event an additional extension is requested, the requirements of the "one year extension" or "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or 2,5 years.

3.2.6 Closed loop system fresh water lubricated shafts

The maximum interval between two surveys carried out according to method 1 shall not exceed 15 years. An extension for no more than three months can be granted.

a) Survey intervals (see Tab 2)

For surveys completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

1) Flanged propeller connection

The following methods are applicable:

- method 1 every 5 years, or
- method 2 every 5 years (prerequisites have to be fulfilled), or
- method 3 every 5 years (prerequisites have to be fulfilled).

2) Keyless propeller connection

The following methods are applicable:

- method 1 every 5 years, or
- method 2 every 5 years (prerequisites have to be fulfilled), or
- method 3 every 5 years (prerequisites have to be fulfilled).

3) Keyed propeller connection

The following methods are applicable:

- method 1 every 5 years, or
- method 2 every 5 years (prerequisites have to be fulfilled).

b) Survey extensions (see Tab 2)

For all types of propeller connections, the interval between two consecutive surveys may be extended after execution of the extension survey, as follows:

- Extension up to a maximum of 2,5 years

  No more than one "2,5 year extension" can be granted. No further extension, of other type, can be granted.

- Extension up to a maximum of 1 year

  No more than two consecutive "one year extension" can be granted. In the event an additional extension is requested, the requirements of the "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.

- Extension up to a maximum of 3 months

  No more than one "three month extension" can be granted. In the event an additional extension is requested, the requirements of the "one year extension" or "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or 2,5 years.

The extension survey should normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date.

If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date the extension survey was completed.

The maximum interval between two surveys carried out according to method 1 shall not exceed 15 years, except in the case when one extension for no more than three months is granted.

Table 2 : Survey intervals for closed loop system fresh water lubricated shafts (closed systems)

	Flanged propeller coupling	Keyless propeller coupling	Keyed propeller coupling **(2)**
Every five years **(1)**	method 1 **(3)** or method 2 or method 3	method 1 **(3)** or method 2 or method 3	method 1 **(3)** or method 2
Extension 2,5 Y	yes **(4)**	yes **(4)**	yes **(4)**
Extension 1 Y	yes **(5)**	yes **(5)**	yes **(5)**
Extension 3 M	yes **(6)**	yes **(6)**	yes **(6)**

Note 1: For surveys (method 1, or method 2, or method 3) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

The extension survey should normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date the extension survey was completed.

(1) Unless an extension type (extension 2,5 Y, or extension 1 Y, or extension 3 M) is applied in between.

(2) Method 3 is not allowed.

(3) The maximum interval between two surveys carried out according to method 1 shall not exceed 15 years.

(4) No more than one "2,5 year extension" can be granted. No further extension, of other type, can be granted.

(5) No more than two consecutive "one year extension" can be granted. In the event an additional extension is requested, the requirements of the "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension(s), is extended for a maximum of 2,5 years.

(6) No more than one "three month extension" can be granted. In the event an additional extension is requested, the requirements of the "one year extension" or "2,5 year extension" are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year or 2,5 years.

3.3 Water lubricated shafts (open systems)

3.3.1 Shaft survey - Method 4

The survey is to consist in:

- Drawing the shaft and examining the entire shaft (including liners, corrosion protection system and stress reducing features, where provided), inboard seal system and bearings
- For keyed and keyless connections:
  - removing the propeller to expose the forward end of the taper
  - performing a non-destructive examination (NDE) by an approved surface crack detection method all around the shaft in way of the forward portion of the taper section, including the keyway (if fitted). For shaft provided with liners, the NDE shall be extended to the after edge of the liner
- For flanged connection:

  Whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs, or when deemed necessary by the Surveyor, the coupling bolts and the flange radius are to be examined by means of an approved surface crack detection method
- Checking and recording the bearing clearances
- Verifying that the propeller is free of damages which may cause the propeller to be out of balance
- Verifying the satisfactory conditions of inboard seal during reinstallation of the shaft and the propeller.

3.3.2 Shaft extension surveys - Extension types

a) Extension up to 1 year

The survey is to consist of:

- Visual inspection of all the accessible parts of the shafting system
- Verification that the propeller is free of damages which may cause the propeller to be out of balance
- Checking and recording of the clearances of bearing
- Verification of the effectiveness of the inboard seal.

Prerequisites, to satisfactorily verify in order to apply extension up to 1 year, are the following ones:

- Review of the previous clearance recordings
- Service records
- Verification of no reported repairs by grinding or welding of shaft and/or propeller
- Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

b) Extension up to 3 months

The survey is to consist of:

- Visual inspection of all the accessible parts of the shafting system
- Verification that the propeller is free of damages which may cause the propeller to be out of balance
- Verification of the effectiveness of the inboard seal.

Prerequisites, to satisfactorily verify in order to apply extension up to 3 months, are the following ones:

- Review of the previous clearance recordings
- Service records
- Verification of no reported repairs by grinding or welding of shaft and/or propeller
- Confirmation from the Chief Engineer that the shafting arrangement is in good working condition.

3.3.3 3.3.3Shaft survey intervals

a) Survey intervals (see Tab 3)

The following survey intervals according to method 4 are applicable to all types of propeller connections:

- for keyless propeller connections, the maximum interval between two consecutive dismantling and verifications of the shaft cone by means of non-destructive examination (NDE) shall not exceed 15 years
- for surveys completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

1) Configurations allowing 5 year intervals
   - single shaft operating exclusively in fresh water
   - single shaft provided with adequate means of corrosion protection, single corrosion resistant shaft
   - all kinds of multiple shafts arrangements.

2) Other systems

   Shaft not belonging to one of the configurations listed in item 1) has to be surveyed according to method 4 every 3 years.

b) Survey extensions (see Tab 3)

For all types of propeller connections, the interval between two consecutive surveys may be extended after execution of the extension survey, as follows:

- Extension up to a maximum of 1 year

  No more than one “one year extension” can be granted. No further extension, of other type, can be granted.
- Extension up to a maximum of 3 months

  No more than one “three month extension” can be granted. In the event an additional extension is requested, the requirements of the “one year extension” are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year.

The extension survey should normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date.

If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date the extension survey was completed.

Table 3 : Survey intervals for water lubricated shafts (open systems)

	All kinds of propeller coupling **(4)**	
• Single shaft operating exclusively in fresh water • Single shaft provided with adequate means of corrosion protection, single corrosion resistant shaft • All kinds of multiple shaft arrangements	Every five years **(1)**	Method 4
	Extension 1 Y	yes **(2)**
	Extension 3 M	yes **(3)**

	All kinds of propeller coupling **(4)**	
Other shaft configuration	Every three years **(1)**	Method 4
	Extension 1 Y	yes **(2)**
	Extension 3 M	yes **(3)**

Note 1: For surveys (method 4) completed within 3 months before the shaft survey due date, the next period will start from the shaft survey due date.

The extension survey should normally be carried out within 1 month of the shaft survey due date and the extension counts from the shaft survey due date. If the extension survey is carried out more than 1 month prior to the shaft survey due date, then the period of extension counts from the date the extension survey was completed.

(1) Unless an extension type (extension 1 Y, or extension 3 M) is applied in between.

(2) No more than one “one year extension” can be granted. No further extension, of other type, can be granted.

(3) No more than one “three month extension” can be granted. In the event an additional extension is requested, the requirements of the “one year extension” are to be carried out and the shaft survey due date, prior to the previous extension, is extended for a maximum of one year.

(4) For keyless propeller connections, the maximum interval between two consecutive dismantling and verifications of the shaft cone by means of non-destructive examination (NDE) shall not exceed 15 years.

Section 6 Boiler Survey

1 Steam boilers

1.1

1.1.1 Steam boilers, superheaters and economisers are to be examined internally on water-steam side and fire side and externally with the periodicity given in Ch 2, Sec 2, [5.6]. To this end, boilers are to be emptied and suitably prepared for the examination, and the water-steam side and fire side are to be cleaned and cleared of soot. Where necessary, the external surfaces are to be made accessible for inspection by removal of insulation and lining.

1.1.2 Subject to the results of this visual examination, the Surveyor may require:

- non-destructive tests for detection of possible defects in critical areas of plating and shells, pipes and stays
- thickness measurements of plating and shells, furnaces, pipes and stays.

If appropriate, a new working pressure may be fixed by the Society.

When situated inside boiler combustion chambers, steam pipes of cylindrical boilers are to be examined at their ends, and if deemed necessary by the Surveyor, a sample pipe is to be removed for examination.

1.1.3 If the internal examination is not carried out for practicable reasons, the parts subject to pressure are to be submitted to a hydraulic test.

1.1.4 Boiler supports and securing arrangements (fixed and sliding seating, chocks, rolling stays, if any, etc.) are to be examined.

Boiler accessories and mountings (such as valves and studs, water level indicators, safety valves) are to be examined at each survey and opened out as considered necessary by the Society.

Forced circulation pumps of fired steam generators are, wherever possible, to be opened up.

Fuel supply pipes between pumps and burners, fuel tank valves, pipes and deck control gear are to be examined.

1.1.5 When direct visual internal inspection is not feasible due to limited size of the internal spaces, such as for small boilers and/or narrow spaces, this may be replaced by a hydrostatic pressure test or by alternative verifications as determined by the Society.

1.1.6 Upon completion of the internal survey, the boiler is to be examined under steam and fuel oil burners and safety devices checked under working conditions.

The adjustment of the safety valves is to be verified during each boiler internal examination.

Boiler safety valve and its relieving gear are to be examined and tested to verify satisfactory operation.

However, for exhaust gas heated economisers, if steam cannot be raised at port, it is the Chief Engineer's responsibility to set the safety valves at sea and the results are to be recorded in the log book for review by the Society.

1.1.7 Review of the following records since the last boiler survey is to be carried out as part of the survey:

- operation
- maintenance
- repair history
- feedwater chemistry.

1.1.8 In addition to the above requirements, in exhaust gas heated economisers of the shell type, accessible welded joints are to be subjected to a visual examination for cracking. Non-destructive testing may be required for this purpose.

1.1.9 For electrical steam generators, in addition to the above requirements on the water-steam side, the following items are to be verified:

- condition of the electrical insulation resistance of the heating elements
- verification of proper operation and functioning of indication, remote control, automatic alarm and safety devices
- verification of absence of signs of corrosion and leakage of water
- opening-up of forced circulation pumps, wherever possible.

2 Thermal oil heaters

2.1

2.1.1 Thermal oil heaters are to be internally and externally examined. The heater tubes are to be visually examined, and the tightness of the installation (including flange connections, valves and pumps) is to be checked through a test at the working pressure.

2.1.2 Thermal oil heater supports and securing arrangements are to be examined.

Heater accessories and mountings are to be externally and (as needed) internally examined.

Forced circulation pumps are, wherever possible, to be opened up.

Fuel supply pipes between pumps and burners, fuel tank valves, pipes and deck control gear are to be examined.

2.1.3 The following safety devices and instrumentation are to be examined and tested:

- thermal fluid temperature safety device and control
- thermal fluid flow meter
- device for low thermal fluid level in the expansion tank
- other regulation and safety systems.

2.1.4 Where repairs and/or renewal of components exposed to pressure are performed, a pressure test is to be carried out to 1,5 times the working pressure.

2.1.5 Upon completion of the survey, the thermal oil heater is to be examined under working conditions, with particular attention to safety devices and controls of the plant.

Section 7 Hull Survey for New Construction

1 General

1.1

1.1.1 In this Section, the Shipbuilder is understood as acting directly or on behalf of the Party requesting classification.

1.1.2 When a hull construction is surveyed by the Society the Shipbuilder is to provide all appropriate evidence required by the Society that the hull is built in compliance with the rules and regulations, taking account of the relevant approved drawings.

1.1.3 For oil tankers and bulk carriers subject to SOLAS Chapter II-1, Part A-1, Regulation 3-10 (goal-based ship construction standards for bulk carriers and oil tankers), the requirements as referred to in Article [6] and sub-articles [3.2] and [5.2] are applicable. https://marine-offshore.bureauveritas.com/rules-guidelines

2 Documentation to be available for the Surveyor during construction

2.1

2.1.1 During the construction, the Shipbuilder is to provide the Surveyors access to documentation required by the Society; this includes documentation retained by the Shipbuilder or other third parties.

2.1.2 The list of documents approved or reviewed by the Society for the specific new construction are to be made available by the Shipbuilder in due time for the Society during the construction as follows:

a) plans and supporting documents required in Ch 2, Sec 1, [2.3]

b) examination and testing plans

c) NDE plans

d) welding consumable details

e) welding procedures specifications & welding procedures qualification records

f) welding plan or details

g) welder's qualification records

h) NDE operators qualification records

i) hot spot map of the structure, when additional class notation **VeriSTAR-HULL CM** is assigned.

2.1.3 As required, evidence of compliance with Ch 2, Sec 1, [2.1.5] is also to be made available by the Shipbuilder to the Surveyor whilst the construction process proceeds to prove that the material and equipment supplied to the ship has been built or manufactured under survey relevant to the classification rules and delegated statutory requirements.

3 Ship construction file

3.1 Ship Construction File (SCF) for all ships, except those specified in [1.1.3]

3.1.1 The Shipbuilder is to deliver documents for the Ship Construction File. In the event that items have been provided by another Party such as the Shipowner and where separate arrangement have been made for document delivery which excludes the Shipbuilder, that Party has the responsibility.

The Ship Construction File shall be reviewed for content in accordance with the requirements of [3.1.3].

3.1.2 The Ship Construction File is to be placed on board the ship by the Shipbuilder to facilitate operation, maintenance, survey and repair.

3.1.3 The Ship Construction File is to include but not limited to:

- as-built structural drawings including scantling details, material details, and, as applicable, wastage allowances, location of butts and seams, cross section details and locations of all partial and full penetration welds, areas identified for close attention and rudders (Refer to Part A, Chapter 3 and Part A, Chapter 4)
- manuals required for classification and statutory requirements, e.g. loading and stability, bow doors and inner doors and side shell doors and stern doors – operations and maintenance manuals (Refer to Pt B, Ch 11, Sec 6, [8] and Pt B, Ch 11, Sec 7, [7]
- ship structure access manual, as applicable
- copies of certificates of forgings and castings welded into the hull (Refer to NR 216 Materials and Welding)
- details of equipment forming part of the watertight and weather tight integrity of the ship
- a Cable Transit Seal Systems Register, to be prepared by the shipbuilder for watertight cable transits. The Register can be in either a hard copy or digitized media. It is to include a marking / identification system, documentation referencing manufacturer manual(s) for each type of cable transit installed, the Type Approval certification for each type of transit system, applicable installation drawings, and a recording of each installed transit documenting the as built condition after final inspection in the shipyard. This is to include sections to record any inspection, modification, repair and maintenance
- tank testing plan including details of the test requirements (Refer to Pt B, Ch 13, Sec 6)
- corrosion protection specifications (Refer to Ch 4, Sec 2, Pt B, Ch 4, Sec 4 and Pt D, Ch 4, Sec 3)
- details for the in-water survey, if applicable, information for divers, clearances measurements instructions etc., tank and compartment boundaries
- docking plan and details of all penetrations normally examined at drydocking
- Coating Technical File, for ships subject to compliance with the IMO Performance Standard for Protective Coatings (PSPC) and for ships assigned with the additional service feature/additional class notation **CPS(WBT**).

3.2 Ship Construction File (SCF) for ships as specified in [1.1.3]

3.2.1 A Ship Construction File (SCF) with specific information on how the functional requirements of the goal-based ship construction standards for bulk carriers and oil tankers have been applied in the ship design and construction is to be provided upon delivery of a new ship, and kept on board the ship and/or ashore and updated as appropriate throughout the ship's service. The content of the Ship Construction File is to conform to the requirements as specified in [3.2.2].

3.2.2 The following design specific information is to be included in the Ship Construction File (SCF):

- areas requiring special attention throughout the ship's life (including the critical structural areas)
- all design parameters limiting the operation of a ship
- any alternatives to the rules, including structural details and equivalency calculations
- "as-built" drawings and information which are verified to incorporate all alterations approved by the recognized organization or flag State during the construction process including scantling details, material details, location of butts and seams, cross-section details and locations of all partial and full penetration welds
- net (renewal) scantlings for all the structural constituent parts, as-built scantlings and voluntary addition thicknesses (refer to Part A, Chapter 3 and Part A, Chapter 4)
- minimum hull girder section modulus along the length of the ship which has to be maintained throughout the ship's life, including cross-section details such as the value of the area of the deck and bottom zones, the renewal value for the neutral axis zone (refer to Part A, Chapter 3)
- a listing of the materials used for construction of the hull structure and provisions for documenting changes to any of the above during the ship's service life
- copies of the certificates of forgings and castings welded into the hull (refer to NR216 Materials and Welding)
- details of the equipment forming part of the watertight and weathertight integrity of the ship
- a Cable Transit Seal Systems Register, to be prepared by the shipbuilder for watertight cable transits. The Register can be in either a hard copy or digitized media. It is to include a marking / identification system, documentation referencing manufacturer manual(s) for each type of cable transit installed, the Type Approval certification for each type of transit system, applicable installation drawings, and a recording of each installed transit documenting the as built condition after final inspection in the shipyard. This is to include sections to record any inspection, modification, repair and maintenance.
- tank testing plan, including details of the test requirements (refer to Pt B, Ch 13, Sec 6)
- details for the in-water survey, when applicable, information for the divers, clearance measurement instructions etc., tank and compartment boundaries
- docking plan and details of all penetrations normally examined at drydocking
- Coating Technical File, for ships subject to compliance with the IMO Performance Standard for Protective Coatings (PSPC), see Note 1.

Note 1: PSPC means Performance Standard for Protective Coatings:

- for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by IMO Res. MSC.215(82), as amended, and
- for cargo oil tanks of crude oil tankers, adopted by IMO Res. MSC.288(87), as amended.

3.2.3 Refer to Tab 1 for details of information to be further included. This information is to be kept on board the ship and/or ashore and updated as appropriate, throughout the ship's life, in order to facilitate safe operation, maintenance, survey, repair and emergency measures.

3.2.4 It is to be noted that parts of the SCF content may be subject to various degrees of restricted access and that such documentation may be appropriately kept ashore.

3.2.5 The SCF is to include the list of the documents constituting the SCF and all information, listed in Tab 1, which is required for a ship's safe operation, maintenance, survey, repair and in emergency situations. Details of specific information that is not considered to be critical to safety might be included, directly or by reference, to the other documents.

3.2.6 When developing a SCF, all the columns in Tab 1 are to be reviewed to ensure that all necessary information has been provided.

3.2.7 It may be possible to provide information listed in this sub-article under more than one Tier II item (see Note 1) as a single item within the SCF; for example, the Coating Technical File required by the PSPC (see Note 1 of [3.2.2]) is relevant for both "Coating life" and "Survey during construction".

Note 1: Tier II items means the functional requirements included in the International Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers (GBS), adopted by IMO Res. MSC.287(87).

3.2.8 The SCF is to remain with the ship and, in addition, be available to the Society and flag State throughout the ship's life. Where information not considered necessary to be on board is stored ashore, procedures to access this information are to be specified in the onboard SCF. The intellectual property provisions within the SCF are to be duly complied with.

3.2.9 The SCF should be updated throughout the ship's life at any major event, including, but not limited to, substantial repair and conversion, or any modification to the ship structure.

3.2.10 The SCF shall be reviewed, at the time of new building, in accordance with the requirements of [3.2.2] and [3.2.3] and the normal storage location shall be distinguished.

Note 1: Note 1: "Reviewed" means the examination of the SCF that is carried out by the Surveyor, at the end of the newbuilding process, in order to confirm that:

- drawings and documents required under [3.2]
- the possible additional drawings/documents provided by the shipyard, as per the Ship Construction File (SCF) list of drawings/documents

are present in the copies of the SCF stored on board and in the ashore archive.

The "review" is not to be intended as an assessment of the drawings/documents in order to verify their compliances with the applicable Rules/ Regulations.

3.2.11 For the SCF stored on board ship, the Surveyor is to verify that the information is placed on board the ship, upon completion of ship construction.

3.2.12 For the SCF stored on shore archive, the Surveyor is to verify that the information is stored on shore archive by examining the list of information included on shore archive, upon completion of ship construction.

Table 1 : List of Information to be Included in the Ship Construction File (SCF)

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location*
DESIGN					
1	Design life	• assumed design life, in years	• statement or note on midship section	• SCF-specific **(1)** • midship section plan	on board on board
2	Environmental conditions	• assumed environmental conditions	• statement referencing data source or Rule (specific rule and data), or • in accordance with Rule (date and revision)	• SCF-specific **(1)**	on board
3	Structural strength				
3.1	General design	• applied Rule (date and revision) • applied alternative to Rule	• applied design method alternative to Rule and subject structure(s)	• SCF-specific **(1)** • capacity plan	on board on board
3.2	Deformation and failure modes	• calculating conditions and results; • assumed loading conditions	• allowable loading pattern • maximum allowable hull girder bending moment and shear force	• loading manual • trim and stability booklet	on board on board

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location*
3.3	Ultimate strength	• operational restrictions due to structural strength	• maximum allowable cargo density or storage factor	• loading instrument instruction manual	on board
				• operation and maintenance manuals	on board
3.4	Safety margins	• strength calculation results	• bulky output of strength calculation	• strength calculation	on shore
			• plan showing highly stressed areas (e.g. critical structural areas) prone to yielding and/or buckling	• areas prone to yielding and/or buckling	on board
		• gross hull girder section modulus			
		• minimum hull girder section modulus along the length of the ship to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone		• general arrangement plan	on board
		• gross scantlings of structural constituent parts	• structural drawings	• key construction plans **(2)**	on board
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses	• rudder and stern frame		
			• structural details of typical members	• rudder and rudder stock plans	on board
				• structural details	on board
				• yard plans **(3)**	on shore
				• dangerous area plan	on board
		• hull form **(4)**	• hull form information indicated in key construction plans **(2)**	• lines plan **(5)**, or	on shore
			• hull form data stored within an onboard computer necessary for trim and stability and longitudinal strength calculations		
				• equivalent **(6)**	on board
4	Fatigue life	• applied Rule (date and revision)	• applied design method alternative to Rule and subject structure(s)	• SCF-specific **(1)**	on board
		• applied alternative to Rule			
		• calculating conditions and results	• assumed loading conditions and rates	• structural details	on board
		• assumed loading conditions			
		• fatigue life calculation results	• bulky output of fatigue life calculation	• fatigue life calculation	on shore
			• plan showing areas (e.g. critical structural areas) prone to fatigue	• areas prone to fatigue	on board
5	Residual strength	• applied Rule (date and revision)		• SCF-specific **(1)**	on board

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location*
6	Protection against corrosion				
6.1	Coating life	• coated areas and target coating life and other measures for corrosion protection in holds, cargo and ballast tanks, other structure-integrated deep tanks and void spaces	• plans showing areas (e.g. critical structural areas) prone to excessive corrosion	• SCF-specific **(1)**	on board
6.2	Corrosion addition			• Coating Technical File required by PSPC **(7)**	on board
		• specification for coating and other measures for corrosion protection in holds, cargo and ballast tanks, other structure-integrated deep tanks and void spaces		• areas prone to excessive corrosion	on board
		• gross scantlings of structural constituent parts		• key construction plans **(2)**	on board
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses			
7	Structural redundancy	• applied Rule (date and revision)		• SCF-specific **(1)**	on board
8	Watertight and weathertight integrity	• applied Rule (date and revision)		• SCF-specific **(1)**	on board
		• key factors for watertight and weathertight integrity	• details of equipment forming part of the watertight and weathertight integrity	• structural details of hatch covers, doors and other closings integral with the shell and bulkheads	on board
9	Human element considerations	• list of ergonomic design principles applied to ship structure design to enhance safety during operations, inspections and maintenance of ship		• SCF-specific **(1)**	on board
10	Design transparency	• applied Rule (date and revision)		• intellectual property provisions	on board
		• applicable industry standards for design transparency and IP protection			
		• reference to part of SCF information kept ashore		• summary, location and access procedure for part of SCF information on shore	on board
CONSTRUCTION					
11	Construction quality procedures	• applied construction quality standard	• recognized national or international construction quality standard	• SCF-specific **(1)**	on board
12	Survey during construction	• survey regime applied during construction (to include all owner and class scheduled inspections during construction)	• applied Rules (date and revision)	• SCF-specific **(1)**	on board
				• tank testing plan	
			• copies of certificates of forgings and castings welded into the hull		on board
		• information on non-destructive examination		• non-destructive testing plan	on board
				• Coating Technical File required by PSPC **(7)**	on board

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location*
IN-SERVICE CONSIDERATIONS					
13	Survey and maintenance	• maintenance plans specific to the structure of the ship where higher attention is called for	• plan showing highly stressed areas (e.g. critical structural areas) prone to yielding, buckling, fatigue and/or excessive corrosion	• SCF-specific **(1)**	on board
				• operation and maintenance manuals (e.g. hatch covers and doors)	on board
		• preparations for survey	• arrangement and details of all penetrations normally examined at dry-docking	• docking plan	on board
		• gross hull girder section modulus	• details for dry-docking	• dangerous area plan	on board
		• minimum hull girder section modulus along the length of the ship to be maintained throughout the ship's life, including cross-section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone	• details for in-water survey	• Ship Structure Access Manual	on board
				• means of access to other structure-integrated deep tanks	on board
				• Coating Technical File required by PSPC **(7)**	on board
		• gross scantlings of structural constituent parts		• key construction plans **(2)**	on board
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses		• rudder and rudder stock	on board
				• structural details	on board
				• yard plans **(3)**	on shore
		• hull form **(4)**	• hull form information indicated in key construction plans **(2)**	• lines plan **(5)**, or	on shore
				• equivalent **(6)**	on board
14	Structural accessibility	• means of access to holds, cargo and ballast tanks and other structure-integrated deep tanks	• plans showing arrangement and details of means of access	• Ship Structure Access Manual	on board
				• means of access to other structure-integrated deep tanks	on board
RECYCLING CONSIDERATIONS					
15	Recycling	• identification of all materials that were used in construction and may need special handling due to environmental and safety concerns	• list of materials used for the construction of the hull structure	• SCF-specific **(1)**	on board

Tier II items	Information to be included	Further explanation of the content	Example documents	Normal storage location*

* Normal storage location means a standard location where each SCF information item should be stored. However, those items listed as being on board should be on board as a minimum to ensure that they are transferred with the ship on a change of owner. on board = on board ship; on shore = on shore archive. Shore archive is to be operated in accordance with applicable international standards.

(1) SCF-specific means documents to be developed especially to meet the requirements of these GBS guidelines (MSC.1/Circ.1343).

(2) Key construction plans means plans such as midship section, main O.T. and W.T. transverse bulkheads, construction profiles/ plans, shell expansions, forward and aft sections in cargo tank (or hold) region, engine-room construction, forward construction and stern construction drawings.

(3) Yard plans means a full set of structural drawings, which include scantling information of all structural members.

(4) Hull form means a graphical or numerical representation of the geometry of the hull. Examples would include the graphical description provided by a lines plan and the numerical description provided by the hull form data stored within an onboard computer.

(5) Lines plan means a special drawing which is dedicated to show the entire hull form of a ship.

(6) Equivalent (to Lines plan) means a set of information of hull form to be indicated in key construction plans for SCF purposes. Sufficient information should be included in the drawings to provide the geometric definition to facilitate the repair of any part of the hull structure.

(7) PSPC means Performance Standard for Protective Coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by IMO Resolution MSC.215(82), as amended and Performance Standard for Protective Coatings for cargo oil tanks of crude oil tankers, adopted by IMO Resolution MSC.288(87), as amended.

4 Newbuilding survey planning

4.1

4.1.1 Prior to commencement of surveys for any newbuilding project, the Shipbuilder is to discuss with the Society at a kick-off meeting the items of specific activities which are relevant to the shipbuilding functions listed in the kick-off meeting templates given in NR540 "Kick-off Meeting Templates for Newbuilding". The purpose of the meeting is to review and agree how the listed items are to be addressed. The meeting is to take into account the Shipbuilder construction facilities and ship type including the list of proposed subcontractors. This list is not exhaustive and can be modified to reflect the construction facilities or specific ship type. A record of the meeting is normally to be prepared and updated by the Shipbuilder, based upon the content of the kick-off meeting templates. The Shipbuilder should agree to undertake ad hoc investigations during construction as may be requested by the Society where areas of concern arise and to keep the Society advised of the progress of any investigation. Whenever an investigation is undertaken, the Shipbuilder is, in principle, to agree to suspend relevant construction activities if warranted by the severity of the problem. The records are to take note of specific published Administration requirements and interpretations of statutory requirements.

4.1.2 The shipyard shall be requested to advise of any changes to the activities agreed at the kick off meeting and these are to be documented in the survey plan. E.g. if the Shipbuilder chooses to use or change sub-contractors, or to incorporate any modification necessitated by changes in production or inspection methods, rules and regulations, structural modifications, or in the event where increased inspection requirements are deemed necessary as a result of a substantial non-conformance or otherwise.

4.1.3 Shipbuilding quality standards for hull structure during new construction are to be reviewed and agreed during the kick-off meeting. Structural fabrication is to be carried out in accordance with IACS Recommendation 47, "Shipbuilding and Repair Quality Standard", or a Recognized Fabrication Standard (RFS) which has been accepted by the Society prior to the commencement of fabrication/construction (Refer to Pt B, Ch 13, Sec 2, [1.1.4]). The work is to be carried out in accordance with these Rules and under survey of the Society.

The Society may accept an RFS as an alternative to IACS Recommendation 47 provided that [4.1.4] or [4.1.5] is complied with as applicable.

4.1.4 Where a RFS is well established and has well documented history (3 or more years prior to the new vessel contract) of successful application to similar designs as the new vessel and that history is for the same Shipyard as the new vessel. Then the Shipyard is to create a summary document referencing the RFS to be used in construction and highlighting any limitations to usage of the selected RFS. This summary document is to be included with the "record of kick-off meeting" for the vessel.

The summary document is also to be included in the SCF, (for Tankers and Bulk Carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10 per App 2, Table A Tier II Item 11), as applicable.

4.1.5 Where a RFS is new or revised or otherwise not as per [4.1.4], the following steps are to be carried out:

a) the tolerances and fabrications standards of the RFS are to be compared with those of Recommendation 47. Any that are less stringent than those of Recommendation 47 are to be identified.

b) the tolerances and fabrication standards of the RFS identified in [4.1.5](a) are to be assessed to determine the acceptability for use and/or any restrictions for usage for the subject (or proposed) design. Details of how the acceptability for use and/or restrictions are to be recorded, and,

c) a summary document including the outcomes of [4.1.5](a) and [4.1.5](b) is to be compiled. This document is to also include a reference to the RFS, details of the tolerance and fabrication standards not analysed as part of [4.1.5](b) and any limitations to the usage of the RFS.

The summary document is to be included with the "record of the kick-off meeting" of the vessel. The summary document is also to be included in the SCF, (for Tankers and Bulk Carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10 per App 2, Table A Tier II Item 11), as applicable.

4.1.6 The kick-off meeting may be attended by other Parties (Owner, Administrations…) subject to agreement by the shipbuilder.

4.1.7 In the event of series ship production, the requirement for a kick off meeting may be waived for the second and subsequent ships provided that no changes to the specific activities agreed in the kick off meeting for the first ship are introduced. If any changes are introduced, these are to be agreed in a new dedicated meeting and documented in a record of such meeting.

5 Examination and test plan for newbuilding activities

5.1 Applicable to all ships

5.1.1 The Shipbuilder is to provide to the Surveyor plans of the items which are intended to be examined and tested. These plans need not be submitted for approval and examination at the time of the kick-off meeting. They are to include:

- proposal for the examination of completed steelwork generally referred to as the block plan and are to include details of joining blocks together at the pre-erection and erection stages or at other relevant stages
- proposal for fit up examinations where necessary
- proposal for testing of the structure (leak and hydrostatic) as well as for all watertight and weathertight closing appliances
- proposal for non-destructive examination
- any other proposal specific to the ship type or to the delegated statutory requirements.

5.1.2 The plans and any modification to them are to be submitted to the Surveyors in sufficient time to allow review before the relevant survey activity commences.

5.2 Applicable for ships as specified in [1.1.3]

5.2.1 In addition to [5.1.1], the Shipbuilder is to provide plans of the items which are intended to be examined and tested in accordance with the Rules in a document known as the Survey Plan, taking into account the ship type and design. This Survey Plan is to be reviewed at the time of the kick-off meeting, and is to include:

- A set of requirements, specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory ship construction standards, including:
  - types of surveys (visual, non-destructive examination, etc.) depending on the location, materials, welding, casting, coatings, etc.
  - establishment of a construction survey schedule for all the assembly stages from the kick-off meeting, through all major construction phases, up to delivery
  - inspection/survey plan, including provisions for the critical areas identified during design approval
  - inspection criteria for acceptance
  - interaction with shipyard, including notification and documentation of survey results
  - correction procedures to remedy the construction defects
  - list of the items that would require scheduling or formal surveys
  - determination and documentation of the areas that need special attention throughout ship's life, including criteria used in making the determination
- A description of the requirements for all types of testing during survey, including test criteria.

6 Design transparency

6.1 Applicable for ships as specified in [1.1.3]

6.1.1 For ships subject to compliance with IMO Res. MSC.287(87), IMO Res. MSC.290(87), IMO Res. MSC.454(100) and IMO MSC.1/Circ.1343, readily available documentation is to include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.

6.1.2 The Shipyard or the Designer is to authorize the Society to make available relevant technical correspondence in relation with the SCF to Owners and Flag states.

Section 8 Survey of Watertight Cable Transits

1 General

1.1 Application

1.1.1 The requirements of this Section apply to all vessels contracted for construction on or after 1st July 2021 and are in addition to the requirements of Ch 2, Sec 2; Ch 3, Sec 1; Ch 3, Sec 2; Ch 3, Sec 3 and Ch 3, Sec 7.

1.1.2 Watertight cable transits are to be installed and maintained in accordance with the manufacturer's requirements and in accordance with the requirements of the relevant Type Approval certification.

2 Cable Transit Seal Systems Register

2.1 New construction

2.1.1 A Cable Transit Seal Systems Register is to be provided by the shipbuilder for all watertight cable transits fitted to the vessel. The Cable Transit Seal Systems Register can be in either a hard copy or digitized media. It is to include a marking / identification system, documentation referencing manufacturer manual(s) for each type of cable transit installed, the Type Approval certification for each type of transit system, applicable installation drawings, and a recording of each installed transit documenting the as built condition after final inspection in the shipyard. It is to include sections to record any inspection, modification, repair and maintenance.

2.1.2 The Cable Transit Seal Systems Register is to be reviewed by the attending Surveyor to confirm it contains a list of the watertight cable transits, applicable cable transit information and sections to maintain in-service maintenance and survey records.

2.1.3 For manned vessels, the Cable Transit Seal Systems Register is to be held onboard of the vessel. For unmanned vessels, if a suitable storage location does not exist onboard, the Register may be held ashore. The Cable Transit Seal Systems Register is to be readily available for the attending surveyor.

2.2 Vessel in service

2.2.1 The owner is to maintain the Cable Transit Seal Systems Register to record any disruption (repair, modification or opening out and closing) to a cable transit or to record the installation of a new cable transit.

3 Installation and maintenance of Watertight Cable transits

3.1

3.1.1 At new construction and periodic surveys it is to be confirmed that:

- cable transits have been installed, and where disrupted have been reinstated, in accordance with the manufacturer's requirements and in accordance with the requirements of Type Approval
- where specified, appropriate specialized tools have been used.

Appendix 1 Class Requirements and Surveys of Laid-up Ships

1 General

1.1

1.1.1 In order to maintain its class during a normal operation period, a ship is to be submitted to the surveys described in Ch 2, Sec 2 at their due dates and to the satisfaction of the Society, and is to be free of overdue surveys and conditions of class during the considered period.

1.1.2 When a ship stops trading and is put out of commission for a certain period, i.e. is laid-up, the normal survey requirements may no longer apply provided that the Owner notifies the Society of this fact. The Owner is also to submit a lay-up maintenance program to the Society for approval.

1.1.3 The lay-up maintenance program includes:

- the safety conditions to be kept throughout the lay-up period
- the measures taken to preserve the maintenance of the ship throughout the lay-up period
- the survey requirements to be complied with for lay-up, maintenance of class in lay-up and re-commissioning.

2 Safety conditions

2.1

2.1.1 Power supply

Adequate power supply is to be supplied, or readily available, all around the clock, either from independent means on board the ship or from shore.

The following safety conditions are to be kept throughout the lay-up period.

2.1.2 Manning

Watch personnel are to be provided. The number of the watch personnel will depend on the size of the ship, the lay-up site and mooring arrangements, the shore assistance available in case of fire, leakage or flooding, the maintenance required to provide adequate preservation. A permanent shore communication installation (radio, telephone) is also to be available.

2.1.3 Fire protection and fire fighting

The following is to be complied with:

- automatic fire alarm systems, where provided, are to be in working order and in operation
- fire-fighting installations are to be tested regularly and readily available
- the fire main is to be readily available and periodically tested under pressure
- ventilation trunks, air inlets and watertight doors are to be kept closed.

2.1.4 Protection against explosion

Cargo spaces and piping systems are to be cleaned and ventilated to prevent gas from forming any pockets.

An inert gas system in operation is recommended for the cargo spaces of oil and chemical tankers.

All flammable materials, sludge, etc. are to be removed from the ship's bilge, tank tops, double bottom tanks, engine room, pump rooms and similar spaces.

Hot work is not be carried out during lay-up, unless special precautionary measures are taken.

2.1.5 Safety equipment

All the equipment usually recommended for the safety of the watch personnel is to be provided, kept in working order and tested regularly.

The usual life-saving equipment such as liferafts, life-buoys, breathing apparatus, oxygen masks and distress signals is to be provided and made accessible.

The requirements of the flag Administration and of the local port authorities of the lay-up site are usually to be applied.

2.1.6 Emergency power

The emergency source of power, emergency generator and/or emergency air compressor are to be kept in working order and tested weekly.

3 Preservation measures for lay-up and maintenance

3.1 General

3.1.1 A lay-up log-book is to be kept on board, in which the maintenance work and tests carried out during the lay-up period are to be entered with the corresponding dates. The nature and frequency of the maintenance, inspections and tests are also to be defined in the lay-up log book.

3.1.2 The following measures for preservation and maintenance during the lay-up period are to be taken by Owners according to the type of ship, hull equipment, machinery installations and the specific cases of lay-up conditions.

3.2 Exposed parts of the hull

3.2.1 Underwater parts of the hull are to be protected against corrosion. It is advisable to provide an impressed current cathodic protection system where the quantity of corrosive waste discharge is particularly high. When such systems are provided they are to be serviced and checked at regular intervals. The condition of sacrificial anodes is to be evaluated at the annual lay-up condition surveys.

3.2.2 The coating of the hull above the waterline, exposed decks, access doors or covers on exposed decks, and hatch covers is to be maintained in satisfactory condition.

All accesses leading to internal spaces are to be kept closed.

All vent pipes and ventilation trunks are to be kept closed.

3.3 Internal spaces

3.3.1 Cargo tanks and cargo holds are to be emptied, cleaned and kept dry.

Ballast tanks are to be kept either full or empty. When ballast spaces are kept filled with sea water, special care is to be taken to keep such spaces topped up and protected against corrosion. When provided, sacrificial anodes are to be renewed when deemed necessary. The topping up is to be regularly verified.

3.3.2 Chain lockers are to be drained, cleaned and kept dry. Coating with bituminous paint is recommended.

3.3.3 Fuel oil and lubricating oil tanks are to be drained regularly.

Lubricating oil analysis is to be performed regularly and the oil renewed when the result is not satisfactory. Prior to being refilled, tanks are to be cleaned.

Empty lubricating oil tanks are to be cleaned and kept dry.

Fresh water or distilled water tanks are to be kept full or empty. Empty tanks are to be cleaned and kept dry. Where cement wash is used as a protective sheathing, this is to be examined and repaired prior to filling.

3.3.4 The bilge and tank top in engine rooms are to be cleaned and kept dry.

Hull sea inlet and outlet valves not in use are to be kept closed.

3.4 Deck fittings

3.4.1 The windlass, capstans and winches are to be regularly greased and turned once a week.

All wire cables are to be kept greased.

Visible parts of chains are to be coal-tarred and examined regularly.

Chocks and hawse pipes are to be coated with bituminous paint or equivalent if deemed necessary.

Cargo piping on deck is to be drained, blown through if deemed necessary and kept dry by opening up drains.

Electrical machinery and navigational equipment are to be protected by watertight covers.

3.5 Machinery

3.5.1 Machinery spaces

The air temperature inside the machinery spaces is normally to be kept above 0°C.

Humidity is to be kept as low as possible and within acceptable limits.

3.5.2 Machinery - General

Exposed mechanical parts of machinery are to be greased.

All rotating machinery such as diesel engines, reciprocating engines, pumps, turbines, electric motors and generators are to be turned at regular intervals with a limited number of revolutions (the lubricating oil system should be put in operation or proper priming applied). Units are not to be stopped in the same position as the previous one.

Bearing boxes are to be emptied, cleaned and refilled with new oil.

3.5.3 Main turbines

Turbines are to be kept dry.

All steam inlets are to be sealed.

Expansion arrangements (sliding feet) are to be suitably greased.

Electric heaters are to be put inside the turbines. Heat drying is to be made in open circuit, all valves shut and gland closing devices withdrawn.

Turbines are to be turned weekly, the lubricating oil system being put in service. The shaft line is to be stopped after turning an integer number of revolutions plus one quarter of a revolution.

3.5.4 Reduction gears

For large reduction gears, a fan activating the circulation of hot air in closed circuit with air hoses is to be fitted (intake at lower part of casing and discharge at upper part).

3.5.5 Auxiliary turbine-driven machinery

Stators are to be drained and kept dry.

Shaft sealing glands are to be lubricated.

Lubricating oil is to be analysed and renewed when deemed necessary. Prior to oil renewal, the oil casings are to be cleaned.

Exhaust steam pipes are to be kept dry.

Stuffing boxes are to be dismantled.

Turbines are to be turned weekly an integer number of revolutions plus one quarter of a revolution.

3.5.6 Condensers and heat exchangers

Condensers and heat exchangers are to be drained and kept dry.

Desiccant is to be placed in steam spaces.

Water sides are to be washed with fresh water.

The condition of the zinc anodes is to be periodically checked.

When tubes are fitted with plastic or fibre packing, water sides are to be filled with alkaline distilled water.

When tubes are expanded or fitted with metal packing, water sides are to be provided with desiccants and kept dry.

3.5.7 Auxiliary machinery

Air receivers are to be drained, opened up and cleaned. Pressure relief valves are to be cleaned and slightly lubricated.

Air compressor crankcases are to be drained, cleaned and refilled with clean oil. Cylinders and valves are to be lubricated. Coolers are to be drained and dried. Air drains are to be opened and the system dried.

Air start lines are to be drained and dried.

Hot-wells/return tanks are to be drained and dried.

De-aerators are to be drained and dried.

Feed pumps and extraction pumps are to be drained and dried.

Air ejectors are to be drained and dried.

Main circulation pumps are to be drained and dried.

Evaporators are to be drained, cleaned and dried.

3.5.8 Piping

Pipes not in use are to be drained and kept dry.

3.5.9 Diesel engines

Daily tank fuel oil outlet pipes and all injection equipment are to be filled with filtered gas oil.

Fresh water circuits are to be filled with water mixed with rust inhibitors. Fresh water pH is to be checked monthly.

Oil of hydraulic regulators is to be replaced.

Sea water cooling pipes are to be drained.

Crankcases are to be provided with desiccant.

Starting valves are to be lubricated (internally and externally).

Motor oil is to be sprayed in cylinders and on all external parts liable to corrosion.

Cams and cylinders are to be motor oil sprayed monthly.

Turbo-compressor/charger ball bearings are to be oil sprayed and rotated for an integer number of revolutions plus one quarter of a revolution.

Engine air inlets and exhaust gas pipes are to be sealed.

Scavenge spaces are to be cleaned

Engines are to be turned weekly.

3.5.10 Shaft lines

Shaft lines are to be coated with grease.

Shaft bearing cooling pipes are to be drained.

For sea water lubricated propeller shafts, the packing gland of the engine room stuffing box is to be tightened.

For oil lubricated sterntubes, lubricating oil is to be analysed and renewed if not satisfactory. The oil level in the tank is to be verified regularly.

Propeller shaft lines are to be rotated an integer number of revolutions plus one quarter of a revolution.

3.6 Electrical installations

3.6.1 Main and secondary switchboards, sub-feeder panels, fuse panels and starters are to be made tight. Desiccant is to be provided.

Contacts of relays, breakers and switch-breakers are to be coated with neutral vaseline.

Bearings of generators are to be cleaned of old grease and protected with new oil or grease.

Carbon brushes are to be lifted off their commutations.

3.6.2 Electrical insulation of each item is to be kept at a minimum 200,000 Ohms and general insulation is to be not less than 50,000 Ohms. Local electric heating may be necessary to improve the level of insulation, particularly in the generators/ alternators and large motors.

A insulation resistance test is to be performed regularly.

3.7 Steering gear

3.7.1 Exposed mechanical parts are to be greased or oil sprayed.

For electrical parts the same preservation measures given in [3.6] are to be taken.

It is recommended that the steering gear should be operated monthly.

3.8 Boilers

3.8.1 Smoke sides of boilers are to be swept, washed clean with basic hot water and hot air dried.

3.8.2 Water and steam sides should preferably be preserved using the dry method, keeping the moisture at the lowest possible level, the ideal level being between 30% and 35%. It is advisable to ensure that no residual water remains to cause rapid corrosion. Drum doors are to be kept closed.

In other cases, it is advisable to keep the boilers, superheaters and economisers filled with water having a pH around 10,5. Hydrazine hydrate treatment of the water is preferable to reduce risks of corrosion caused by dissolved oxygen. The water is to be regularly analysed.

3.8.3 Air heaters are to be cleaned and kept dry.

Uptake, shell and fan outlets are to be cleaned and kept closed with watertight hoods.

Burners are to be dismantled, and atomisers greased.

Desiccant is to be provided in furnaces where deemed necessary.

Expansion arrangements (sliding feet) are to be suitably greased.

The internal condition of boilers is to be checked every three months.

3.8.4 Boilers may also be preserved sealed with inert gas (nitrogen), provided that cocks and valves are tight and the installation allows an internal pressure of at least 0,05 bar to be maintained to prevent air penetration. Regular checks of the overpressure are to be carried out and results recorded in the log-book.

3.9 Automated installation

3.9.1 Recommendations for electronic components are the same as those given for electrical installations.

For pneumatic parts the manufacturers' recommendations are to be followed and the system is to be checked regularly.

Pressure, temperature or level sensors are generally not affected by damage when not used. However, when available, the manufacturers' recommendations are to be followed.

4 Lay-up site and mooring arrangements

4.1 General

4.1.1 The choice and suitability of the lay-up site, as well as the type of mooring conditions, the mooring arrangements and their efficiency during the lay-up period remain the responsibility of the Owner.

However, at the Owner's request, the mooring arrangement may be reviewed by the Society.

4.2 Recommendations for the lay-up site

4.2.1 The following recommendations are to be considered by Owners regarding the choice and suitability of the lay-up site.

The site should be:

- sheltered from open sea, strong currents and waves
- not exposed to whirling winds or turbulent tidal waves
- not exposed to moving ice
- clear of corrosive waste waters
- provided with adequate ship/shore communications.

4.3 Recommendations for the mooring arrangements

4.3.1 The following recommendations are to be considered by Owners with respect to the mooring arrangements:

- ground holding should be adequate
- vessels laid-up to buoys or anchored should be moored in such a way as to be prevented from swinging with normal wind and tidal changes
- chain cables should not be subject to cross-contact or twisting and stern anchorage should generally be provided
- laid-up ships should be in ballast condition in order to reduce the effects of wind. Due consideration should be given to the still water bending moment. For guidance, normal ballast draft should be roughly between 30% and 50% of the maximum draft.

4.3.2 Ships should normally be moored singly. However, when several ships are moored together, the following provisions are to be made:

- ships are to be moored bow to stern
- ships are to be of approximately the same size
- the number of ships moored together is, in principle, not to exceed six
- breast-lines are to be of similar elasticity
- fenders are to be provided.

4.4 Review of the mooring arrangements

4.4.1 As indicated in [4.1.1], at the Owners' request, the mooring arrangements may be reviewed by the Society.

4.4.2 The proposal for the mooring arrangements is in such case to be submitted by the Owner and is to include the following information.

a) Mooring site:
   - geographical area (to be specified on a map)
   - characteristics of the sea bottom
   - water depth
   - preferential angular sectors (effects of wind / tide / current) indicated according to statistical studies
   - wave characteristics (amplitude, periods)

b) Geometry of mooring arrangements:
   - ship's position and direction
   - shore anchorage
   - diagram showing mooring equipment (fore and aft)
   - angle between chain cables and ship's centreline

c) Characteristics of mooring equipment:
- maximum holding strength of each anchor
- type of mooring lines (chains, cables, sinkers, etc.)
- length of each section
- weight of each section
- mechanical characteristics of each section (breaking load)
- weight of sinkers.

4.4.3 On completion of the installation, the mooring arrangements are to be surveyed by the Society. When the ship is anchored, the underwater installation is to be inspected by a diver whose report is to be presented to the Society.

4.4.4 It is the responsibility of the Owners to ascertain the efficiency of the mooring arrangements during the lay-up period. The mooring arrangements are to be re-examined at regular intervals (at least each year when the ship is anchored) and when abnormal weather conditions occur at the lay-up site.

5 Surveys

5.1 Laying-up survey

5.1.1 At the beginning of the lay-up period a laying-up survey is to be carried out whose scope is to verify that the safety conditions, preservation measures, lay-up site and mooring arrangements are in accordance with the program agreed by the Society.

5.1.2 Upon satisfactory completion of this survey, a memorandum is issued to confirm that the ship has been placed in lay-up, which is subsequently to be kept on board.

5.2 Annual lay-up condition survey

5.2.1 As described in Ch 2, Sec 2, [8], an annual lay-up condition survey is to be performed in lieu of the normal annual class surveys. The purpose of this survey is to ascertain that the lay-up maintenance program implemented is continuously complied with.

5.2.2 It is to be checked that the arrangements made for the lay-up are unchanged and that the maintenance work and tests are carried out in accordance with the maintenance manual and recorded in the lay-up log-book.

5.2.3 Upon satisfactory completion of the survey, the Certificate of Classification is endorsed.

5.3 Re-commissioning survey

5.3.1 Owners are to make the necessary arrangements to remove the temporary lay-up installations provided for preservation measures and the protective materials and coatings (oil, grease, inhibitors, desiccants), before the survey is commenced.

It is the Owners' responsibility to verify that the ship parts that are not covered by class are reactivated in satisfactory operational condition.

5.3.2 The scope of the re-commissioning survey is to include:
- a general examination of the hull, deck fittings, safety systems, machinery installations (including boilers whose survey is not due) and steering gear
- all periodical surveys due at the date of re-commissioning or which became overdue during the lay-up period
- dealing with the conditions of class due at the date of recommissioning or which became due during the lay-up period.

5.3.3 For the hull the following is to be carried out:
- examination of shell plating above the waterline, deck plating, hatch covers and coamings
- examination of load line items
- overall survey of all cargo tanks/holds
- overall survey of representative ballast tanks when the lay-up period does not exceed two years
- overall survey of all ballast tanks when the lay-up period is two years and over
- function tests of bilge and ballast systems.

5.3.4 For the deck fittings the following is to be carried out:
- examination of the fire main under working pressure
- where possible, examination of deck piping under working pressure
- function tests of class items
- checking inert gas installation under working condition after inspection of water seal and function test of deck non-return valve and pressure/vacuum valves.

5.3.5 For machinery installations the following is to be checked:

- the analysis of lubricating oil of main engines, auxiliary engines, reduction gears, main thrust bearings and sterntube
- the general condition of crankcase, crankshaft, piston rods and connecting rods of diesel engines
- the crankshaft deflections of diesel engines. In addition when engines have been laid-up for more than two years, one piston is to be disconnected and one liner is to be removed for examination. Dismantling is to be extended if deemed necessary
- the condition of blades of turbines through the inspection doors
- the condition of the water side of condensers and heat exchangers
- the condition of expansion arrangements
- the condition of reduction gears through the inspection doors
- the condition after overhauling of pressure relief devices
- the test of bilge level alarms, when fitted.

5.3.6 The main and emergency electrical installations are to be tested. The parallel shedding of main generators and main switchboard safety devices are to be checked. An insulation resistance test of the electrical installation is to be performed.

5.3.7 For the fire prevention, detection and fire-fighting systems, the following is to be examined and/or tested:

- remote control for quick closing of fuel oil valves, stopping of fuel oil pumps and ventilation systems, closing of fire doors and watertight doors
- fire detectors and alarms
- fire-fighting equipment.

5.3.8 The automated installation is to be checked for proper operation.

5.3.9 When classed, the installations for refrigerated cargo are to be examined under working conditions. Where the lay-up period exceeds two years, representative components of the installation are to be dismantled.

5.3.10 For cargo installations on liquefied gas carriers, the following is to be carried out:

- inspection of the primary barrier in tanks
- for membrane tanks, a global gas test of tanks whose results are to be compared with those obtained at ship's delivery
- testing of gas piping at working pressure using inert gas.

A Surveyor of the Society is to attend the first cooling down and loading of the ship.

5.3.11 For other specific classed installations, the Owners are to submit a survey program to the Society.

5.3.12 On completion of the above surveys, sea trials are to be performed in the presence of a Surveyor of the Society.

The sea trials are to include:

- verification of the satisfactory performance of the deck installations, main propulsion system and essential auxiliaries, including a test of the safety devices
- an anchoring test
- complete tests of steering gear
- full head and full astern tests
- tests of automated machinery systems, where applicable.

5.3.13 Upon satisfactory completion of the surveys, a memorandum is issued to confirm the carrying out of all relevant surveys and the recommissioning of the ship.

CHAPTER 4
SCOPE OF SURVEYS IN RESPECT OF THE DIFFERENT SERVICES OF SHIPS

Section 1	General
Section 2	Single Skin and Double Skin Bulk Carriers
Section 3	Oil Tankers and Combination Carriers
Section 4	Chemical Tankers
Section 5	Liquefied Gas Carriers
Section 6	Ro-Ro Cargo Ships and Pure Car and/or Truck Carriers, Passenger Ships and Ro-Ro Passenger Ships
Section 7	General Cargo Ships
Section 8	Other Service Notations
Section 9	Ships using Low Flashpoint Liquid or Gas Fuels
Section 10	Ships using Fuel Cells
Section 11	Ships using Onboard Carbon Capture and Storage Systems
Section 12	Ships using Wind Propulsion Systems
Section 13	Ships using Battery Systems
Appendix 1	Oil Tanker Longitudinal Strength Assessment

Section 1 General

1 General

1.1

1.1.1 The purpose of this Chapter is to give details on the scope of surveys of certain ships which, due to the service notation and/or the additional service feature assigned, and related equipment, need specific requirements to be verified for the maintenance of their class.

1.1.2 These specific requirements either are additional to or supersede those stipulated in Part A, Chapter 3, which gives general requirements for surveys applicable to all types of ships: this is indicated in each Section of this Chapter. These surveys are to be carried out at intervals as described in Ch 2, Sec 2, concurrently with the surveys of the same type, i.e. annual, intermediate or class renewal surveys, detailed in Part A, Chapter 3.

1.1.3 Owners are reminded that a general examination of the ship having the same scope of an annual survey is to be carried out at the completion of the class renewal survey, see Ch 3, Sec 3, [1.1.7]. Where specific requirements are given in this Chapter for the class renewal survey, they are additional to the applicable requirements for the annual survey.

2 Service notations and/or additional service features subject to additional surveys

2.1

2.1.1 The specific requirements detailed in this Chapter are linked to the service notation(s) and/or the additional service feature(s) assigned to the ship at the request of the Owner. Where a ship has more than one service notation, the specific requirements linked to each one are applicable, insofar as they are not contradictory (in such case, the most stringent requirement will be applied).

2.1.2 Tab 1 indicates which service notations and/or the additional service features are subject to specific requirements, and in which Section or Article they are specified.

Table 1 : Service notations and/or additional service features for which specific requirements are applicable

Service notation and/or additional service feature assigned	Section or Article applicable in this Chapter	Type of surveys affected by these specific requirements	Remarks
bulk carrier ESP **bulk carrier BC-A ESP** **bulk carrier BC-B ESP** **bulk carrier BC-C ESP** **self-unloading bulk carrier ESP** **ore carrier ESP** **combination carrier/OBO ESP** **combination carrier/OOC ESP**	Ch 4, Sec 2	annual survey intermediate survey class renewal survey	subject to enhanced survey program
oil tanker ESP **combination carrier/OBO ESP** **combination carrier/OOC ESP**	Ch 4, Sec 3	annual survey intermediate survey class renewal survey	subject to enhanced survey program
oil storage service	Ch 4, Sec 8, [7]	hull class renewal survey	subject to enhanced survey program
chemical tanker ESP	Ch 4, Sec 4	annual survey intermediate survey class renewal survey	subject to enhanced survey program
liquefied gas carrier **liquefied gas carrier - FSRU** **liquefied gas carrier - FSU**	Ch 4, Sec 5	annual survey intermediate survey class renewal survey	
ro-ro cargo ship **PCTC** or **PCC** **passenger ship** **ro-ro passenger ship**	Ch 4, Sec 6	annual survey class renewal survey	survey of shell and inner doors is included

Service notation and/or additional service feature assigned	Section or Article applicable in this Chapter	Type of surveys affected by these specific requirements	Remarks
general cargo ship	Ch 4, Sec 7	annual survey intermediate survey class renewal survey	
container ship or ship **equipped for carriage of containers**	Ch 4, Sec 8, [2]	annual survey class renewal survey	
livestock carrier	Ch 4, Sec 8, [3]	annual survey class renewal survey	
FLS tanker	Ch 4, Sec 8, [4]	annual survey intermediate survey class renewal survey	
dredger **hopper dredger**, **hopper unit** **split hopper unit**, **split hopper dredger**	Ch 4, Sec 8, [5]	annual survey class renewal survey	
tug, **salvage tug** or **escort tug**	Ch 4, Sec 8, [6]	annual survey class renewal survey	
supply	Ch 4, Sec 8, [7]	annual survey intermediate survey class renewal survey	
fire-fighting	Ch 4, Sec 8, [8]	annual survey class renewal survey	
oil recovery	Ch 4, Sec 8, [9]	annual survey class renewal survey	
anchor handling	Ch 4, Sec 8, [10]	annual survey class renewal survey	
cable laying	Ch 4, Sec 8, [11]	annual survey class renewal survey	
lifting	Ch 4, Sec 8, [12]	annual survey class renewal survey	
diving support-integrated **diving support-portable**	Ch 4, Sec 8, [13]	annual survey class renewal survey	
fishing vessel	Ch 4, Sec 8, [14]	annual survey class renewal survey	
standby rescue	Ch 4, Sec 8, [15]	annual survey class renewal survey	
yacht **charter-yacht**	Ch 4, Sec 8, [16]	intermediate survey class renewal survey	
semi-submersible cargo ship	Ch 4, Sec 8, [17]	annual survey intermediate survey class renewal survey	
diving system-integrated **diving system-portable** **hyperbaric reception facility**	Ch 4, Sec 8, [18]	annual survey intermediate survey class renewal survey	
LNGfuel, **CNGfuel**, **LPGfuel** **methanolfuel** **ammoniafuel** **hydrogenfuel** **LFPfuel**	Ch 4, Sec 9	annual survey intermediate survey class renewal survey	
fuelcell	Ch 4, Sec 10	annual survey intermediate survey class renewal survey	
OCC	Ch 4, Sec 11	annual survey class renewal survey	
WIND PROPULSION-1 **WIND PROPULSION-2**	Ch 4, Sec 12	annual survey class renewal survey	
battery system	Ch 4, Sec 13	annual survey class renewal survey	

Section 2 Single Skin and Double Skin Bulk Carriers

1 General

1.1 Application

1.1.1 The requirements of this Section apply to all self-propelled ships which have been assigned one of the following service notations:

- **bulk carrier ESP** (whether of single or double skin construction)
- **bulk carrier BC-A ESP** (whether of single or double skin construction)
- **bulk carrier BC-B ESP** (whether of single or double skin construction)
- **bulk carrier BC-C ESP** (whether of single or double skin construction)
- **self-unloading bulk carrier ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**

Note 1: A bulk carrier is a ship which is constructed generally with single deck, double bottom, topside tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk. Combination carriers are included. Ore carriers and combination carriers are not covered by the Common Structural Rules.

Note 2: A double skin bulk carrier is a ship which is constructed generally with single deck, double bottom, topside tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers, in which all cargo holds are bounded by a double-side skin (regardless of the width of the wing space). Ore carriers and combination carriers are not covered by the Common Structural Rules.

Note 3: For bulk carriers with hybrid cargo hold arrangements, e.g. with some cargo holds of single side skin and others of double side skin, the requirements of single side skin bulk carriers are to apply to cargo holds of single side skin and the requirements of double skin bulk carriers are to apply to cargo holds of double side skin and associated wing spaces.

Note 4: For combination carriers with longitudinal bulkheads, additional requirements are specified in Ch 4, Sec 3, as applicable.

1.1.2 The requirements apply to the surveys of the hull structure and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces, fuel oil tanks within the cargo length area and all ballast tanks. They are additional to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3 according to the relevant surveys.

1.1.3 The requirements contain the minimum extent of examination, thickness measurements and tank testing. When substantial corrosion, as defined in Ch 2, Sec 2, [2.2.7], and/or structural defects are found, the survey is to be extended and is to include additional close-up surveys when necessary.

1.1.4 In any kind of survey, i.e. class renewal, intermediate, annual or other surveys having the same scope, thickness measurements, when required by Tab 11, of structures in areas where close-up surveys are required are to be carried out simultaneously with close-up surveys.

1.1.5 In all cases the extent of thickness measurements is to be sufficient as to represent the actual average condition.

1.1.6 When, in any survey, thickness measurements are required:

- the procedure detailed in Ch 2, Sec 2, [2.3] is to be applied
- the thickness measurement firm is to be part of the survey planning meeting to be held prior to commencing the survey.

1.1.7 Special consideration may be given to the extent of close-up surveys and/or thickness measurements in cargo holds as required below for class renewal, intermediate or annual surveys, when all internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of the cargo holds, excluding the flat tank top areas and the hopper tank sloped plating approximately 300 mm below the side shell frame end brackets, have protective coating in good condition.

The above special consideration may also be given to existing bulk carriers, where Owners elect to coat or recoat cargo holds, in accordance with the Manufacturers' recommendations. However, prior to re-coating the cargo holds, scantlings are to be assessed in the presence of a Surveyor of the Society.

Note 1: Special consideration (or specially considered) as used in this Section is intended to mean as a minimum, that sufficient close-up inspection and thickness measurements are taken to confirm the actual average condition of the structure under the coating.

1.1.8 Ships which are required to comply with Ch 6, Sec 2, [1.3] are subject to the additional thickness measurements contained in Ch 6, Sec 2, [1.3.4] and Ch 6, Sec 2, [1.3.5] with respect to the vertically corrugated transverse watertight bulkhead between cargo holds Nos. 1 and 2 for purposes of determining compliance with Ch 6, Sec 2, [1.3] prior to the relevant compliance deadline stipulated in Ch 6, Sec 2, [1.2.1] and at subsequent intermediate surveys (for ships over 10 years of age) and class renewal surveys for purposes of verifying continuing compliance with Ch 6, Sec 2, [1.3].

1.1.9 Ships which are required to comply with Ch 6, Sec 2, [5] are subject to the additional thickness measurements contained in Ch 6, Sec 2, [5.3] with respect to the side shell frames and brackets for the purposes of determining compliance with Ch 6, Sec 2, [5] prior to the relevant compliance deadline stipulated in Ch 6, Sec 2, [5.2] and at subsequent intermediate and class renewal surveys for purposes of verifying continuing compliance with Ch 6, Sec 2, [5].

1.2 Documentation on board

1.2.1 The Owner is to obtain, supply and maintain documentation on board as specified in [1.2.2] and [1.2.3], which is to be readily available for examination by the Surveyor.

The documentation is to be kept on board for the lifetime of the ship.

For bulk carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10, the Owner is to arrange the updating of the Ship Construction File (SCF) throughout the ship's life whenever a modification of the documentation included in the SCF has taken place. Documented procedures for updating the SCF are to be included within the Safety Management System.

1.2.2 A survey report file is to be a part of the documentation on board consisting of:

- reports of structural surveys
- hull condition evaluation report (summarising the results of class renewal surveys)
- thickness measurement reports.

The survey report file is also to be available in the Owner's management office.

1.2.3 The following additional supporting documentation is to be available on board:

- survey programme as required by [4.1.1] until such time as the class renewal survey or intermediate survey, as applicable, has been completed
- main structural plans of cargo holds and ballast tanks (for CSR ships, these plans are to include, for each structural element, both the as-built and the renewal thicknesses. Any thickness for voluntary addition is also to be clearly indicated on the plans. The midship section plan to be supplied on board the ship is to include the minimum allowable hull girder sectional properties for hold transverse section in all cargo holds)
- previous repair history
- cargo and ballast history
- extent of use of inert gas plant and tank cleaning procedures
- ship's personnel reports on:
  - structural deterioration/defects in general
  - leakage in bulkheads and piping systems
  - condition of corrosion prevention system, if any
- any other information that may help to identify critical structural areas and/or suspect areas requiring inspection.

1.2.4 For bulk carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10, the Ship Construction File (SCF), limited to the items to be retained onboard, is to be available on board.

1.2.5 Prior to survey, the Surveyor examines the documentation on board and its contents, which are used as a basis for the survey.

1.2.6 For bulk carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10:

- on completion of the survey, the surveyor is to verify that the update of the Ship Construction File (SCF) has been done whenever a modification of the documentation included in the SCF has taken place
- for the SCF stored on board ship, the Surveyor is to examine the information on board ship. In cases where any major event, including, but not limited to, substantial repair and conversion, or any modification of the ship structures, the Surveyor is also to verify that the updated information is kept on board the ship. If the updating of the SCF onboard is not completed at the time of survey, the Surveyor records it and requires confirmation at the next periodical survey
- for the SCF stored on shore archive, the Surveyor is to examine the list of information included on shore archive. In cases where any major event, including, but not limited to, substantial repair and conversion, or any modification of the ship structures, the Surveyor is also to verify that the updated information is stored on shore archive by examining the list of information included on shore archive or kept on board the ship. In addition, the surveyor is to confirm that the service contract with of the Archive Center is valid. If the updating of the SCF Supplement ashore is not completed at the time of survey, the Surveyor records it and requires confirmation at the next periodical survey.

1.2.7 For bulk carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10, on completion of the survey, the Surveyor is to verify that any addition and/or renewal of materials used for the construction of the hull structure is/are documented within the SCF list of materials.

1.3 Reporting and evaluation of surveys

1.3.1 The data and information on the structural condition of the ship collected during survey are evaluated for acceptability and structural integrity of the ship's cargo area.

1.3.2 For CSR bulk carriers, the ship longitudinal strength is to be evaluated, using thickness of the structural members measured, renewed and reinforced, as appropriate, during the renewal surveys carried out after the ship reached 15 years of age (or during the 3rd renewal survey, if this one is carried out before the ship reaches 15 years), in accordance with the criteria for longitudinal strength of the ship hull girder for CSR bulk carriers specified in NR522 CSR for Bulk Carriers, Chapter 13 or in NR606 CSR for Bulk Carriers and Oil Tankers, Part 1, Chapter 13, as applicable.

1.3.3 The final result of evaluation of the ship longitudinal strength required in [1.3.2], after renewal or reinforcement work of structural members, if carried out as a result of initial evaluation, is to be reported as a part of the hull condition evaluation report.

1.3.4 When a survey is split between different survey stations, a report is to be made for each portion of the survey. A list of items examined and/or tested (pressure testing, thickness measurement etc.) and an indication of whether the item has been credited, are to be made available to the next attending Surveyor(s), prior to continuing or completing the survey.

1.3.5 A hull condition evaluation report (summarising the results of class renewal surveys) is issued by the Society to the Owner, who is to place it on board the ship for reference at future surveys. The hull condition evaluation report is endorsed by the Society.

1.4 Conditions for survey

1.4.1 In order to enable the attending surveyors to carry out the survey, provisions for proper and safe access are to be agreed between the Owner and the Society.

Details of the means of access are to be provided in the survey planning questionnaire.

In cases where the provisions of safety and required access are judged by the attending surveyor(s) not to be adequate, the survey of the spaces involved is not to proceed.

1.5 Access to structures

1.5.1 For overall surveys, means are to be provided to enable the Surveyor to examine the hull structure in a safe and practical way.

1.5.2 For close-up surveys of the hull structure, other than cargo hold shell frames, one or more of the following means for access, acceptable to the Surveyor, is/are to be provided:

- permanent staging and passages through structures
- temporary staging and passages through structures
- hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
- portable ladders
- boats or rafts
- other equivalent means.

1.5.3 For close-up surveys of the cargo hold shell frames of bulk carriers less than 100,000 dwt, one or more of the following means for access, acceptable to the Surveyor, is/are to be provided:

- permanent staging and passages through structures
- temporary staging and passages through structures
- portable ladder restricted to not more than 5 m in length may be accepted for surveys of lower section of a shell frame including bracket
- hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
- boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water
- other equivalent means.

1.5.4 For close-up surveys of the cargo hold shell frames of bulk carriers 100,000 dwt and above, the use of portable ladders is not accepted, and one or more of the following means for access, acceptable to the Surveyor, is/are to be provided:

a) Annual surveys, intermediate surveys for ships less than ten years of age and class renewal surveys for ships five years of age or less:
   - permanent staging and passages through structures
   - temporary staging and passages through structures
   - hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
   - boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water
   - other equivalent means.

b) Subsequent intermediate surveys and class renewal surveys:

- either permanent or temporary staging and passages through structures for close-up survey of at least the upper part of hold frames
- hydraulic arm vehicles such as conventional cherry pickers for surveys of lower and middle part of shell frames as alternative to staging
- lifts and movable platforms
- boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water
- other equivalent means.

c) Notwithstanding the above requirements:

1) The use of a portable ladder fitted with a mechanical device to secure the upper end of the ladder is acceptable for the:

- close-up survey of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approximately the lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in the forward cargo hold at annual survey of cargo holds for single skin bulk carriers between 10 and 15 years
- close-up survey of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approximately the lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in the forward cargo hold and one other selected cargo hold at annual survey of cargo holds for single skin bulk carriers over 15 years.

2) The use of hydraulic arm vehicles or aerial lifts (“Cherry picker”) may be accepted by the attending surveyor for the close-up survey of the upper part of side shell frames or other structures in all cases where the maximum working height is not more than 17 m.

2 Annual survey

2.1 General

2.1.1 The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition and should take into account the service history, condition and extent of the corrosion prevention system of ballast tanks and areas identified in the survey report file.

2.2 Hatch covers and coamings, weather decks

2.2.1 Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.

2.2.2 A thorough survey of cargo hatch covers and coamings is only possible by examination in the open as well as closed positions and is to include verification of proper opening and closing operation. As a result, the hatch cover sets within the forward 25% of the ship's length and at least one additional set, such that all sets on the ship are assessed at least once in every five year period, are to be surveyed open, closed and in operation to the full extent on each direction, including:

a) stowage and securing in open condition

b) proper fit and efficiency of sealing in closed condition, and

c) operational testing of hydraulic and power components, wires, chains, and link drives.

The closing of the covers is to include the fastening of all peripheral, and cross joint cleats or other securing devices. Particular attention is to be paid to the condition of the hatch covers in the forward 25% of the ship's length, where sea loads are normally greatest.

2.2.3 If there are indications of difficulty in operating and securing hatch covers, additional sets above those required by [2.2.2], at the discretion of the Surveyor, are to be tested in operation.

2.2.4 Where the cargo hatch securing system does not function properly, repairs are to be carried out under the supervision of the Society.

Where hatch covers or coamings undergo substantial repairs, the strength of securing devices should be upgraded to comply with the requirements laid down in Ch 6, App 1, [6.2], Ch 6, App 1, [6.3] and Ch 6, App 1, [6.4].

2.2.5 For each cargo hatch cover set, the following items are to be surveyed:

a) cover panels, including side plates, and stiffener attachments that may be accessible in the open position by close-up survey (for corrosion, cracks, deformation)

b) sealing arrangements of perimeter and cross joints (gaskets for condition and permanent deformation, flexible seals on combination carriers, gasket lips, compression bars, drainage channels and non return valves)

c) clamping devices, retaining bars, cleating (for wastage, adjustment, and condition of rubber components)

d) closed cover locating devices (for distortion and attachment)

e) chain or rope pulleys

f) guides

g) guide rails and track wheels

h) stoppers

i) wires, chains, tensioners, and gypsies

j) hydraulic system, electrical safety devices and interlocks, and

k) end and interpanel hinges, pins and stools where fitted.

2.2.6 At each hatchway, the coamings, with plating stiffeners and brackets, are to be checked for corrosion, cracks and deformation, especially of the coaming tops, including close-up survey.

2.2.7 Where considered necessary, the effectiveness of sealing arrangements may be proved by hose or chalk testing supplemented by dimensional measurements of seal compressing components.

2.2.8 Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition, where applicable, of:

- wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices
- steel pontoons, including close-up survey of hatchcover plating
- tarpaulins
- cleats, battens and wedges
- hatch securing bars and their securing devices
- loading pads/bars and the side plate edge
- guide plates and chocks
- compression bars, drainage channels and drain pipes (if any).

2.2.9 The annual survey is also to include:

- examination of flame screens on vents to all bunker tanks
- examination of bunker and vent piping systems, including ventilators
- confirmation, when appropriate and as far as practicable when examining internal spaces, that the means of access to cargo and other spaces remain in good condition.
- examination of watertight penetrations as far as practicable.

2.3 Cargo holds

2.3.1 The requirements given in Tab 1 for single skin bulk carriers or Tab 2 for double skin bulk carriers are to be complied with.

2.4 Ballast tanks

2.4.1 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey or the intermediate survey; see [4.3.6] and footnote **(3)** of Tab 4 for single skin bulk carriers or footnote **(3)** of Tab 6 for double skin bulk carriers.

2.4.2 When considered necessary by the Surveyor or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 12 to Tab 16 for single skin bulk carriers or Tab 17 to Tab 20 for double skin bulk carriers. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous surveys are to be examined.

Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

For ships built under the Common Structural Rules, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition.

2.5 Double-skin void spaces

2.5.1 Examination of double-side skin void spaces, for bulk carriers exceeding 20 years of age and of 150 m in length and upwards, are to be carried out when required as a consequence of the results of the renewal survey (as required by [4.3.8]) and intermediate survey (as required by [3.3.1]).

2.5.2 When considered necessary by the Administration, or when extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements are to be increased in accordance with Tab 17. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous survey are to be examined.

Areas of substantial corrosion identified at previous survey are to have thickness measurements taken.

For bulk carriers built under the IACS Common Structural Rules, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition.

Table 1 : Annual survey of cargo holds for single skin bulk carriers

Age of ship (in years at time of annual survey)	
10 < age ≤ 15	age > 15
Overall survey of all cargo holds	Overall survey of all cargo holds
Close-up survey of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approximately the lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in the forward cargo hold. See **(1)**	Close-up survey of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approximately the lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in the forward cargo hold and one other selected cargo hold. See **(1)**
See **(2)** and **(3)**	See **(2)** and **(3)**
Examination of all piping and penetrations, including overboard piping, in cargo holds	Examination of all piping and penetrations, including overboard piping, in cargo holds

(1) Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a close-up survey of all of the shell frames and adjacent shell plating of that cargo hold as well as a close-up survey of sufficient extent of all remaining cargo holds.

(2) When considered necessary by the Surveyor or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is present, the extent of thickness measurements is to be increased in accordance with Tab 12 to Tab 16. These extended thickness measurements are to be carried out before the annual survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
For ships built under the Common Structural Rules, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition.

(3) Where a hard protective coating in cargo holds as provided in [1.1.7] is found in good condition, the extent of close-up survey and thickness measurements may be specially considered.

Table 2 : Annual survey of cargo holds for double skin bulk carriers

Age of ship (in years at time of annual survey)	
10 < age ≤ 15	age > 15
Overall survey of two selected cargo holds	Overall survey of all cargo holds
See **(1)**	See **(1)**
Examination of all piping and penetrations, including overboard piping, in cargo holds	Examination of all piping and penetrations, including overboard piping, in cargo holds

(1) When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 17 to Tab 20. These extended thickness measurements are to be carried out before the survey is credited as complete. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
For ships built under the Common Structural Rules, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition.

3 Intermediate survey

3.1 Ships 10 years of age or less

3.1.1 The requirements for survey of cargo holds given in Tab 3 for single skin bulk carriers or Tab 5 for double skin bulk carriers are to be complied with.

3.1.2 The requirements for survey of salt water ballast tanks given in Tab 4 for single skin bulk carriers or Tab 6 for double skin bulk carriers are to be complied with.

3.2 Ships between 10 and 15 years of age

3.2.1 The scope of intermediate survey of ships between 10 and 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in Article [4] with bottom survey in dry condition or bottom in water survey as applicable. However, internal examination of fuel oil tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.

3.3 Ships over 15 years of age

3.3.1 The scope of intermediate survey of ships over 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [4] with bottom survey in dry condition. However, internal examination of fuel oil tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.

The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and water ballast tanks are to be carried out during the bottom survey in accordance with the applicable requirements for intermediate surveys, if not already performed.

Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

Table 3 : Intermediate survey of cargo holds for single skin bulk carriers - Ships 10 years of age or less at time of the intermediate survey

Overall survey of all cargo holds. See **(1)**
Close-up survey in the forward cargo hold and one other selected cargo hold, to establish the condition of: • at least 25% of the side shell frames including their upper and lower end attachments, and adjacent shell plating • the transverse bulkheads Examination of suspect areas identified at previous surveys See **(1)**
Thickness measurements to an extent sufficient to determine both general and local corrosion levels in areas subject to close-up survey. The minimum requirements for thickness measurements are areas found to be suspect areas at the previous surveys. See **(2)**, **(3)** and **(4)**.
(1) Where considered necessary by the Surveyor as a result of the overall and close-up surveys, the survey is to be extended to include a close-up survey of all the shell frames and adjacent shell plating of that cargo hold as well as a close-up survey of sufficient extent of all remaining cargo holds. **(2)** Where the hard protective coating in cargo holds as provided in [1.1.7] is found to be in good condition, the extent of close-up survey and thickness measurements may be specially considered. **(3)** The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the close-up survey, that there is no structural diminution and the hard protective coatings are found to be in a good condition. **(4)** Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 12 to Tab 16. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For ships built under the Common Structural Rules, the identified substantial corrosion areas may be: • protected by coating, applied in accordance with the coating manufacturer's requirements and examined at annual intervals to confirm the coating in way is still in good condition, or, alternatively • required to be measured at annual intervals. **Note 1:** For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the close-up and thickness measurement surveys. Prior to the coating of cargo holds of existing ships, scantlings are to be ascertained in the presence of a Surveyor.

Table 4 : Intermediate survey of salt water ballast spaces for single skin bulk carriers - Ships 10 years of age or less at time of the intermediate survey

Overall survey of representative water ballast spaces selected by the Surveyor. The selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks. See **(1)**, **(2)** and **(3)** Overall and close-up survey of suspect areas identified at previous surveys The minimum requirements for thickness measurements are areas found to be suspect areas at previous surveys. See **(4)** and **(5)**
(1) If such overall survey reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains efficient. **(2)** Where a hard coating is found to be in less than GOOD condition, corrosion or other defects are found in water ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type. **(3)** For ballast tanks other than double bottom tanks, where a hard protective coating is found to be in less than GOOD condition, and it is not renewed, or where soft or semi-hard coating has been applied or where a hard protective coating was not applied from the time of construction, the tanks in question are to be internally examined and thickness measurement carried out as considered necessary at annual surveys. When such breakdown of hard protective coating is found in ballast double bottom tanks or where a soft or semi-hard coating has been applied or where a hard protective coating has not been applied, the tanks in question may be internally examined at annual surveys. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. **(4)** The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the close-up survey, that there is no structural diminution and the hard protective coatings are found to be in a good condition. **(5)** Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the requirements of Tab 12 to Tab 16. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

Table 5 : Intermediate survey of cargo holds for double skin bulk carriers - Ships 10 years of age or less at time of the intermediate survey

Overall survey of all cargo holds. See **(1)**
Thickness measurements to an extent sufficient to determine both general and local corrosion levels at areas subject to close-up survey. See **(2)**, **(3)** and **(4)**
(1) Where considered necessary by the Surveyor as a result of the overall survey, the survey is to be extended to include a close-up survey of those areas of structure in the cargo holds selected by the Surveyor. **(2)** The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the close-up survey that there is no structural diminution and the hard protective coatings are found to be in a good condition. **(3)** Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 17 to Tab 20. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken. For ships built under the Common Structural Rules, the identified substantial corrosion areas may be: • protected by coating, applied in accordance with the coating manufacturer's requirements and examined at annual intervals to confirm the coating in way is still in good condition, or, alternatively • required to be measured at annual intervals. **(4)** Where a hard protective coating in cargo holds as provided in [1.1.7] is found in good condition, the extent of close-up survey and thickness measurements may be specially considered. **Note 1:** For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the close-up and thickness measurement surveys. Prior to the coating of cargo holds of existing ships, scantlings are to be ascertained in the presence of a Surveyor.

Table 6 : Intermediate survey of ballast tanks for double skin bulk carriers - Ships 10 years of age or less at time of the intermediate survey

Overall survey of representative water ballast tanks selected by the Surveyor. The selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks. See **(1)**, **(2)** and **(3)** Overall and close-up survey of suspect areas identified at previous surveys.
Thickness measurements to an extent sufficient to determine both general and local corrosion levels at areas subject to close-up survey. See **(4)** and **(5)**
(1) If such overall survey reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains efficient. **(2)** Where a hard coating is found to be in less than GOOD condition, corrosion or other defects are found in water ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type. **(3)** In ballast tanks other than double bottom tanks, where a hard protective coating is found to be in less than GOOD condition and it is not renewed, or where soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual surveys. When such breakdown of hard protective coating is found in ballast double bottom tanks, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied, the tanks in question may be examined at annual surveys. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. **(4)** The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the close-up survey that there is no structural diminution and the hard protective coatings are found to be in a good condition. **(5)** Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 17 to Tab 20. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

4 Class renewal survey

4.1 Survey programme and preparation for survey

4.1.1 The Owner in cooperation with the Society is to work out a specific Survey Programme prior to the commencement of any part of:

- the class renewal survey
- the intermediate survey for bulk carriers over 10 years of age.

The survey programme is to be in a written format. The survey is not to commence until the Survey Programme has been agreed.

Prior to the development of the Survey Programme, the survey planning questionnaire is to be completed by the Owner and forwarded to the Society.

The survey programme at intermediate survey may consist of the survey programme at the previous class renewal survey supplemented by the hull condition evaluation report of that class renewal survey and later relevant survey reports.

The survey programme is to be worked out taking into account any amendments to the survey requirements after the last class renewal survey carried out.

4.1.2 In developing the survey programme, the following documentation is to be collected and consulted with a view to selecting holds, tanks, areas and structural elements to be examined:

a) survey status and basic ship information

b) documentation on board, as described in [1.2.2] and [1.2.3]

c) main structural plans (scantling drawings), including information on use of high tensile steels (HTS)

d) relevant previous survey and inspection reports from both the Society and the Owner

e) information regarding the use of ship's holds and tanks, typical cargoes and other relevant data

f) information regarding corrosion prevention level on the newbuilding

g) information regarding the relevant maintenance level during operation.

4.1.3 The submitted Survey Programme is to account for and comply, as a minimum, with the requirements of [4.3], [4.4], [4.5], [4.6] and [4.7], for scope of survey, hatch covers and coamings, close-up survey, thickness measurement and tank testing, respectively, and is to include relevant information including at least:

a) basic ship information and particulars

b) main structural plans (scantling drawings), including information regarding use of high tensile steels (HTS)

c) plan of holds and tanks

d) list of holds and tanks with information on use, protection and condition of coating

e) conditions for survey (e.g. information regarding hold and tank cleaning, gas freeing, ventilation, lighting, etc.)

f) provisions and methods for access to structures

g) equipment for surveys

h) nomination of holds and tanks and areas for close-up surveys according to [4.5]

i) nomination of sections for thickness measurements according to [4.6]

j) nomination of tanks for tank testing according to [4.7]

k) damage experience related to the ship in question.

4.1.4 The Society is to advise the Owner of the maximum acceptable structural corrosion diminution levels applicable to the ship.

4.2 Survey planning meeting

4.2.1 The establishment of proper preparation and the close co-operation between the attending surveyor(s) and the owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board, safety meetings are to be held regularly.

4.2.2 Prior to commencement of any part of the renewal and intermediate survey, a survey planning meeting is to be held between the attending surveyor(s), the owner's representative in attendance, the thickness measurement firm representative, where involved, and the master of the ship or an appropriately qualified representative appointed by the master or Company for the purpose to ascertain that all the arrangements envisaged in the survey programme are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out. See also Ch 2, Sec 2, [2.3.2].

4.2.3 The following is an indicative list of items that are to be addressed in the meeting:

a) schedule of the ship (i.e. the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations, etc.)

b) provisions and arrangements for thickness measurements (i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety)

c) extent of the thickness measurements

d) acceptance criteria (refer to the list of minimum thicknesses)

e) extent of close-up survey and thickness measurements considering the coating condition and suspect areas/areas of substantial corrosion

f) execution of thickness measurements

g) taking representative readings in general and where uneven corrosion/pitting is found

h) mapping of areas of substantial corrosion, and

i) communication between attending surveyor(s), the thickness measurement firm operator(s) and owner representative(s) concerning findings.

4.3 Scope of survey

4.3.1 In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in [4.3.3] is in satisfactory condition for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

4.3.2 All cargo holds, ballast tanks, including double bottom tanks, double side tanks as applicable, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing required in [4.6] and [4.7], to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration that may be present.

4.3.3 All piping systems within the above spaces are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

4.3.4 The survey extent of ballast tanks converted to void spaces will be specially considered by the Society in relation to the requirements for ballast tanks.

4.3.5 As indicated in Ch 3, Sec 3, [2.1.1], a bottom survey in dry condition is to be a part of the class renewal survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out during this bottom survey in accordance with the applicable requirements for class renewal surveys, if not already performed.

Note 1: Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

4.3.6 Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined.

For ballast tanks, excluding double bottom tanks, where a hard protective coating is found to be in less than GOOD condition, and it is not renewed, or where soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual surveys. Thickness measurement are to be carried out as deemed necessary by the Surveyor.

When such a breakdown of hard protective coating is found in water ballast double bottom tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual surveys. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement are to be carried out.

4.3.7 Where hard protective coating in cargo holds, as provided in [1.1.7], is found in good condition, the extent of close-up surveys and thickness measurements may be specially considered.

4.3.8 For double-side skin void spaces bounding cargo holds for bulk carriers exceeding 20 years of age and of 150 m in length and upwards, where provided, the condition of the corrosion prevention system of void spaces shall be examined. Where a hard protective coating is found to be in POOR condition, and it is not renewed, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the void spaces in question shall be examined at annual intervals. Thickness measurements shall be carried out as deemed necessary by the surveyor.

4.4 Hatch covers and coamings

4.4.1 A survey of the items listed in [2.2] is to be carried out, in addition to all hatch covers and coamings.

4.4.2 Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:

- stowage and securing in open condition
- proper fit and efficiency of sealing in closed condition
- operational testing of hydraulic and power components, wires, chains, and link drives.

4.4.3 Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent.

4.4.4 The close-up survey and thickness measurements in accordance with the requirements given in Tab 8, Tab 9, Tab 10 and Tab 11, respectively, are to be carried out.

Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/ thickness measurement is to be done of the accessible parts of hatch cover structures.

4.5 Overall and close-up surveys

4.5.1 An overall survey of all tanks and spaces is to be carried out at each class renewal survey. Fuel oil tanks in the cargo length area are to be surveyed as per Tab 7.

4.5.2 The minimum requirements for close-up surveys are given in Tab 8 for single skin bulk carriers, in Tab 9 for double skin bulk carriers excluding ore carriers and in Tab 10 for ore carriers.

4.5.3 The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

4.5.4 For areas in spaces where hard protective coatings are found to be in a good condition, the extent of close-up surveys according to Tab 8 for single skin bulk carriers Tab 9 for double skin bulk carriers excluding ore carriers and Tab 10 for ore carriers, may be specially considered. Refer also to [4.3.7].

Table 7 : Requirements for internal examination of fuel oil tanks in the cargo length area

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 & subsequent age > 15
none	one	two **(1)**	half (min. two) **(1)**

(1) One deep tank for fuel oil in the cargo area is to be included, if fitted.

Note 1: Tanks considered are of the integral (structural) type.

Note 2: If a selection of tanks is accepted to be examined, then different tanks are to be examined at each class renewal survey, on a rotational basis.

Note 3: Peak tanks (all uses) are subject to internal examination at each class renewal survey.

Table 8 : Requirements for close-up survey at class renewal survey of single skin bulk carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
25% of shell frames in the forward cargo hold at representative positions ① Selected shell frames in all remaining cargo holds ①	All shell frames in the forward cargo hold and 25% of shell frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating ① For bulk carriers 100,000 dwt and above, all shell frames in the forward cargo hold and 50% of shell frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating ①	All shell frames in the forward and one other selected cargo hold and 50% of shell frames in each of the remaining cargo holds including upper and lower end attachments and adjacent shell plating ①	All shell frames in all cargo holds including upper and lower end attachments and adjacent shell plating ①
One transverse web with associated plating and longitudinals in two representative water ballast tanks of each type (i.e. topside or hopper side tank) ②	One transverse web with associated plating and longitudinals in each water ballast tank ② Forward and aft transverse bulkheads in one ballast tank, including stiffening system ②	All transverse webs with associated plating and longitudinals in each water ballast tank ② All transverse bulkheads in ballast tanks, including stiffening system ②	Areas ② to ⑤ as for class renewal survey for ships between 10 and 15 years of age
Two selected cargo hold transverse bulkheads ③	All cargo hold transverse bulkheads ③	All cargo hold transverse bulkheads ③	
All cargo hold hatch covers and coamings ④	All cargo hold hatch covers and coamings ④	All cargo hold hatch covers and coamings ④	
	All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches ⑤	All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches ⑤	

Note 1: See Fig 1 for areas ①, ②, ③, ④ and ⑤. See also Ch 6, Sec 2, Fig 3 for zones of side shell frames for ships subject to compliance with Ch 6, Sec 2, [5].

① Cargo hold transverse frames.

② Transverse web frame or transverse watertight bulkhead in water ballast tanks.

③ Cargo hold transverse bulkhead plating, stiffeners and girders, including internal structure of upper and lower stools, where fitted.

④ Cargo hold hatch covers and coamings (plating and stiffeners).Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of the accessible parts of hatch cover structures.

⑤ Deck plating and under deck structure inside line of hatch openings between cargo hold hatches.

Note 2: Close-up survey of transverse bulkheads to be carried out at four levels (see Fig 2):

- immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for bulkheads without lower stool
- immediately above and below the lower stool shelf plate (for bulkheads fitted with lower stools), and immediately above the line of the shedder plates
- about mid-height of the bulkhead
- immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for bulkheads fitted with upper stools, or immediately below the top side tanks.

Figure 1 : Close-up surveys and thickness measurement areas for single skin bulk carriers

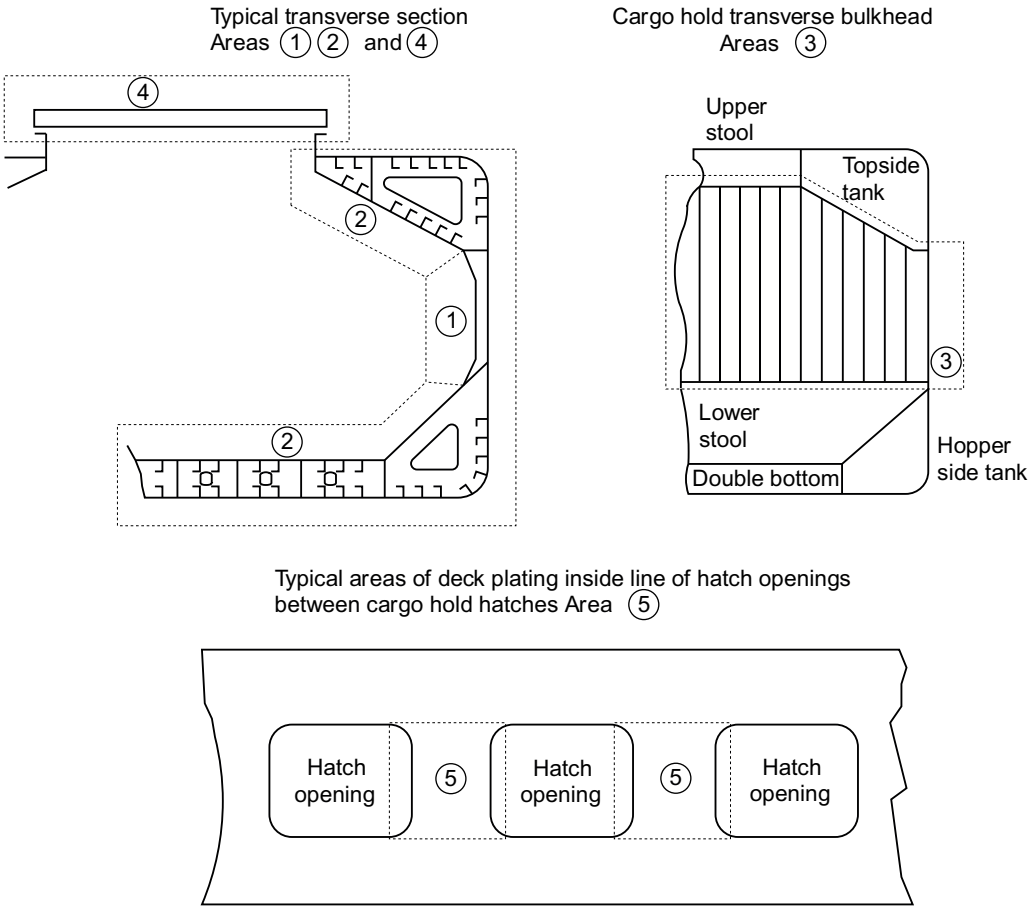


Figure 2 : Transverse bulkhead: close-up survey areas

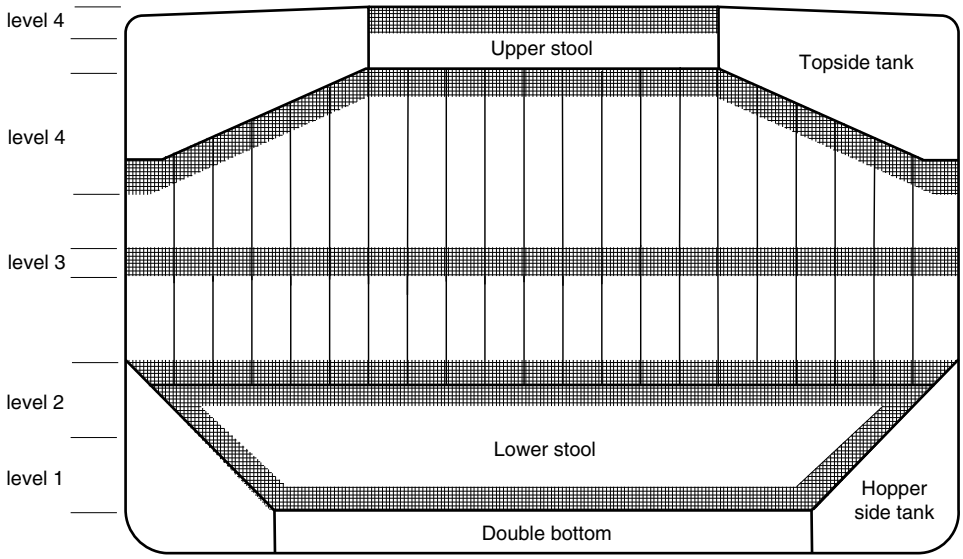


Table 9 : Requirements for close-up survey at class renewal survey of double skin bulk carriers, excluding ore carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
One transverse web with associated plating and longitudinals in two representative water ballast tanks of each type (this is to include the foremost topside and double side water ballast tanks on either side) ①	One transverse web with associated plating and longitudinals as applicable in each water ballast tank ① Forward and aft transverse bulkheads including stiffening system in a transverse section including topside, hopper side and double side ballast tanks, on one side of the ship (i.e. port or starboard) ①	All transverse webs with associated plating and longitudinals as applicable in each water ballast tank ① All transverse bulkheads including stiffening system in each water ballast tank ①	All transverse webs with associated plating and longitudinals as applicable in each water ballast tank ① All transverse bulkheads including stiffening system in each water ballast tank ①
	25% of ordinary transverse frames for transverse framing system or 25% of longitudinals for longitudinal framing system on side shell and inner side plating at forward, middle and aft parts, in the foremost double side tanks ②	25% of ordinary transverse frames for transverse framing system or 25% of longitudinals for longitudinal framing system on side shell and inner side plating at forward, middle and aft parts, in all double side tanks ②	All ordinary transverse frames for transverse framing system or all longitudinals for longitudinal framing system on side shell and inner side plating at forward, middle and aft parts, in all double side tanks ②
Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted ③	One transverse bulkhead in each cargo hold, including internal structure of upper and lower stools, where fitted ③	All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted ③	Areas ③ to ⑤ as for class renewal survey for ships between 10 and 15 years of age
All cargo hold hatch covers and coamings (platings and stiffeners) ④	All cargo hold hatch covers and coamings (platings and stiffeners) ④	All cargo hold hatch covers and coamings (platings and stiffeners) ④	
	All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches ⑤	All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches ⑤	

Note 1: See Fig 4 and Fig 3 for areas ①, ②, ③, ④ and ⑤.

① Transverse web frame or watertight transverse bulkhead in topside, hopper side and double side ballast tanks. In fore and aft peak tanks, transverse web frame means a complete transverse web frame ring including adjacent structural members.

② Ordinary transverse frame in double side tanks.

③ Cargo hold transverse bulkheads plating, stiffeners and girders.

④ Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of the accessible parts of hatch cover structures.

⑤ Deck plating and underdeck structure inside line of hatch openings between cargo hold hatches.

Note 2: Close-up survey of transverse bulkheads to be carried out at four levels (see Fig 2):

- immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower tool
- immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates
- about mid-height of the bulkhead
- immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate (for those ships fitted with upper stools), or immediately below the topside tanks.

Table 10 : Requirements for close-up survey at class renewal survey of ore carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
One web frame ring complete, including adjacent structural members, in a ballast wing tank ① One transverse bulkhead lower part, including girder system and adjacent structural members, in a ballast tank ①	All web frame rings complete, including adjacent structural members, in a ballast wing tank ① One deck transverse, including adjacent deck structural members, in each remaining ballast tank ① Forward and aft transverse bulkheads complete, including girder system and adjacent structural members, in a ballast wing tank ① One transverse bulkhead lower part, including girder system and adjacent structural members, in each remaining ballast tank ①	All web frame rings complete, including adjacent structural members, in each ballast tank ① All transverse bulkheads complete, including girder system and adjacent structural members, in each ballast tank ① One web frame ring complete, including adjacent structural members, in each wing void space ① Additional web frame rings in void spaces, as deemed necessary by the Society ①	As for class renewal survey for ships between 10 and 15 years of age
Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted ③	One transverse bulkhead in each cargo hold, including internal structure of upper and lower stools, where fitted ③	All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted ③	Areas ③ to ⑤ as for class renewal survey for ships between 10 and 15 years of age
All cargo hold hatch covers and coamings (platings and stiffeners) ④	All cargo hold hatch covers and coamings (platings and stiffeners) ④	All cargo hold hatch covers and coamings (platings and stiffeners) ④	
	All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches ⑤	All deck plating and underdeck structure inside line of hatch openings between all cargo hold hatches ⑤	

Note 1: See Fig 4 and Fig 3 for areas ①, ③, ④ and⑤ (area ② not used).

① Transverse web frame or watertight transverse bulkhead in ballast wing tanks and void spaces. In fore and aft peak tanks, transverse web frame means a complete transverse web frame ring including adjacent structural members.

② (not used in this Table).

③ Cargo hold transverse bulkheads plating, stiffeners and girders.

④ Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of the accessible parts of hatch cover structures.

⑤ Deck plating and underdeck structure inside line of hatch openings between cargo hold hatches.

Note 2: Close-up survey of transverse bulkheads to be carried out at four levels (see Fig 2):

Level 1 : Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.

Level 2 : Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.

Level 3 : About mid-height of the bulkhead.

Level 4 : Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate (for those ships fitted with upper stools), or immediately below the topside tanks.

Figure 3 : Areas subject to close-up surveys and thickness measurements for ore carriers

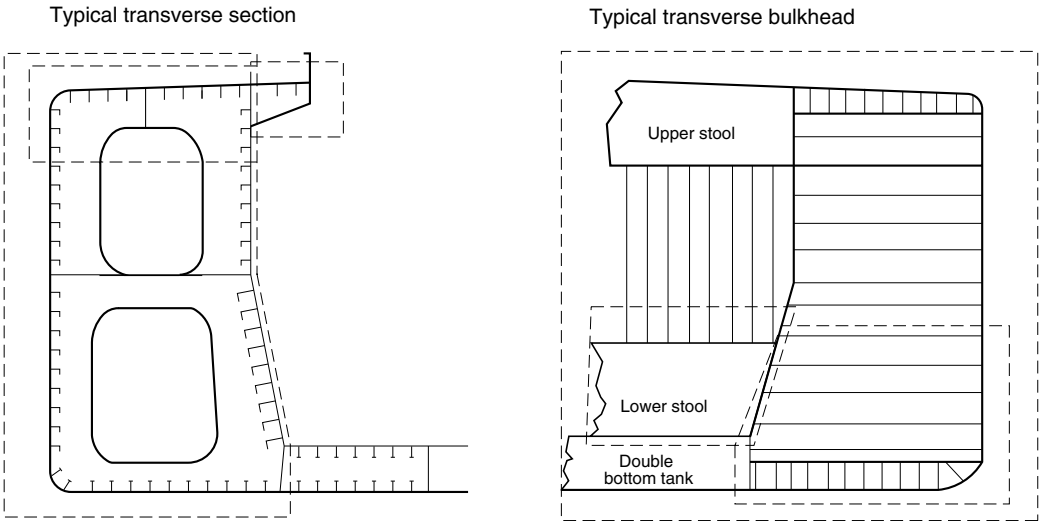
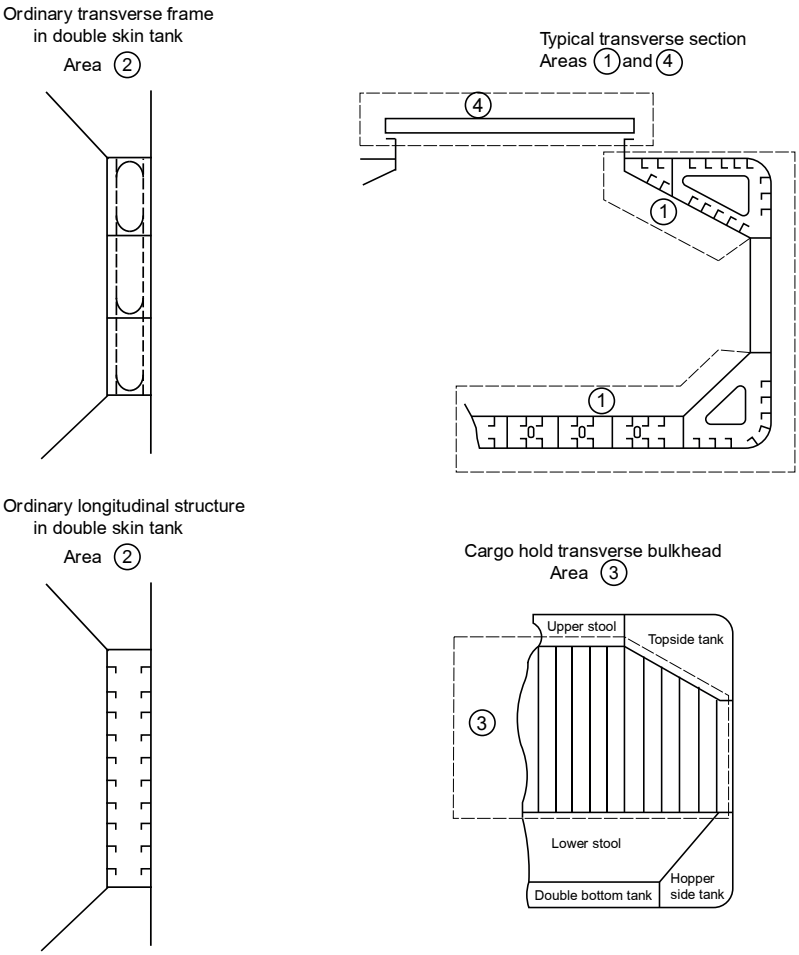


Figure 4 : Areas subject to close-up surveys and thickness measurements for double skin bulk carriers



4.6 Thickness measurements

4.6.1 The minimum requirements for thickness measurements at class renewal survey are given in Tab 11.

Note 1: Attention is drawn to specific thickness measurements to be carried out on the bulkhead between the two foremost cargo holds for ships which are to comply with retroactive requirements as detailed in Ch 6, Sec 2, [1.3] and to additional thickness measurements applicable to the side shell frames and brackets on ships subject to compliance with Ch 6, Sec 2, [5].

4.6.2 Provisions for extended measurements for areas with substantial corrosion are given in Tab 12 to Tab 20 and as may be additionally specified in the survey programme as required by [4.1]. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

Note 1: For ships built under the Common Structural Rules, the identified substantial corrosion areas may be:

- protected by coating, applied in accordance with the coating manufacturer's requirements and examined at annual intervals to confirm the coating in way is still in good condition, or, alternatively
- required to be measured at annual intervals.

4.6.3 The Surveyor may further extend the thickness measurements as deemed necessary.

4.6.4 When pitting is found on bottom plating and its intensity is 20% or more, thickness measurements are to be extended in order to determine the actual plate thickness out of the pits and the depth of the pits. Where the wastage is in the substantial corrosion range or the average depth of pitting is 1/3 or more of the actual plate thickness, the pitted plate is to be considered as a substantially corroded area.

4.6.5 For areas in tanks where hard protective coatings are found to be in a good condition (see Ch 2, Sec 2, [2.2.14]), the extent of thickness measurements according to Tab 11 may be specially considered by the Society. Refer also to [4.3.7].

4.6.6 For single skin bulk carriers, representative thickness measurements to determine both general and local levels of corrosion in the shell frames and their end attachments in all cargo holds and water ballast tanks is to be carried out. For double skin bulk carriers, representative thickness measurement to determine both general and local levels of corrosion in the transverse web frames in all water ballast tanks is to be carried out.

Thickness measurements is also to be carried out to determine the corrosion levels on the transverse bulkhead plating. The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the close-up survey, that there is no structural diminution, and the hard protective coating where applied remains efficient.

Table 11 : Requirements for thickness measurements at class renewal survey of bulk carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤15	Class renewal survey No.4 and subsequent age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
	Within the cargo length area: • two transverse sections of deck plating outside line of cargo hatch openings **(1)**	Within the cargo length area: • each deck plate outside line of cargo hatch openings • two transverse sections, one in the amidship area, outside line of cargo hatch openings, **(1)**	Within the cargo length area: • each deck plate outside line of cargo hatch openings • three transverse sections, one in the amidship area, outside line of cargo hatch openings, **(1)** • each bottom plate
	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 8 or Tab 9 or Tab 10, as applicable	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 8 or Tab 9 or Tab 10, as applicable	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 8 or Tab 9 or Tab 10, as applicable
	Wind and water strakes in way of the transverse sections considered above	All wind and water strakes within the cargo area	All wind and water strakes, full length
	Selected wind and water strakes outside the cargo area	Selected wind and water strakes outside the cargo area	
(1) Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements, one of which is to be in the midship area.			

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤15	Class renewal survey No.4 and subsequent age > 15
		Additional thickness measurements given in Ch 6, Sec 2, [1.3] are to be taken on the transverse watertight bulkhead between the two foremost cargo holds on ships to which the requirements given in Ch 6, Sec 2, [1.1.1] apply	Additional thickness measurements given in Ch 6, Sec 2, [1.3] are to be taken on the transverse watertight bulkhead between the two foremost cargo holds on ships to which the requirements given in Ch 6, Sec 2, [1.1.1] apply
	Additional thickness measurements given in Ch 6, Sec 2, [5.3]are to be taken on the side shell frames and brackets on ships subject to compliance with Ch 6, Sec 2, [5]	Additional thickness measurements given in Ch 6, Sec 2, [5.3] are to be taken on the side shell frames and brackets on ships subject to compliance with Ch 6, Sec 2, [5]	Additional thickness measurements given in Ch 6, Sec 2, [5.3] are to be taken on the side shell frames and brackets on ships subject to compliance with Ch 6, Sec 2, [5]
(1) Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements, one of which is to be in the midship area.			

Table 12 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of single skin bulk carriers within the cargo area

BOTTOM AND SIDE SHELL STRUCTURES		
Structural member	Extent of measurement	Pattern of measurement
Bottom and side shell plating	Suspect plate, plus 4 adjacent plates See other tables for particulars on gauging in way of tanks and cargo holds	5-point pattern for each panel between longitudinals
Bottom and side shell longitudinals	Minimum of 3 longitudinals in way of suspect areas	3 measurements in line across web 3 measurements on flange

Table 13 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of single skin bulk carriers within the cargo area

TRANSVERSE BULKHEADS IN CARGO HOLDS		
Structural member	Extent of measurement	Pattern of measurement
Lower stool	Transverse band within 25 mm of welded connection to inner bottom Transverse band within 25 mm of welded connection to shelf plate	5-point pattern between stiffeners over one metre length 5-point pattern between stiffeners over one metre length
Transverse bulkhead	Transverse band at approximately mid-height Transverse band at part of bulkhead adjacent to upper deck or below upper stool shelf plate (for bulkheads fitted with lower stool)	5-point pattern over 1 m^2 of plating 5-point pattern over 1 m^2 of plating

Table 14 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of single skin bulk carriers within the cargo area

DECK STRUCTURE AND HATCH COVERS		
Structural member	Extent of measurement	Pattern of measurement
Cross deck strip plating	Suspect cross deck strip plating	5-point pattern between underdeck stiffeners over one metre length
Underdeck stiffeners	Transverse members Longitudinal members	5-point pattern at each end and mid-span 5-point pattern on both web and flange
Hatch covers	Skirt: 3 locations on each side and each end 3 longitudinal bands, outboard strakes (2) and centreline strake (1)	5-point pattern at each location 5-point measurement each band
Hatch coamings	Both sides and ends of coaming: one band lower 1/3 and one band upper 2/3 of coaming	5-point measurement each band

DECK STRUCTURE AND HATCH COVERS		
Structural member	Extent of measurement	Pattern of measurement
Topside water ballast tanks	Transverse watertight bulkhead: (a) lower 1/3 of bulkhead (b) upper 2/3 of bulkhead (c) stiffeners	 (a) 5-point pattern over 1 m^2 of plating (b) 5-point pattern over 1 m^2 of plating (c) 5-point pattern over 1 m length
	Two representative transverse wash bulkheads: (a) lower 1/3 of bulkhead (b) upper 2/3 of bulkhead (c) stiffeners	 (a) 5-point pattern over 1 m^2 of plating (b) 5-point pattern over 1 m^2 of plating (c) 5-point pattern over 1 m length
	Three representative bays of sloped plating: (a) lower 1/3 of tank (b) upper 2/3 of tank	 (a) 5-point pattern over 1 m^2 of plating (b) 5-point pattern over 1 m^2 of plating
	Longitudinals: suspect and adjacent	5-point pattern both web and flange over 1 m length
Main deck plating	Suspect plates and adjacent	5-point pattern over 1 m^2 of plating
Main deck longitudinals	Minimum of 3 longitudinals where plating measured	5-point pattern both web and flange over 1 m length
Web frames/transverses	Suspect plates	5-point pattern over 1 m^2 of plating

Table 15 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of single skin bulk carriers within the cargo area

DOUBLE BOTTOM AND HOPPER STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Inner bottom plating	Suspect plate plus all adjacent plates	5-point pattern for each panel between longitudinals over one metre length
Inner bottom longitudinals	Three longitudinals where plates measured	3 measurements in line across and 3 measurements on flange
Longitudinal girders and transverse floors	Suspect plates	5-point pattern over approximately 1 m^2 of plating
Watertight bulkheads (floors and girders)	(a) lower 1/3 of tank (b) upper 2/3 of tank	(a) 5-point pattern over 1 m^2 of plating (b) 5-point pattern alternate plates over 1 m^2 of plating
Transverse web frames	Suspect plate	5-point pattern over 1 m^2 of plating

Table 16 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of single skin bulk carriers within the cargo area

CARGO HOLDS		
Structural member	Extent of measurement	Pattern of measurement
Side shell frames	Suspect frame and each adjacent	(a) At each end and mid-span: 5-point pattern of both web and flange (b) 5-point pattern within 25 mm of welded attachment to both shell and lower sloped plate

Table 17 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of double skin bulk carriers within the cargo length area

BOTTOM, INNER BOTTOM AND HOPPER STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom, inner bottom and hopper structure plating	Minimum of 3 bays across double bottom tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
Bottom, inner bottom and hopper structure longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on the vertical web

BOTTOM, INNER BOTTOM AND HOPPER STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with 1 measurement between each panel stiffener, or a minimum of 3 measurements
Bottom floors, including the watertight ones	3 floors in the bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over 2 square metre area
Hopper structure web frame ring	3 floors in the bays where bottom plating measured	5-point pattern over 1 square metre of plating Single measurements on flange
Hopper structure transverse watertight bulkhead or swash bulkhead	• lower 1/3 of bulkhead • upper 2/3 of bulkhead • stiffeners (minimum of 3)	5-point pattern over 1 square metre of plating 5-point pattern over 2 square metre of plating for web, 5-point pattern over span (2 measurements across web at each end and one at centre of span). For flange, single measurements at each end and centre of span
Panel stiffening	Where applicable	Single measurements

Table 18 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of double skin bulk carriers within the cargo length area

DECK STRUCTURE INCLUDING CROSS STRIPS, MAIN CARGO HATCHWAYS, HATCH COVERS, COAMINGS AND TOPSIDE TANKS		
Structural member	Extent of measurement	Pattern of measurement
Cross deck strip plating	Suspect cross deck strip plating	5-point pattern between underdeck stiffeners over 1 metre length
Underdeck stiffeners	Transverse members Longitudinal members	5-point pattern at each end and mid span 5-point pattern on both web and flange
Hatch covers	Side and end skirts, each 3 locations 3 longitudinal bands: 2 outboard strakes and 1 centreline strake	5-point pattern at each location 5-point measurement each band
Hatch coamings	Each side and end of coaming, one band lower 1/3, one band upper 2/3 of coaming	5-point measurement each band i.e. end or side coaming
Topside ballast tanks	a) Watertight transverse bulkheads: • lower 1/3 of bulkhead • upper 2/3 of bulkhead • stiffeners	 5-point pattern over 1 square metre of plating 5-point pattern over 1 square metre of plating 5-point pattern over 1 metre length
Topside ballast tanks	b) Two representative swash transverse bulkheads: • lower 1/3 of bulkhead • upper 2/3 of bulkhead • stiffeners	 5-point pattern over 1 square metre of plating 5-point pattern over 1 square metre of plating 5-point pattern over 1 metre length
Topside ballast tanks	c) Three representative bays of slope plating: • lower 1/3 of tank • upper 2/3 of tank	2 5-point pattern over 1 square metre of plating 5-point pattern over 1 square metre of plating
Topside ballast tanks	d) Longitudinals, suspect and adjacent	5-point pattern on both web and flange over 1 metre length
Main deck plating	Suspect plates and adjacent (4)	5-point pattern over 1 square metre of plating
Main deck longitudinals	Suspect plates	5-point pattern on both web and flange over 1 metre length
Web frames / Transverses	Suspect plates	5-point pattern over 1 square metre

Table 19 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of double skin bulk carriers within the cargo length area

STRUCTURE IN DOUBLE SIDE SPACES OF DOUBLE SKIN BULK CARRIERS INCLUDING WING VOID SPACES OF ORE CARRIERS		
Structural member	Extent of measurement	Pattern of measurement
Side shell and inner plating: • upper strake and strakes in way of horizontal girders • all other strakes	 • plating between each pair of transverse frames/longitudinals in a minimum of 3 bays (along the tank) • plating between every third pair of longitudinals in same 3 bays	 • Single measurement • Single measurement
Side shell and inner side transverse frames / longitudinals on: • upper strake • all other strakes	 • each transverse frame/longitudinal in same 3 bays • every third transverse frame/longitudinal in same 3 bays	 • 3 measurements across web and 1 measurement on flange • 3 measurements across web and 1 measurement on flange
Transverse frames / longitudinals: • brackets	 Minimum of 3 at top, middle and bottom of tank in same 3 bays	 5-point pattern over area of bracket
Vertical web and transverse bulkheads: • strakes in way of horizontal girders • other strakes	 • minimum of 2 webs and both transverse bulkheads • minimum of 2 webs and both transverse bulkheads	 • 5-point pattern over approx. 2 square metre area • 2 measurements between each pair of vertical stiffeners
Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners
Panel stiffening	Where applicable	Single measurements

Table 20 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of double skin bulk carriers within the cargo length area

TRANSVERSE BULKHEADS IN CARGO HOLDS		
Structural member	Extent of measurement	Pattern of measurement
Lower stool, where fitted	• transverse band within 25 mm of welded connection to inner bottom • transverse band within 25 mm of welded connection to shelf plate	• 5-point pattern between stiffeners over 1 metre length • 5-point pattern between stiffeners over 1 metre length
Transverse bulkheads	• transverse band at approx. mid height • transverse band at part of bulkhead adjacent to upper deck or below upper stool shelf plate (for those ships fitted with upper stools)	• 5-point pattern over 1 square metre of plating • 5-point pattern over 1 square metre of plating

4.7 Tank testing

4.7.1 All boundaries of water ballast tanks, deep tanks and cargo holds used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks, only representative tanks are to be pressure tested.

4.7.2 The Surveyor may extend the tank testing as deemed necessary.

4.7.3 Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

Boundaries of ballast holds are to be tested with a head of liquid to near to the top of hatches.

Boundaries of fuel oil tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

4.7.4 The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tanktop is carried out.

Section 3 Oil Tankers and Combination Carriers

1 General

1.1 Application

1.1.1 The requirements of this Section apply to all self-propelled ships which have been assigned one of the following service notations:

- **oil tanker ESP** (whether of single or double hull construction)
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**.

Note 1: A double hull oil tanker is a ship which is constructed primarily for the carriage of oil (MARPOL Annex I cargoes) in bulk, which have the cargo tanks protected by a double hull which extends for the entire length of the cargo area, consisting of double sides and double bottom spaces for the carriage of water ballast or void spaces. The requirements of this Section for double hull tankers are also applicable to existing double hull tankers not complying with MARPOL Regulation 13F, but having a U-shaped midship section.

1.1.2 Ships granted with the service notation **oil storage service** are only concerned by the requirements laid down in [6] for class hull renewal surveys.

1.1.3 The requirements for hull surveys apply to the surveys of the hull structure and piping systems in way of cargo tanks, pump rooms, cofferdams, pipe tunnels and void spaces within the cargo area and all ballast tanks. They are additional to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3 according to the relevant surveys.

1.1.4 The requirements contain the minimum extent of examination, thickness measurements and tank testing. When substantial corrosion, as defined in Ch 2, Sec 2, [2.2.7], and/or structural defects are found, the survey is to be extended and is to include additional close-up surveys when necessary.

1.1.5 In any kind of survey, i.e. class renewal, intermediate, annual or other surveys having the same scope, thickness measurements, when required by Tab 3, of structures in areas where close-up surveys are required are to be carried out simultaneously with close-up surveys.

1.1.6 In all cases the extent of thickness measurements is to be sufficient as to represent the actual average condition.

1.1.7 When, in any survey, thickness measurements are required:

- the procedure detailed in Ch 2, Sec 2, [2.3] is to be applied
- the thickness measurement firm is to be part of the survey planning meeting to be held prior to commencing the survey.

1.1.8 The requirements for machinery surveys apply to surveys of the machinery and equipment in the cargo area or dedicated to cargo service systems and are additional to those given in Part A, Chapter 3 for all ships.

1.2 Documentation on board

1.2.1 The Owner is to obtain, supply and maintain documentation on board as specified in [1.2.2] and [1.2.3], which is to be readily available for examination by the Surveyor. The documentation is to be kept on board for the lifetime of the ship.

For oil tankers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10, the Owner is to arrange the updating of the Ship Construction File (SCF) throughout the ship's life whenever a modification of the documentation included in the SCF has taken place. Documented procedures for updating the SCF are to be included within the Safety Management System.

1.2.2 A survey report file is to be a part of the documentation on board consisting of:

- reports of structural surveys
- hull condition evaluation report (summarising the results of class renewal surveys)
- thickness measurement reports.

The survey report file is also to be available in the Owner's management office.

1.2.3 The following additional supporting documentation is to be available on board:

- main structural plans of cargo and ballast tanks (for CSR ships, these plans are to include, for each structural element, both the as-built and the renewal thicknesses. Any thickness for voluntary addition is also to be clearly indicated on the plans. The midship section plan to be supplied on board the ship is to include the minimum allowable hull girder sectional properties for the tank transverse section in all cargo tanks)
- previous repair history
- cargo and ballast history

- extent of use of inert gas system and tank cleaning procedures
- ship's personnel reports on:
  - structural deterioration/defects in general
  - leakage in bulkheads and piping systems
  - condition of coatings or corrosion prevention systems, if any
- survey program, as required in [6.1], until such time as the class renewal survey or intermediate survey, as applicable, has been completed
- any other information that may help to identify critical structural areas and/or suspect areas requiring inspection.

1.2.4 For oil tankers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10, the Ship Construction File (SCF), limited to the items to be retained onboard, is to be available on board.

1.2.5 Prior to survey, the Surveyor examines the documentation on board and its contents, which are used as a basis for the survey.

1.2.6 For oil tankers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10:

- on completion of the survey, the Surveyor is to verify that the update of the Ship Construction File (SCF) has been done whenever a modification of the documentation included in the SCF has taken place.
- for the SCF stored on board ship, the Surveyor is to examine the information on board ship. In cases where any major event, including, but not limited to, substantial repair and conversion, or any modification of the ship structures, the Surveyor is also to verify that the updated information is kept on board the ship. If the updating of the SCF onboard is not completed at the time of survey, the Surveyor records it and requires confirmation at the next periodical survey
- for the SCF stored on shore archive, the Surveyor is to examine the list of information included on shore archive. In cases where any major event, including, but not limited to, substantial repair and conversion, or any modification of the ship structures, the Surveyor is also to verify that the updated information is stored on shore archive by examining the list of information included on shore archive or kept on board the ship. In addition, the surveyor is to confirm that the service contract with of the Archive Center is valid. If the updating of the SCF Supplement ashore is not completed at the time of survey, the Surveyor records it and requires confirmation at the next periodical survey.

1.2.7 For oil tankers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10, on completion of the survey, the Surveyor is to verify that any addition and/or renewal of materials used for the construction of the hull structure is/are documented within the SCF inventory list.

1.3 Reporting and evaluation of surveys

1.3.1 The data and information on the structural condition of the ship collected during survey are evaluated for acceptability and structural integrity of the ship's cargo area.

1.3.2 In case of oil tankers of 130 m in length and upwards (as defined in the International Convention on Load Lines in force), the ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during the class renewal survey carried out after the ship reached 10 years of age in accordance with the criteria for longitudinal strength of the ship's hull girder for oil tankers specified in Ch 4, App 1.

The final result of evaluation of the ship's longitudinal strength, after renewal or reinforcement work of structural members, if carried out as a result of initial evaluation, is to be reported as a part of the hull condition evaluation report.

1.3.3 When a survey is split between different survey stations, a report is to be made for each portion of the survey. A list of items examined and/or tested (pressure testing, thickness measurements etc.) and an indication of whether the item has been credited, are to be made available to the next attending Surveyor(s), prior to continuing or completing the survey.

1.3.4 A hull condition evaluation report (summarizing the results of class renewal surveys) is issued by the Society to the Owner, who is to place it on board the ship for reference at future surveys. The hull condition evaluation report is endorsed by the Society.

1.4 Conditions for survey

1.4.1 In order to enable the attending surveyor(s) to carry out the survey, provisions for proper and safe access are to be agreed between the Owner and the Society.

Details of the means of access are to be provided in the survey planning questionnaire.

In cases where the provisions of safety and required access are judged by the attending surveyor(s) not to be adequate, the survey of the spaces involved is not to proceed.

1.5 Access to structures

1.5.1 For overall survey, means are to be provided to enable the surveyor(s) to examine the hull structure in a safe and practical way.

1.5.2 For close-up survey, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

- permanent staging and passages through structures
- temporary staging and passages through structures
- hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
- boats or rafts
- portable ladders
- other equivalent means.

2 Annual survey - Hull items

2.1 General

2.1.1 The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition and should take into account the service history, condition and extent of the corrosion prevention system of ballast tanks and areas identified in the survey report file.

2.2 Weather decks

2.2.1 The survey is to include:

- examination of cargo tank openings, including gaskets, covers, coamings and screens
- examination of cargo tank pressure/vacuum valves and flame screens
- examination of flame screens on vents to all bunker, oily-ballast and oily slop tanks and void spaces
- examination of cargo, crude oil washing, bunker, ballast and vent piping systems, including remote control valves, safety valves and various safety devices, as well as vent masts and headers
- confirmation that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends facing the cargo area are in satisfactory condition
- confirmation that the requisite arrangements to regain steering capability in the event of the prescribed single failure are being maintained
- examination of the cargo tank venting, purging and gas freeing systems and other ventilation systems
- examination, for oil tankers of 150 m in length and above, where appropriate, of the ship's structure in accordance with the Ship Construction File, taking into account identified areas that need special attention.
- examination of watertight penetrations as far as practicable.

2.3 Cargo pump rooms and pipe tunnels

2.3.1 The survey is to include:

- examination of all pump room bulkheads and pipe tunnels (if any) for signs of oil leakage or fractures and, in particular, the sealing arrangements of penetrations in these bulkheads
- examination of the condition of all piping systems, in cargo pump rooms and pipe tunnels (if any)
- examination of the bilge and ballast arrangements.

2.4 Ballast tanks

2.4.1 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey or the intermediate survey.

2.4.2 When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the requirements of Tab 4 or Tab 5. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

2.4.3 For ships built under the Common Structural Rules, the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out.

2.4.4 For ships with dedicated ballast water tanks, confirmation, through documentary evidence, that the corrosion prevention system fitted to these dedicated ballast water tanks has been maintained.

2.5 Emergency towing arrangement

2.5.1 The Owner or his representative is to declare to the attending Surveyor that no significant alterations have been made, without prior approval from the Society, to the equipment and arrangements fitted on board in accordance with the provisions given in Pt B, Ch 12, Sec 4, [3].

2.5.2 The survey is to include:

- an examination, as far as practicable, of the emergency towing arrangement
- confirmation that the aft towing arrangement is pre-rigged and forward chafing gear is secured to the strong-point
- confirmation of the proper functioning of the light, where it is provided, on the pick-up gear marker buoy.

2.6 Safe access to tanker bows

2.6.1 The access to bow arrangement is to be examined, as applicable.

2.7 Means of access

2.7.1 When appropriate and as far as practicable when examining internal spaces, the condition of the means of access to cargo and other spaces is to be ascertained.

2.8 Coating systems

2.8.1 When appropriate, confirmation that the coating system in cargo oil tanks of crude oil tankers, is maintained and that in-service maintenance and repair activities are recorded in the coating technical file.

3 Annual survey - Cargo machinery items

3.1 Cargo area and cargo pump rooms

3.1.1 The Owner or his representative is to declare to the attending Surveyor that no modifications or alterations which might impair safety have been made to the various installations in dangerous zones without prior approval from the Society.

The survey is to include:

- check of the protection of cargo pump room, as applicable, and in particular, check of:
  - temperature sensing devices for bulkheads glands and alarms
  - interlock between lighting and ventilation
  - gas detection system
  - bilge level monitoring devices and alarms
- examination of the emergency lighting in cargo pump rooms of ships constructed after 1st July 2002
- confirmation that potential sources of ignition in or near the cargo pump rooms, such as loose gear, excessive product in bilge, excessive vapours, combustible materials, etc., are eliminated and that access ladders are in satisfactory condition
- examination, as far as practicable, of cargo, bilge, ballast and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of the pump room bilge system, and checking that pump foundations are intact
- confirmation that the ventilation system, including portable equipment, if any, of all spaces in the cargo area (including cargo pump rooms) is operational, ducting is intact, dampers are operational and screens are clean
- confirmation that electrical equipment in dangerous zones, cargo pump rooms and other spaces is in satisfactory condition and has been properly maintained
- confirmation that the remote operation of the cargo pump room bilge system is satisfactory
- examination of the cargo heating system, as appropriate
- examination of the cargo-transfer arrangement and confirmation that the ship's cargo hoses are suitable for their intended purpose and in satisfactory condition
- confirmation that any special arrangement made for bow or stern loading/unloading is in satisfactory condition and test of the means of communication and remote shutdown of the cargo pumps.

3.2 Instrumentation and safety devices

3.2.1 The survey is to include:

- examination of cargo tank gauging devices, high level alarms and valves associated with overflow control
- verification that installed pressure gauges on cargo discharge lines are properly operational
- confirmation that the required gas detection instruments are on board and satisfactory arrangements have been made for the supply of any required vapour detection tubes
- confirmation that at least one (1) portable instrument for measuring oxygen and one (1) for measuring flammable vapour concentrations, together with a sufficient set of spares, and suitable means of calibration of these instruments are available on board
- examination of the arrangements for gas measurement in double-hull spaces and double bottom spaces, including the fitting of permanent gas sampling lines, where appropriate
- examination as far as possible, and testing of the fixed hydrocarbon gas detection system

- confirmation that devices provided for measuring the temperature of the cargo, if any, operate satisfactorily.

3.3 Fire-fighting systems in cargo area

3.3.1 The survey is to include:

- external examination of piping and cut-out valves of fixed fire-fighting systems related to cargo tanks and cargo pump rooms
- confirmation, as far as practicable and when appropriate, that the remote means for closing the various openings are operable
- examination of the appropriate portable fire-extinguishing equipment for the cargoes to be carried in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.3]
- examination of fire-fighting systems of any type fitted on board such as deck foam, water-spraying, etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4].

3.4 Inert gas system

3.4.1 The survey is to include:

- external examination of the whole system, to check the condition of all piping, including vent piping above the upper deck in the cargo tank area and overboard discharges through the shell so far as practicable, and associated components to verify, in particular, the absence of signs of corrosion and leakage of gas, water or other liquid from inert gas and water piping systems or from the pressure/vacuum breaking device
- check of proper operation of both inert gas blowers
- check of proper operation of ventilation system required for scrubber room (if any)
- check of deck water seal for automatic water filling and draining
- check of absence of water carry over in the inert gas from the deck water seal and check of the condition of the non-return valve
- check of proper operation of all remotely operated or automatically controlled valves and, in particular, of the flue gas isolating valve located on the inert gas supply main after the blowers
- check of proper operation of the interlocking feature fitted to prevent soot blowers from operating when the inert gas system is working
- check that the gas pressure regulating valve automatically closes when gas blowers are stopped
- check, as far as practicable and using simulated conditions where necessary, of the following alarms and safety devices of the inert gas system:
  - high oxygen content of gas in the inert gas main
  - low gas pressure in the inert gas main
  - low pressure in the supply to the deck water seal
  - high temperature of gas in the inert gas main, including automatic shutdown devices
  - low water pressure to the scrubber, including automatic shutdown devices
  - accuracy of portable and fixed oxygen measuring equipment by means of calibration gases
  - high water level in the scrubber, including automatic shutdown devices
  - failure of the inert gas blowers
  - failure of the power supply to the automatic control system for the gas regulating valve and to the instrumentation for continuous indication and permanent recording of pressure and oxygen content in the inert gas main
  - high pressure of gas in the inert gas main
- check, when practicable, of the proper operation of the inert gas system on completion of the checks listed above.

4 Intermediate survey - Hull items

4.1 General

4.1.1 The survey of weather decks is to include:

- examination, as far as applicable, of cargo, crude oil washing, bunker, ballast, steam and vent piping systems as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both. Particular attention is to be paid to repairs such as welded doublers
- confirmation, if applicable, that cargo pipes are electrically bonded to the hull
- examination of vent line drainage arrangements.

4.1.2 For ships built under the Common Structural Rules, the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out.

4.2 Ships between 5 and 10 years of age

4.2.1 For single hull oil tankers and combination carriers, all ballast tanks are to be examined.

When considered necessary by the Surveyor, thickness measurements and testing are to be carried out to ensure that the structural integrity remains effective.

4.2.2 For double hull oil tankers, an overall survey of representative salt water ballast tanks selected by the Surveyor is to be carried out.

If such overall survey reveals no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in good condition.

4.2.3 A ballast tank is to be examined at subsequent annual surveys where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than good condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurement is to be carried out as deemed necessary by the Surveyor.

4.2.4 In addition to the requirements above, suspect areas identified at previous surveys are to be examined.

4.3 Ships between 10 and 15 years of age

4.3.1 The scope of intermediate survey of ships between 10 and 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [6] with bottom survey in dry condition or bottom in water survey as applicable. However, pressure testing of all cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girder as required in [6.5.5] are not required unless deemed necessary by the attending Surveyor.

4.4 Ships over 15 years of age

4.4.1 The scope of intermediate survey of ships over 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [6] with bottom survey in dry condition, except that pressure testing of ballast and cargo tanks and the requirements for longitudinal strength evaluation of hull girder as required in [6.5.5] is not required unless deemed necessary by the Surveyor.

The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and water ballast tanks are to be carried out during the bottom survey in accordance with the applicable requirements for intermediate surveys, if not already performed.

Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

The requirements of [6.8] are not applicable.

5 Intermediate survey - Cargo machinery items

5.1 Cargo area and cargo pump rooms

5.1.1 A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment and fixtures, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

5.1.2 The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship's personnel.

5.1.3 The satisfactory condition of the cargo heating system is to be verified.

5.2 Inert gas system

5.2.1 The following is to be carried out:

- main parts such as the scrubber, washing machines, blowers, deck water seal and non-return valve are to be opened out as considered necessary and examined
- gas distribution lines and shut-off valves, including soot blower interlocking devices, are to be examined as deemed necessary
- all automatic shutdown devices and alarms are to be examined and tested.

6 Class renewal survey - Hull items

6.1 Survey programme and preparation for hull survey

6.1.1 The Owner in cooperation with the Society is to work out a specific Survey Programme prior to the commencement of any part of:

- the class renewal survey
- the intermediate survey for oil tankers over 10 years of age.

The survey programme is to be in a written format. The survey is not to commence until the Survey Programme has been agreed.

Prior to the development of the Survey Programme, the survey planning questionnaire is to be completed by the Owner and forwarded to the Society.

The survey programme at intermediate survey may consist of the survey programme at the previous class renewal survey supplemented by the hull condition evaluation report of that class renewal survey and later relevant survey reports.

The survey programme is to be worked out taking into account any amendments to the survey requirements after the last class renewal survey carried out.

6.1.2 In developing the survey programme, the following documentation is to be collected and consulted with a view to selecting tanks, areas and structural elements to be examined:

a) survey status and basic ship information

b) documentation on board, as described in [1.2.2] and [1.2.3]

c) main structural plans of cargo and ballast tanks (scantlings drawings), including information regarding use of high-tensile steels (HTS)

d) Hull Condition Evaluation Report

e) relevant previous damage and repair history

f) relevant previous survey and inspection reports from both the Society and the Owner

g) cargo and ballast history for the last 3 years, including carriage of cargo under heated conditions

h) details of the inert gas plant and tank cleaning procedures

i) information and other relevant data regarding conversion or modification of the ship's cargo and ballast tanks since the time of construction

j) description and history of the coating and corrosion protection system (including previous class notations), if any

k) inspections by the Owner's personnel during the last 3 years with reference to structural deterioration in general, leakages in tank boundaries and piping and condition of the coating and corrosion protection system if any

l) information regarding the relevant maintenance level during operation including port state control reports of inspection containing hull related deficiencies, Safety Management System non-conformities relating to hull maintenance, including the associated corrective action(s), and

m) any other information that will help identify suspect areas and critical structural areas.

6.1.3 The submitted survey programme is to account for and comply, as a minimum, with the requirements of [6.3], [6.4], [6.5], [6.6], [6.7] and [6.8], for scope of survey, overall and close-up survey, thickness measurements, tank testing, cargo piping, area and pump rooms and emergency towing arrangement respectively, and is to include relevant information including at least:

a) basic ship information and particulars

b) main structural plans of cargo and ballast tanks (scantling drawings), including information regarding use of high tensile steels (HTS)

c) arrangement of tanks

d) list of tanks with information on their use, extent of coatings and corrosion protection systems

e) conditions for survey (e.g., information regarding tank cleaning, gas freeing, ventilation, lighting, etc.)

f) provisions and methods for access to structures

g) equipment for surveys

h) identification of tanks and areas for close-up survey (see [6.4])

i) identification of areas and sections for thickness measurement (see [6.5])

j) identification of tanks for tank testing (see [6.6])

k) identification of the thickness measurement firm

l) damage experience related to the ship in question, and

m) critical structural areas and suspect areas, where relevant.

6.1.4 The Society is to advise the Owner of the maximum acceptable structural corrosion diminution levels applicable to the ship.

6.2 Survey planning meeting

6.2.1 The establishment of proper preparation and the close co-operation between the attending surveyor(s) and the owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board, safety meetings are to be held regularly.

6.2.2 Prior to commencement of any part of the renewal and intermediate survey, a survey planning meeting is to be held between the attending surveyor(s), the owner's representative in attendance, the thickness measurement firm operator (as applicable) and the master of the ship or an appropriately qualified representative appointed by the master or Company for the purpose to ascertain that all the arrangements envisaged in the survey programme are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out. See also [1.1.7].

6.2.3 The following is an indicative list of items that are to be addressed in the meeting:

a) schedule of the ship (i.e. the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations, etc.)

b) provisions and arrangements for thickness measurements (i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety)

c) extent of the thickness measurements

d) acceptance criteria (refer to the list of minimum thicknesses)

e) extent of close-up survey and thickness measurements considering the coating condition and suspect areas/areas of substantial corrosion

f) execution of thickness measurements

g) taking representative readings in general and where uneven corrosion/pitting is found

h) mapping of areas of substantial corrosion, and

i) communication between attending surveyor(s), the thickness measurement firm operator(s) and owner representative(s) concerning findings.

6.3 Scope of survey

6.3.1 In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the hull and related piping are in satisfactory condition for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

6.3.2 All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in [6.5] and [6.6], to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

6.3.3 As indicated in Ch 3, Sec 3, [2.1.1], a bottom survey in dry condition is to be a part of the class renewal survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out during this bottom survey in accordance with the applicable requirements for class renewal surveys, if not already performed.

Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

6.3.4 Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined.

A ballast tank is to be examined at subsequent annual surveys where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than good condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurement is to be carried out as deemed necessary by the Surveyor.

6.4 Overall and close-up surveys

6.4.1 Each class renewal survey is to include an overall survey of all tanks and spaces.

6.4.2 The minimum requirements for close-up surveys are given in Tab 1 for single hull oil tankers and combination carriers or Tab 2 for double hull oil tankers.

6.4.3 The Surveyor may extend the close-up survey as deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

- where tanks have structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information
- where tanks have structures approved with reduced scantlings.

6.4.4 For areas in tanks where hard protective coatings are found to be in good condition, as defined in Ch 2, Sec 2, [2.2.14], the extent of close-up surveys required according to Tab 1 or Tab 2 may be specially considered.

Table 1 : Close-up survey at class renewal survey of single hull oil tankers and combination carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
One web frame ring ①: - in a ballast wing tank, if any, or - in a cargo wing tank used primarily for water ballast	All web frame rings ①: - in a ballast wing tank, if any, or - in a cargo wing tank used primarily for water ballast	All web frame rings ① in all ballast tanks All web frame rings ① in a cargo wing tank A minimum of 30% **(1)** of all web frame rings ① in each remaining cargo wing tank	As class renewal survey for ships between 10 and 15 years of age Additional transverse areas as deemed necessary by the Society
One deck transverse ② in a cargo tank	One deck transverse ②: - in each remaining ballast tank, if any - in a cargo wing tank - in two cargo centre tanks		
	Both transverse bulkheads ③: - in a wing ballast tank, if any, or - in a cargo wing tank used primarily for water ballast	All transverse bulkheads (area ③) in all cargo and ballast tanks	
One transverse bulkhead ④ in a ballast tank One transverse bulkhead ④ in a cargo wing tank One transverse bulkhead ④ in a cargo centre tank	One transverse bulkhead ④ in each remaining ballast tank One transverse bulkhead ④ in a cargo wing tank One transverse bulkhead ④ in two cargo centre tanks		
		A minimum of 30% **(1)** of deck and bottom transverses ⑤ in each cargo centre tank	
		Additional web frame ring(s) ①, as considered necessary by the Surveyor	

(1) The 30% is to be rounded up to the next whole integer.

Note 1: See Fig 1 or Fig 2 for areas ①, ②, ③, ④ and ⑤.

① Complete transverse web frame ring including adjacent structural member.

② Deck transverse including adjacent deck structural members.

③ Transverse bulkhead complete, including girder system and adjacent structural members.

④ Transverse bulkhead lower part, including girder system and adjacent structural members.

⑤ Deck and bottom transverse, including adjacent structural members.

Table 2 : Close-up survey at class renewal survey of double hull oil tankers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
One web frame ① in a ballast tank **(1)**	All web frames ① in a ballast tank **(1)** The knuckle area ⑥ and the upper part (5 meters approximately) of one web frame in each remaining ballast tank	All web frames ① in all ballast tanks	As class renewal survey for ships between 10 and 15 years of age Additional transverse areas as deemed necessary by the Society
One deck transverse ② in a cargo tank	One deck transverse ② in two cargo tanks	All web frames ⑦ including deck transverse and cross ties, if fitted, in a cargo tank One web frame ⑦ including deck transverse and cross ties, if fitted, in each remaining cargo tank	
One transverse bulkhead ④ in a ballast tank **(1)**	One transverse bulkhead ④ in each ballast tank **(1)**	All transverse bulkheads in all cargo ③ and ballast tanks ④	
One transverse bulkhead ⑤ in a cargo wing tank **(2)** One transverse bulkhead ⑤ in a cargo centre tank	One transverse bulkhead ⑤ in a cargo wing tank **(2)** One transverse bulkhead ⑤ in two cargo centre tanks		

(1) Ballast tank: apart from the fore and aft peak tanks, the term "ballast tank" has the following meaning:

- all ballast compartments (hopper tank, side tank and double-deck tank, if separate from double-bottom tank) located on one side, i.e. portside or starboard side, and additionally double-bottom tank on portside plus starboard side, when the longitudinal central girder is not watertight and, therefore, the double-bottom tank is a unique compartment from portisde to starboard side; or
- all ballast compartments (double-bottom tank, hopper tank, side tank and double-deck tank) located on one side, i.e. portside or starboard side, when the longitudinal central girder is watertight and, therefore, the portside double-bottom tank separate from the starboard side double-bottom tank.

(2) Where no centre cargo tank is fitted (as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

Note 1: ①, ②, ③, ④, ⑤, ⑥ and ⑦ are areas to be subjected to close-up surveys and thickness measurements (see Fig 3).

① Web frame in a ballast tank means vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in double deck tank (where fitted), including adjacent structural members. In fore and aft peak tank, web frame means a complete transverse web frame ring including adjacent structural members

② Deck transverse including adjacent deck structural members (or external structure on deck in way of the tank, where applicable)

③ Transverse bulkhead complete in cargo tanks, including girder system adjacent structural members (such as longitudinal bulkheads) and internal structure of lower and upper stools, where fitted

④ Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members, such as longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, inner hull longitudinal bulkhead, connecting brackets

⑤ Transverse bulkhead lower part in cargo tank, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower stool where fitted

⑥ Knuckle area is the area of the web frame around the connections of the slope hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 meters from the corners both on the bulkhead and the double bottom

⑦ Web frame in a cargo tank means deck transverse, longitudinal bulkhead structural elements and cross ties, where fitted, including adjacent structural members

Figure 1 : Areas subject to close-up surveys and thickness measurements - Single hull oil tanker

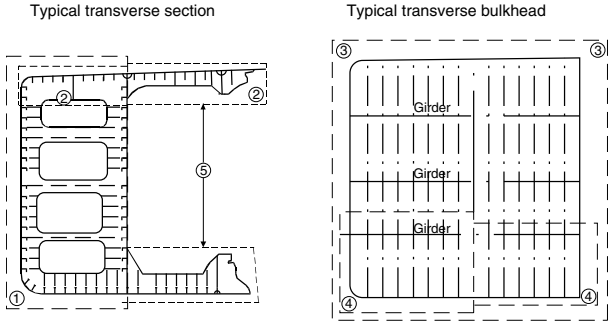


Figure 2 : Areas subject to close-up surveys and thickness measurements - Combination carrier / OOC

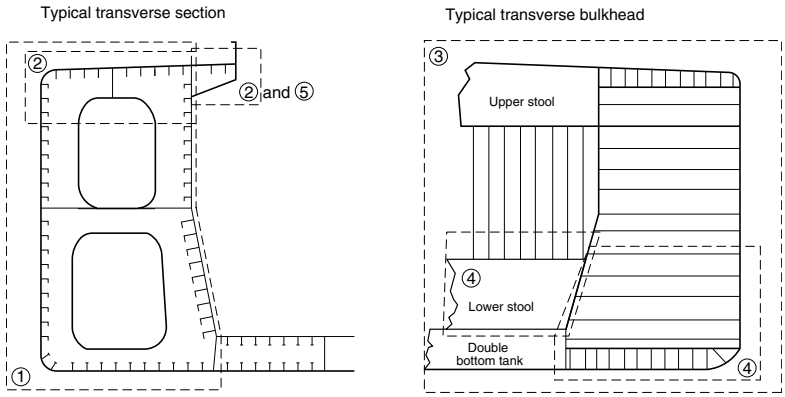
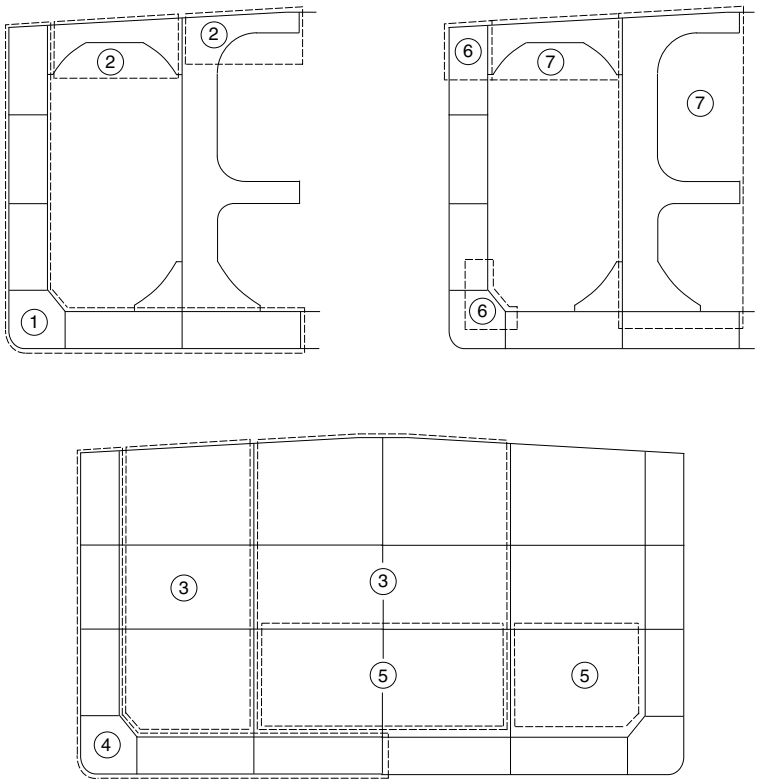


Figure 3 : Areas subject to close-up surveys and thickness measurements - Double hull oil tanker



6.5 Thickness measurements

6.5.1 The minimum requirements for thickness measurements at class renewal survey are given in Tab 3.

6.5.2 Provisions for extended measurements for areas with substantial corrosion are given in Tab 4 for single hull oil tankers and combination carriers or Tab 5 for double hull oil tankers and as may be additionally specified in the survey program as required in [6.1]. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous surveys are to be examined.

Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

The Surveyor may further extend the thickness measurements as deemed necessary.

Note 1: For ships built under the Common Structural Rules, the identified substantial corrosion areas are required to be examined and additional thickness measurements are to be carried out at annual and intermediate surveys.

6.5.3 When pitting is found on bottom plating and its intensity is 20% or more, thickness measurements are to be extended in order to determine the actual plate thickness out of the pits and the depth of the pits. Where the wastage is in the substantial corrosion range or the average depth of pitting is 1/3 or more of the actual plate thickness, the pitted plate is to be considered as a substantially corroded area.

6.5.4 For areas in tanks where hard protective coatings are found to be in good condition as defined in Ch 2, Sec 2, [2.2.14], the extent of thickness measurements according to Tab 3 may be specially considered.

6.5.5 On oil tankers of 130 m in length and upwards (as defined in the International Convention on Load Lines in force) and more than 10 years of age, the longitudinal strength of the ship's hull girder is to be evaluated in compliance with the requirements of Ch 4, App 1 on the basis of the thickness of the structures measured, renewed or reinforced, as appropriate, during the class renewal survey.

Table 3 : Thickness measurements at class renewal survey of oil tankers and combination carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
One section of deck plating for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast) **(4)**	Within the cargo area: • each deck plate **(1)** • 1 transverse section **(2)**	Within the cargo area: • each deck plate **(1)** • 2 transverse sections **(2) (3)** • all wind and water strakes	Within the cargo area: • each deck plate **(1)** • 3 transverse sections **(2) (3)** • each bottom plate
Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 **(4)**	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 and Tab 2	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 and Tab 2	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 and Tab 2
	Selected wind and water strakes outside the cargo area	Selected wind and water strakes outside the cargo area	All wind and water strakes, full length

(1) For combination carriers only the deck plating outside line of cargo hold hatch openings is to be measured.

(2) Transverse sections are to be chosen where the largest reductions are likely to occur or as revealed by deck plating measurements.

(3) At least one section is to be within 0,5 L amidships and, where applicable, in way of a ballast tank.

(4) Not applicable to double hull oil tankers.

Table 4 : Extended thickness measurements at those areas of substantial corrosion Single hull oil tankers and combination carriers

BOTTOM STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom plating	Minimum of 3 bays across tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and webs
Bottom longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
Bottom girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat. 5-point pattern on girder/bulkhead brackets.
Bottom transverse webs	3 webs in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over 2 square metre area. Single measurements on face flat.
Panel stiffening	Where provided	Single measurements

DECK STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Deck plating	2 bands across tank	Minimum of 3 measurements per plate per band
Deck longitudinals	Minimum of 3 longitudinals in each of 2 bays	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
Deck girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat. 5-point pattern on girder/bulkhead brackets.
Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5-point pattern over 2 square metre area. Single measurements on face flat.
Panel stiffening	Where provided	Single measurements
SIDE SHELL AND LONGITUDINAL BULKHEADS		
Structural member	Extent of measurement	Pattern of measurement
Deckhead and bottom strakes and strakes in way of stringer platforms	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
All other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
Longitudinals on deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
All other longitudinals	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
Longitudinal brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Web frames and cross ties	3 webs with minimum of 3 locations on each web, including in way of cross tie connections	5-point pattern over approximately 2 square metre area, plus single measurements on web frame and cross tie face flats
TRANSVERSE BULKHEADS AND SWASH BULKHEADS		
Structural member	Extent of measurement	Pattern of measurement
Deckhead and bottom strakes, and strakes in way of stringer platforms	Plating between pair of stiffeners at 3 locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over 1 metre length
All other strakes	Plating between pair of stiffeners at middle location	Single measurement
Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about 1 square metre of plating
Stiffeners	Minimum of 3 typical stiffeners	For web, 5-point pattern over span between bracket connections (2 measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
Brackets	Minimum of 3 at top, middle and bottom of tank	5-point pattern over area of bracket
Deep webs and girders	Measurements at toe of bracket and at centre of span	For web, 5-point pattern over about 1 square metre 3 measurements across face flat
Stringer platforms	All stringers with measurements at both ends and middle	5-point pattern over 1 square metre of area plus single measurements near bracket toes and on face flats

Table 5 : Extended thickness measurements at those areas of substantial corrosion
Double hull oil tankers

BOTTOM, INNER BOTTOM AND HOPPER STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom, inner bottom and hopper structure plating	Minimum of 3 bays across double bottom tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
Bottom, inner bottom and hopper structure longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of 3 measurements
Bottom floors, including the watertight ones	3 floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over 2 square metre area
Hopper structure web frame ring	3 floors in bays where bottom plating measured	5-point pattern over about 1 square metre of plating. Single measurements on flange.
Hopper structure transverse watertight bulkhead or swash bulkhead	• lower 1/3 of bulkhead	5-point pattern over about 1 square metre of plating
	• upper 2/3 of bulkhead	5-point pattern over 2 square metre of plating
	• stiffeners (minimum of 3)	For web, 5-point pattern over span (2 measurements across web at each end and one at centre of span). For flange, single measurements at each end and centre of span.
Panel stiffening	Where provided	Single measurements
DECK STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Deck plating	2 transverse bands across tank	Minimum of 3 measurements per plate per band
Deck longitudinals	Every third longitudinal in each of 2 bands with a minimum of one longitudinal	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
Deck girders and brackets (usually in cargo tanks only)	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across flange. 5-point pattern on girder/bulkhead brackets.
Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5-point pattern over 1 square metre area. Single measurements on flange.
Vertical web and transverse bulkhead in wing ballast tank (2 metres from deck)	Minimum of 2 webs, and both transverse bulkheads	5-point pattern over 1 square metre area
Panel stiffening	Where provided	Single measurements
STRUCTURE IN WING BALLAST TANKS		
Structural member	Extent of measurement	Pattern of measurement
Side shell and longitudinal bulkhead plating:		
• upper strake and strakes in way of horizontal girders	Plating between each pair of longitudinals in a minimum of 3 bays (along the tank)	Single measurement
• all other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
Side shell and longitudinal bulkhead longitudinals on:		
• upper strake	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
• all other strakes	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange

Longitudinal brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Vertical web and transverse bulkheads (excluding deckhead area):		
• strakes in way of horizontal girders	Minimum of 2 webs and both transverse bulkheads	5-point pattern over 2 square metre area
• other strakes	Minimum of 2 webs and both transverse bulkheads	2 measurements between each pair of vertical stiffeners
Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners
Panel stiffening	Where provided	Single measurements
LONGITUDINAL BULKHEADS IN CARGO TANKS		
Structural member	Extent of measurement	Pattern of measurement
Deckhead and bottom strakes and strakes in way of the horizontal stringers of transverse bulkheads	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
All other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
Longitudinals on deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
All other longitudinals	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
Longitudinal brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Web frames and cross ties	3 webs with minimum of 3 locations on each web, including in way of cross tie connections	5-point pattern over approximately 2 square metre area of webs, plus single measurements on flanges of web frame and cross ties
Lower end brackets (opposite side of web frame)	Minimum of 3 brackets	5-point pattern over approximately 2 square metre area of brackets, plus single measurements on bracket flanges
TRANSVERSE WATERTIGHT AND SWASH BULKHEADS IN CARGO TANKS		
Structural member	Extent of measurement	Pattern of measurement
Upper and lower stool, where fitted	• Transverse band within 25mm of welded connection to inner bottom/ deck plating • Transverse band within 25mm of welded connection to shelf plate	5-point pattern between stiffeners over 1 metre length
Deckhead and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at 3 locations: approximately 1/4, 1/2 and 3/ 4 width of tank	5-point pattern between stiffeners over 1 metre length
All other strakes	Plating between pair of stiffeners at middle location	Single measurement
Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about 1 square metre of plating
Stiffeners	Minimum of 3 typical stiffeners	For web, 5-point pattern over span between bracket connections (2 measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
Brackets	Minimum of 3 at top, middle and bottom of tank	5-point pattern over area of bracket
Horizontal stringers	All stringers with measurements at both ends and middle	5-point pattern over 1 square metre of area plus single measurements near bracket toes and on flange

6.6 Tank testing

6.6.1 The requirements for tank testing at class renewal survey are given in Tab 6.

6.6.2 Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor, provided the following conditions are complied with:

a) a tank testing procedure, specifying fill heights, tanks being filled and bulkheads being tested, has been submitted by the Owner and reviewed by the Society prior to the testing being carried out

b) the tank testing is carried out prior to overall survey or close-up survey

c) the tank testing is carried out within the renewal survey window and not more than 3 months prior to the date on which the overall or close-up survey is completed

d) the tank testing has been satisfactorily carried out and there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank

e) the satisfactory results of the testing is recorded in the ship's logbook; and

f) the internal and external conditions of the tanks and associated structures are found satisfactory by the Surveyor at the time of the overall and close-up surveys.

6.6.3 The Surveyor may extend the tank testing as deemed necessary.

6.6.4 Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions

For double hull oil tankers, the testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tanktop is carried out.

Table 6 : Tank testing at class renewal survey of oil tankers and combination carriers

Age of ship (in years at time of class renewal survey)	
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 and subsequent age > 5
All ballast tank boundaries	All ballast tank boundaries
Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	All cargo tank bulkheads

6.7 Cargo piping, area and pump rooms

6.7.1 Cargo and crude oil washing piping on deck and cargo and ballast piping systems within the cargo area are to be examined and operationally tested to working pressure to the attending Surveyor's satisfaction to ensure that their tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces. Surveyors are to be advised on all occasions when this piping, including valves and fittings, is opened during repair periods and can be examined internally.

The surveyor may require dismantling and/or thickness measurements of piping. A hydraulic test is to be carried out in the event of repair or dismantling or cargo, crude oil washing, or ballast piping, or where doubts arise.

6.7.2 All safety valves on cargo piping and of cargo tanks are to be dismantled for examination, adjusted and, as applicable, resealed.

6.7.3 All cargo pump room boundaries are to be generally examined. All gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms is to be presented clean for the examination of stripping devices and gutters.

6.8 Emergency towing arrangement

6.8.1 The survey is to include:

- an examination of the emergency towing arrangement
- confirmation that the arrangement is readily available with aft towing arrangement pre-rigged and forward chafing gear secured to the strong-point
- an examination of the pick-up gear, towing pennant and chafing gear over the full length for possible deterioration. Where the pennant line is stored in a watertight condition and can be confirmed as being maintained, consideration may be given to waiving the requirement to examine the pennant line over the full length
- an examination of the strong-points, fairleads and pedestal roller together with their attachments to the hull structure.

7 Class renewal survey - Cargo machinery items

7.1 Cargo area and cargo pump rooms

7.1.1 Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out, as far as practicable.

Maintenance records of cargo pumps are to be made available to the Surveyor.

7.1.2 Where a crude oil washing system is fitted, piping, pumps, valves and deck-mounted washing machines are to be examined and tested for signs of leakage, and anchoring devices of deck-mounted washing machines are to be checked to the Surveyor's satisfaction.

7.1.3 The satisfactory condition of the cargo heating system is to be verified and, if deemed necessary by the Surveyor, the system is to be pressure tested.

7.1.4 An operating test of the remote control of pumps and valves and of automatic closing valves is to be carried out.

7.1.5 A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment and fixtures, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship’s personnel.

7.2 Fire-fighting systems in cargo area

7.2.1 The survey is to include the examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room and other dangerous spaces, such as deck foam, water-spraying systems, etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

7.3 Inert gas system

7.3.1 In addition to the inspections required at the intermediate survey, the following is to be carried out:

a) an internal examination of:
- the inert gas generator, where fitted
- the scrubber
- the deck water seal including the non-return valve
- the pressure/vacuum breaking device
- the cooling water systems including overboard discharge from the scrubber
- all valves

b) a test to verify the proper operation of the system upon completion of all survey checks.

Section 4 Chemical Tankers

1 General

1.1 Application

1.1.1 The requirements of this Section apply to all self-propelled ships which have been assigned the service notation **chemical tanker ESP**. If such a ship is constructed with both integral and independent tanks, these requirements are applicable only to that portion of the cargo length containing integral tanks. Combined gas carriers/chemical tankers with independent tanks within the hull are to be surveyed as gas carriers.

1.1.2 The requirements apply to the surveys of the hull structure and piping systems in way of cargo tanks, pump rooms, cofferdams, pipe tunnels and void spaces within the cargo area and all ballast tanks. These requirements, however, do not apply to independent tanks on deck. They are additional to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3 according to the relevant surveys.

1.1.3 The requirements contain the minimum extent of examination, thickness measurements and tank testing. When substantial corrosion and/or structural defects are found, the survey is to be extended and is to include additional close-up surveys when necessary.

1.1.4 In any kind of survey, i.e. class renewal, intermediate, annual or other surveys having the same scope, thickness measurements, when required by Tab 3, of structures in areas where close-up surveys are required are to be carried out simultaneously with close-up surveys.

1.1.5 Consideration may be given by the attending Surveyor to allow use of Remote Inspection Techniques (RIT) as an alternative to close-up survey, as defined in Ch 2, Sec 2. Surveys conducted using a RIT are to be completed to the satisfaction of the attending Surveyor.

1.1.6 In all cases the extent of the thickness measurements are to be sufficient as to represent the actual average condition.

1.1.7 When, in any survey, thickness measurements are required:

- the procedure detailed in Ch 2, Sec 2, [2.3] is to be applied
- the thickness measurement firm is to be part of the survey planning meeting to be held prior to commencing the survey.

1.1.8 The requirements for machinery surveys apply to surveys of the machinery and equipment in the cargo area or dedicated to cargo service systems and are additional to those given in Part A, Chapter 3 for all ships.

1.2 Documentation on board

1.2.1 The Owner is to obtain, supply and maintain documentation on board as specified in [1.2.2] and [1.2.3], which is to be readily available for examination by the Surveyor. The documentation is to be kept on board for the lifetime of the ship.

1.2.2 A survey report file is to be a part of the documentation on board consisting of:

- reports of structural surveys
- hull condition evaluation report (summarising the results of class renewal surveys)
- thickness measurement reports.

The survey report file is also to be available in the Owner's management office.

1.2.3 The following additional supporting documentation is to be available on board:

- survey program, as required in [6.1], until such time as the class renewal survey or intermediate survey, as applicable, has been completed
- main structural plans of cargo and ballast tanks
- previous repair history
- cargo and ballast history
- extent of use of inert gas system and tank cleaning procedures
- ship's personnel reports on:
  - structural deterioration/defects in general
  - leakage in bulkheads and piping systems
  - condition of coatings or corrosion prevention systems, if any
- any other information that may help identify critical structural areas and/or suspect areas requiring inspection.

1.2.4 Prior to survey, the Surveyor examines the documentation on board and its contents, which are used as a basis for the survey.

1.3 Reporting and evaluation of surveys

1.3.1 The data and information on the structural condition of the ship collected during survey are evaluated for acceptability and structural integrity of the ship's cargo area.

1.3.2 A hull condition evaluation report (summarising the results of class renewal surveys) is issued by the Society to the Owner, who is to place it on board the ship for reference at future surveys. The hull condition evaluation report is endorsed by the Society.

1.3.3 When a survey is split between different survey stations, a report is to be made for each portion of the survey. A list of items examined and/or tested (pressure testing, thickness measurements, etc.) and an indication of whether the item has been credited, are to be made available to the next attending Surveyor(s), prior to continuing or completing the survey.

1.4 Conditions for survey

1.4.1 In order to enable the attending surveyors to carry out the survey, provisions for proper and safe access are to be agreed between the Owner and the Society.

Details of the means of access are to be provided in the survey planning questionnaire.

In cases where the provisions of safety and required access are judged by the attending surveyors not to be adequate, the survey of the spaces involved is to not proceed.

1.5 Access to structures

1.5.1 For overall survey, means are to be provided to enable the surveyor to examine the hull structure in a safe and practical way.

1.5.2 For close-up survey, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

- permanent staging and passages through structures
- temporary staging and passages through structures
- hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
- boats or rafts
- portable ladders
- other equivalent means.

1.5.3 For surveys conducted by use of remote inspection technique, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

- unmanned robot arm
- remote operated vehicle (ROV)
- unmanned aerial vehicles/drones
- other means acceptable to the Society.

2 Annual survey - Hull items

2.1 General

2.1.1 The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition and should take into account the service history, condition and extent of the corrosion prevention system of ballast tanks and areas identified in the survey report file.

2.2 Weather decks

2.2.1 The survey is to include:

- examination of cargo tank openings, including gaskets, covers, coamings and flame screens
- examination of cargo tank vent system, including the pressure/vacuum valves and secondary means to prevent over- or under-pressure and devices to prevent the passage of flames
- examination of flame screens on vents to all bunker tanks
- examination of cargo, bunker, ballast and vent piping systems, including remote control valves, safety valves and various safety devices, as well as vent masts and headers
- confirmation that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends facing the cargo area are in satisfactory condition
- confirmation that pumps, valves and pipelines are identified and distinctively marked.
- examination of watertight penetrations as far as practicable.

2.3 Cargo pump rooms and pipe tunnels

2.3.1 The survey is to include:

- examination of all pump room bulkheads and pipe tunnels (if any) for signs of chemical cargo leakage or fractures and, in particular, the sealing arrangements of penetrations in pump room bulkheads
- examination of the condition of all piping systems, in cargo pump rooms and pipe tunnels (if any)
- examination of the bilge and ballast arrangements and confirmation that pumps and pipelines are identified.

2.4 Ballast tanks

2.4.1 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey or the intermediate survey; see [6.3.4] and [4.2.2], respectively.

2.4.2 When considered necessary by the Surveyor or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 4. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous surveys are to be examined.

Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

2.5 Emergency towing arrangement

2.5.1 The Owner or his representative is to declare to the attending Surveyor that no significant alterations have been made, without prior approval from the Society, to the equipment and arrangements fitted on board in accordance with the provisions given in Pt B, Ch 12, Sec 4, [3].

2.5.2 The survey is to include:

- an examination, as far as practicable, of the emergency towing arrangement
- confirmation that the aft towing arrangement is prerigged and forward chafing gear is secured to the strong-point
- confirmation of the proper functioning of the light, where it is provided, on the pick-up gear marker buoy.

3 Annual survey - Cargo machinery items

3.1 Cargo area and cargo pump rooms

3.1.1 The Owner or his representative is to declare to the attending Surveyor that no modifications or alterations which might impair safety have been made to the various installations in dangerous zones without prior approval from the Society.

The survey is to include:

- confirmation that potential sources of ignition in or near the cargo pump rooms, such as loose gear, excessive product in bilge, excessive vapours, combustible materials, etc., are eliminated and that access ladders are in satisfactory condition
- examination, as far as practicable, of cargo, bilge, ballast and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of the pump room bilge system, and checking that pump foundations are intact
- confirmation that the ventilation system, including portable equipment, if any, of all spaces in the cargo area (including cargo pump rooms) is operational, ducting is intact, dampers are operational and screens are clean
- confirmation that electrical equipment in dangerous zones, cargo pump rooms and other spaces is in satisfactory condition and has been properly maintained
- confirmation that the remote operation of the cargo pump room bilge system is satisfactory
- confirmation that cargo pump room rescue arrangements are in order
- confirmation that removable pipe lengths or other approved equipment necessary for cargo separation are available and in satisfactory condition
- examination of the cargo heating/cooling system and sampling arrangements where required
- examination of the cargo-transfer arrangement and confirmation that the ship's cargo hoses are suitable for their intended purpose and in satisfactory condition and, where appropriate, type approved or marked with date of testing
- confirmation that any special arrangement made for bow or stern loading/unloading is in satisfactory condition and test of the means of communications and the remote shutdown for the cargo pumps
- confirmation that, if applicable, the provisions made for chemical products which have special requirements as per Pt D, Ch 8, Sec 15 are satisfactory.

3.2 Instrumentation and safety devices

3.2.1 The survey is to include the following items, as far as required or fitted:

- confirmation that installed pressure gauges on cargo discharge lines are properly operational
- examination of gauging devices, high level alarms and valves associated with overflow control
- confirmation that devices provided for measuring the temperature of the cargo and associated alarms operate satisfactorily
- confirmation that the required gas detection instruments are on board and satisfactory arrangements have been made for the supply of any required vapour detection tubes.

3.3 Fire-fighting systems in cargo area

3.3.1 The survey is to include:

- external examination of piping and cut-out valves of fixed fire-fighting systems related to cargo tanks and cargo pump rooms
- confirmation, as far as practicable and when appropriate, that the remote means for closing the various openings are operable
- examination of the appropriate portable fire-extinguishing equipment for the chemical cargoes to be carried in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.3]
- examination of fire-fighting systems of any type fitted on board such as deck foam, water-spraying, etc. as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.2].

3.4 Inert gas system and inert/padding/ drying gas

3.4.1 If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [3.4] are to be complied with.

3.4.2 If an inert gas system consisting of a gas container package is fitted, arrangements are to be made for sufficient inert or padding gas to be carried to compensate for normal losses and means are to be provided for monitoring of ullage spaces.

3.4.3 If drying gas is necessary to supply the cargo spaces, arrangements are to be made for sufficient drying gas to be carried to compensate for normal losses and means are to be provided for monitoring of ullage spaces.

3.4.4 When drying agents are used on air inlets to cargo tanks, it is to be verified that arrangements are made for sufficient medium to be carried.

4 Intermediate survey - Hull items

4.1 General

4.1.1 For weather decks, an examination as far as applicable of cargo, bunker, ballast, steam and vent piping systems as well as vent masts and headers is to be carried out. If upon examination, there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both.

The survey is also to include:

- confirmation that the pipelines and independent cargo tanks where applicable, are electrically bonded to the hull
- examination of vent line drainage arrangements.

4.2 Ships between 5 and 10 years of age

4.2.1 For ballast tanks, an overall survey of representative tanks selected by the Surveyor is to be carried out. If such inspection reveals no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in good condition.

4.2.2 A ballast tank is to be examined at subsequent annual surveys where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than good condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

4.2.3 In addition to the requirements above, suspect areas identified at previous surveys are to be examined.

4.3 Ships between 10 and 15 years of age

4.3.1 The scope of intermediate survey of ships between 10 and 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in Article [6] with bottom survey in dry condition or bottom in water survey as applicable. However, pressure testing of all cargo and ballast tanks are not required unless deemed necessary by the attending Surveyor.

4.4 Ships over 15 years of age

4.4.1 The scope of intermediate survey of ships over 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [6] with bottom survey in dry condition, except that pressure testing of ballast and cargo tanks as detailed in [6.6] is not required unless deemed necessary by the Surveyor.

The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and water ballast tanks are to be carried out during the bottom survey in accordance with the applicable requirements for intermediate surveys, if not already performed.

Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

The requirements of [6.8] are not applicable.

5 Intermediate survey - Cargo machinery items

5.1 Cargo area and cargo pump rooms

5.1.1 A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

5.1.2 The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship's personnel.

5.1.3 The satisfactory condition of the cargo heating/cooling system is to be verified.

5.1.4 The spares for cargo area mechanical ventilation fans are to be available on board.

5.2 Inert gas system

5.2.1 If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [5.2] for intermediate survey of oil tankers are to be complied with.

5.2.2 For ships fitted with another type of inert gas producing system, the main parts such as the inert gas generator, deck water seal or equivalent back flow arrangement, segregation devices, as fitted are to be overhauled for examination and alarms are to be tested.

Inert gas producer isolating valves, when fitted, are to be dismantled for examination.

5.3 Personnel protection

5.3.1 The survey is to include:

- confirmation that the protective clothing for crew engaged in loading and discharging operations and its stowage is in satisfactory condition
- confirmation that the required safety equipment and associated breathing apparatus and associated air supplies and, when appropriate, emergency escape respiratory and eye protection are in a satisfactory condition and properly stowed
- confirmation that the medical first-aid equipment, including stretchers and oxygen resuscitation equipment are in a satisfactory condition
- confirmation that arrangements have been made for the antidotes for the cargoes actually carried to be on board
- confirmation that decontamination arrangements and eyewashes are operational
- confirmation that the required gas detection instruments are on board and that arrangements have been made for the supply of the appropriate vapour detection tubes
- confirmation that the arrangements for the stowage of cargo samples are satisfactory.

6 Class renewal survey - Hull items

6.1 Survey program and preparation for survey

6.1.1 The Owner in cooperation with Society is to work out a specific Survey Programme prior to the commencement of any part of:

- the class renewal survey
- the intermediate survey for chemical tankers over 10 years of age.

The survey programme is to be in a written format.

Prior to the development of the survey programme, the survey planning questionnaire is to be completed by the Owner, and forwarded to the Society.

The survey programme at intermediate survey may consist of the survey programme at the previous class renewal survey supplemented by the hull condition evaluation report of that class renewal survey and later relevant survey reports.

The survey program is to be worked out taking into account any amendments to the survey requirements after the last class renewal survey carried out.

6.1.2 In developing the Survey Programme, the following documentation is to be collected and consulted with a view to selecting tanks, areas, and structural elements to be examined:

a) survey status and basic ship information

b) documentation on board, as described in [1.2.2] and [1.2.3]

c) main structural plans of cargo and ballast tanks (scantling drawings), including information on use of high tensile steels (HTS), clad steel and stainless steel

d) hull condition evaluation report

e) relevant previous damage and repair history

f) relevant previous survey and inspection reports from both the Society and the Owner

g) information regarding the use of the ship's tanks, typical cargoes and other relevant data

h) details of the inert gas plant and tank cleaning procedures

i) information and other relevant data regarding conversion or modification of the ship's cargo and ballast tanks since the time of construction

j) description and history of the coating and the corrosion prevention system (previous class notations), if any

k) inspections by the Owner's personnel during the last three years with reference to structural deterioration in general, leakages in tank boundaries and piping and condition of the coating and corrosion prevention system, if any

l) information regarding the relevant maintenance level during operation including port state control reports of inspection containing hull related deficiencies, Safety Management System non-conformities relating to hull maintenance, including the associated corrective action(s); and

m) any other information that will help identify suspect areas and critical structural areas.

6.1.3 The submitted Survey Programme is to account for and comply, as a minimum, with the requirements of [6.3], [6.4], [6.5], [6.6], [6.7] and [6.8] for scope of survey, overall and close-up survey, thickness measurements, tank testing, cargo piping, cargo pump rooms, cargo tanks and emergency towing arrangement respectively and is to include relevant information including at least:

a) basic ship information and particulars

b) main structural plans (scantling drawings), including information on the use of high tensile steels (HTS), clad steel and stainless steel

c) plan of tanks

d) list of tanks with information on their use, corrosion prevention and condition of coating

e) conditions for survey (e.g., information regarding tank cleaning, gas freeing, ventilation, lighting, etc.)

f) provisions and methods for access to structures

g) equipment for surveys

h) nomination of tanks and areas for close-up surveys according to [6.4]

i) nomination of sections and areas for thickness measurements according to [6.5]

j) nomination of tanks for tank testing according to [6.6], and the pipes that are to undergo pipe testing according to [6.7.3]

k) identification of the thickness measurement firm

l) damage experience related to the ship in question

m) critical structural areas and suspect areas, where relevant.

6.1.4 The survey program is also to include the maximum acceptable structural corrosion diminution levels applicable to the ship. The Society will advise the Owner of this information.

6.2 Survey planning meeting

6.2.1 Proper preparation and close co-operation between the attending surveyor(s) and the Owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board safety meetings are to be held regularly.

6.2.2 Prior to commencement of any part of the renewal and intermediate survey, a survey planning meeting is to be held between the attending surveyor(s), the owner's representative in attendance, the thickness measurement firm representative, where involved, and the master of the ship or an appropriately qualified representative appointed by the master or Company for the purpose to ascertain that all the arrangements envisaged in the survey programme are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out. See also Ch 2, Sec 2, [2.3.2].

6.2.3 The following is an indicative list of items that are to be addressed in the meeting:

- schedule of the ship (i.e. the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations etc.)
- provisions and arrangements for thickness measurements (i.e. access, cleaning/descaling, illumination, ventilation, personal safety)
- extent of the thickness measurements
- acceptance criteria (refer to the list of minimum thicknesses)
- extent of close-up survey and thickness measurement considering the coating condition and suspect areas/areas of substantial corrosion
- execution of thickness measurements
- taking representative readings in general and where uneven corrosion/pitting is found
- mapping of areas of substantial corrosion; and
- communication between attending surveyor(s), the thickness measurement firm operator(s) and owner representative(s) concerning findings.

6.3 Scope of survey

6.3.1 In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the hull and related piping are in satisfactory condition for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

6.3.2 All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in [6.5] and [6.6] to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration that may be present.

6.3.3 As indicated in Ch 3, Sec 3, [2.1.1], a bottom survey in dry condition is to be a part of the class renewal survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out during this bottom survey in accordance with the applicable requirements for class renewal surveys, if not already performed.

Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

6.3.4 Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual surveys where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than good condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as considered necessary by the Surveyor.

6.3.5 In the case of independent cargo tanks, the survey consists of:

- an external examination of cargo tanks
- an examination of cargo tank supports, chocks, keys and the adjacent hull structure with non-destructive testing if deemed necessary.

6.3.6 The Owner or his representative is to declare to the attending Surveyor that the arrangements in cargo tanks (including coating) related to the transported products are suitable for the purpose.

6.4 Overall and close-up surveys

6.4.1 Each class renewal survey is to include an overall survey of all tanks and all spaces.

6.4.2 The minimum requirements for close-up surveys are given in Tab 1 and Tab 2.

Table 1 : Requirements for close-up survey at class renewal survey of single skin chemical tankers

<table>
<tr><td colspan="4">Age of ship (in years at time of class renewal survey)</td></tr>
<tr><td>Class renewal survey No.1
age ≤ 5</td><td>Class renewal survey No.2
5 < age ≤ 10</td><td>Class renewal survey No.3
10 < age ≤15</td><td>Class renewal survey No.4 and subsequent
age > 15</td></tr>
<tr><td>One web frame ring ①:
- in a ballast wing tank</td><td>All web frame rings ①:
- in a ballast wing tank, or
- in a double bottom ballast tank (1)</td><td>All web frame rings ①:
- in all ballast tanks
- in a cargo wing tank
One web frame ring ①:
- in each remaining cargo tank</td><td rowspan="4">As class renewal survey for ships between 10 and 15 years of age

Additional transverse areas as deemed necessary by the Society</td></tr>
<tr><td>One deck transverse ②:
- in a cargo tank or on deck</td><td>One deck transverse ②:
- in each remaining ballast tank or on deck
- in a cargo wing tank or on deck
- in two cargo centre tanks or on deck</td><td></td></tr>
<tr><td></td><td>Both transverse bulkheads ③:
- in a ballast wing tank</td><td>All transverse bulkheads ③:
- in all cargo tanks
- in all ballast tanks</td></tr>
<tr><td>Lower part of one transverse bulkhead ④:
- in a ballast tank
- in a cargo wing tank
- in a cargo centre tank (2)</td><td>Lower part of one transverse bulkhead ④:
- in each remaining ballast tank
- in two cargo centre tanks (2)
- in a cargo wing tank</td><td></td></tr>
<tr><td colspan="4">(1) Ballast double hull tank means double bottom tank plus double side tank plus double deck tank, as applicable, even if these tanks are separate.
(2) Where no centre cargo tanks are fitted (as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.
Note 1: ①, ②, ③ and ⑤ are areas to be subjected to close-up surveys and thickness measurements (see Fig 1 and Fig 2):
① Complete transverse web frame ring, including adjacent structural members.
② Deck transverse, including adjacent deck structural members.
③ Transverse bulkhead complete, including girder system and adjacent structural members.
⑤ Transverse bulkhead lower part, including girder system and adjacent structural members.</td></tr>
</table>

6.4.3 The survey of stainless steel tanks may be carried out as an overall survey supplemented by close-up survey as deemed necessary by the Surveyor.

6.4.4 The Surveyor may extend the close-up survey as deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

- where tanks have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information
- where tanks have structures approved with reduced scantlings.

6.4.5 For areas in tanks where hard protective coatings are found to be in good condition, as defined in Ch 2, Sec 2, [2.2.14], the extent of close-up surveys required according to Tab 1 and Tab 2 may be specially considered.

Figure 1 : Representative transverse section of chemical tanker - Areas ① and ②

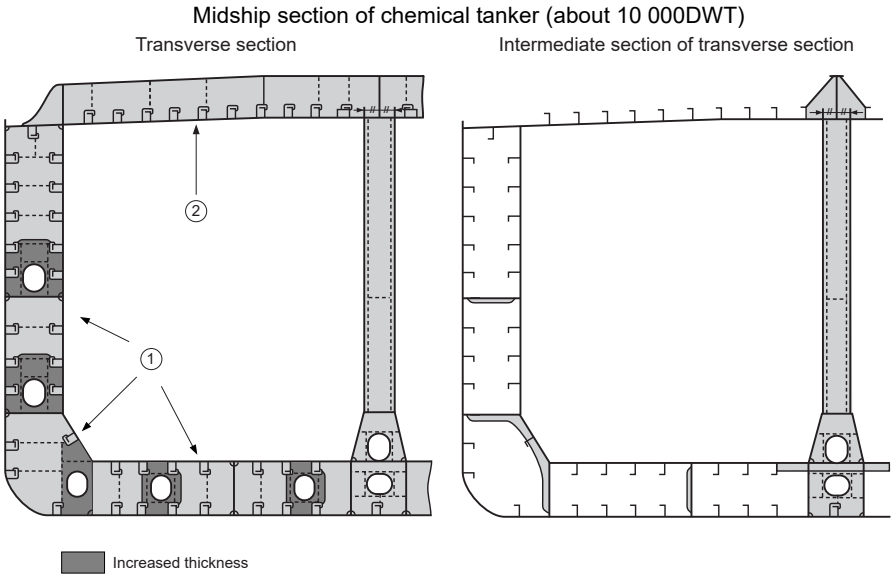


Figure 2 : Representative transverse section of chemical tanker - Areas ③, ④ and ⑤

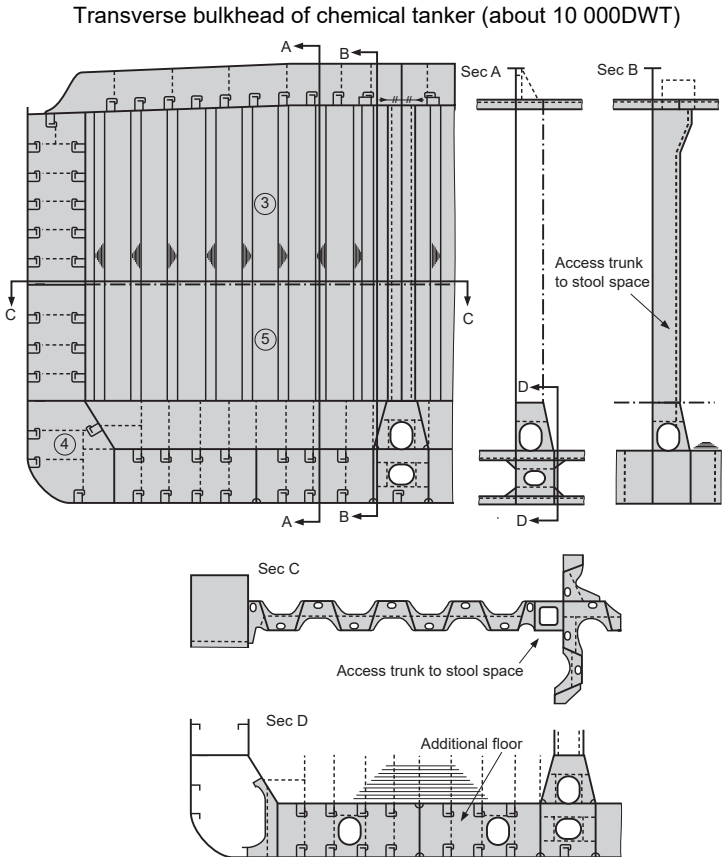


Table 2 : Requirements for close-up survey at class renewal survey of double skin chemical tankers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤15	Class renewal survey No.4 and subsequent age > 15
One web frame ring ①: - in a ballast double hull tank **(1)**	All web frame rings ①: - in a ballast wing tank, or - in a ballast double hull tank **(1)** The knuckle area and the upper part (3 metres approximately) of one web frame in each remaining ballast tank ⑥	All web frame rings: - in all ballast tanks ① - in a cargo wing tank ⑦ One web frame ring: - in each remaining cargo tank ⑦	As class renewal survey for ships between 10 and 15 years of age Additional transverse areas as deemed necessary by the Society
One deck transverse ②: - in a cargo tank or on deck	One deck transverse ②: - in two cargo tanks		
One transverse bulkhead ④: - in a ballast tank **(1)**	One transverse bulkhead ④: - in each ballast tank **(1)**	All transverse bulkheads: - in all cargo tanks ③ - in all ballast tanks ④	
One transverse bulkhead ⑤: - in a cargo wing tank - in a cargo centre tank **(2)**	One transverse bulkhead ⑤: - in a cargo wing tank - in two cargo centre tanks **(2)**		

(1) Ballast double hull tank means double bottom tank plus double side tank plus double deck tank, as applicable, even if these tanks are separate.

(2) Where no centre cargo tanks are fitted (as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

Note 1: ①, ②, ③, ④, ⑤, ⑥ and ⑦ are areas to be subjected to close-up surveys and thickness measurements (see Fig 1, Fig 2 and Fig 3).

① Web frame in a ballast tank means vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in double deck tank (where fitted), including adjacent structural members. In fore and aft peak tanks web frame means a complete transverse web frame ring including adjacent structural members.

② Deck transverse including adjacent deck structural members (or external structure on deck in way of the tank, where applicable).

③ Transverse bulkhead complete in cargo tanks, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower and upper stools, where fitted.

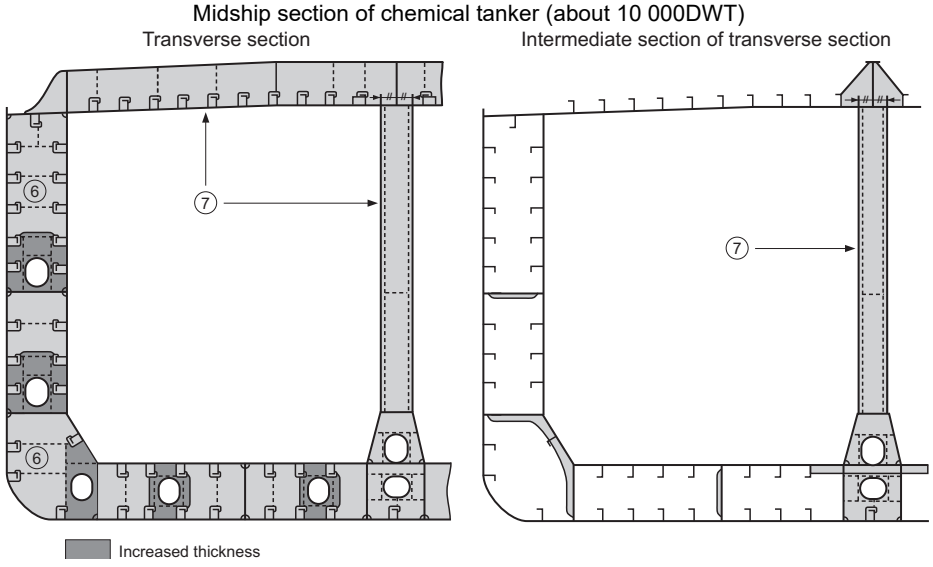
④ Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members, such as longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, connecting brackets.

⑤ Transverse bulkhead lower part in cargo tanks, including girder system, adjacent structural members (such as longitudinal bulkheads) and internal structure of lower stool, where fitted.

⑥ The knuckle area and the upper part (3 metres approximately), including adjacent structural members. Knuckle area is the area of the web frame around the connections of the slope hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 metres from the corners both on the bulkhead and the double bottom.

⑦ Web frame in a cargo tank means deck transverse, longitudinal bulkhead structural elements and cross ties, where fitted, including adjacent structural members.

Figure 3 : Representative transverse section of chemical tanker - Areas ⑥ and ⑦



6.5 Thickness measurements

6.5.1 The minimum requirements for thickness measurements at class renewal survey are given in Tab 3. Thickness measurement of stainless steel hull structure and piping may be waived, except for clad steel plating.

6.5.2 Provisions for extended measurements for areas with substantial corrosion are given in Tab 4 and as may be additionally specified in the survey program as required in [6.1]. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous class renewal surveys are to be examined.

Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

The Surveyor may further extend the thickness measurements as deemed necessary.

6.5.3 When pitting is found on bottom plating and its intensity is 20% or more, thickness measurements are to be extended in order to determine the actual plate thickness out of the pits and the depth of the pits. Where the wastage is in the substantial corrosion range or the average depth of pitting is 1/3 or more of the actual plate thickness, the pitted plate is to be considered as a substantially corroded area.

6.5.4 For areas in tanks where hard protective coatings are found to be in good condition, the extent of thickness measurements according to Tab 3 may be specially considered by the Society.

Table 3 : Requirements for thickness measurements at class renewal survey of chemical tankers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
	Within the cargo area: • each deck plate • one transverse section **(1)**	Within the cargo area: • each deck plate • two transverse sections **(1) (2)** • selected bottom plates • all wind and water strakes	Within the cargo area: • each deck plate • three transverse sections **(1) (2)** • each bottom plate
	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 or Tab 2, as applicable	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 or Tab 2, as applicable	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 1 or Tab 2, as applicable
	Selected wind and water strakes outside the cargo area	Selected wind and water strakes outside the cargo area	All wind and water strakes full length

(1) Transverse sections are to be chosen where the largest reductions are likely to occur or as revealed by deck plating measurements.

(2) At least one section is to be within 0,5 L amidships and, where applicable, in way of a ballast tank.

Table 4 : Extended thickness measurements at those areas of substantial corrosion Class renewal survey of chemical tankers within the cargo area length

BOTTOM, INNER BOTTOM AND HOPPER STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom, inner bottom and hopper structure plating	Minimum of 3 bays across tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
Bottom, inner bottom and hopper structure longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across the flange and 3 measurements on vertical web
Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of 3 measurements 2 measurements across face flat where fitted

Bottom floors, including the watertight ones	3 floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over 2 m^2 area
Hopper structure web frame ring	3 floors in bays where bottom plating measured	5-point pattern over 1 m^2 of plating Single measurements on flange
Hopper structure transverse watertight bulkhead or swash bulkhead	• lower 1/3 of bulkhead	• 5-point pattern over 1 m^2 of plating
	• upper 2/3 of bulkhead	• 5-point pattern over 2 m^2 of plating
	• stiffeners (minimum of 3)	• For web, 5-point pattern over span (2 measurements across web at each end and 1 at centre of span). For flange, single measurements at each end and centre of span
Panel stiffening	Where applicable	Single measurements
DECK STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Deck plating	2 transverse bands across tank	Minimum of 3 measurements per plate per band
Deck longitudinals	Every third longitudinal in each of 2 bands with a minimum of one longitudinal	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
Deck girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements 2 measurements across flange 5-point pattern on girder/bulkhead brackets
Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5-point pattern over 1 m^2 area Single measurements on flange
Vertical web and transverse bulkhead in wing ballast tank for double hull design (2 metres from deck)	Minimum of 2 webs, and both transverse bulkheads	5-point pattern over 1 m^2 area
Panel stiffening	Where applicable	Single measurements
SIDE SHELL AND LONGITUDINAL BULKHEADS		
Structural member	Extent of measurement	Pattern of measurement
Side shell and longitudinal bulkhead plating: • deckhead and bottom strakes and strakes in way of the horizontal girders • all other strakes	• Plating between each pair of longitudinals in a minimum of 3 bays (along the tank) • Plating between every third pair of longitudinals in same 3 bays	Single measurement
Side shell and longitudinal bulkhead longitudinals on: • deckhead and bottom strakes • all other strakes	• Each longitudinal in same 3 bays • Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
Longitudinals - brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Vertical web and transverse bulkheads of double side tanks (excluding deck area): • strakes in way of horizontal girders • other strakes	• Minimum of 2 webs and both transverse bulkheads • Minimum of 2 webs and both transverse bulkheads	• 5-point pattern over approximately 2 m^2 area • 2 measurements between each pair of vertical stiffeners
Web frames and cross ties for other tanks than double side tanks	3 webs with minimum of 3 locations on each web, including in way of cross tie connections and lower end bracket	5-point pattern over approximately 2 m^2 area of webs, plus single measurements on flanges of web frame and cross ties
Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners

Panel stiffening	Where applicable	Single measurements
TRANSVERSE WATERTIGHT AND SWASH BULKHEADS		
Structural member	Extent of measurement	Pattern of measurement
Upper and lower stool, where fitted	• Transverse band within 25 mm of welded connection to inner bottom/ deck plating • Transverse band within 25 mm of welded connection to shelf plate	5-point pattern between stiffeners over 1 m length
Deckhead and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at 3 locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over 1 m length
All other strakes	Plating between pair of stiffeners at middle location	Single measurement
Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about 1 m^2 of plating
Stiffeners	Minimum of 3 typical stiffeners	For web, 5-point pattern over span between bracket connections (2 measurements across web at each bracket connection and 1 at centre of span). For flange, single measurements at each bracket toe and at centre of span
Brackets	Minimum of 3 at top, middle and bottom of tank	5-point pattern over area of bracket
Horizontal stringers	All stringers with measurements at both ends and middle	5-point pattern over 1 m^2 area, plus single measurements near bracket toes and on flanges
Deep webs and girders	Measurements at toe of bracket and at centre of span	For web, 5 point pattern over about 1 m^2. 3 measurements across face flat

6.6 Tank testing

6.6.1 The requirements for tank testing at class renewal survey are given in Tab 5.

Table 5 : Requirements for tank testing at class renewal survey of chemical tankers

Age of ship (in years at time of class renewal survey)	
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 and subsequent age >5
All ballast tank boundaries	All ballast tank boundaries
Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	All cargo tank bulkheads

6.6.2 Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor, provided the following conditions are complied with:

a) a tank testing procedure, specifying fill heights, tanks being filled and bulkheads being tested, has been submitted by the Owner and reviewed by the Society prior to the testing being carried out

b) there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank

c) the tank testing has been satisfactorily carried out within the class renewal survey window, not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed

d) the satisfactory results of the testing is recorded in the ship's logbook

e) the internal and external conditions of the tanks and associated structures are found satisfactory by the Surveyor at the time of the overall and close-up surveys.

6.6.3 The Surveyor may extend the tank testing as deemed necessary.

6.6.4 Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

6.7 Cargo piping, cargo pump rooms and cargo tanks

6.7.1 Cargo piping on deck and cargo and ballast piping within the tanks specified in [6.3.2] are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces. Surveyors are to be advised on all occasions when this piping, including valves and fittings, is opened during repair periods and can be examined internally.

The Surveyor may require dismantling and/or thickness measurements of piping. A hydraulic test is to be carried out in the event of repair or dismantling of cargo or ballast piping, or where doubts arise.

Vent line drainage arrangements are to be examined.

6.7.2 It is to be verified that cargo piping and independent cargo tanks, where applicable, are electrically bonded to the hull.

6.7.3 For ships over 10 years of age, selected steel cargo pipes outside cargo tanks, cargo/slop discharge pipes passing through ballast tanks and void spaces and ballast pipes passing through cargo tanks are to be:

- subjected to thickness measurement at random, or selected pipe lengths are to be opened for internal inspection
- pressure tested to the maximum working pressure.

6.7.4 All safety valves on cargo piping and of cargo tanks are to be dismantled for examination, adjusted and, as applicable, resealed.

6.7.5 All cargo pump room boundaries are to be generally examined. All gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms is to be presented clean for the examination of stripping devices and gutters.

6.8 Emergency towing arrangement

6.8.1 The survey is to include:

- an examination of the emergency towing arrangement
- confirmation that the arrangement is readily available with aft towing arrangement pre-rigged and forward chafing gear secured to the strong-point
- an examination of the pick-up gear, towing pennant and chafing gear over the full length for possible deterioration. Where the pennant line is stored in a watertight condition and can be confirmed as being maintained, consideration may be given to waiving the requirement to examine the pennant line over the full length
- an examination of the strong-points, fairleads and pedestal roller together with their attachments to the hull structure.

7 Class renewal survey - Cargo machinery items

7.1 Cargo area and cargo pump rooms

7.1.1 Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out.

Maintenance records of cargo pumps are to be made available to the Surveyor.

7.1.2 Where a washing system is fitted, piping, pumps, valves and deck-mounted washing machines are to be examined and tested for signs of leakage, and anchoring devices of deck-mounted washing machines are to be checked to the Surveyor's satisfaction.

7.1.3 The satisfactory condition of the cargo heating/cooling system is to be verified and, if deemed necessary by the Surveyor, the system is to be pressure tested.

7.1.4 Spares for cargo area mechanical ventilation fans are to be available on board.

7.1.5 Heat exchangers and anti-sparking fans are to be examined.

7.1.6 An operating test of the remote control of pumps and valves and of automatic closing valves is to be carried out.

7.1.7 A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship's personnel.

7.2 Fire-fighting systems in cargo area

7.2.1 The survey is to include the examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room and other dangerous spaces, such as deck foam, water-spraying and dry powder systems, as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

7.3 Inert gas system

7.3.1 The requirements given in [5.2] for intermediate survey are to be complied with.

7.3.2 If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [7.3] for class renewal survey of oil tankers are to be complied with.

7.4 Personnel protection

7.4.1 The requirements given in [5.3] are to be complied with.

8 Methanol bunkering

8.1 Application

8.1.1 The requirements of this Article apply to **chemical tankers** which have been assigned the additional service feature **Methanol bunkering**.

8.2 General

8.2.1 The bunkering installation including piping, inerting systems, electric installations, fire fighting systems and safety and control systems are to be examined during annual and class renewal surveys as required for cargo related systems.

8.3 Annual survey

8.3.1 In addition to [8.2.1], the annual survey is to include the following items:

- visual examination of the bunkering station
- checking the proper functioning of the mechanical ventilation of the bunkering station
- checking the availability of the required documents for bunkering hoses
- checking the maintenance and inspection records of the transfer system
- inspection of the bunkering hoses
- inspection of the Quick Connect Disconnect couplers (QCDC)
- inspection of the break-away and Emergency Release Couplings (ERC)
- checking the proper functioning of the transfer arm, if applicable
- checking the proper functioning of the communication system.

8.4 Class renewal surveys

8.4.1 The requirements given in [8.3.1] for annual survey are to be complied with.

Section 5 Liquefied Gas Carriers

1 General

1.1 Application

1.1.1 The requirements of this Section apply after construction to all self-propelled ships which have been assigned one of the following service notations:

- **liquefied gas carrier**
- **liquefied gas carrier - FSRU**
- **liquefied gas carrier - FSU**

1.1.2 The requirements apply to:

- the surveys of installations and equipment related to the carriage and handling of liquefied and revaporized gas when applicable, and
- the surveys of hull structure and related piping systems in way of cargo tanks, pump rooms, compressor rooms, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo area, and
- the surveys of all ballast tanks, and
- when fitted: revaporization area and area of equipment for non permanent mooring, and for unloading to single buoy.

They are additional to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3, according to the relevant surveys.

1.1.3 The requirements contain the minimum extent of examination, thickness measurements and tank testing. When substantial corrosion, as defined in Ch 2, Sec 2, [2.2.7], and/or structural defects are found, the survey is to be extended and is to include additional close-up surveys when necessary.

1.1.4 In any kind of survey, i.e. class renewal, intermediate, annual or other surveys having the same scope, thickness measurements, when required by Tab 3, of structures in areas where close-up surveys are required are to be carried out simultaneously with close-up surveys.

1.1.5 Consideration may be given by the attending Surveyor to allow use of remote inspection techniques (RIT) as an alternative to close-up survey, as defined in Ch 2, Sec 2. Surveys conducted using a RIT are to be completed to the satisfaction of the attending Surveyor.

When RIT is used for a close-up survey, temporary means of access for the corresponding thickness measurements as specified in this section is to be provided unless such RIT is also able to carry out the required thickness measurements.

For surveys conducted by use of a remote inspection technique, one or more of the following means of access, acceptable to the Surveyor, is to be provided:

- unmanned robot arm
- remote operated vehicle (ROV)
- unmanned aerial vehicles/drones
- other means acceptable to the Society.

1.1.6 When, in any survey, thickness measurements are required:

- the procedure detailed in Ch 2, Sec 2, [2.3] is to be applied
- the thickness measurement operator is to attend the survey planning meeting held prior to commencing the survey.

2 Annual survey - Hull items

2.1 General

2.1.1 The annual survey of cargo containment and cargo handling systems is preferably carried out during loading or unloading operations. Access to cargo tanks and/or inerted hold spaces is normally not required.

2.1.2 Gas plant operational record (log) entries since the last survey are to be examined in order to check the past performance of the system and to establish whether certain parts have shown any irregularities in operation. The boil-off rate, the hours per day of the reliquefaction plants and the inert gas consumption are also to be considered.

2.1.3 The relevant instruction and information material such as cargo handling plans, filling limit information, cooling down procedures, are to be verified as being onboard.

2.1.4 Examination of the condition of all piping systems, except those covered by [2.3].

Note 1: For survey of air pipes, flame screens on vents and ventilators, refer to Ch 3, Sec 1, [2.1.1].

2.2 Weather decks and suspect areas

2.2.1 Examination of flame screens on vents to all bunker tanks.

2.2.2 Examination the cargo, bunker, ballast and vent piping systems, including PRVs, vacuum relief valves, vent masts and protective screens.

2.2.3 Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion, as per the requirements of Tab 4.

These extended thickness measurements are to be carried out before the annual survey is credited as completed.

2.3 Cargo handling rooms and piping

2.3.1 The survey is to include:

- examination of cargo pump rooms, compressor rooms and cargo control rooms and, as far as practicable, pipe tunnels if fitted
- examination of the cargo machinery spaces and turret compartments, including their escape routes
- examination of all pump room and compressor room bulkheads for signs of leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room and compressor room bulkheads
- examination of all accessible gas-tight bulkhead penetrations including gas-tight shaft sealings
- examination of the sealing arrangements for tanks or tank domes penetrating decks or tank covers
- examination of the means for accomplishing gas tightness of the wheelhouse doors and windows. All windows and sidescuttles within the area required to be of the fixed type (non-opening) are to be examined for gas tightness. The closing devices for all air intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and approved openings in superstructures and deckhouses facing the cargo area or bow and stern loading/unloading arrangements, are to be examined
- examination of cargo and process piping, including the expansion arrangements, insulation from the hull structure, pressure relief and drainage arrangements and water curtain protection as appropriate
- examination of venting systems, including vent masts and protective screens, for cargo tanks, interbarrier spaces, hold spaces, fuel tanks and ballast tanks
- examination of cargo tank and interbarrier space relief valves and associated safety systems and alarms
- confirmation that the certificate for the relief valve opening/closing pressures is on board and that the cargo tank relief valves are sealed
- examination of drip trays or insulation for deck protection against cargo leakage
- confirmation of proper maintenance of arrangements for the airlocks
- confirmation that all accessible cargo piping systems are electrically bonded to the hull
- visual examination of arrangements for burning methane boil-off as far as practicable.

2.4 Other arrangements or devices

2.4.1 The survey is to include:

- confirmation that any liquid and vapour hoses are suitable for their intended purpose and in satisfactory condition and, where appropriate, type-approved or marked with date of testing
- confirmation that any special arrangement made for bow or stern loading/unloading is satisfactory
- confirmation that, if applicable, the provisions made for products which have special arrangements as per Pt D, Ch 9, Sec 17 are satisfactory
- confirmation that any special arrangements to survive conditions of damage are satisfactory
- examination, where applicable, of the alternative design and arrangements for the segregation of the cargo area, in accordance with the test, inspection and maintenance requirements, if any, specified in the approved documentation

2.5 Ballast tanks

2.5.1 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey or the intermediate survey; see [6.3.7] and footnote **(3)** of Tab 1, respectively.

2.5.2 When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements are to be increased to determine the extent of areas of substantial corrosion in accordance with the requirements given in Tab 4. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

2.6 Emergency towing arrangement

2.6.1 The Owner or his representative is to declare to the attending Surveyor that no significant alterations have been made, without prior approval from the Society, to the equipment and arrangements fitted on board in accordance with the provisions given in Pt B, Ch 12, Sec 4, [3].

2.6.2 The survey is to include:

- an examination, as far as practicable, of the emergency towing arrangement
- confirmation that the aft towing arrangement is pre-rigged and forward chafing gear is secured to the strong-point
- confirmation of the proper functioning of the light, where it is provided, on the pick-up gear marker buoy.

3 Annual survey - Cargo machinery items

3.1 Cargo area and cargo pump rooms

3.1.1 The survey is to include:

- examination of mechanical ventilation fans in gas-dangerous spaces and zones
- examination, as far as practicable, and confirmation of the satisfactory operation of the arrangements for the artificial ventilation of spaces in the cargo area normally entered during operation
- examination and confirmation of the arrangements for the artificial ventilation of spaces normally entered other than above
- examination, as far as possible during operation, of the cargo handling piping and machinery, e.g. cargo and process piping, cargo heat exchangers, vaporizers, pumps, compressors and hoses.
- confirmation that fixed and/or portable ventilation arrangements provided for spaces not normally entered are satisfactory
- confirmation that the manually operated ESD (emergency shutdown) system together with the automatic shutdown of the cargo pumps and compressors are satisfactory
- examination of the gas detection safety arrangements for cargo control rooms and of the measures taken to exclude ignition sources when such spaces are classified as hazardous areas
- examination of cargo (if accessible), bilge, ballast and stripping pumps for excessive gland seal leakage
- confirmation that electrical equipment in hazardous areas is in satisfactory condition and has been properly maintained
- examination, as far as possible, of arrangements for the use of cargo as fuel, and associated instrumentation and safety devices.
- confirmation that, if fitted, cargo reliquefaction or refrigeration equipment is in satisfactory condition
- confirmation that relevant instruction and information material such as cargo handling plans, filling limit information, cooling down procedures, etc., is available on board.

3.2 Instrumentation and safety devices

3.2.1 The survey is to include:

- confirmation that installed pressure gauges on cargo discharge lines are operational (see Note 1)
- confirmation that cargo tank liquid level gauges are operational and that high level alarms as well as automatic shut-off systems are satisfactory (see Note 1)
- confirmation that the temperature indicating equipment of the cargo containment system and associated alarms are satisfactory (see Note 1)
- examination of the logbooks for confirmation that the emergency shutdown system has been tested
- confirmation that cargo tank, hold and insulation space pressure gauging systems and associated alarms are satisfactory (see Note 1)
- examination, and testing as appropriate, of fixed gas detection equipment
- examination of the arrangements for the cargo pressure / temperature control including, when fitted, the thermal oxidation systems and any refrigeration system and confirming that any associated safety measures and alarms are satisfactory
- confirmation of the availability and suitability of the portable gas detection equipment and instruments for measuring oxygen levels

Note 1: Verification of these devices is to be done by one or more of the following methods:

- visual external examination
- comparing of read outs from different indicators
- consideration of read outs with regard to the actual cargo and/ or actual conditions
- examination of maintenance records with reference to cargo plant instrumentation maintenance manual
- verification of calibration status of the measuring instruments.

3.3 Fire-fighting systems in cargo area

3.3.1 The survey is to include:

- examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room, cargo compressor room and other dangerous spaces, such as deck foam, water-spraying and dry powder systems, as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4], including testing of the remote means of starting one main fire pump
- examination of the fixed fire-fighting system for the enclosed cargo machinery spaces, and the enclosed cargo motor room within the cargo area, and confirmation that its means of operation is clearly marked
- examination of the appropriate fire-extinguishing system for the enclosed cargo machinery spaces for ships that are dedicated to the carriage of a restricted number of cargoes and the internal water-spray system for the turret compartments and confirmation that their means of operation is clearly marked.

3.4 Environmental control for cargo containment systems

3.4.1 The survey is to include:

- the examinations and tests as provided for the annual survey of inert gas systems of oil tankers, given in Ch 4, Sec 3, [3.4]
- confirmation that the use of inert gas has not increased beyond that needed to compensate for normal losses by examining records of inert gas usage
- confirmation that arrangements are made for sufficient inert gas to be carried to compensate for normal losses and that means are provided for monitoring the spaces
- confirmation that the means for prevention of backflow of cargo vapour to gas-safe spaces are in satisfactory operating condition
- confirmation that any air drying system and any interbarrier and hold space purging inert gas system are satisfactory
- for membrane containment systems normal operation of the nitrogen control system for insulation and interbarrier spaces shall be confirmed to the Surveyor by the Master.

4 Intermediate survey - Hull items

4.1 General

4.1.1 A survey planning meeting is to be held prior to the commencement of the survey.

4.2 Weather decks, cargo handling rooms and piping

4.2.1 The survey is to include:

- examination, as far as applicable, of cargo and process, liquid nitrogen (if any), ballast, stripping and vent piping systems as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, pressure testing, thickness measurement or both may be required
- examination of vent line drainage arrangements
- confirmation that cargo pipes and independent cargo tanks, where applicable, are electrically bonded to the hull.

4.3 Ballast tanks

4.3.1 The requirements for survey of ballast tanks given in Tab 1 are to be complied with.

4.3.2 For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of close-up surveys may be specially considered by the Society.

Table 1 : Intermediate survey of ballast tanks for liquefied gas carriers

Age of ship (in years at time of intermediate survey)		
5 < age ≤ 10	10 < age ≤ 15	age > 15
Overall survey of representative ballast tanks, selected by the attending Surveyor See **(1)**, **(2)** and **(3)**	Overall survey of all ballast tanks See **(1)** and **(3)**	Overall survey of all ballast tanks See **(1)** and **(3)**
	Close-up survey of: - all web frames and both transverse bulkheads in a representative ballast tank **(4)** and **(5)** - the upper part of one web frame in another representative ballast tank - one transverse bulkhead in another representative ballast tank **(5)** See **(6)**, **(7)** and **(8)**	Close-up survey of all web frames and both transverse bulkheads in two representative ballast tanks **(4)** and **(5)** See **(6)**, **(7)** and **(8)**

(1) If such surveys reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient.

(2) If there is no hard protective coating, soft or semi-hard coating or poor coating condition, the examination is to be extended to other ballast tanks of the same type.

(3) For ballast tanks, excluding double bottom tanks, if there is no hard protective coating, soft or semi-hard coating, or poor coating condition and it is not renewed, the tanks in question are to be internally examined at annual intervals.

When such conditions are found in double bottom ballast tanks, the tanks in question may be internally examined at annual intervals.

(4) Complete transverse web frame including adjacent structural members.

(5) Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure.

(6) The extent of close-up surveys may be extended in accordance with the requirements of [6.4.3].

(7) For areas in ballast tanks where protective coating is found to be in good condition, as defined in Ch 2, Sec 2, [2.2.14], the extent of close-up survey may be specially considered.

(8) Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted.

5 Intermediate survey - Cargo machinery items

5.1 General

5.1.1 The aim of the intermediate survey is to supplement the annual survey by testing cargo handling installations with related automatic control, alarm and safety systems for correct functioning.

5.1.2 The intermediate survey is preferably to be carried out with the ship in a gas-free condition. In fact, the extent of the testing required for the intermediate survey will normally be such that the survey cannot be carried out during a loading or discharging operation.

5.2 Cargo area and cargo pump rooms

5.2.1 Electrical equipment and cables in hazardous areas and zones such as cargo machinery spaces and areas adjacent to and above cargo tanks are to be examined for defective equipment, fixtures and cables as far as practicable and tested with particular regard to:

- protective earthing (spot check)
- integrity of enclosures
- damage of outer sheath of cables
- function test of pressurised equipment and associated alarms
- test of systems for de-energising non-certified safe electrical equipment located in spaces protected by air-locks, such as electric motor rooms, cargo control rooms, etc.

5.2.2 The electrical insulation resistance of the electrical equipment and circuits in dangerous zones is to be measured. These measurements are only to be effected when the ship is in a gas-free or inerted condition. Where a proper record of testing is maintained, consideration may be given to accepting recent readings by the ship's personnel.

5.2.3 In addition to the requirements of [5.2.1] and [5.2.2], the survey also consists of:

- confirmation that the cargo heating/cooling system is in satisfactory condition
- confirmation that spares are provided for cargo area mechanical ventilation fans
- confirmation that the heating system of the hull structure is in satisfactory working condition
- general examination and test of leakage detection systems in interbarrier and hold spaces.

5.3 Instrumentation and safety devices

5.3.1 The survey is to include:

- examination of the installed pressure gauging systems on cargo discharge lines, cargo tanks, holds and insulation spaces and associated alarms
- examination of the cargo tank liquid level gauges and high level alarms as well as automatic shut-off systems
- examination of the temperature indicating equipment of the cargo containment system and associated alarms
- test of the above-mentioned instrumentation by changing pressure, level and temperature as applicable and comparing with test instruments. Simulated tests may be accepted for sensors which are not accessible or located within cargo tanks or inerted hold spaces. The test is to include alarm and safety functions
- examination, as far as practicable, of the piping of the gas detection system for corrosion and damage. The integrity of the suction lines between suction points and analysing units is to be verified as far as possible
- calibration of gas detectors or verification thereof with sample gases
- confirmation that two sets of portable gas detection equipment suitable for the cargoes to be carried and a suitable instrument for measuring oxygen levels are provided
- test of the manually operated emergency shutdown system (without flow in the pipelines) to verify that the system will cause the cargo pumps and compressors to stop.

5.3.2 The arrangements for the use of cargo as fuel are to be examined, when applicable. It is to be tested, as far as practicable, that the gas supply to the machinery space is cut-off should the exhaust ventilation not be functioning correctly and that master gas fuel valve may be remotely closed from within the machinery space.

The instrumentation and safety systems for burning cargo as fuel are to be examined in accordance with [5.3.1].

5.4 Inert gas system

5.4.1 If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [5.2] for intermediate survey of oil tankers are to be complied with.

5.4.2 In the case of low temperature liquid nitrogen storage, the plant and its associated arrangements for protecting the hull structure against liquid nitrogen leakage are to be examined.

5.5 Personnel protection

5.5.1 The survey is to include:

- confirmation that two complete sets of safety equipment each permitting personnel to enter and work in a gas-filled space are provided and properly stowed
- confirmation that the requisite supply of compressed air is provided and examination, when applicable, of the arrangements for any special air compressor and low-pressure air line system
- confirmation that the medical first-aid equipment, including stretchers and oxygen resuscitation equipment and antidotes, when available, for the products to be carried are provided
- confirmation that respiratory and eye protection suitable for emergency escape purposes are provided
- confirmation that decontamination arrangements and eyewashes are operational
- examination, when applicable, of the arrangements to protect personnel against the effects of a major cargo release by a special suitably designed and equipped space within the accommodation spaces.

6 Class renewal survey - Hull items

6.1 Preparation for survey

6.1.1 The Owner is to provide the necessary facilities for a safe and practical execution of the surveys, including the means of providing access to structures for close-up survey, thickness measurements and tank testing. All other provisions described in Ch 2, Sec 2, [2.3], Ch 2, Sec 2, [2.5], Ch 2, Sec 2, [2.6], Ch 2, Sec 2, [2.7] and Ch 2, Sec 2, [2.9] regarding procedures for thickness measurements, conditions for survey, access to structures, equipment for survey and survey at sea or at anchorage, respectively, are also to be complied with.

6.2 Survey programme

6.2.1 A specific survey programme is recommended to be worked out in advance of the class renewal survey by the Owner in cooperation with the Society.

6.2.2 The survey programme is to include the scope of survey specified in [6.3] taking into account the minimum requirements of Tab 2 and Tab 3 for close-up survey and thickness measurements and [6.6] for tank testing, conditions for survey, access to structures and equipment for surveys.

6.3 Scope of survey

6.3.1 A survey planning meeting is to be held prior to the commencement of the survey.

6.3.2 In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in [6.3.4], are in satisfactory condition and fit for the intended purpose for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

6.3.3 Ballast tanks, including double bottom tanks, pump rooms, compressor rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in [6.5] and [6.6], to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration that may be present.

6.3.4 All piping systems within the above spaces, are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

6.3.5 The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.

Note 1: For survey of automatic air pipe heads, refer to Ch 3, Sec 3, Tab 1.

6.3.6 As indicated in Ch 3, Sec 3, [2.1.1], a bottom survey in dry condition is to be a part of the class renewal survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and water ballast tanks are to be carried out in accordance with the applicable requirements for class renewal surveys, if not already performed.

Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

6.3.7 Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined.

For ballast tanks, excluding double bottom tanks, where a hard protective coating is found in poor condition and it is not renewed, where soft or semi-hard coating has been applied, or where a hard protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.

When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

6.3.8 Where the hard protective coating in ballast tanks is found to be in a good condition, the extent of close-up surveys and thickness measurements may be specially considered.

6.4 Overall and close-up surveys

6.4.1 An overall survey of all tanks and spaces, excluding fuel oil, lube oil and fresh water tanks, is to be carried out at each class renewal survey. However, for fuel oil, lube oil and fresh water tanks, the requirements given in Ch 3, Sec 3, Tab 2 are to be complied with.

6.4.2 Each class renewal survey is to include a close-up examination of sufficient extent to establish the condition of cargo tanks and ballast tanks. The minimum requirements for close-up surveys are given in Tab 2 for ballast tanks and in [6.7.3] for cargo tanks.

Table 2 : Requirements for close-up survey of ballast tanks at class renewal survey of liquefied gas carriers

Age of ship (in years at time of class renewal survey)		
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 and subsequent age > 10
One web frame in a representative ballast tank of the topside, hopper side and double hull side type **(1)**	All web frames in a ballast tank, which is to be a double hull side tank or a topside tank. If such tanks are not fitted, another ballast tank is to be selected **(1)**	All web frames in all ballast tanks **(1)**
	One web frame in each remaining ballast tank **(1)**	
One transverse bulkhead **(3)**, in a ballast tank	One transverse bulkhead in each ballast tank **(2)**	All transverse bulkheads in all ballast tanks **(2)**
(1) Complete transverse web frame including adjacent structural members. **(2)** Transverse bulkhead complete, including girder system and adjacent members, and adjacent longitudinal bulkhead structure. **(3)** Transverse bulkhead lower part, including girder system and adjacent structural members. **Note 1:** Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted.		

6.4.3 The Surveyor may extend the close-up survey as deemed necessary, taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

- in particular, in tanks having structural arrangements or details which have suffered defects in similar tanks, or on similar ships according to available information
- in tanks having structures approved with reduced scantlings.

6.4.4 For areas in tanks where hard protective coatings are found to be in good condition, as defined in Ch 2, Sec 2, [2.2.14], the extent of close-up surveys required according to Tab 2 may be specially considered by the Society.

For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of close-up surveys of ballast tanks may be specially considered by the Society.

Note 1: For survey of automatic air pipe heads, reference is to be made to Ch 3, Sec 3, Tab 1.

6.5 Thickness measurements

6.5.1 The minimum requirements for thickness measurements at class renewal survey are given in Tab 3.

6.5.2 The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion in accordance with the requirements given in Tab 4.

6.5.3 For areas in tanks where hard protective coatings are found to be in good condition as defined in Ch 2, Sec 2, [2.2.14], the extent of thickness measurements according to Tab 3 may be specially considered by the Society.

6.5.4 For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of thickness measurements may be increased to the tank top plating to the satisfaction of the Surveyor.

6.5.5 Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

Table 3 : Requirements for thickness measurements at class renewal survey of liquefied gas carriers

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
One section of deck plating for the full beam of the ship within 0,5 L amidships in way of a ballast tank, if any	Within the cargo area: • each deck plate • one transverse section within 0,5 L amidships in way of a ballast tank, if any	Within the cargo area: • each deck plate • two transverse sections **(1)** • all wind and water strakes	Within the cargo area: • each deck plate • three transverse sections **(1)** • each bottom plate • duct keel plating and internals
Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 2	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 2	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 2	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 2
	Selected wind and water strakes outside the cargo area	Selected wind and water strakes outside the cargo area	All wind and water strakes full length
(1) at least one section is to include a ballast tank within 0,5 L amidships, if any.			

Table 4 : Requirements for extent of thickness measurements at those areas of substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect area and adjacent plates	5-point pattern over 1 m^2 of plating
Stiffeners	Suspect area	3 measurements each in line across web and flange

6.6 Tank testing

6.6.1 All boundaries of ballast tanks and deep tanks used for water ballast within the cargo area are to be pressure tested. For fuel oil tanks, the representative tanks are to be pressure tested.

6.6.2 The Surveyor may extend the tank testing as deemed necessary.

6.6.3 Tank testing of fuel oil tanks is to be carried out with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

6.7 Cargo tank structure

6.7.1 All cargo tanks are to be cleaned and examined internally.

6.7.2 When accessible, the outer surface of uninsulated cargo tanks or the outer surface of cargo tank insulation together with any vapour or protective barrier is to be examined. Special attention is to be given to the tank and insulation in way of chocks, supports and keys. Removal of insulation, in part or entirely, may be required in order to verify the condition of the tank or the insulation itself if deemed necessary by the Surveyor.

Where the arrangement is such that the insulation cannot be examined entirely, the surrounding structures of wing tanks, double bottom tanks and cofferdams are to be examined for cold spots when the cargo tanks are in the cold condition, unless voyage records together with the instrumentation give sufficient evidence of the integrity of the insulation system.

6.7.3 Thickness measurements may be required if deemed necessary by the Surveyor.

Close-up surveys are to be carried out in independent cargo tanks of type B and C at those areas where corrosion may develop.

6.7.4 Non-destructive testing is to supplement cargo tank inspection with special attention to be given to the integrity of the main structural members, tank shell and highly stressed parts, including welded connections as deemed necessary by the Surveyor.

However, for type C tanks, this does not mean that non-destructive testing can be dispensed with totally.

The following items are, inter alia, considered highly stressed areas:

- cargo tank supports and anti-rolling or anti-pitching devices
- web frames or stiffening rings
- Y-connection of shell plates and longitudinal bulkhead of bilobe tanks
- swash bulkhead boundaries
- dome and stump connections to the shell plating
- foundations for pumps, towers, ladders, etc.
- pipe connections.

6.7.5 For independent tanks of type B, the extent of non-destructive testing is to be as given in a program specially prepared for the cargo tank design.

6.7.6 The tightness of all cargo tanks is to be verified by an appropriate procedure. Provided that the effectiveness of the ship's gas detection equipment has been confirmed, it will be acceptable to utilise this equipment for the tightness test of independent tanks below deck.

6.7.7 Where the results of the examinations dealt with in [6.7.1] to [6.7.6] or the examination of the voyage records raise doubts as to the structural integrity of a cargo tank, a hydraulic or hydropneumatic test is to be carried out.

For integral tanks and for independent tanks of type A and B, the test pressure is not to be less than the MARVS.

For independent tanks of type C, the test pressure is not to be less than 1,25 times the MARVS.

6.7.8 When the ship is 10 years old, at every alternate class renewal survey, independent cargo tanks of type C are to be either:

- hydraulically or hydro-pneumatically tested to 1,25 times the MARVS, and thereafter non-destructively tested in accordance with [6.7.4], or
- subjected to thorough non-destructive testing in accordance with a program specially prepared for the tank design submitted by the Owner to the Society for acceptance. If a special program of non-destructive testing does not exist, special attention is to be given to the detection of surface cracks in welded connections in highly stressed areas as listed in [6.7.4]. At least 10% of the length of the welded connections in each of the above-mentioned areas is to be tested. This testing is to be carried out internally and externally, as applicable. Insulation is to be removed as necessary for the required non-destructive testing.

Where hold space atmosphere control is permanently maintained, the scope of external examination of the tanks and their supports may be reduced at the Surveyor's discretion.

6.7.9 As far as accessible, hold spaces and hull insulation (if provided), secondary barriers and tank supporting structures are to be visually examined. The secondary barrier of tanks is to be checked for its effectiveness by means of a pressure/vacuum test, a visual examination or any other acceptable method.

6.7.10 For membrane, semi-membrane and internal insulation tank systems, inspection and testing are to be carried out in accordance with programmes specially prepared in accordance with an approved method for the actual tank system.

For membrane containment systems, a tightness test of the primary and secondary barriers shall be carried out in accordance with the system designers' procedures and acceptance criteria as approved by the Society. Low differential pressure tests may be used for monitoring the cargo containment system performance, but they are not considered as an acceptable test for the tightness of the secondary barrier.

For membrane containment systems with glued secondary barriers, if the designer's threshold values are exceeded, an investigation is to be carried out and additional testing such as thermographic or acoustic emission testing should be carried out.

6.7.11 All gas-tight bulkheads are to be examined and the effectiveness of gas-tight shaft sealing is to be verified.

6.7.12 It is to be verified that independent cargo tanks are electrically bonded to the hull.

6.7.13 The pressure relief valves for the cargo tanks are to be opened for examination, adjusted, function tested and sealed. If the cargo tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, these non-metallic membranes are to be replaced. Where a proper record of continuous overhaul and re-testing of individually identifiable relief valves is maintained, consideration may be given to acceptance on the basis of opening, internal examination and testing of a representative sample of valves, including each size and type of liquefied gas or vapour relief valves in use, provided there is evidence in the log-book that the remaining valves have been overhauled and tested since crediting of the previous class renewal survey.

6.8 Weather decks, cargo handling rooms and piping

6.8.1 Piping for cargo and process, liquid nitrogen (if any), ballast, stripping and venting systems is to be examined to the Surveyor's satisfaction and opened as deemed necessary. Insulation is to be removed as deemed necessary to ascertain the condition of the pipes. If the visual examination raises doubts as to the integrity of the pipelines, a pressure test at 1,25 times the MARVS for the pipeline is to be carried out. After reassembly the complete piping systems are to be tested for leaks.

It is to be verified that cargo piping systems are electrically bonded to the hull.

6.8.2 The pressure relief valves on cargo piping are to be function tested. A random selection of valves is to be opened for examination and adjusted.

6.8.3 All cargo pump room, compressor room and control room boundaries are to be generally examined. Gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms and cargo compressor rooms is to be presented clean for the examination of stripping devices and gutters.

6.8.4 Pressure/vacuum relief valves, rupture discs and other pressure relief devices for interbarrier spaces and/or hold spaces are to be examined and, if necessary, opened and tested in accordance with their design.

Vent line drainage arrangements are to be examined.

6.9 Emergency towing arrangement

6.9.1 The survey is to include:

- an examination of the emergency towing arrangement
- confirmation that the arrangement is readily available with aft towing arrangement pre-rigged and forward chafing gear secured to the strong-point
- an examination of the pick-up gear, towing pennant and chafing gear over the full length for possible deterioration. Where the pennant line is stored in a watertight condition and can be confirmed as being maintained, consideration may be given to waiving the requirement to examine the pennant line over the full length
- an examination of the strong-points, fairleads and pedestal roller together with their attachments to the hull structure.

7 Class renewal survey - Cargo machinery items

7.1 Cargo area, cargo pump rooms, cargo compressor rooms

7.1.1 Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out.

Maintenance records of cargo pumps are to be made available to the Surveyor.

7.1.2 Electrical equipment and cables in dangerous zones such as cargo pump rooms, cargo compressor rooms and spaces adjacent to and areas above cargo tanks are to be examined as far as practicable and tested with particular regard to:

- protecting earthing (spot check)

- integrity of enclosures
- damage of outer sheath of cables
- function testing of pressurised equipment and associated alarms
- testing of systems for de-energising non-certified safe electrical equipment located in spaces protected by air-locks, such as electric motor rooms, cargo control rooms, etc.

7.1.3 The electrical insulation resistance of the electrical equipment and circuits in dangerous zones is to be measured. These measurements are only to be effected when the ship is in a gas-free or inerted condition. Where a proper record of testing is maintained, consideration may be given to accepting recent readings by the ship's personnel.

7.1.4 When there is a reliquefaction or refrigeration plant, and/or arrangements for the use of cargo as fuel, the corresponding machinery and equipment, such as cargo pumps, compressors, heat exchangers, condensers and process pressure vessels, are to be surveyed to the same extent as required for similar equipment on board oil tankers at the class renewal survey (refer to Ch 4, Sec 3).

7.1.5 In addition to the requirements of [7.1.1] to [7.1.4], the survey also consists of:

- confirmation that spares are provided for cargo area mechanical ventilation fans
- confirmation that the installation for heating the hull structure is in satisfactory working condition
- general examination and testing of leakage detection systems in interbarrier spaces and hold spaces
- examination of gas detection piping system for corrosion or damage; checking, as far as possible, of the integrity of suction lines between suction points and analysing units
- examination and tests of systems for the removal of water from interbarrier spaces and hold spaces
- examination of portable equipment, such as hoses and spool pieces used for segregation of piping systems for cargo, inert gas and bilge pumping.

7.1.6 Cargo pumps, compressors, process pressure vessels, liquid nitrogen tanks, heat exchangers and other components, including prime movers, used in connection with cargo handling and methane boil-off burning are to be surveyed according to the requirements of Part A, Chapter 3.

7.2 Fire-fighting systems in cargo area

7.2.1 The survey is to include the examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room, cargo compressor room and other dangerous spaces, such as deck foam, water-spraying, dry powder systems etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

7.3 Inert gas system

7.3.1 If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [7.3] are to be complied with.

7.3.2 In the case of low temperature liquid nitrogen storage, the plant and its associated arrangements for protecting the hull structure against liquid nitrogen leakage are to be examined.

7.4 Personnel protection

7.4.1 The requirements given in [5.5] are to be complied with.

8 First loaded voyage of ships carrying liquefied natural gases (LNG) in bulk

8.1

8.1.1 The survey requirements for the examination before and after the first loaded voyage for ships assigned with the service notation **liquefied gas carrier**, carrying liquefied natural gases (LNG) in bulk are to be carried out in accordance with Pt D, Ch 9, Sec 1, [6.2.4].

9 Revaporization installation

9.1 Application

9.1.1 The requirements of this Article are applicable to self-propelled ships which have been assigned the notations:

- **liquefied gas carrier REGAS**, or
- **liquefied gas carrier REGAS STL-SPM**

These requirements apply to the revaporization installation and to the area in way of this installation.

Reference is also made to other Articles of this Section for items dedicated to the revaporization installation such as cargo tanks or control stations.

9.2 Annual survey

9.2.1 General

The annual survey of the revaporization installation is preferably carried out during unloading operations with this installation in operation.

Revaporization installation operational record entries (Bridge and Cargo logbooks) since the last survey are to be examined in order to check the past performance of the system and to establish whether certain parts have shown any irregularities in operation.

9.2.2 Equipment in contact with gas or in gas dangerous areas

The survey is to include:

a) examination of the cargo suction drum(s) and their sealing arrangements if applicable

b) examination of the areas dedicated to revaporization equipment

c) examination of closing devices of air intakes and openings into dedicated spaces for revaporization if applicable

d) examination of cargo and process piping, including the expansion arrangements, insulation from the hull structure, pressure control valves, inlet/outlet valves, drainage arrangements and high pressure manifolds

e) examination of the relief valves, their sealing and associated safety systems and alarms

f) confirmation that the certificate for the relief valves opening/closing pressures is on board

g) examination of high pressure pumps as far as practicable (including gland leakage and vibration indications)

h) external examination of vaporizers and their fittings

i) external examination of heat exchangers

j) examination of drip trays or insulation for deck protection and recesses against cargo leakage in revaporization area

k) confirmation that all accessible cargo piping systems and components (cargo suction drum(s), vaporizers, high pressure pumps) are electrically bonded to the hull.

9.2.3 Instrumentation and safety devices

The survey is to include examination of pressure gauges, control valves, metering unit, temperature and vibration indicating equipment. Particular attention is to be given to high pressure pumps instrumentation and safety devices.

Confirmation that the instrumentation fitted on revaporization equipment and in contact with gas and associated alarms are satisfactory.

Examination and testing, as appropriate, of fixed gas detection equipment.

Examination of the logbooks for confirmation that the automatic emergency shut-down system has been tested. Confirmation that the automatic shut-down system is satisfactory.

9.2.4 Other arrangements or devices

The survey is to include confirmation that:

- relevant shipboard instructions and procedures of the revaporization installation are available
- the revaporization control station is in satisfactory working condition.

Water-spraying system against gas leakage is to be surveyed in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4].

Water deluge system is to be examined, including piping nozzles if fitted, and distribution valves. The starting of the pump is to be tested.

9.3 Intermediate survey

9.3.1 General

The aim of the intermediate survey is to supplement the annual survey by testing the revaporization installation with related automatic control, alarm and safety systems for correct functioning.

9.3.2 Equipment in contact with gas or in gas dangerous areas

The maintenance records of vaporizers are to be reviewed. If deemed necessary by the Surveyor, thickness measurements, pressure test and/or opening-up and internal examination as far as practicable may be required. Particular attention is to be given to rupture device if fitted.

The survey is also to include:

a) examination, as far as applicable, of stripping and vent piping systems and high pressure manifolds of cargo and process. If upon examination there is any doubt as to the condition of the piping, pressure testing, thickness measurement or both may be required

b) examination of vent line drainage arrangements

c) confirmation that cargo pipes and revaporization components are electrically bonded to the hull

d) random test of high pressure pumps lifting device

e) thickness measurements of cargo suction drum(s) if deemed necessary by the Surveyor

f) examination of electrical equipment according to [5.2].

9.3.3 Instrumentation and safety devices

The survey is to include examination of pressure gauges, control valves, metering unit, liquid level gauges, temperature and vibration indicating equipment, and associated alarms. Particular attention is to be given to high pressure pumps instrumentation and safety devices.

The above mentioned instrumentation is to be tested by changing pressure, level and temperature as far as practicable and comparing with test instruments. Simulated tests may be accepted for sensors which are not accessible. The test is to include alarms and safety functions.

The manually operated emergency shut-down system is to be operationally tested to verify that the system will cause the revaporization installation to stop.

9.3.4 Other arrangements or devices

Water deluge system is to be tested as deemed necessary by the Surveyor.

9.4 Class renewal survey

9.4.1 General

In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the revaporization installation is in satisfactory condition for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

9.4.2 Cargo suction drum

The following requirements apply:

a) Cargo suction drum(s) is (are) to be presented clean and examined internally.

b) When accessible, the outer surface of uninsulated cargo suction drum(s) or the outer surface of unit insulation together with any vapour or protective barrier is to be examined. Particular attention is to be given to the stocking unit and insulation in way of supports. Removal of insulation, in part or entirely, may be required in order to verify the condition of the unit or the insulation itself if deemed necessary by the Surveyor.

c) Thickness measurements or non-destructive testing may be required if deemed necessary by the Surveyor.

d) The tightness of cargo suction drums is to be verified by an appropriate procedure.

e) Where the results of the examinations in items a) to e) or the examination of the operational records raise doubts as to the structural integrity of the unit, a hydraulic or hydro pneumatic test is to be carried out. The test pressure is not to be less than 1,25 times the MARVS.

f) When the ship is 10 years old, at every alternate class renewal survey, cargo suction drum(s) is (are) to be either: hydraulically tested and thereafter non-destructively tested or subjected to thorough non-destructive testing as per [6.7.8].

g) As far as accessible, the cargo suction drum(s) supporting structures are to be visually examined.

h) Their fittings, valves and safety devices are to be opened up, as deemed necessary by the Surveyor, for visual examination and pressure tested as appropriate.

9.4.3 Equipment in contact with gas or in gas dangerous areas

Piping for cargo and process, stripping, venting systems high pressure manifolds are to be examined to the Surveyor's satisfaction. Insulation is to be removed as deemed necessary to ascertain the condition of the pipes. If the visual examination raises doubts as to the integrity of the pipelines, a pressure test at 1,25 times the MARVS for the pipeline is to be carried out. After reassembly the complete piping systems are to be tested for leaks.

Maintenance records and log books of high pressure pumps including starting pumps are to be made available to the Surveyor. As deemed necessary by the Surveyor, the high pressure pumps are to be opened up for visual examination and their parts and components pressure tested. The lifting device is to be tested.

The bottom of the high pressure pump recess and vaporizer spaces are to be presented clean for the examination of gutters and stripping devices.

The pressure relief valves are to be opened for examination, adjusted, function tested and sealed. The valves including inlet/outlet valves, pressure control valves and discharge valves are to be tested for proper operation.

The maintenance records of vaporizers are to be reviewed. The Surveyor may require as considered necessary:

- external and internal examination of vaporizers which are to be presented clean
- opening up of their fittings, valves and safety devices for visual examination and pressure tests
- thickness measurements and/or pressure test
- confirmation that cargo pipes and revaporization components are electrically bonded to the hull.

Particular attention is to be taken in way of the vaporizer rupture device if fitted.

As deemed necessary by the Surveyor, the vaporizers heat exchangers are to be opened up for visual examination and their parts and components are to be pressure tested, as appropriate. A working test is also to be carried out, including testing of alarms and safety devices.

The electrical equipment are to be surveyed according to [7.1.2] and [7.1.3].

9.4.4 Instrumentation and safety devices

The survey is to include examination of pressure gauges, control valves, metering unit, liquid level gauges, temperature and vibration indicating equipment, and associated alarms. Particular attention is to be given to high pressure pumps instrumentation and safety devices.

The above mentioned instrumentation is to be tested by changing pressure, level and temperature as applicable and comparing with test instruments. Simulated tests may be accepted for sensors which are not accessible. The test is to include alarms and safety functions.

The emergency shut-down system is to be tested.

9.4.5 Other arrangements or devices

Water-spraying system against gas leakage, when fitted, are to be surveyed in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

For water deluge system:

- the associated pumps are to be opened up and examined at the Surveyor's discretion
- a working test is to be carried out.

10 STL-SPM

10.1 Application

10.1.1 The requirements of this Article apply to self-propelled ships which have been assigned the notations **liquefied gas carrier REGAS STL-SPM**. These requirements apply to the installation for non permanent mooring or for connection to single buoy and for cargo unloading and to the area in way of this installation.

Reference is also made to above Articles of this Section for items dedicated to the STL-SPM installation such as ventilation or fire fighting.

10.2 Annual survey

10.2.1 General

The Owner or his representative is to declare to the attending Surveyor that no significant alterations have been made without the prior approval of the Society.

Operational record (log) entries since the last survey are to be examined in order to check the past performance of the installation and to establish whether certain parts have shown any irregularities in operation.

10.2.2 Piping and flexible riser

The survey is to include:

- external examination of readily accessible parts including the outer sheath and the end fittings
- examination of pipes and their connections, of accessories including gas vent systems, bending restrictors, clamps and supports. Confirmation that there is no loose holding or connection
- examination of gas vent valves.

10.2.3 STL-SPM compartment, handling and connecting systems

The annual survey is to include:

- a general examination of components of the installation including winches, heave compensator and sheaves, rope guides, capstans, rope, hatch system, locking mechanism, quick release unit, sealing devices, chain stoppers, fairleads, pedestal roller and covers to verify their satisfactory condition.
- an examination of the hull structures supporting and adjacent to the installation, to verify that no deformations or fractures have developed. Particular attention is to be given to the lower part of the trunk, intermittently in contact with sea water.
- confirmation that emergency escape route is practicable and not blocked

- a visual examination of the lower hatch covers, the sealing arrangements as far as practicable, the supporting and locking devices.

10.2.4 Swivel system

The survey is to include:

a) external examination of gas, electrical or/and hydraulic swivels with instrumentation and safety devices

b) examination of piping systems including leak drainage system

c) examination of connectors

d) examination of handling arm when fitted

e) tests of protective devices

f) examination of support structure.

10.2.5 Others

The survey is to include:

a) examination of pressure gauges, control valves, temperature and vibration indicating equipment

b) confirmation that the instrumentation dedicated to STL-SPM and associated alarms are satisfactory

c) examination and testing, as appropriate, of fixed gas detection equipment

d) examination of the vent line drainage arrangements and the trunk structure

e) examination of blast relief panels and verification that they are kept clear

f) examination of the logbooks for confirmation that the emergency and automatic shutdown systems have been tested and confirmation that they are satisfactory

10.3 Intermediate survey

10.3.1 Cargo tanks requirements originated from STL-SPM

The review of logbooks is to be carried out with particular attention to control and surveillance data such as temperature, pressure, gas leakage detection.

Cargo tank(s) may be internally examined if deemed necessary by the Surveyor.

10.3.2 Instrumentation, safety device and others

The survey is to include examination of pressure gauges, control valves, liquid level gauges, temperature and vibration indicating equipment, and associated alarms.

The above mentioned instrumentation is to be tested by changing pressure, level and temperature as far as practicable and comparing with test instruments. Simulated tests may be accepted for sensors which are not accessible. The test is to include alarms and safety functions.

The emergency shutdown system is to be tested according to standard procedures (dry test).

If applicable, a test of quick disconnection (without flow in the pipelines) is to be carried out as far as practicable.

The drain pumps, including emergency pump are to be operationally tested.

10.4 Class renewal survey

10.4.1 General

In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the STL-SPM installation is in satisfactory condition for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

Remote and/or automatic controls, alarms and safety devices are to be tested to demonstrate that they are in satisfactory condition.

10.4.2 Cargo tanks requirements originated from STL-SPM

The surveys detailed in [6.7] are to be carried out taking into account possible sloshing at intermediate filling levels (i.e. for independent cargo tank, with particular attention to upper and lower parts of the pump tower and its supports).

10.4.3 Piping and flexible riser

The survey is to include:

- a vacuum testing at vent holes in flexible pipe end fitting
- a pressure test if deemed necessary by the Surveyor
- an examination of the outer sheath. Removal of equipment hiding part of the pipe, may be required if deemed necessary by the Surveyor
- an internal examination, as far as practicable
- gas vent valves are to be examined and tested and, if deemed necessary by the Surveyor, opened up for internal examination.

10.4.4 STL-SPM compartment, handling and connecting systems

An examination of components is to be carried out with opening as deemed necessary by the Surveyor to verify their condition. Control and safety devices are to be tested. Guides and sheaves are to be examined for wear.

Satisfactory operation of the hatch covers is to be checked.

Thickness measurements or other non-destructive tests may be required by the Surveyor, where deemed necessary.

10.4.5 Swivel systems

The survey is to include:

- an internal examination of swivels
- a pressure test if deemed necessary by the Surveyor
- rotation tests, if deemed necessary, measurement of starting and running moments is to be carried out.

10.4.6 Instrumentation and safety devices

The survey is to include examination of pressure gauges, control valves, metering unit, liquid level gauges, temperature and vibration indicating equipment, and associated alarms.

The above mentioned instrumentation is to be tested by changing pressure, level and temperature as far as practicable and comparing with test instruments. Simulated tests may be accepted for sensors which are not accessible. The test is to include alarms and safety functions.

The emergency shut-down system is to be tested according to standard procedures.

A test of quick disconnection (without flow in the pipelines) is to be carried out.

The drain pumps, including emergency pump are to be operationally tested.

10.5 Bottom survey

10.5.1 The bottom survey is to include, as far as practicable:

- a visual examination of the shell plating in the submerged buoy recess
- a visual examination and an operational test of the lower hatch, including opening, closing and securing.

11 Bunkering installations

11.1 Application

11.1.1 The requirements of this Article apply to **liquefied gas carriers** which have been assigned the additional service feature **LNG bunkering** or **Ammonia bunkering**.

11.2 General

11.2.1 The bunkering installation including piping, inerting systems, electric installations, fire fighting systems and safety and control systems are to be examined during annual and class renewal surveys as required for cargo related systems.

11.3 Annual surveys

11.3.1 In addition to [11.2.1], the annual survey is to include the following items:

- visual examination of the bunkering station
- checking the proper functioning of the mechanical ventilation of the bunkering station
- checking the availability of the required documents for bunkering hoses
- checking the maintenance and inspection records of the transfer system
- inspection of the bunkering hoses
- inspection of the Quick Connect Disconnect couplers (QCDC)
- inspection of the break-away and Emergency Release Couplings (ERC)
- checking the proper functioning of the transfer arm, if applicable
- checking the proper functioning of the communication system.

11.4 Class renewal surveys

11.4.1 The requirements given in [11.3] for annual survey are to be complied with.

Section 6 Ro-Ro Cargo Ships and Pure Car and/or Truck Carriers, Passenger Ships and Ro-Ro Passenger Ships

1 General

1.1

1.1.1 The requirements of this Section are applicable after construction to all self-propelled ships which have been assigned one of the following service notations:

- **ro-ro cargo ship**
- **PCTC**
- **PCC**
- **passenger ship**
- **ro-ro passenger ship**.

1.1.2 These requirements are additional to those laid down in Part A, Chapter 3, according to the relevant surveys.

2 Ro-ro cargo ships and pure car and/or truck carriers - Annual survey

2.1 Shell and inner doors

2.1.1 The requirements of this item apply to all shell and inner doors fitted on these ships.

2.1.2 For the scope of survey of shell and inner doors, the following definitions are applicable:

- Securing device: a device used to keep the door closed by preventing it from rotating about its hinges
- Supporting device: a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure
- Locking device: a device that locks a securing device in the closed position.

2.1.3 It is to be checked that the operating procedures for closing the shell and inner doors are kept on board and posted at appropriate places.

When required, the Operating and Maintenance Manual is also to be checked for the verification of its approval and of any modification, reported repairs and proper endorsement by operating personnel.

Confirmation is to be obtained that no unapproved changes have been made to the bow, inner, side shell and stern doors since the last survey.

2.1.4 The structural arrangements as well as welding are to be examined, including:

- plating, primary structure and secondary stiffeners
- hinging arms, hinges and bearings, thrust bearings
- hull and door side supports of securing, supporting and locking devices
- shell plating surrounding the openings and the securing, supporting and locking devices.

Clearances of hinges, bearings and thrust bearings are to be taken, where no dismantling is required. Where the function test is not satisfactory, dismantling may be required to measure the clearances. If dismantling is carried out, a visual examination of hinge pins and bearings together with NDT of the hinge pin is to be carried out. Clearances of securing, supporting and locking devices are to be measured, where indicated in the OMM.

2.1.5 A close-up survey of securing, supporting and locking devices as listed below, including welding, is to be carried out:

- cylinder securing pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- hinge pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- locking hooks, securing pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- locking pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- locating and stopper devices and their welded connections.

2.1.6 A close visual inspection of sealing arrangements (packing material, rubber gaskets, packing retaining bars or channels) is to be carried out. For the tightness hose test, refer to [2.1.8].

2.1.7 The drainage arrangements including bilge wells, drain pipes and non-return valves are to be visually examined; confirmation that the provision of means to prevent blockage of drainage arrangements, for closed vehicle and ro-ro spaces and special category spaces where fixed pressure water-spraying systems are used, are satisfactory. A test of the bilge system between the inner and outer doors and that of the vehicle deck is to be carried out.

2.1.8 Function tests are to be carried out as follows, according to the required and/or existing equipment on board:

a) doors are to be examined during a complete opening and closing operation; during this operation, the proper working of hinging arms and hinges, proper engagement of the thrust bearings and proper working of devices for locking the door in open position are to be checked

b) securing, supporting and locking devices are to be examined during a complete opening and closing operation; the following items are to be checked:
   - opening/closing system and securing/locking devices are interlocked in such a way that they can only operate in proper sequence
   - mechanical lock of the securing devices
   - the securing devices remain locked in the event of loss of hydraulic fluid, if they are of hydraulic type

c) indicators of open/closed position of doors and of securing/locking devices at navigation bridge and other remote control stations are to be checked; other safety devices such as isolation of securing/locking hydraulic system from other hydraulic systems, access to operating panels, notice plates and warning indicator lights are to be checked

d) a tightness hose test or equivalent of sealing arrangements is to be carried out

e) a working test of the indicator system is to be carried out, including checking of:
   - visual indicators and audible alarms on the navigation bridge and operating panel
   - lamp test function, fail safe performance, power supply for indicator system
   - proper condition of sensors and their protection from water, ice formation and mechanical damage
   - confirmation that power supply for indicator system is supplied by the emergency source or other secure power supply and is independent of the power supply for operating the doors

f) a working test of the water leakage detection system for inner doors and for the area between the bow door and the inner door (as applicable) is to be carried out and the proper function of audible alarms on the navigation bridge and the engine control room panel (as applicable) is to be ascertained

g) the television surveillance system is to be verified with proper indication on the navigation bridge and engine control room monitors

h) electrical equipment for opening, closing and securing the doors is to be examined.

2.1.9 Non-destructive tests and/or thickness measurements may be required by the Surveyor after visual examination and function test or in cases where cracks or deformations have been found.

2.2 Internal platforms and ramps

2.2.1 The annual survey of internal movable platforms and ramps (excluding those considered as inner doors and covered in [2.1]) and related equipment consists of:

- a general examination of the installation, particular attention being paid to the condition of steel cables
- confirmation of the proper operation of platforms/ramps and of mechanical stops and locks
- checking, as far as practicable, of the alarms and safety devices.

2.3 Fire protection, detection and extinction

2.3.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the annual survey of all ships in Ch 3, Sec 1, [3.4], attention is to be given to the particular arrangements related to ro-ro cargo spaces, such as:

- fire detection systems and alarms
- fixed fire-extinguishing arrangements (gas, water-spraying or foam systems)
- means of control provided for closing various openings
- portable fire extinguishers in spaces and at entrances
- ventilation and related safety devices (including remote control on the bridge)
- electrical equipment of a safe type
- examination of the fire protection arrangements in cargo, vehicle and ro-ro spaces, including the fire safety arrangements for vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo, as applicable, and
- examination and test of the portable gas detectors suitable for the detection of the gas fuel, for vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo.

3 Ro-ro cargo ships and pure car and/or truck carriers - Class renewal survey

3.1 Shell and inner doors

3.1.1 The class renewal survey is to include, in addition to the requirements of the annual survey as required in [2], examination, tests and checks of sufficient extent to verify that the bow, inner, side shell and stern doors are in satisfactory condition and considered able to remain in compliance with the applicable requirements, subject to proper maintenance and operation in accordance with the Operation and Maintenance Manual (OMM) or the manufacturer's recommendations and the periodical surveys being carried out at the due dates for the five-year period until the next class renewal survey.

3.1.2 The examinations of the doors are to be supplemented by thickness measurements and testing to verify compliance with the applicable requirements so that the structural and weathertight integrity remains effective. The aim of the examination is to identify corrosion, significant deformation, fractures, damages or other structural deterioration that may be present.

3.1.3 A close visual inspection of structural arrangements is to be carried out, supplemented by non-destructive tests and/or thickness measurements, as deemed necessary by the Surveyor.

3.1.4 A survey of the items listed in [2.1.4] and [2.1.5], including close-up survey of securing, supporting and locking devices, together with welding, is to be carried out.

Non-destructive testing and thickness measurements are to be carried out on securing, supporting and locking devices, including welding, to the extent considered necessary by the Surveyor. Whenever a crack is found, an examination with NDT is to be carried out in the surrounding area and for similar items, as considered necessary by the Surveyor.

3.1.5 Clearances of hinges, bearings and thrust bearings are to be taken. Unless otherwise specified in the OMM or by the manufacturer's recommendation, the measurement of clearances on ro-ro cargo ships may be limited to representative bearings where dismantling is needed in order to measure the clearances.

If dismantling is carried out, a visual examination of hinge pins and bearings together with NDT of the hinge pins are to be carried out.

3.1.6 Non-return valves of drainage arrangements are to be checked after dismantling.

3.1.7 The maximum thickness diminution of hinging arms, securing, supporting and locking devices is to be treated according to the normal procedure for primary structures, but is not to be more than 15% of the as-built thickness or the maximum corrosion allowance of the Society, whichever is less. Certain designs may be subject to the Society's special consideration.

3.1.8 Checking the effectiveness of sealing arrangements by hose testing or equivalent is to be carried out.

3.2 Internal platforms and ramps

3.2.1 The condition of pulleys, axles, cables and structure of the platforms and ramps is to be checked.

Electric motors and/or hydraulically operated equipment are to be surveyed according to the scope detailed in Ch 3, Sec 3, [3] for the class renewal survey of machinery installations.

3.3 Fire protection, detection and extinction

3.3.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the class renewal survey of all ships in Ch 3, Sec 3, [3.8], attention is to be given to the particular arrangements related to ro-ro cargo spaces, such as those indicated in [2.3.1].

4 Passenger ships - Annual survey

4.1 Watertight bulkheads

4.1.1 The survey of watertight bulkheads and arrangements consists of:

- examination, as far as practicable, of collision and watertight bulkheads, and confirmation that their watertight integrity has not been impaired
- checking the diagram provided on the navigation bridge showing the location of the watertight doors and related indicators for their open/closed position
- testing operation of local and remote control (from the navigation bridge) of the watertight doors, and in particular, operation from each side of the bulkhead of audible alarms or visual signals and control handles, as required or fitted
- confirmation of operation of watertight doors in the event of failure of main and emergency sources of power
- confirmation that notices are affixed at appropriate locations.

4.2 Openings in shell plating

4.2.1 The survey consists of:

- examination of the arrangements for closing sidescuttles and their deadlights, as well as scuppers, sanitary discharges and similar openings and other inlets and discharges in the shell plating below the bulkhead deck
- confirmation that valves for closing the main and auxiliary sea inlets and discharges in the machinery spaces are readily accessible, and that indicators showing the status of the valves are provided, as required or fitted
- confirmation that gangway access and cargo ports fitted below the bulkhead deck may be effectively closed and that the inboard ends of any ash or rubbish chutes are fitted with an effective cover.

4.3 Miscellaneous

4.3.1 It is to be verified that the emergency escape routes from passenger and crew spaces, including related stairways and ladders, are kept clear.

5 Passenger ships - Class renewal survey

5.1

5.1.1 A lightweight survey is to be carried out to verify any changes in lightship displacement and in the longitudinal position of the centre of gravity. Where, in comparison with the approved stability information, a deviation exceeding 2% in the lightship displacement or a deviation of the longitudinal centre of gravity exceeding 1% of the length between perpendiculars is found or anticipated, the ship is to be submitted to a new inclining test.

5.1.2 The condition of the Low Location Lighting (LLL) system, where fitted, and its power source(s) is to be verified.

6 Ro-ro passenger ships - Annual and class renewal surveys

6.1

6.1.1 The scope of the annual survey and class renewal survey of **ro-ro passenger ship** is to include the scope of surveys required for the service notations **ro-ro cargo ship** and **passenger ship**, as detailed in [2] and [4] for annual survey and in [3] and [5] for class renewal survey.

6.1.2 In addition to [6.1.1], for both annual survey and class renewal survey, the condition of means of escape as well as of fire protection, detection and extinction in special category spaces is to be checked.

Section 7 General Cargo Ships

1 General

1.1 Application

1.1.1 The requirements of this Section apply to all self-propelled ships which have been assigned the service notation **general cargo ship** or **bulk carrier** (without the **ESP** additional service feature) of 500 GT and above carrying solid cargoes other than dedicated wood chip carriers and dedicated cement carriers.

The requirements of this Section do not apply to general dry cargo ships of double side-skin construction, with double side-skin extending for the length of the cargo area, and over the height of the cargo hold to the upper deck.

Note 1: Special consideration may also be given to ships that are of double-skin construction but with single skin in way of several frame spaces, e.g. in way of a cargo hold entrance or in way of forebody hull form at the forward end of the foremost cargo hold.

In case of ships with hybrid cargo hold arrangements, e.g. with some cargo holds of single-side skin and others of double-side skin, the requirements of this Section are to be applied only to the structure in way of the single-side skin cargo hold region.

1.1.2 The requirements apply to surveys of hull structure and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo area and all ballast tanks. They are additional to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3 according to the relevant surveys.

1.1.3 The requirements contain the minimum extent of examination, thickness measurements and tank testing.

When substantial corrosion, as defined in Ch 2, Sec 2, [2.2.7], and/or structural defects are found, the survey is to be extended and is to include additional close-up surveys when necessary.

1.1.4 In any kind of survey, i.e. class renewal, intermediate, annual or other surveys having the same scope, thickness measurements, when required by Tab 5, of structures in areas where close-up surveys are required are to be carried out simultaneously with close-up surveys.

1.1.5 Consideration may be given by the attending Surveyor to allow use of Remote Inspection Techniques (RIT) as an alternative to close-up survey, as defined in Ch 2, Sec 2. Surveys conducted using a RIT are to be completed to the satisfaction of the attending Surveyor.

When RIT is used for a close-up survey, temporary means of access for the corresponding thickness measurements as specified in this section is to be provided unless such RIT is also able to carry out the required thickness measurements.

For surveys conducted by use of a remote inspection technique, one or more of the following means of access, acceptable to the Surveyor, is to be provided:

- unmanned robot arm
- remote operated vehicle (ROV)
- unmanned aerial vehicles/drones
- other means acceptable to the Society.

1.1.6 When, in any survey, thickness measurements are required, the procedure detailed in Ch 2, Sec 2, [2.3] is to be applied.

Note 1: Special consideration or specially considered (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

1.2 Reporting and evaluation of surveys

1.2.1 A hull condition evaluation report (summarising the results of the class renewal surveys) is issued by the Society to the Owner, who is to place it on board the ship for reference at future surveys. The hull condition evaluation report is endorsed by the Society.

Note 1: Note 1: This report does not apply to general dry cargo ships of double side-skin construction, with double side-skin extending over the entire length of the cargo area, and over the entire height of the cargo hold to the upper deck.

2 Annual survey

2.1 General

2.1.1 Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion, as per the requirements of Tab 6. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

2.1.2 For survey of air pipes, flame screens on vents and ventilators, refer to Ch 3, Sec 1, [2.1.1].

2.1.3 For ships granted with the additional class notation **OPEN-HATCH**:

- confirmation that the operability and condition of the hold dewatering systems and freeing ports, if they are fitted, have been checked by the crew on a monthly basis and recorded in the ship's log book for annual verification by the Society
- examination of the water-spray system for open-top cargo holds in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.2], item d).

2.2 Hatch covers and coamings

2.2.1 The annual survey of hatch covers is to be carried out according to the requirements of Ch 3, Sec 1, [2.3].

In addition to these requirements, a close-up survey of hatch cover and hatch coaming plating and its stiffeners is to be carried out.

2.3 Cargo holds

2.3.1 The requirements given in Tab 1 are to be complied with.

Table 1 : Annual survey of cargo holds for general cargo ships

Age of ship (in years at time of annual survey)	
10 < age ≤ 15	age > 15
Overall survey of one forward and one after cargo hold and their associated 'tweendeck spaces See **(2)**	Overall survey of all cargo holds and 'tweendeck spaces Close-up survey of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approximately the lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating in a forward lower cargo hold and one other selected lower cargo hold Examination of all piping and penetrations, including overboard piping, in all cargo holds See **(1)**, **(2)** and **(3)**

(1) Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a close-up survey of all the shell frames and adjacent shell plating of those cargo holds and associated 'tweendeck spaces (as applicable) as well as a close-up survey of sufficient extent of all remaining cargo holds and 'tweendeck spaces (as applicable).

(2) When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion, in accordance with Tab 6. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

(3) Where protective coating in cargo holds, as applicable, is found in good condition, the extent of close-up survey may be specially considered.

2.4 Ballast tanks

2.4.1 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey or the intermediate survey; see [4.2.7] and footnote **(3)** of Tab 3.

2.4.2 When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements are to be increased to determine the extent of areas of substantial corrosion, in accordance with Tab 6. These extended thickness measurements are to be carried out before the annual survey is credited as completed.

3 Intermediate survey

3.1 General

3.1.1 A survey planning meeting is to be held prior to the commencement of the survey.

3.2 Ships 15 years of age or less

3.2.1 The requirements for survey of cargo holds given in Tab 2 are to be complied with.

3.2.2 The requirements for survey of ballast tanks given in Tab 3 are to be complied with.

Table 2 : Intermediate survey of cargo holds for general cargo ships

Age of ship (in years at time of intermediate survey)	
5 < age ≤ 10	10 < age ≤ 15
Overall survey of one forward and one after cargo hold and their associated 'tweendeck spaces Areas found suspect at the previous surveys are to be surveyed in accordance with the provisions indicated in [2.1.1]	Overall survey of all cargo holds and 'tweendeck spaces Areas found suspect at the previous surveys are to be surveyed in accordance with the provisions indicated in [2.1.1] See **(1)**
(1) When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion, in accordance with Tab 6. These extended thickness measurement are to be carried out before the survey is credited as completed.	

Table 3 : Intermediate survey of ballast tanks for general cargo ships

Age of ship (in years at time of intermediate survey)	
5 < age ≤ 10	10 < age ≤ 15
Overall survey of representative ballast tanks selected by the Surveyor See **(1)**, **(2)** and **(3)**	Overall survey of all ballast tanks See **(1)** and **(3)**
Areas found suspect at the previous surveys are to be surveyed in accordance with the provisions indicated in [2.1.1]	Areas found suspect at the previous surveys are to be surveyed in accordance with the provisions indicated in [2.1.1]
(1) If such overall survey reveals no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient. **(2)** Where poor coating condition, soft or semi-hard coating, corrosion or other defects are found in ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type. **(3)** In ballast tanks other than double bottom tanks, where a hard protective coating is found in poor condition and it is not renewed, where a soft or semi-hard coating has been applied or where a hard protective coating was not applied from time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual surveys. When such breakdown of hard protective coating is found in double bottom ballast tanks, where a soft or semi-hard coating has been applied or where a hard protective coating has not been applied, the tanks in question may be examined at annual surveys. When considered necessary by the Surveyor or where extensive corrosion exists, thickness measurements are to be carried out.	

3.3 Ships over 15 years of age

3.3.1 The scope of the intermediate survey of ships over 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [4], except for thickness measurements of each bottom plate within the cargo length area, and with bottom survey in dry condition or bottom in water-survey as applicable.

However, tank testing specified in [4.6], survey of automatic air pipe heads and internal examination of fuel oil, lube oil and fresh water tanks are not required unless deemed necessary by the attending surveyor.

This intermediate survey may be commenced at the second annual survey of the class period and be progressed during the succeeding year with a view to completion at the third annual survey.

4 Class renewal survey

4.1 Preparation for survey

4.1.1 The Owner is to provide the necessary facilities for a safe and practical execution of the surveys, including the means of providing access to structures for close-up survey, thickness measurements and tank testing. All other provisions described in Ch 2, Sec 2, [2.3], Ch 2, Sec 2, [2.5], Ch 2, Sec 2, [2.6], Ch 2, Sec 2, [2.7] and Ch 2, Sec 2, [2.9] regarding procedures for thickness measurements, conditions for survey, access to structures, equipment for survey and survey at sea or at anchorage, respectively, are also to be complied with.

4.2 Scope of survey

4.2.1 A survey planning meeting is to be held prior to the commencement of the survey.

4.2.2 In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in [4.2.4]are in satisfactory condition and fit for the intended purpose for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

4.2.3 All cargo holds, ballast tanks, including double bottom tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in [4.5] and [4.6] to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deformation, that may be present.

4.2.4 All piping systems within the above spaces are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

4.2.5 The survey extent of ballast tanks converted to void spaces is to be specially considered by the Society in relation to the requirements for ballast tanks.

Note 1: For survey of automatic air pipe heads, refer to Ch 3, Sec 3, Tab 1.

4.2.6 As indicated in Ch 3, Sec 3, [2.1.1], a bottom survey in dry condition is to be a part of the class renewal survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for class renewal surveys, if not already performed.

Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

4.2.7 Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined.

For ballast tanks, excluding double bottom tanks, where a hard protective coating is found in poor condition and it is not renewed, where soft or semi-hard coating has been applied, or where a hard protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as found necessary by the Surveyor.

When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

4.2.8 Where the hard protective coating in tanks is found to be in good condition, the extent of close-up surveys and thickness measurements may be specially considered.

4.2.9 For ships granted with the additional class notation **OPEN-HATCH**:

- examination and complete test of the hold dewatering systems to check their proper functioning
- complete inspection of the open cargo holds
- operational testing and internal examination, as required by the Surveyor, of the relevant pumps for the water-spray system for open-top cargo holds.

4.3 Hatch covers and coamings

4.3.1 The requirements listed in Ch 3, Sec 3, [2.2.2] for all ships are to be complied with.

4.3.2 In addition to [4.3.1], the close-up survey and thickness measurements in accordance with the requirements given in Tab 4 and Tab 5, respectively, are to be carried out.

Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/ thickness measurement is to be done of the accessible parts of hatch cover structures.

4.4 Overall and close-up surveys

4.4.1 An overall survey of all cargo holds, tanks and spaces is to be carried out at each class renewal survey. However, for fuel oil, lube oil and fresh water tanks, the requirements given in Ch 3, Sec 3, Tab 2 are to be complied with.

4.4.2 The minimum requirements for close-up surveys at class renewal survey are given in Tab 4.

The Surveyor may extend the close-up survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.

For areas in spaces where hard protective coatings are found to be in a good condition, the extent of close-up surveys according to Tab 4 may be specially considered.

Note 1: For survey of automatic air pipe heads, reference is to be made to Ch 3, Sec 3, Tab 1.

4.5 Thickness measurements

4.5.1 The minimum requirements for thickness measurements at class renewal survey are given in Tab 5.

4.5.2 The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion in accordance with the requirements given in Tab 6.

4.5.3 For areas in spaces where hard protective coatings are found to be in a good condition, the extent of thickness measurements according to Tab 5 may be specially considered.

Table 4 : Requirements for close-up survey at class renewal survey of general cargo ships

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal survey No.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤ 15	Class renewal survey No.4 and subsequent age > 15
Selected shell frames in one forward and one aft cargo hold and associated 'tweendeck spaces ①	Selected shell frames in all cargo holds and 'tweendeck spaces ①	All shell frames in the forward lower cargo hold and 25% of shell frames in each of the remaining cargo holds and 'tweendeck spaces including upper and lower end attachments and adjacent shell plating ①	All shell frames in all cargo holds and 'tweendeck spaces including upper and lower end attachments and adjacent shell plating ①
One selected cargo hold transverse bulkhead ②	One transverse bulkhead in each cargo hold ② Forward and aft transverse bulkheads in one side ballast tank, including stiffening system ②	All cargo hold transverse bulkheads ② All transverse bulkheads in ballast tanks, including stiffening system ②	Areas ② to ⑥ as for class renewal survey for ships between 10 and 15 years of age
	One transverse web with associated plating and framing in two representative ballast tanks of each type (i.e. topside, hopper side, side tank or double bottom tank) ③	All transverse webs with associated plating and framing in each ballast tank ③	
All cargo hold hatch covers and coamings (plating and stiffeners) ④	All cargo hold hatch covers and coamings (plating and stiffeners) ④	All cargo hold hatch covers and coamings (plating and stiffeners) ④	
	Selected areas of all deck plating and underdeck structure inside line of hatch openings between cargo hold hatches ⑤	All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches ⑤	
	Selected areas of inner bottom plating ⑥	All areas of inner bottom plating ⑥	

Note 1: See Fig 1, Fig 2, Fig 3 and Fig 4 for areas ①, ②, ③, ④, ⑤ and ⑥.

① Cargo hold transverse frames.

② Cargo hold transverse bulkhead plating, stiffeners and girders.

③ Transverse web frame or watertight transverse bulkhead in ballast tanks.

④ Cargo hold hatch covers and coamings. Subject to cargo hold hatch covers of approved design which structurally have no access to the internals, close-up survey/thickness measurement is to be done of the accessible parts of hatch cover structures.

⑤ Deck plating and underdeck structure inside line of hatch openings between cargo hold hatches.

⑥ Inner bottom plating.

Note 2: Close-up survey of cargo hold transverse bulkheads to be carried out at the following levels:

- immediately above the inner bottom and immediately above the 'tweendecks, as applicable
- mid-height of the bulkheads for holds without 'tweendecks
- immediately below the main deck plating and 'tweendeck plating.

Figure 1 : Areas subject to close-up surveys and thickness measurements of general cargo ships

Single deck ship

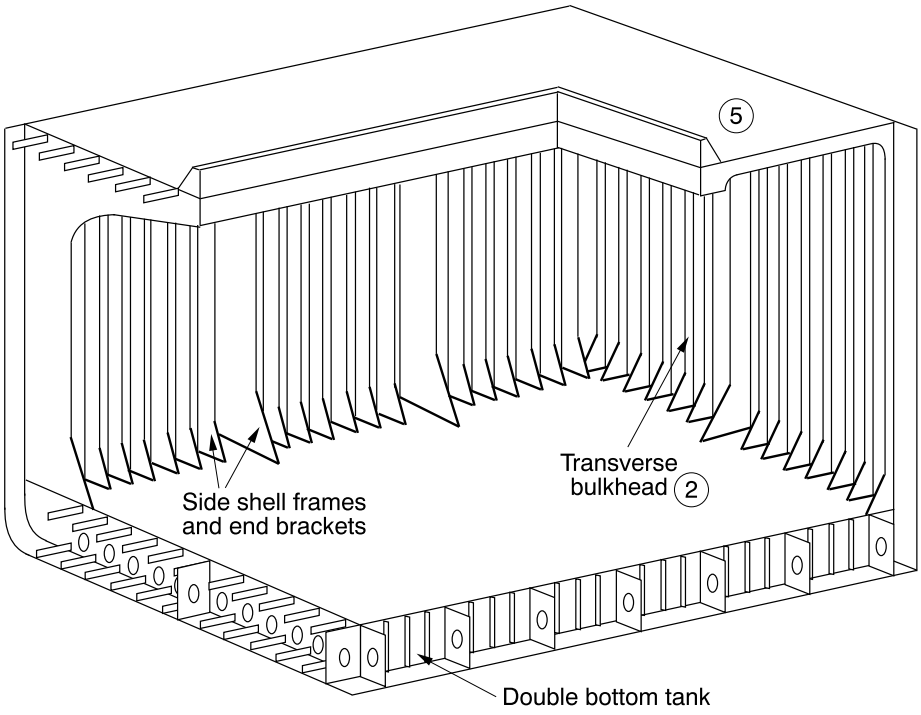


Figure 2 : Areas subject to close-up surveys and thickness measurements of general cargo ships

'Tweendeck ship

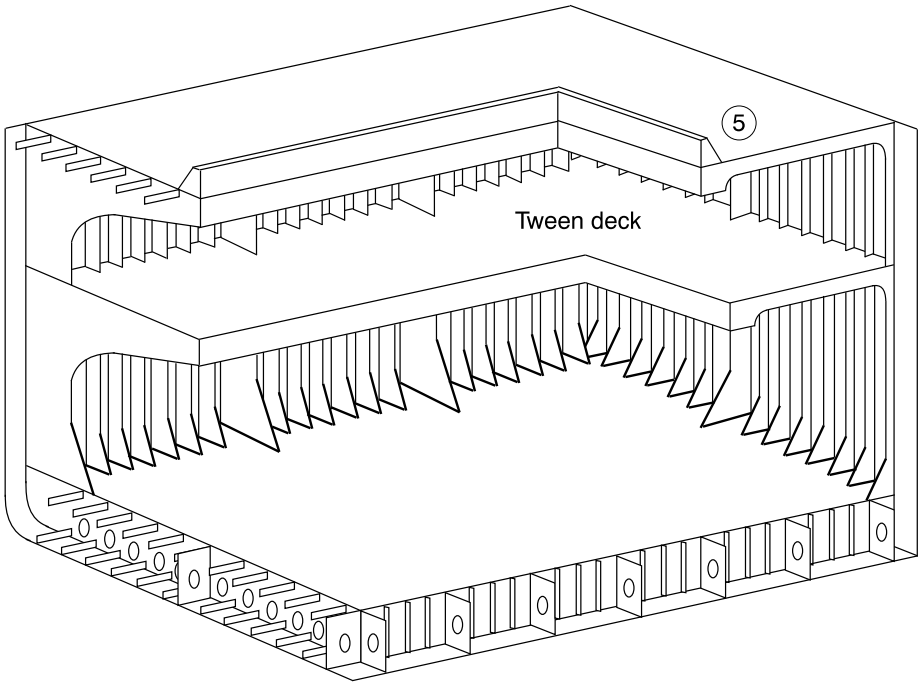


Figure 3 : Areas subject to close-up surveys and thickness measurements of general cargo ships

Single deck ship

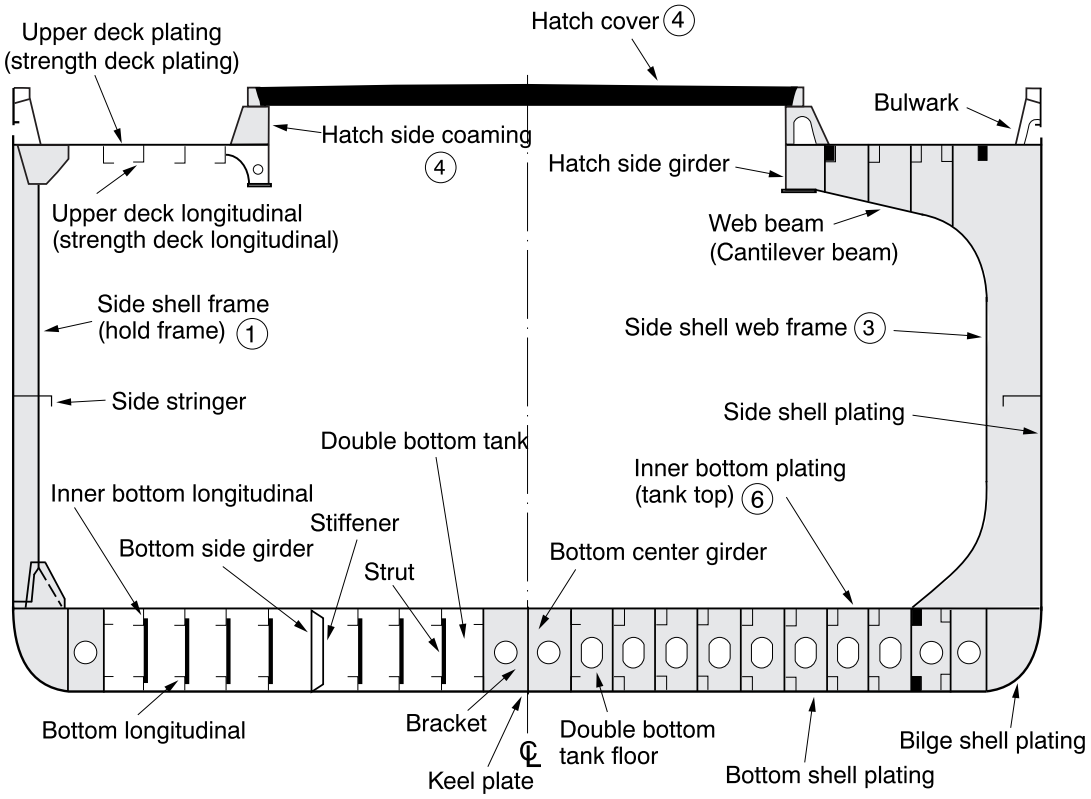


Figure 4 : Areas subject to close-up surveys and thickness measurements of general cargo ships

'Tweendeck ship

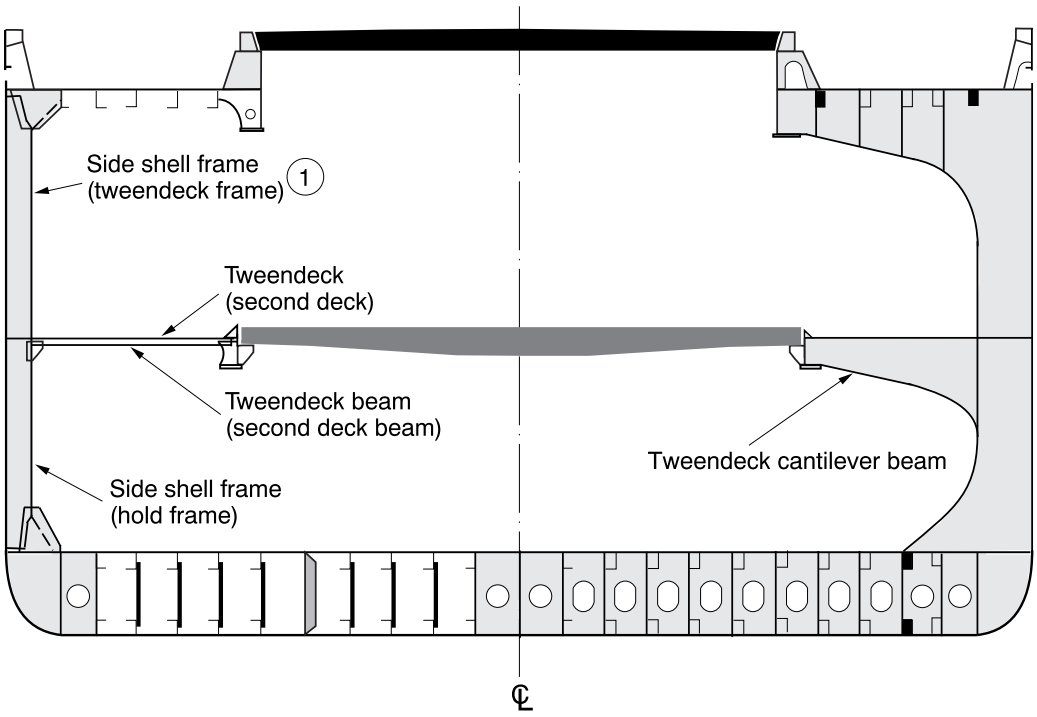


Table 5 : Requirements for thickness measurements at class renewal surveys of general cargo ships

Age of ship (in years at time of class renewal survey)			
Class renewal survey No.1 age ≤ 5	Class renewal surveyNo.2 5 < age ≤ 10	Class renewal survey No.3 10 < age ≤15	Class renewal survey No.4 and subsequent age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
	One transverse section of deck plating in way of a cargo space within the amidships 0,5 L **(1)**	Two transverse sections within the amidships 0,5 L in way of two different cargo spaces **(1)** Within the cargo length area, each deck plate outside line of cargo hatch openings	Within the cargo length area: • a minimum of three transverse sections within the amidships 0,5 L **(1)** • each deck plate outside line of cargo hatch openings • each bottom plate, including lower turn of bilge • duct keel or pipe tunnel plating and internals
	Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 4	Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 4	Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Tab 4
		All wind and water strakes within the cargo area	All wind and water strakes full length
		Selected wind and water strakes outside the cargo area	

(1) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

Note 1: Thickness measurement locations should be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.

Note 2: For ships less than 100 metres in length, the number of transverse sections required for ships between 10 and 15 years of age may be reduced to one and the number of transverse sections for ships over 15 years of age may be reduced to two.

Table 6 : Requirements for extent of thickness measurements at those areas of substantial corrosion Class renewal survey of general cargo ships

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect area and adjacent plates	5-point pattern over 1 m^2 of plating
Stiffeners	Suspect area	3 measurements each in line across web and flange

4.6 Tank testing

4.6.1 All boundaries of ballast tanks and deep tanks used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks, the representative tanks are to be pressure tested.

4.6.2 The Surveyor may extend the tank testing as deemed necessary.

4.6.3 Tank testing of fuel oil tanks is to be carried out with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

Section 8 Other Service Notations

1 General

1.1

1.1.1 The requirements of this Section are applicable to ships to be assigned one of the following service notations, and given in the Articles specified below:

- **container ship**, or ship **equipped for carriage of containers**, in Article [2]
- **livestock carrier**, in Article [3]
- **FLS tanker**, in Article [4]
- dredging units, i.e. ships with the service notations **dredger**, **hopper dredger**, **hopper unit**, **split hopper unit**, **split hopper dredger**, in Article [5]
- **tug**, **salvage tug**, **escort tug**, in Article [6]
- **supply**, in Article [7]
- **fire-fighting**, in Article [8]
- **oil recovery**, in Article [9]
- **anchor handling**, in Article [10]
- **cable laying**, in Article [11]
- **lifting**, in Article [12]
- diving support, i.e. **diving support-integrated** or **diving support-portable**, in Article [13]
- **fishing vessel**, in Article [14]
- **standby rescue**, in Article [15]
- **yacht** and **charter yacht**, in Article [16].
- **semi-submersible cargo ship**, in Article [17].
- **diving systems**, in Article [18]
- **pipe laying**, in Article [19].

1.1.2 These requirements are additional to those given in Part A, Chapter 3, according to the relevant surveys.

1.1.3 The requirements for survey of diving systems assigned with one of the following notations are given in Article [18]:

- **diving system-integrated**
- **diving system-portable**
- **hyperbaric reception facility**.

2 Container ship or ship equipped for carriage of containers

2.1 Annual survey

2.1.1 The survey is to include:

- confirmation of the availability of instructions and instruments for stowage of containers, as required or fitted
- examination of container supports welded to the ship's structure or on to the hatch covers
- examination of cell guides, if fitted.

2.2 Class renewal survey

2.2.1 The renewal is to include:

- examination of container supports welded to the ship's structure or on to the hatch covers, checking for possible cracks and deformations
- examination of cell guides and associated elements, checking for possible cracks, deformations or corrosion.

2.2.2 For ships assigned the service notation **container ship**, examination of the torsion box girder or equivalent structure at the top sides. Thickness measurements additional to those related to the transverse sections may be required

3 Livestock carrier

3.1 Annual survey

3.1.1 The survey is to include a general examination of:

- spaces for the livestock and related hatch covers (to be surveyed according to Ch 3, Sec 1, [2])
- ventilation means, including prime movers
- main, emergency and portable lighting systems in livestock spaces, passageways and access routes
- the drainage system
- fodder and fresh water systems
- fire-fighting appliances, with working test as far as necessary and practicable (according to Ch 3, Sec 1, [3.4])
- means of escape, with confirmation they are kept clear.

3.2 Class renewal survey

3.2.1 The equipment related to ventilation, lighting and the related power supply is to be submitted to a survey to the same extent as required for similar equipment at the class renewal survey as indicated in Ch 3, Sec 3.

3.2.2 The drainage, fodder and fresh water systems, including piping and pumps, are to be surveyed to the same extent as required for similar equipment at the class renewal survey as indicated in Ch 3, Sec 3.

The fresh water tanks are to be internally examined in accordance with the periodicity given in Ch 3, Sec 3, Tab 2.

3.2.3 The fire-fighting systems are to be thoroughly examined and tested.

4 FLS tanker

4.1 Annual survey - Hull items

4.1.1 Weather decks

The survey is to include:

- examination of cargo tank openings, including gaskets, covers, coamings and screens
- examination of cargo tank pressure/vacuum valves and flame screens
- examination of flame screens on vents to all bunker, oily ballast and oily slop tanks
- examination of cargo, bunker, ballast and vent piping systems, including remote control valves, safety valves and various safety devices, as well as vent masts and headers
- confirmation that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends facing the cargo area are in satisfactory condition
- confirmation that pumps, valves and pipelines are identified and distinctively marked.

4.1.2 Cargo pump rooms and pipe tunnels

The survey is to include:

- examination of all pump room bulkheads and pipe tunnels (if any) for signs of chemical cargo leakage or fractures and, in particular, the sealing arrangements of penetrations in pump room bulkheads
- examination of the condition of all piping systems, in cargo pump rooms and pipe tunnels (if any)
- examination of the bilge and ballast arrangements and confirmation that pumps and pipelines are identified.

4.2 Annual survey - Cargo machinery items

4.2.1 Cargo area and cargo pump rooms

The Owner or his representative is to declare to the attending Surveyor that no modifications or alterations which might impair safety have been made to the various installations in dangerous zones without prior approval from the Society.

The survey is to include:

- confirmation that potential sources of ignition in or near the cargo pump rooms, such as loose gear, excessive product in bilge, excessive vapours, combustible materials, are eliminated and that access ladders are in satisfactory condition
- examination, as far as practicable, of cargo, bilge, ballast and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump room bilge system, and checking that pump foundations are intact
- confirmation that the ventilation system, including portable equipment, if any, of all spaces in the cargo area (including cargo pump room) is operational, ducting is intact, dampers are operational and screens are clean
- confirmation that electrical equipment in dangerous zones, cargo pump rooms and other spaces is in satisfactory condition and has been properly maintained

- confirmation that the remote operation of the cargo pump room bilge system is satisfactory
- examination of the cargo heating system
- examination of the cargo-transfer arrangement and confirmation that the ship's cargo hoses are suitable for their intended purpose and in satisfactory condition
- confirmation that any special arrangement made for bow or stern loading/unloading is in satisfactory condition.

4.2.2 Instrumentation and safety devices

The survey is to include the following items, as far as required or fitted:

- examination of cargo tank gauging devices, high level alarms and valves associated with overflow control
- confirmation that installed pressure gauges on cargo discharge lines are properly operational
- confirmation that the required gas detection instruments are on board and satisfactory arrangements have been made for the supply of any required vapour detection tubes
- confirmation that devices provided for measuring the temperature of the cargo, if any, operate satisfactorily.

4.2.3 Fire-fighting systems

The survey is to include:

- external examination of piping and cut-out valves of fixed fire-fighting systems related to cargo tanks and cargo pump rooms
- confirmation, as far as practicable and when appropriate, that the remote means for closing the various openings are operable
- examination of the appropriate portable fire-extinguishing equipment for the chemical cargoes to be carried in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.3]
- examination of fire-fighting systems of any type fitted on board such as deck foam, water-spraying, etc. as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.2].

4.2.4 Inert gas system

If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [3.4] are to be complied with.

4.3 Intermediate survey - Hull items

4.3.1 The survey is to include:

- examination, as far as applicable, of cargo, stripping, cargo washing, bunker, ballast, steam and vent piping systems as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, pressure testing, thickness measurement or both may be required
- confirmation, if applicable, that cargo pipes are electrically bonded to the hull
- examination of vent line drainage arrangements.

4.4 Intermediate survey - Cargo machinery items

4.4.1 Electrical equipment in dangerous zones

A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship’s personnel.

4.4.2 Cargo heating system

The satisfactory condition of the cargo heating system is to be verified.

4.4.3 Inert gas system

For ships over 10 years old at the time of the intermediate survey due date, if an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [5.2] for intermediate survey of oil tankers are to be complied with.

4.5 Class renewal survey - Hull items

4.5.1 Piping

Piping for cargo, ballast, stripping and venting systems is to be examined to the Surveyor's satisfaction. Dismantling and/or thickness measurements of these items may be required. A hydraulic test is to be carried out in the event of repair or dismantling of cargo or ballast piping, or where doubts arise.

Vent line drainage arrangements are to be examined.

It is to be verified, when applicable, that cargo piping is electrically bonded to the hull.

4.5.2 Safety valves

All safety valves on cargo piping and of cargo tanks are to be dismantled for examination, adjusted and, as applicable, resealed.

4.5.3 Cargo pump rooms

All cargo pump room boundaries are to be generally examined. All gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms is to be presented clean for the examination of stripping devices and gutters.

4.6 Class renewal survey - Cargo machinery items

4.6.1 Pumps

Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out.

Maintenance records of cargo pumps are to be made available to the Surveyor.

4.6.2 Washing system

Where a washing system is fitted, piping, pumps, valves and deck-mounted washing machines are to be examined and tested for signs of leakage, and anchoring devices of deck-mounted washing machines are to be checked to the Surveyor's satisfaction.

4.6.3 Cargo heating system

The apparent satisfactory condition of the cargo heating system such as clamping, external condition of piping is to be verified and, if deemed necessary by the Surveyor, the system is to be pressure tested.

4.6.4 Remote controls

An operating test of the emergency remote control of pumps and valves and of automatic closing valves is to be carried out.

4.6.5 Electrical equipment in dangerous zones

A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship’s personnel.

4.6.6 Fire-fighting systems

The survey is to include the examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room and other dangerous spaces, such as deck foam, water-spraying, etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

4.6.7 Inert gas system

If an inert gas system such as that installed on board oil tankers is fitted, the requirements given in Ch 4, Sec 3, [5.2] for intermediate survey and in Ch 4, Sec 3, [7.3] for class renewal survey of oil tankers are to be complied with.

5 Dredging units

5.1 Annual survey

5.1.1 The survey is to include the following items, as far as required or fitted, according to the service notation of the ship:

- for **split hopper unit**, **split hopper dredger**, visual examination, as far as practicable, of superstructure hinges and blocks, deck hinges, hydraulic jacks and associated piping systems and alarms
- for **dredger**, **hopper dredger**, **split hopper dredger**:
  - visual examination, as far as practicable, of attachments of suction piping and lifting systems to the structure and external examination of piping in dredging machinery spaces for absence of corrosion and leakage
  - checking the condition of the dredging machinery space and related equipment with regard to electrical shocks, protection from rotating machinery, fire and explosion hazards.

5.2 Class renewal survey

5.2.1 The survey is to include the following items, as far as required or fitted, according to the service notation of the ship:

- for **hopper dredger**, **hopper unit**, visual examination of hopper bottom doors or valves and accessories, such as hinges, actuating rods, hydraulic systems, with dismantling as deemed necessary by the Surveyor
- for **split hopper unit**, **split hopper dredger**, visual examination, as far as practicable, of superstructure hinges and blocks, deck hinges, hydraulic jacks and associated piping systems and alarms, with dismantling and/or further checks as deemed necessary by the Surveyor

- for **dredger**, **hopper dredger**, **split hopper dredger**:
  - visual examination, as far as practicable, of attachments of suction piping and lifting systems to the structure and external examination of piping in dredging machinery spaces for absence of corrosion and leakage
  - checking the condition of the dredging machinery space and related equipment with regard to electrical shocks, protection from rotating machinery, fire and explosion hazards.

6 Tug, salvage tug, escort tug

6.1 Annual survey

6.1.1 The survey is to include a general external examination of the towing hook or towing winch, as fitted, and unhooking device, as far as practicable.

6.1.2 In addition to [6.1.1], for **salvage tug**, the availability and satisfactory condition of specific equipment as required in Pt E, Ch 1, Sec 3, [4] is to be verified.

6.1.3 For **tug-barge combined**, an examination of the accessible parts of the connection system is to be carried out.

6.1.4 For tugs fitted with towing winch emergency release systems subject to Pt E, Ch 1, Sec 3, [2.7.4], the annual survey is to include:

- confirmation of the operation of the towing winch emergency release system with the reference to the documented instructions for surveys provided by the manufacturer. Operation of the winch emergency release system under no load condition is to be verified. Where practical, activation of the emergency release system may be confirmed by observation of the winch brake
- verification of the function of the alarms associated with the emergency release system, as far as practicable and reasonable
- visual examination of the condition of the emergency release system to confirm it remains in satisfactory condition
- examination of the means of emergency release of the towline in the event of a blackout, and where additional sources of energy are arranged for this purpose, visual inspection and operational test of the sources of energy
- verification that the performance capabilities and operating instructions of the emergency release system are documented and made available on board the ship on which the winch has been installed.

6.2 Class renewal survey

6.2.1 The survey is to include:

- checking the condition of the connection of the towing hook or towing winch to the structure, including related reinforcements of the structure
- checking the external condition of the towing hook or towing winch; when applicable, a no-load test of the unhooking device is to be carried out.

6.2.2 In addition to [6.2.1], for **salvage tug**, the survey is to include:

- a check and working test of specific equipment as required in Pt E, Ch 1, Sec 3, [4]
- checking by a specialist of the satisfactory condition of the towing line(s). A report is to be presented to the Surveyor by the Owner and kept on board.

6.2.3 For **tug-barge combined**, a visual examination of components of the connection system is to be carried out, completed by thickness measurements and non-destructive tests as deemed necessary by the Surveyor. A connection/disconnection test is to be carried out, including a check of related remote control, safety and alarm devices.

6.2.4 For ships granted with the additional service feature **standardized design bollard pull = [T_{BP}/9,81] t**, the survey is to include a new bollard pull test as defined in Pt E, Ch 1, App 1, [9].

6.2.5 For tugs fitted with towing winch emergency release systems subject to Pt E, Ch 1, Sec 3, [2.7.4], the annual survey requirements are to be carried out, with the additional instructions for the class renewal survey provided by the manufacturer, as appropriate, being followed.

The full functionality of the emergency release system is to be tested to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the load against a strong point on the deck of the tug or the shore that is certified to the appropriate load.

The emergency release system is to be tested at a towline load that is equal to the lesser of 30% of the maximum design load or 80% of vessel bollard pull in both a normal power condition and power blackout condition to the satisfaction of the surveyor.

7 Supply vessel

7.1 General

7.1.1 The additional survey items for annual survey, intermediate survey and class renewal survey are applicable only to ships having the service notation **supply** assigned the additional service features **HNLS** or **WELLSTIM**.

7.2 Annual survey - Hull items

7.2.1 Weather decks

The survey is to include:

- examination of cargo tank openings, including gaskets, covers, coamings and screens
- examination of cargo tank pressure/vacuum valves and flame screens
- examination of flame screens on vents to all bunker, oily ballast and oily slop tanks
- examination of cargo, bunker, ballast and vent piping systems, including remote control valves, safety valves and various safety devices, as well as vent masts and headers
- confirmation that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends facing the cargo area are in satisfactory condition
- confirmation that pumps, valves and pipelines are identified and distinctively marked.

7.2.2 Cargo pump rooms and pipe tunnels

The survey is to include:

- examination of all pump room bulkheads and pipe tunnels (if any) for signs of oil or chemical product leakage or fractures and, in particular, the sealing arrangements of penetrations in pump room bulkheads
- examination of the condition of all piping systems, in cargo pump rooms and pipe tunnels (if any)
- examination of the bilge and ballast arrangements and confirmation that pumps and pipelines are identified.

7.3 Annual survey - Cargo machinery items

7.3.1 Cargo area and cargo pump rooms

The Owner or his representative is to declare to the attending Surveyor that no modifications or alterations which might impair safety have been made to the various installations in dangerous zones without prior approval from the Society.

The survey is to include:

- confirmation that potential sources of ignition in or near the cargo pump rooms, such as loose gear, excessive product in bilge, excessive vapours, combustible materials, etc., are eliminated and that access ladders are in satisfactory condition
- examination, as far as practicable, of cargo, bilge, ballast and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump room bilge system, and checking that pump foundations are intact
- confirmation that the ventilation system, including portable equipment, if any, of all spaces in the cargo area (including cargo pump rooms) is operational, ducting is intact, dampers are operational and screens are clean
- confirmation that electrical equipment in dangerous zones, cargo pump rooms and other spaces is in satisfactory condition and has been properly maintained
- confirmation that the remote operation of the cargo pump room bilge system, if fitted, is satisfactory
- examination of the cargo heating system
- examination of the cargo-transfer arrangement and confirmation that the ship's cargo hoses are suitable for their intended purpose and in satisfactory condition.

7.3.2 Instrumentation and safety devices

The survey is to include the following items, as far as required or fitted:

- examination of cargo tank gauging devices, high level alarms and valves associated with overflow control
- confirmation that installed pressure gauges on cargo discharge lines are properly operational
- confirmation that the required gas detection instruments are on board and satisfactory arrangements have been made for the supply of any required vapour detection tubes
- confirmation that devices provided for measuring the temperature of the cargo, if any, operate satisfactorily.

7.3.3 Fire-fighting systems

The survey is to include:

- external examination of piping and cut-out valves of fixed fire-fighting systems related to cargo tanks and cargo pump rooms
- confirmation, as far as practicable and when appropriate, that the remote means for closing the various openings are operable
- examination of the appropriate portable fire-extinguishing equipment for the cargoes to be carried in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.3]

- examination of fire-fighting systems of any type fitted on board such as deck foam, water-spraying etc. as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.2].

7.4 Intermediate survey - Hull items

7.4.1 The survey is to include:

- examination, as far as applicable, of cargo, stripping, bunker, ballast, steam and vent piping systems as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, pressure testing, thickness measurement or both may be required
- confirmation that the pipelines are electrically bonded to the hull
- examination of vent line drainage arrangements.

7.5 Intermediate survey - Cargo machinery items

7.5.1 Electrical equipment in dangerous zones

A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship's personnel.

7.5.2 Cargo heating system

The satisfactory condition of the cargo heating system is to be verified.

7.6 Class renewal survey - Hull items

7.6.1 Piping

Piping for cargo, ballast, stripping and venting systems is to be examined to the Surveyor's satisfaction. Dismantling and/or thickness measurements of these items may be required. A hydraulic test is to be carried out in the event of repair or dismantling of cargo or ballast piping, or where doubts arise.

Vent line drainage arrangements are to be examined.

It is to be verified that cargo piping is electrically bonded to the hull.

7.6.2 Safety valves

All safety valves on cargo piping and of cargo tanks are to be dismantled for examination, adjusted and, as applicable, resealed.

7.6.3 Cargo pump rooms

All cargo pump room boundaries are to be generally examined. All gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms is to be presented clean for the examination of stripping devices and gutters.

7.6.4 Tank testing

Confirmation that cargo tank boundaries adjacent to machinery spaces, propeller shaft tunnels, if fitted, dry cargo spaces, accommodation and service spaces have been pressure tested.

If deemed necessary by the Surveyor, the tank testing may be extended.

7.7 Class renewal survey - Cargo machinery items

7.7.1 Pumps

Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out.

Maintenance records of cargo pumps are to be made available to the Surveyor.

7.7.2 Cargo heating system

The apparent satisfactory condition of the cargo heating system such as clamping, external condition of piping is to be verified and, if deemed necessary by the Surveyor, the system is to be pressure tested.

7.7.3 Remote controls

An operating test of the emergency remote control of pumps and valves and of automatic closing valves is to be carried out.

7.7.4 Electrical equipment in dangerous zones

A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship's personnel.

7.7.5 Fire-fighting systems

The survey is to include the examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room and other dangerous spaces, such as deck foam, water-spraying, dry powder systems etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

8 Fire-fighting ship

8.1 Annual survey

8.1.1 Ship's fire protection

The survey is to include:

- general examination of arrangements for structural fire protection
- ships equipped with a self-protection water-spraying system: general examination of all parts, as far as practicable and visible, of self-protection water-spraying system, and of scuppers and freeing ports for water drainage from deck surfaces
- ships not equipped with a self-protection water-spraying system: general examination of steel deadlights and shutters.

8.1.2 Water monitor system

The survey is to include:

- general examination of all parts of the water monitor system (pumps, piping system, valves and other fittings)
- checking for proper operation of the system, including local manual control
- general examination of foundations of water monitors and check of local manual control.

8.1.3 Fixed and portable foam systems

The survey is to include:

- general examination of the systems
- confirmation that the foam concentrates are periodically tested, either by the Manufacturer or by an organisation agreed by him
- general examination of foundations of foam monitors and check of local manual control
- for fixed foam systems, reference is to be made to Ch 3, Sec 1, [3.4.2], item e).

8.1.4 Machinery installations, control room and other devices

The survey is to include:

- general examination of spaces containing auxiliary machinery for fire-fighting systems, particular attention being paid to arrangements, piping systems and instruments; check of tools and of pressure vessels and their fittings, if any
- general examination of the control station and check of all communication and remote control means, of ventilation system
- general examination of sea suctions of fire-fighting systems, of relevant remote and local control and of piping systems, including the relevant protection against corrosion
- general external examination of electrical installations for fire-fighting systems, with particular regard to the alarms and searchlights,
- checking of other fire-fighting arrangements
- checking of fire-fighter's outfits, confirmation that they are stored in the appropriate locations, and checking of air compressor and other equipment.

8.2 Class renewal survey

8.2.1 The survey is to include:

- complete test of water fire-extinguishing systems, including the internal examination, as required by the Surveyor, of the relevant pumps
- partial test, at the Surveyor's discretion, of fixed foam fire-extinguishing systems
- test of self-protection fixed water-spraying systems, putting into operation the spray nozzles, including the internal examination, as required by the Surveyor, of the relevant pumps
- examination and test of prime movers of machinery relevant to fire-fighting systems and of the air compressor for refilling of air bottles of breathing apparatuses
- examination and test of the electrical generating plant supplying power to fire-fighting systems and searchlights
- test of searchlights.

9 Oil recovery ship

9.1 Annual survey

9.1.1 The survey is to include:

- confirmation of the availability of the operating manual
- examination of cargo tank openings, including gaskets, covers, coamings and screens
- general examination of cargo, ballast and vent piping systems, including control, gauging, alarm and safety devices
- general examination of the cargo pump room, as regards ventilation systems, fire protection, detection and fire-fighting systems, condition of pumps and piping systems, and signs of any oil leakage
- confirmation that electrical equipment in dangerous areas, cargo pump rooms and other spaces, if fitted, is in satisfactory condition; the Owner or his representative is to declare to the attending Surveyor that this equipment has been properly maintained
- general examination of the dry powder fire extinguishers, as well as, if fitted, of the fixed or semi-fixed foam extinguishing system; the Owner is to show evidence that the foam concentrates have been periodically tested, either by the manufacturer or by an organisation agreed by him
- confirmation of the availability and satisfactory condition of the fixed cargo gas detection system, including related alarms, portable gas detection equipment, and oil flash point measurement equipment.

If any inert gas system is fitted, the requirements for the annual survey of such installations given in Ch 4, Sec 3, [3.4] are applicable.

9.2 Class renewal survey

9.2.1 Piping

Cargo, ballast, stripping and vent piping is to be examined to the Surveyor's satisfaction. Dismantling and/or thickness measurements may be required. Tightness or working tests are to be carried out. A hydraulic or hydropneumatic test is to be carried out in the event of repair or dismantling of cargo or ballast piping, or where doubts arise.

Vent line drainage arrangements are to be examined.

It is to be verified that cargo piping is electrically bonded to the hull.

9.2.2 Safety valves

Safety valves on cargo piping and of cargo tanks are to be dismantled for examination, adjusted and, as applicable, resealed.

9.2.3 Pumps

Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out.

Maintenance records of cargo pumps are to be made available to the Surveyor.

9.2.4 Cargo pump rooms

Cargo pump room boundaries are to be generally examined. Gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms is to be presented clean for the examination of stripping devices and gutters.

9.2.5 Tank testing

Confirmation that oil recovery tank boundaries adjacent to engine rooms, if any, have been pressure tested.

If deemed necessary by the Surveyor, the tank testing may be extended.

9.2.6 Electrical equipment in dangerous zones

A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

An insulation test of circuits is to be carried out; however, where a proper record of testing is maintained, consideration may be given to accepting recent readings effected by the ship’s personnel.

9.2.7 Fire-fighting system

A partial test of fixed foam fire-extinguishing systems, if fitted, is to be carried out at the Surveyor's discretion.

9.2.8 Instrumentation and safety devices

The fixed cargo gas detection system, including related alarms, portable gas detection equipment, and oil flashpoint measurement equipment, is to be tested.

9.2.9 Inert gas system

If any inert gas system is fitted, the requirements for the class renewal survey of such installations given in Ch 4, Sec 3, [7.3] are applicable.

10 Anchor handling vessel

10.1 Annual survey

10.1.1 The survey is to include:

- visual examination of winch, including drum, end flanges, reduction gears and brakes
- visual examination of wire stopper (i.e. shark jaw, karm fork), stern roller, guide pins
- visual examination of the wire length (wire rope or chain cable)
- visual examination of equipment foundations, including related reinforcements of the structure
- general examination of hydraulic and electric systems
- winch functional test with no load in order to detect vibration, leaks, shocks or sticking points and to check emergency stop and alarms
- braking system functional test with no load
- general examination and test, as far as practicable, of emergency quick-release system
- verification of manual or planning for anchor handling operation
- the review of the Owner's service record books is to be carried out. The purpose is to verify that:
  - periodical testing of the equipment has been carried out in accordance with relevant standards, when applicable
  - eventual repair, maintenance or replacement of equipment or components are done in accordance with applicable standards
  - on-board record showing the testing of the emergency quick-release system was checked.

10.2 Class renewal survey

10.2.1 In addition to the requirements of annual survey, the class renewal survey is to include, as a minimum:

- verification of the equipment condition with disassembly, as deemed necessary
- control of the safety devices with disassembly, as deemed necessary
- examination of the wire length (wire rope or chain cable) and gauging
- winch static load test, as deemed necessary
- testing of emergency quick-release system, as far as practicable
- examination of the integrity of critical components with respect to corrosion, wear, overload, fatigue and other possible modes of degradation, by visual inspection and other appropriate methods
- examination of bitter end connection to ship's structure.

11 Cable laying ship

11.1 Annual survey

11.1.1 The survey is to include:

- general examination of the connections of sheaves, drums and tensioners to the structure
- general examination of fire fighting equipment, if fitted, in way of cable storage spaces and working areas.

11.2 Class renewal survey

11.2.1 The equipment mentioned in [11.1.1] is to be dismantled, to the extent deemed necessary by the Surveyor, in order to check its condition. Clearances of sheaves and cable drum axles are to be ascertained.

11.2.2 Fire-fighting equipment is to be submitted to a survey to the same extent as required for similar equipment at the class renewal survey for all ships (see Ch 3, Sec 3).

12 Lifting

12.1 General

12.1.1 The requirements of this Article are additional to those laid down in NR526 Rules for the Certification of Lifting Appliances onboard Ships and Offshore Units or NR595 Classification of Offshore Handling Systems, whichever is applicable.

12.2 Annual survey

12.2.1 The survey is to include verification and testing of the lifting equipment, as follows:

- verification of the presence onboard of the following documents:
  - technical manual

- planned maintenance system

- general examination of the electrical cabling
- functional testing of the main and alternative two-way communication system at the lifting operating position
- verification of the structural arrangement and foundations of the lifting equipment
- testing of hydraulic installations
- load tests in accordance with the rules or requirements referred to in the lifting equipment certificate.

12.3 Class renewal survey

12.3.1 The requirements given in Rule Notes NR526 and NR595 are applicable for renewal survey.

In addition, load tests in accordance with the rules or requirements referred to in the lifting equipment certificate are to be carried out.

13 Diving support-integrated and diving support-portable

13.1 Annual survey

13.1.1 The survey of the spaces containing the diving system, is to include:

a) For non-permanent diving systems, verification that the service notation **diving support-capable** or **diving support-portable** is specified on the Certificate of Classification, in accordance with the configuration of the system

b) Verification of the presence on-board of the following system documentation:
   - diving equipment technical manual
   - planned maintenance system
   - type approval certificates for the oxygen-measuring equipment

c) Verification of the structural arrangement and scantling of the foundations of pressure vessels and bell handling system

d) Verification of the fastening arrangement of the diving equipment

e) Functional testing of the main source of electrical power, emergency source of electrical power and switching from one to the other. Verification of the satisfactory operation of the alarms and indications

f) General examination of the electrical cabling

g) Functional testing of the main and alternative two-way communication system at the dive location i.e. between divers, chambers, control rooms, launch point and other important locations

h) Testing of the breathing gas installations:
   - general examination of the storage of the gas cylinders
   - verification of cleanliness of the breathing gas piping system according to the approved procedure
   - confirmation of the proper operation of the forced ventilation of the enclosed spaces for gas storage
   - verification of the means for the protection against overpressure of the oxygen installation
   - verification of the alarms of oxygen-measuring equipment
   - verification of the signboards in the area containing the gas cylinders

i) General examination of the automatic fire detection and alarm system

j) Verification of the suitable fixed fire-extinguishing system intended for interior spaces containing diving equipment

k) Confirmation that the fire fighters' outfits including their self-contained compressed air breathing apparatus, and two-way portable communication apparatus, and emergency breathing masks are complete and in good condition and that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged

l) Confirmation that doors located in bulkheads forming boundaries with adjacent spaces are in a satisfactory condition

m) General examination of the visible parts of items forming the structural fire protection, such as bulkheads, decks, doors and trunks, due attention being given to their integrity and to integrity of the insulating material.

13.2 Class renewal survey

13.2.1 In addition to the requirements of annual survey, the class renewal survey of the spaces containing the diving system is to include:

a) testing of the breathing gas installations, i.e. testing of the gas-tightness of all sealing devices of the enclosed spaces for breathing gas storage

b) functional testing of self closing systems of door located in bulkheads forming boundaries with adjacent spaces

c) verification of accuracy of oxygen-measuring equipment by means of calibration gas, as far as practicable

d) verification of the sea inlet protective structure, as relevant.

14 Fishing vessel

14.1 Annual survey

14.1.1 The survey is to include:

- general examination of areas subject to damage, corrosion or wastage, such as the stern ramp, weather deck in way of the working area of the nets, connections to hull structure of masts, gantries, winches and trawl gallows (for side trawlers)
- general examination of the measures for the protection of the crew against falling overboard, such as storm rails, means of protection near stern ramp, etc.

14.2 Class renewal survey

14.2.1 For fishing vessels 10 years age and over, the class renewal survey is to include thickness measurements of structural elements prone to rapid wastage, such as the stern ramp, weather deck in way of the working area of the nets, connections to hull structure of masts, gantries, winches and trawl gallows (for side trawlers).

15 Standby and rescue vessel

15.1 Annual survey - Rescue arrangement, survivors accommodation and safety equipment

15.1.1 A general examination of rescue equipment and facilities, survivors spaces, safety equipment, personal care and medical provisions, in accordance with the requirements given in Part E, Chapter 10, is to be carried out.

15.2 Annual survey - Towing arrangements

15.2.1 A general external examination of the towing hook or towing winch, as fitted, and unhooking device, as far as practicable, is to be carried out.

15.3 Class renewal survey - Rescue arrangement, survivors accommodation and safety equipment

15.3.1 A general examination of rescue equipment and facilities, survivors spaces, safety equipment, personal care and medical provisions, in accordance with the requirements given in Part E, Chapter 10, is to be carried out.

Testing of rescue and safety equipment, as applicable, is to be carried out.

15.4 Class renewal survey - Towing arrangements

15.4.1 The survey is to include:

- checking the condition of the connection of the towing hook or towing winch to the structure, including related reinforcements of the structure
- checking the external condition of the towing hook or towing winch; when applicable, a no-load test of the unhooking device is to be carried out.

16 Yacht and charter yacht

16.1 Intermediate survey

16.1.1 The survey requirements for intermediate survey of hull and hull equipment are given in Ch 3, Sec 2 and in Rule Note NR500, Rules for the Classification and Certification of Yachts.

The survey requirements for intermediate survey of machinery and systems for ships assigned with the service notation **yacht** and having a length less than 24 m are indicated in Ch 3, Sec 1, [3].

16.2 Class renewal survey

16.2.1 The requirements for class renewal survey are given in Ch 3, Sec 3 for all yachts.

16.2.2 Additional survey requirements are given in NR500 for yachts with additional service feature **C** or **W** or **A**.

17 Semi-submersible cargo ship

17.1 Annual survey

17.1.1 The survey is to include a general examination and testing, where appropriate, of the following items, as applicable:

- watertightness of immersed parts on the open deck and buoyancy towers up to the maximum submerged draft
- ballast system, including:

- tank level gauges
- remote valves and position status indicator in the central ballast station
- remote pumps and status indicator in the central ballast station
- alarms of the overflow tank
- air pipe and fittings
- means to prevent overpressure for pressurized ballast tanks
- other examination and testing as per the Planned Maintenance System

- means of communication between the central ballast control system and:
  - ballast pump room
  - bridge
  - dynamic positioning control stand, when relevant
- draft mark automatic gauging system up to a representative submerged draft
- draft marks on the ship's hull up to the maximum submerged draft
- on-board stability software including:
  - special procedure when cargo is considered buoyant
  - interface with the tank level gauging system
- submersion operating manual
- ship's records and logbooks
- navigational and communication equipment, visibility and habitability, in case a secondary look-out point has been fitted.

17.2 Intermediate survey

17.2.1 The survey is to include:

- examination and thickness measurements of the submerged area, as deemed necessary by the Surveyor
- examination of critical areas of the structure, such as internal connection of the buoyancy towers, including thickness measurements and non-destructive examination, as deemed necessary. When the connection is bolted, a representative number of bolts are to be dismantled, to the satisfaction of the attending Surveyor
- internal examination of representative ballast tanks in buoyancy towers, when applicable, and thickness measurement, as deemed necessary.

Note 1: Note: If such examinations reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains effective.

17.3 Class renewal survey

17.3.1 In addition to the requirements for annual survey, the renewal survey is to include:

- examination and thickness measurements, as deemed necessary by the attending Surveyor, of submerged shell above summer waterline
- examination and thickness measurements, including non-destructive examination if required, of critical areas of the structure such as buoyancy towers connection with hull or other critical areas, as found necessary by the Surveyor
- testing of submersion operation to a representative submerged draft.

18 Diving systems

18.1 Surveys

18.1.1 For survey requirements, refer to Chapter 4 of NR610, Rules for the Classification of Diving Systems.

19 Pipe laying ship

19.1 Annual survey

19.1.1 The annual survey is to include:

- verification of the presence onboard of the operating manual as defined in Pt E, Ch 12, Sec 1
- inspection of the structural arrangement and scantlings of the foundations of the pipe laying equipment.

19.2 Class renewal survey

19.2.1 In addition to the requirements of annual survey, the class renewal survey is to include:

- load tests in accordance with the pipe laying equipment testing program.

Section 9 Ships using Low Flashpoint Liquid or Gas Fuels

1 General

1.1 Application

1.1.1 The requirements of this Section apply to all self-propelled ships, other than those covered by Ch 4, Sec 5, which utilize gas or other low flash points fuels as a fuel for propulsion prime mover/auxiliary power generation arrangements and associated systems, or which have been assigned one of the following additional service features:

- **LNGfuel**,
- **CNGfuel**,
- **LPGfuel**,
- **methanolfuel**,
- **ammoniafuel**,
- **hydrogenfuel**, or
- **LFPfuel**.

Note 1: These additional service features are always completed by **singlefuel** of **dualfuel** as defined in Ch 1, Sec 2, [4.16.4].

1.1.2 These requirements are in addition to those laid down in Ch 3, Sec 1, [3.2.1], Ch 3, Sec 3, [3.1.1], Ch 3, Sec 3, [3.2.3], and Ch 3, Sec 6 as applicable.

These survey requirements do not cover fire protection, fire-fighting installation, and personnel protection equipment.

2 Annual survey - Hull items

2.1 General

2.1.1 The following requirements are to be verified during the survey of the fuel storage, fuel bunkering system and fuel supply system.

2.1.2 The logbooks and operating records are to be examined with regard to correct functioning of the gas detection systems, fuel supply/gas systems, etc. The hours per day of the reliquefaction plant, gas combustion unit, as applicable, the boil-off rate, and nitrogen consumption (for membrane containment systems) are to be considered together with gas detection records.

2.1.3 The manufacturer/builder instructions and manuals covering the operations, safety and maintenance requirements and occupational health hazards relevant to fuel storage, fuel bunkering, and fuel supply and associated systems for the use of the fuel, are to be confirmed as being aboard the vessel.

2.2 Gas related spaces, fuel preparation and handling rooms and piping

2.2.1 The survey is to include:

- examination of portable and fixed drip trays and insulation for the protection of the ship's structure in the event of a leakage
- examination of electrical bonding arrangements in hazardous areas, including bonded straps where fitted.

2.3 Fuel storage, bunkering and supply systems

2.3.1 The following requirements are to be examined, so far as applicable. Insulation need not to be removed, but any deterioration or evidence of dampness is to be investigated.

2.3.2 For fuel storage, the survey is to include:

- external examination of the storage tanks including secondary barrier if fitted and accessible
- general examination of the fuel storage hold place
- internal examination of tank connection space
- external examination of tank and relief valves
- verification of satisfactory operation of tank monitoring system
- examination and testing of installed bilge alarms and means of drainage of the compartment
- testing of the remote and local closing of the installed main tank valve.

2.3.3 For fuel bunkering system, the survey is to include:

- examination of bunkering stations and the fuel bunkering system
- verification of the satisfactory operation of the fuel bunkering control, monitoring and shutdown systems.

2.3.4 For fuel supply system, during working condition as far as practicable, the survey is to include:

- verification of the satisfactory operation of the fuel supply system control, monitoring and shutdown systems
- testing of the remote and local closing of the master fuel valve for each engine compartment.

3 Annual survey - Gas fuel machinery items

3.1 Control, monitoring and safety systems

3.1.1 The survey is to include:

- confirmation that gas detection and other leakage detection equipment in compartments containing fuel storage, fuel bunkering, and fuel supply equipment or components or associated systems, including indicators and alarms are in satisfactory operating condition
- verification that recalibration of the gas detection systems is done in accordance with the manufacturer's recommendations.
- verification of the satisfactory operation of the control, monitoring and automatic shutdown systems as far as practicable of the fuel supply and bunkering systems
- operational test, as far as practicable, of the shutdown of ESD protected machinery spaces.

3.2 Fuel handling piping, machinery and equipment

3.2.1 The survey is to include:

- examination, as far as practicable, of piping, hoses, emergency shutdown valves, relief valves, machinery and equipment for fuel storage, fuel bunkering, and fuel supply such as venting, compressing, refrigerating, liquefying, heating, cooling or otherwise handling the fuel
- examination of the means for inerting
- confirmation, as far as practicable, of the stopping of pumps and compressors upon emergency shutdown of the system.

3.3 Ventilating systems

3.3.1 The survey is to include:

- examination of the ventilation system, including portable ventilating equipment where fitted, is to be made for spaces containing fuel storage, fuel bunkering, and fuel supply units or components or associated systems, including air locks, pump rooms, compressor rooms, fuel preparation rooms, fuel valve rooms, control rooms and spaces containing gas burning equipment
- operational test, as far as practicable, of alarms, such as differential pressure and loss of pressure, where fitted.

3.4 Hazardous areas

3.4.1 The survey is to include:

- examination of electrical equipment and bulkhead/deck penetrations including access openings in hazardous areas, for continued suitability for their intended service and installation area.

4 Intermediate survey

4.1 General

4.1.1 In addition to the applicable requirements of the annual surveys, the intermediate survey is also to include:

- random test of gas detectors, temperature sensors, pressure sensors, level indicators, and other equipment providing input to the fuel safety system, to confirm their satisfactory operating condition
- verification of the proper response of the fuel safety system upon fault conditions.

5 Class renewal survey - Hull items

5.1 General

5.1.1 The class renewal survey is to include, in addition to the requirements of the annual surveys, examinations, tests and checks of sufficient extent to ensure that the fuel installations are in satisfactory condition and fit for intended purpose for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

5.2 Fuel handling and piping

5.2.1 All piping for fuel storage, fuel bunkering, and fuel supply such as venting, compressing, refrigerating, liquefying, heating, storing, burning or otherwise handling the fuel and liquid nitrogen installations are to be examined.

5.2.2 Removal of insulation from the piping and opening for examination may be required.

5.2.3 Where deemed suspect, a hydrostatic test to 1,25 times the maximum allowable relief valve setting (MARVS) for the pipeline is to be carried out.

5.2.4 After reassembly, the complete piping is to be tested for leaks.

5.2.5 Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the surveyor may accept alternative fluids or alternative means of testing.

5.3 Fuel valves

5.3.1 All emergency shutdown valves, check valves, block and bleed valves, master gas valves, remote operating valves, isolating valves for pressure relief valves in the fuel storage, fuel bunkering, and fuel supply piping systems are to be examined and proven operable.

5.3.2 A random selection of valves is to be opened for examination.

5.4 Pressure relief valves

5.4.1 Fuel storage tank pressure relief valves

The survey is to include:

- opening for examination, adjustment and function test of the pressure relief valves for the fuel storage tanks
- if the tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, replacement of such non-metallic membranes.

5.4.2 Fuel supply and bunkering piping pressure relief valves

The survey is to include:

- opening for examination, adjustment and function test of pressure relief valves for the fuel supply and bunkering piping
- where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves, including each size and type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since crediting the previous class renewal survey.

5.4.3 Pressure/vacuum relief valves

The survey is to include:

- opening, examination, test and readjustment as necessary, depending on their design, of the pressure/vacuum relief valves, rupture disc and other pressure relief devices for interbarrier spaces and hold spaces.

5.5 Fuel storage tanks

5.5.1 Fuel storage tanks are to be examined in accordance with an approved survey plan.

5.5.2 Liquefied gas fuel storage tanks are to be examined based on a survey/inspection plan, in which requirements for the survey of liquefied gas fuel containment systems are to be in accordance with the requirements laid down in Ch 4, Sec 5, [6.7] and Ch 4, Sec 5, [6.8.4], except as noted below:

- the tank insulation and tank support arrangements shall be visually examined. Non-destructive testing may be required if conditions raise doubt to the structural integrity
- vacuum insulated independent fuel storage tanks of type C without access openings need not be examined internally. Where fitted, the vacuum monitoring system shall be examined and records should be reviewed.

6 Class renewal survey - Gas fuel machinery items

6.1 Fuel handling equipment

6.1.1 Fuel pumps, compressors, process pressure vessels, inert gas generators, heat exchangers and other components used in connection with fuel handling are to be examined according to the requirement of Part A, Chapter 3 or Ch 4, Sec 3, [7.3], as applicable.

6.2 Electrical equipment

6.2.1 The survey is to include:

- examination of electrical equipment to include the physical condition of electrical cables and supports, intrinsically safe, explosion proof, or increased features of electrical equipment
- function testing of pressurized equipment and associated alarms
- testing of systems for de-energizing electrical equipment which is not certified for use in hazardous areas
- electrical insulation resistance test of the circuit terminating in, or passing through, the hazardous zones and spaces is to be carried out.

6.3 Safety systems

6.3.1 Gas detectors, temperature sensors, pressure sensors, level indicators, and other equipment providing input to the fuel safety system are to be tested to confirm satisfactory operating condition.

6.3.2 Proper response of the fuel safety system upon fault conditions is to be verified.

6.3.3 Pressure, temperature and level indicating equipment are to be calibrated in accordance with the manufacturer's requirements.

7 Hydrogen fuel

7.1 General

7.1.1 In addition to the requirements set out in [2] to [6], the requirements of this Article apply to ships assigned the additional service feature **hydrogenfuel**.

7.2 Annual survey

7.2.1 Multiple-element gas containers (MEGCs)

MEGC are to be subject to an external examination of the structure, the elements and the service equipment.

When the MEGC shows evidence of damaged or corroded areas, leakage, or other conditions that indicate a deficiency that could affect the integrity of the MEGC, additional inspection is to be performed. The extent of the additional inspection is to depend on the amount of damage or deterioration of the MEGC. It is to include at least the examinations required under [7.3.2].

7.3 Class renewal survey

7.3.1 Compressed hydrogen cylinders

The class renewal survey of compressed hydrogen cylinders is to include the following:

- checking of the external conditions of the cylinder and verification of the equipment and the external marks
- checking of the internal conditions of the cylinder (e.g. internal inspection verification of minimum wall thickness)
- checking of the threads if there is evidence of corrosion or if the fittings are removed
- hydraulic pressure testing, and, if necessary, verification of the characteristics of the material by suitable tests
- checking of service equipment, other accessories and pressure-relief devices, if to be reintroduced into service.

Periodic inspection and tests for composite cylinders (Type 2, 3 and 4) are to be done in accordance with ISO 11623:2015.

7.3.2 MEGCs

In addition to the requirements of annual survey, the class renewal survey of MEGC is to include:

- external inspection of elements for pitting, corrosion, abrasions, dents, distortions, defects in welds or any other conditions, including leakage, that might render the MEGC unsafe for transport
- inspection of piping, valves, and gaskets for corroded areas, defects, and other conditions, including leakage, that might render the MEGC unsafe for filling, discharge or transport
- verification that bolts or nuts on any flanged connection or blank flange are adequately tightened.
- inspection of emergency devices and valves for corrosion, distortion and any damage or defect that could prevent their normal operation
- checking of the remote closure devices and self-closing stop-valves to demonstrate proper operation
- confirmation that the required marks on the MEGC are legible and in accordance with the applicable requirements
- verification that the framework, the supports and the arrangements for lifting the MEGC are in satisfactory condition
- pressure testing of the elements and equipment
- leak testing of the assembly of elements and equipment.

Section 10 Ships using Fuel Cells

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned the additional service feature **fuelcell**.

1.1.2 These requirements are in addition to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3, and Ch 4, Sec 9, according to the relevant surveys.

2 Annual surveys

2.1 General

2.1.1 The logbooks and operating records are to be examined with regards to correct functioning of the gas detection systems, fuel systems, etc. The hours per day of the gas combustion unit, as applicable, and the fuel cell operation are to be considered together with gas detection records.

2.1.2

The manufacturer/builder instructions and manuals covering the operations, safety and maintenance requirements and occupational health hazards relevant to systems for the use of the fuel, are to be confirmed as being available on board the vessel.

2.2 Fuel cell spaces

2.2.1 The following requirements are to be examined, so far as applicable. Insulation need not to be removed, but any deterioration or evidence of dampness is to be investigated.

2.2.2 The survey is to include:

- confirmation of satisfactory operating condition of gas detection and other leakage detection equipment in fuel cell spaces or associated systems, including indicators and alarms as applicable
- verification of recalibration of the gas detection systems in accordance with the manufacturers' recommendations
- operational test, as far as practicable, of the emergency shutdown system
- examination of the ventilation system, including portable ventilating equipment where fitted, for fuel cell spaces and associated air locks. Where alarms, such as differential pressure and loss of pressure alarms, are fitted, these should be operationally tested as far as practicable
- examination of means for inerting
- examination of the required fire protection and fire extinguishing system contained in fuel cell spaces and operational test, as far as practicable
- examination of electrical equipment and bulkhead/deck penetrations including access openings in hazardous areas for continued suitability for their intended service and installation area
- examination of portable and fixed drip trays and insulation for the protection of the ship's structure in the event of leakage
- examination of electrical bonding arrangements in hazardous areas, including bonding straps where fitted
- examination and testing of installed bilge alarms and means of drainage of the fuel cell space
- testing of the remote and local closing of the master fuel valve for each fuel cell space.

2.3 Fuel cell installation system

2.3.1 The survey is to include:

- examination of the fuel cell system installation during working condition as far as practicable
- verification of satisfactory operation of the fuel cell system installation control, monitoring and shut-down systems
- examination of piping, hoses, emergency shut-down valves, remote operating valves, relief valves, machinery and equipment for handling the fuel, as far as practicable
- examination of means for inerting
- verification of stopping of reformer, pumps and compressors upon emergency shutdown of the system, as far as practicable.

3 Intermediate surveys

3.1 General

3.1.1 In addition to the applicable requirements of the annual surveys, the intermediate survey is also to include:

- random test of gas detectors, temperature sensors, pressure sensors, level indicators, and other equipment providing input to the fuel safety system, to confirm their satisfactory operating condition
- verification of the proper response of the fuel safety system upon fault conditions.

4 Class renewal surveys

4.1 General

4.1.1 The class renewal survey is to include, in addition to the requirements of the annual surveys, examinations, tests and checks of sufficient extent to ensure that the fuel installations are in satisfactory condition and fit for intended purpose for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

4.1.2 All fuel cell installation system piping are to be examined. Removal of insulation from the piping and opening for examination may be required. Where deemed suspect, a hydrostatic test to 1,25 times the Maximum Allowable Relief Valve Setting (MARVS) for the pipeline is to be carried out. After reassembly, the complete piping is to be tested for leaks. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the Surveyor may accept alternative testing fluids or alternative means of testing.

4.1.3 All emergency shut-down valves, check valves, block and bleed valves, master gas valves, remote operating valves, isolating valves for pressure relief valves in the fuel cell installation system are to be examined and proven operable. A random selection of valves is to be opened for examination.

4.1.4 The survey is to include:

- examination of electrical equipment to include the physical condition of electrical cables and supports, intrinsically safe, explosion proof, or increased safety features of electrical equipment
- functional testing of pressurized equipment and associated alarms
- testing of systems for de-energizing electrical equipment which is not certified for use in hazardous areas
- an electrical insulation resistance test of the circuits terminating in, or passing through, the hazardous zones and spaces.

4.1.5 Gas detectors, temperature sensors, pressure sensors, level indicators, and other equipment providing input to the fuel safety system are to be tested to confirm satisfactory operating condition.

4.1.6 Proper response of the fuel safety system upon fault conditions is to be verified.

4.1.7 Pressure, temperature and level indicating equipment are to be calibrated in accordance with the manufacturer's requirements.

4.1.8 Fuel pumps, compressors, process pressure vessels, inert gas generators, heat exchangers and other components used in connection with fuel handling and parts of the fuel cell installation systems are to be examined according to the requirement of Part A, Chapter 3 or Ch 4, Sec 3, [7.3], as applicable.

Section 11 Ships using Onboard Carbon Capture and Storage Systems

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to ships assigned the additional service feature **OCC**.

1.1.2 These requirements are in addition to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3, according to the relevant surveys.

2 Annual survey

2.1 General

2.1.1 The logbooks and operating records are to be examined with regards to correct functioning of the carbon capture and storage system.

2.1.2 The manufacturer/builder instructions and manuals covering the operations, safety and maintenance requirements and occupational health hazards relevant to the system are to be confirmed as being available on board the vessel.

2.2 Solvent system

2.2.1 The solvent system and related accessories including piping, pumps and heat exchangers are to be examined externally and in running condition. The tightness of the system is to be ascertained.

2.2.2 The following alarm and safety devices are to be examined for correct functioning, if fitted:

- alarm and emergency safety devices
- solvent leakage detectors
- temperature control sensors
- cut off of the electric power supply in case of excessive temperature

2.3 Carbon capture system

2.3.1 The annual survey of the carbon capture system is to include the following items, when fitted:

- examination of the logbooks with regard to correct functioning of the carbon capture system
- confirmation that the Instrumentation, control, monitoring, and safety equipment of each system unit are operating satisfactorily
- examination of emergency shutdown or bypass valves, remote operating valves, and machinery and equipment and, as far as practicable, testing of the emergency shutdown of the system
- examination and functional test of all tanks, piping, hoses, pumps, strainers, separators, filtration units, dosing systems, and associated equipment
- examination of drip trays, shielding or insulation installed for the protection of personnel or of the ship
- examination of electrical equipment associated with the operation or monitoring of the carbon capture system
- confirmation that Personal Protective Equipment (PPE) and facilities are available onboard and maintained in good conditions
- external examination of all components including foundations and attachments
- verification of the correct operation of all remotely operated or automatically controlled valves in the handling systems
- examination of the carbon capture system during working condition, as far as practicable.

2.4 CO_2 storage system

2.4.1 The annual survey of the CO_2 storage system is to include the following items, when fitted:

- The logbooks and operating records are to be examined with regard to correct functioning of the gas detection systems, reliquefaction system, compression system, etc.
- the manufacturer/builder instructions and manuals covering the operations, safety and maintenance requirements are to be confirmed as being onboard
- examination of portable and fixed drip trays and insulation for the protection of the ship's structure
- external examination of the storage tanks
- external examination of the tank and relief valves
- verification of satisfactory operation of the tank pressure control, monitoring and shutdown system
- testing of the remote and local closing of the installed main tank valve
- confirmation that gas detection and other leakage detection equipment in compartments containing CO_2 storage, CO_2 handling equipment or associated systems, including indicators and alarms are in satisfactory operating condition
- verification that recalibration of the gas detection system is done in accordance with the manufacturer's recommendations
- verification of the satisfactory operation of the control, monitoring and automatic shutdown systems as far as practicable of the CO_2 handling systems
- confirmation, as far as practicable, of the stopping of pumps and compressors upon emergency shutdown of the system
- examination of the ventilation system, where fitted, is to be made for spaces containing CO_2 storage and handling systems.

3 Class renewal surveys

3.1 General

3.1.1 The class renewal survey is to include, in addition to the requirements of the annual survey, examinations, tests and checks of sufficient extent to ensure that the carbon capture and storage systems are in satisfactorily condition and fit for the intended purpose for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

3.2 Solvent system

3.2.1 Solvent piping are to be examined and operationally tested to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.

The Surveyor may require dismantling and/or thickness measurements of piping. A hydraulic test is to be carried out in the event of repair or dismantling of solvent piping, or where doubts arise.

3.2.2 The satisfactory condition of the heating/cooling system is to be verified and, if deemed necessary by the Surveyor, the system is to be pressure tested.

3.3 Carbon capture system

3.3.1 For the carbon capture system, the associated systems and monitoring equipment, the following is also to be carried out:

- visual inspection of all pumps
- visual inspection of all bypass, mixing, isolating, shut-down or control valves
- visual examination and test of all mechanical, hydraulic and pneumatic control actuators and their power systems, as deemed necessary by the Surveyor
- dock trials on control systems, in order to verify correct operation of the automatic functions, monitoring and alarms systems, safety systems, including override of system functions if provided, manual control and automatic changeover of designated machinery associated with the carbon capture system.

3.4 CO_2 Storage system

3.4.1 For the CO_2 storage system, the associated systems and monitoring equipment, the following is also to be carried out:

- all piping for CO_2 handling and storage, such as venting, compressing, refrigerating, liquefying, storing or otherwise handling the CO_2 are to be examined
- removal of insulation from the piping and opening for examination may be required
- where deemed suspect, a hydrostatic test to 1,25 time the maximum allowable relief valve setting for the pipeline is to be carried out
- after reassembly, the complete piping is to be tested for leaks

- all emergency shutdown valves, check valves, remote operating valves, isolating valves for pressure relief valves are to be examined and proven operable
- a random selection of valves is to be opened for examination
- opening for examination, adjustment and function test of the pressure relief valves for the CO_2 storage tanks
- CO_2 storage tanks are to be examined in accordance with an approved survey plan
- examination of electrical equipment to include the physical condition of electrical cables and supports
- function testing of pressurized equipment and associated alarms
- gas detectors, temperature sensors, pressure sensors, level indicators and other equipment providing input to the CO_2 safety system are to be tested to confirm satisfactory operating condition
- proper response of the CO_2 safety system upon fault conditions is to be verified
- pressure, temperature and level indicating equipment are to be calibrated in accordance with the manufacturer's requirements.

Section 12 Ships using Wind Propulsion Systems

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional service features or additional class notations described respectively in Ch 1, Sec 2, [4.16.3] or Ch 1, Sec 2, [6.25.5]:

WIND PROPULSION-1

WIND PROPULSION-2

1.1.2 In order to allow a correct examination of the wind propulsion system, it is necessary to check that all the elements of it are accessible in good safety conditions.

Depending on the type of wind propulsion system, a convenient means of access, such as a basket or an equivalent system, is to be provided to the Surveyor to allow access to all elements in a safe way and a correct examination of the wind propulsion system.

1.1.3 If sails control and manoeuvring systems are covered by **WIND PROPULSION-1** or **WIND PROPULSION-2** (for instance: furling or reefing systems), it is necessary to check that it is possible to use them during the survey without difficulty, according for instance to wind direction and speed, power supply and any other factor which may influence the survey.

1.1.4 The laying down of the mast(s) may be requested for the survey, if the Society considers that otherwise the examination cannot be carried out satisfactorily.

2 Annual survey

2.1 General

2.1.1 As a rule, the scope of examination is applicable to metallic system.

In the case of the use of particular materials (aluminium alloys, plastic reinforced with fibreglass or other fibre, sandwich panels,...) an adapted programme of inspection is to be carried out, after approval by the Society.

2.1.2 For internal controls, endoscope, x-rays or any other usable means may be accepted.

2.1.3 The annual survey programme is detailed in:

- [2.2] for wind propulsion systems less than 18 months old, and
- [2.3] for other wind propulsion systems.

Further examination and testing may be conducted if considered necessary by the Surveyor.

2.2 Systems less than 18 months old

2.2.1 The scope of the annual survey of wind propulsion systems less than 18 months old is defined in [3.1] to [3.4].

2.3 Systems 18 months old or more

2.3.1 The scope of the annual survey of wind propulsion systems of 18 months old or more is defined in:

- for ships assigned a notation **WIND PROPULSION-1**: [2.3.2], [2.3.4] and [2.3.5]
- for ships assigned a notation **WIND PROPULSION-2**: [2.3.2], [2.3.3], [2.3.4] and [2.3.5].

2.3.2 Safety rigging parts

As a rule, the programme of survey consists of:

- visual examination of all the concerned parts
- additional examinations to the Surveyor's satisfaction on areas highly stressed or subject to severe working conditions (corrosion, vibrations,...).

2.3.3 Operating rigging parts

As a rule, the programme of survey consists of:

- visual examination of all the elements and connections of the concerned items. Moving elements are to be dismantled if considered necessary by the Surveyor
- operating tests.

2.3.4 Drive system

Depending on the type of drive systems, inspections are to be carried out to check:

- the working condition of the systems
- the working condition of the safety devices
- the working condition of the automated control system if such an equipment is provided.

2.3.5 Additional examinations depending on items within the scope of the notation **WIND PROPULSION-1** or **WIND PROPULSION-2**, may be required to the Surveyor's satisfaction.

3 Class renewal survey

3.1 General

3.1.1 In addition to the annual survey, the class renewal survey is to include:

- for ships assigned a notation **WIND PROPULSION-1**: [3.2] and [3.4]
- for ships assigned a notation **WIND PROPULSION-2**: [3.2], [3.3] and [3.4].

3.2 Safety rigging parts

3.2.1 Systematic dismantling may be required by the Society, depending on a maintenance programme, to the Surveyor's satisfaction.

As a rule, a mast and its safety rigging parts are to be entirely dismantled once every five years. This duration may be modified after a probationary period determined on case by case basis by the Society.

3.2.2 Mast or rotor structure

The examination of mast or rotor structure, including spreaders if applicable, consists of close up survey of:

- the masts or rotor and of their assembling zones (welded, riveted zones)
- all the connecting elements. Additional examinations and non destructive tests may be required by the Surveyor
- the rigging connection elements
- the internal corrosion of the structure
- the structure of the lower part of the masts: additional controls and/or non-destructive tests are to be carried out to check the good behaviour of the base of the masts (connections to the decks)
- equipment fittings on the masts or rotors.

The extent of the non-destructive tests is determined by the Surveyor taking into account the general maintenance conditions and previous test results.

The Surveyor may require an examination of the uprightness of the spreaders. The sags are to be compared with the previous or initial data.

3.2.3 Connection fittings and ropes

The examination of the connection fittings and ropes consists of:

- visual examination of the connection fittings: turnbuckles, forks, chainplates, etc...
- visual examination of the wire ends (about 10% of the wire lengths) to check the absence of corrosion cracks or broken wires.

The forestay wire ropes are to be carefully examined, especially if furling systems are fitted:

- upper and lower ends
- wire areas on which furling system bearings are supported.

3.2.4 Control of pretensioning

If the safety rigging parts has been examined by the Society for precise working conditions (pretensioning, fitting of additional movable forestays or backstays) the Surveyor is to be able to check that these working conditions are complied with.

Additional tests and/or measurements may be required.

3.3 Operating rigging parts

3.3.1 Examination of operating rigging parts includes:

- general examination of related items (halyards, sheets, blocks...), in accordance with the maintenance plan
- non-destructive tests on mounting and slewing rings to detect possible cracks.

3.3.2 Moving elements

Moving elements are to be dismantled at the Surveyor's satisfaction.

As a rule, the following elements are to be removed:

- every hinged connection to allow checking of the state of pins and bearings
- several fixing bolts of the mounting and slewing rings of rotative systems to check their state.

The replacement of the removed bolts (screws, nuts and washers) is recommended.

3.3.3 Manoeuvring system

Examination of manoeuvring system, for example furling or reefing system, consists of an extensive examination to detect any abnormal wearing, clearance:

- checking of external and internal state of the furling rods (paint or cathodic protection, corrosion, residual thickness,...)
- checking of the state of the connections of the furling rods, (for riveted or glued connections, it may be required to dismantle some of the elements to check the general condition of the system)
- checking of the state of the bearings:
  - end bearings (stay) are to be dismantled at each survey. If not possible, tests are to be carried out at the Surveyor' satisfaction
  - intermediate bearings: depending on the type.

3.3.4 Sails

When the sails are within the scope of the notation, additional examination may be required in accordance with the maintenance plan.

3.4 Drive system

3.4.1 The extent of annual survey of drive system as described in [2.3.4] is applicable.

Section 13 Ships using Battery Systems

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned the additional service feature **battery system** as defined in Ch 1, Sec 2, [4.16.6].

1.2 Annual survey

1.2.1 The annual survey is to include:

- general examination of the battery pack(s)
- general examination of the battery monitoring system
- general examination of the battery support system
- general examination of the battery room, including visual check of the safety measures and functions related to battery rooms, i.e. battery installation, ventilation, fire safety measures and alarms
- check of the electrolyte level and pH level
- check of State of health (SOH) of battery system according to the Manufacturer's specification and verification that the battery capacity has been regularly recorded and complies with the parameters specified by the Manufacturer
- test of sensor and alarm associated to the battery at random
- undertaking of measurement of insulation of battery packs
- additional checks when some specific part of battery is or has been replaced (e.g. battery cells, BMS) according to the Manufacturer specification and to the satisfaction of the Surveyor.

1.3 Class renewal survey

1.3.1 The requirements given in [1.2.1] for annual survey are to be complied with.

In addition:

- a comprehensive test of indication and alarms is to be carried out
- the traceability of cells replacement is to be checked
- the traceability of software modification is to be checked
- a battery capacity (State of Health - SOH) test is to be witnessed when:
  - release of flammable or toxic gases during battery operation was identified (e.g. hydrogen for lead-acid batteries)
  - loss of battery might jeopardize manoeuvrability of the ship.

Appendix 1 Oil Tanker Longitudinal Strength Assessment

1 General

1.1

1.1.1 The criteria indicated in this Appendix are to be used for the evaluation of longitudinal strength of the ship's hull girder as required by Ch 4, Sec 3, [1.3.2].

1.1.2 In order that ship's longitudinal strength to be evaluated can be recognized as valid, fillet welding between longitudinal internal members and hull envelopes are to be in sound condition so as to keep integrity of longitudinal internal members with hull envelopes.

2 Evaluation of longitudinal strength

2.1 Application

2.1.1 The requirements given in this Article apply to ships contracted for construction before 1st July 2022. For ships contracted for construction on or after 1st July 2022, general criteria given in Ch 2, App 3, [4.5.4] apply.

2.2 Transverse sectional areas

2.2.1 The transverse sectional areas of deck flange (deck plating and deck longitudinals) and bottom flange (bottom shell plating and bottom longitudinals) of the ship's hull girder are to be calculated by using the thickness measured, renewed or reinforced, as appropriate, during the class renewal survey.

2.2.2 If the diminution of sectional areas of either deck or bottom flange exceeds 10% of their respective as-built area (i.e. original sectional area when the ship was built), either one of the following measures is to be taken:

a) to renew or reinforce the deck or bottom flanges so that the actual sectional area is not less than 90% of the as-built area; or

b) to calculate the actual section moduli (Z_{act}) of transverse section of the ship's hull girder by applying the calculation method specified in [2.4], by using the thickness measured, renewed or reinforced, as appropriate, during the class renewal survey.

2.3 Transverse section modulus

2.3.1 The actual section modulus (Z_{act}) of the transverse section of the ship's hull girder calculated in accordance with item b) of [2.2.2] is not to be less than 90% of the required section modulus for new buildings $Z_{R, MIN}$ or Z_R , whichever is the greater, specified in Pt B, Ch 6, Sec 1 of the edition July 2021 of NR467 Rules for the Classification of Steel Ships, as amended in January 2022.

2.4 Calculation criteria of section modulus

2.4.1 When calculating the transverse section modulus of the ship's hull girder, the requirements under Pt B, Ch 6, Sec 1 of the edition July 2021 of NR467 Rules for the Classification of Steel Ships, as amended in January 2022, should be applied.

3 Sampling method of thickness measurements

3.1 Extent of evaluation

3.1.1 Longitudinal strength should be evaluated within 0,4L amidships for the extent of the hull girder length that contains tanks therein and within 0,5L amidships for adjacent tanks which may extend beyond 0,4L amidships where tanks means ballast tanks and cargo tanks.

3.2 Sampling method of thickness measurements

3.2.1 Transverse sections should be chosen such that thickness measurements can be taken for as many different tanks in corrosive environment as possible, e.g. ballast tanks sharing a common plane boundary with cargo tanks fitted with heating coils, other ballast tanks, cargo tanks permitted to be filled with sea water and other cargo tanks. Ballast tanks sharing a common plane boundary with cargo tanks fitted with heating coils and cargo tanks permitted to be filled with sea water should be selected where present.

3.2.2 The minimum number of transverse sections to be sampled should be in accordance with the requirements for the current class renewal survey. The transverse sections should be located where the largest thickness reductions are suspected to occur or are revealed from deck and bottom plating measurements required in Ch 4, Sec 3, Tab 5 and should be clear of areas which have been locally renewed or reinforced.

3.2.3 At least two points should be measured on each deck plate and/or bottom shell plate required to be measured within the cargo area in accordance with the requirements for the current class renewal survey.

3.2.4 Within 0,1 D (where D is the ship's moulded depth) of the deck and the bottom at each transverse section to be measured, every longitudinal and girder should be measured on the web and face plate, and every plate should be measured at one point between longitudinals.

3.2.5 For longitudinal members other than those specified in [3.2.4] to be measured at each transverse section, every longitudinal and girder should be measured on the web and face plate, and every plate should be measured at least in one point per strake.

3.2.6 The thickness of each component should be determined by averaging all of the measurements in way of the transverse section on each component.

3.3 Additional measurements

3.3.1 Where one or more of the transverse sections are found to be deficient in respect of the longitudinal strength requirements given in this Appendix, the number of transverse sections for thickness measurements should be increased such that each tank within the 0,5L amidships region has been sampled. Tank spaces that are partially within, but extend beyond, the 0,5 L region should be sampled.

3.3.2 Additional thickness measurements should also be performed on one transverse section forward and one aft of each repaired area to the extent necessary to ensure that the areas bordering the repaired section also comply with the requirements of this Appendix.

3.4 Repair methods

3.4.1 The extent of renewal or reinforcement carried out to comply with this Appendix should be in accordance with [3.4.2].

3.4.2 The minimum continuous length of a renewed or reinforced structural member should be not less than twice the spacing of the primary members in way. In addition, the thickness diminution in way of the butt joint of each joining member forward and aft of the replaced member (plates, stiffeners, girder webs and flanges, etc.) should not be within the substantial corrosion range (75% of the allowable diminution associated with each particular member). Where differences in thickness at the butt joint exceed 15% of the lower thickness, a transition taper should be provided.

3.4.3 Alternative repair methods involving the fitting of straps or structural member modification should be subject to special consideration. In considering the fitting of straps, it should be limited to the following conditions:

- to restore and/or increase longitudinal strength;
- the thickness diminution of the deck or bottom plating to be reinforced should not be within the substantial corrosion range (75% of the allowable diminution associated with the deck plating)
- the alignment and arrangement, including the termination of the straps, is in accordance with a standard recognized by the Society
- the straps are continuous over the entire 0,5 L amidships length; and
- continuous fillet welding and full penetration welds are used at butt welding and, depending on the width of the strap, slot welds. The welding procedures applied must be acceptable to the Society.

3.4.4 The existing structure adjacent to replacement areas and in conjunction with the fitted straps should be capable of withstanding the applied loads, taking into account the buckling resistance and the condition of welds between the longitudinal members and hull envelope plating.

CHAPTER 5
SCOPE OF SURVEYS RELATED TO ADDITIONAL CLASS NOTATIONS

Section 1 General
Section 2 VeriSTAR and STAR Notations
Section 3 Availability of Machinery
Section 4 Automated Machinery Systems
Section 5 Integrated and Digital Systems
Section 6 Monitoring Equipment
Section 7 Comfort on Board and Habitability
Section 8 Environmental Protection
Section 9 Refrigerating Installations
Section 10 Navigation in Cold Environment
Section 11 Protection against Chemical, Biological, Radiological and Nuclear Risk
Section 12 Manoeuvring, Mooring, Anchoring and Position Keeping
Section 13 Cargo Operation, Securing and Safety
Section 14 Additional Notations for Hull Structure Assessment
Section 15 Electric Propulsion or Electric Power Supply
Section 16 Additional Notations for Fire Protection
Section 17 Additional Notations for Computer Based Systems and Cyber Security
Section 18 Additional Notations for Corrosion Protection
Section 19 Other Notations

Section 1 General

1 General

1.1

1.1.1 The purpose of this Chapter is to give details on the scope of surveys of specific equipment and systems fitted on board the ship, which are covered by an additional class notation. Unless otherwise specified in Ch 1, Sec 2, [6], the scope of these surveys provides the requirements to be complied with for the maintenance of the relevant additional class notation.

1.1.2 These specific requirements are additional to those laid down in Part A, Chapter 3 and Part A, Chapter 4. These surveys are to be carried out at intervals as described in Ch 2, Sec 2, as far as possible concurrently with the surveys of the same type, i.e. annual, intermediate or class renewal survey.

1.1.3 The equipment and systems are also to be submitted to occasional survey whenever one of the cases indicated in Ch 2, Sec 2, [6] occurs.

1.1.4 Where specific requirements are given for the class renewal survey, they are additional to the requirements for the annual survey, which, in accordance with Ch 3, Sec 3, [1.1.7], is to be carried out at the completion of the class renewal survey.

1.1.5 For the assignment of the additional class notations, ships are to be submitted to an admission to class survey as described in Ch 2, Sec 1, [2] and Ch 2, Sec 1, [3] for new and existing installations, respectively, as applicable.

2 Additional class notations subject to additional surveys

2.1

2.1.1 The specific requirements detailed in this Chapter are linked to the additional class notation(s) assigned to the ship. Where a ship has more than one additional class notation, the specific requirements linked to each additional class notation are applicable as long as they are not contradictory.

2.1.2 Tab 1 indicates which additional class notations are subject to specific requirements, and in which Section and/or Article they are specified.

Table 1 : Additional class notations for which specific survey requirements are applicable

Additional class notation	Section or Article applicable in this Chapter	Type of surveys affected by these specific requirements
STAR-HULL **VeriSTAR-HULL SIS** **STAR-MACH SIS**	Ch 5, Sec 2	class renewal survey annual audits
Availability of machinery: **AVM-APS** **AVM-DPS** **AVM-IPS** **AVM-FIRE**	Ch 5, Sec 3	annual survey class renewal survey
Automated machinery systems: **AUT-UMS** **AUT-CCS** **AUT-PORT** **AUT-IMS**	Ch 5, Sec 4	annual survey class renewal survey
Integrated and digital systems: **SYS-NEQ** and **SYS-NEQ-1** **SYS-COM** **SYS-IBS** and **SYS-IBS-1** **ASYNC-COM** and **ASYNC-COM-R** **SYNC-COM** and **SYNC-COM-R** **DATA-INFRA** and **DATA-INFRA-STAND** **DATA-CENTRIC**	Ch 5, Sec 5	annual survey class renewal survey

Additional class notation	Section or Article applicable in this Chapter	Type of surveys affected by these specific requirements
Monitoring equipment: **MON-HULL** **MON-SHAFT** **MON-ICE L(i)** and **MON-ICE G** **REALTIME ( )**	Ch 5, Sec 6	annual survey class renewal survey tailshaft survey
Comfort and habitability: **COMF-NOISE-SIS**, **COMF-NOISE-Pax-SIS**, **COMF-NOISE-Crew-SIS** **COMF-VIB-SIS**, **COMF-VIB-Pax-SIS**, **COMF-VIB-Crew-SIS** **COMF+-SIS** **HABITABILITY**	Ch 5, Sec 7	annual survey class renewal survey
Environmental protection: **CLEANSHIP** and **CLEANSHIP CEMS** **CLEANSHIP SUPER( )** and **CLEANSHIP SUPER( ) CEMS** **AWT-A**, **AWT-B** and **AWT-A/B** **BWE** **BWT** **GWT** **GWT-B** **NDO-x days** **OWS-x ppm** **NOX-x%** **SOX-x%** **EGCS-SCRUBBER** **SEEMP** **ULEV** **VCS**	Ch 5, Sec 8	annual survey intermediate survey class renewal survey
Refrigerating installations: **REF-CARGO** **REF-CONT** **REF-STORE**	Ch 5, Sec 9	annual survey class renewal survey
Navigation in cold environment: **ICE** **ICE CLASS IA SUPER**, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC** **ICE CLASS ID** **YOUNG ICE 1**, **YOUNG ICE 2** **COLD DI** **COLD BASIC (H t_{DH}, E t_{DE})** **COLD (H t_{DH}, E t_{DE})** **COLD CARGO**	Ch 5, Sec 10	annual survey class renewal survey
Protection against chemical, biological, radiological and nuclear risk: **CBRN**, **CBRN-WASHDOWN** **BIORISK MANAGED**, **BIORISK SECURED**	Ch 5, Sec 11	annual survey class renewal survey
Manoeuvring, mooring, anchoring and position keeping: **HEADING CONTROL** **SPM** **DYNAPOS**	Ch 5, Sec 12	annual survey class renewal survey
Cargo operation, securing and safety: **CARGOCONTROL** **EVOC** **PaRoll1** or **PaRoll2** **LI-LASHING**	Ch 5, Sec 13	as applicable in accordance with the related Articles in Ch 5, Sec 13
Additional notations for hull structure assessment: **STRENGTHBOTTOM** **GRABLOADING** **GRAB [X]**	Ch 5, Sec 14	dry docking survey class renewal survey

Additional class notation	Section or Article applicable in this Chapter	Type of surveys affected by these specific requirements
Electric propulsion or electric power supply: **ELECTRIC HYBRID** **HMPS** **OPS**	Ch 5, Sec 15	annual survey class renewal survey
Additional notations for fire protection: **EFP-M**, **EFP-AMC** **ECFP** **COVENT** **EVFP-1**, **EVFP-2**, **EVFP-3**	Ch 5, Sec 16	annual survey class renewal survey
Additional notations for cyber security and computer based systems: **CYBER MANAGED** **CYBER RESILIENT** **CYBER SECURE** **SMART( )**	Ch 5, Sec 17	annual survey intermediate survey class renewal survey
Additional notations for corrosion protection: **CPS(COT)** **CPS(MFT)** **CPS(VSP)** **CPS(WBT)**	Ch 5, Sec 18	annual survey
Other notations: **ACCESS** **HEL** **OAS** **OHS**	Ch 5, Sec 19	as applicable in accordance with the related Articles in Ch 5, Sec 19

Section 2 VeriSTAR and STAR Notations

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to the **VeriSTAR** system, as described in Ch 1, Sec 2, [6.2]:

STAR-HULL

VeriSTAR-HULL SIS

STAR-MACH SIS

2 VeriSTAR-HULL SIS

2.1 General

2.1.1 The additional class notation **VeriSTAR-HULL SIS** was assigned at the design stage or after construction, and is maintained during the service life, to ships complying with the requirements of Ch 1, Sec 2, [6.2.2] and Ch 1, Sec 2, [6.2.3].

2.1.2 The additional class notation **VeriSTAR-HULL SIS** was assigned to a ship in order to reflect the following:

- a structural tridimensional analysis has been performed for the hull structures, as defined in Pt B, Ch 7, App 1 or Pt B, Ch 7, App 2 or Pt B, Ch 7, App 3, as applicable, of NR 467 Rules for the classification of steel ships, edition July 2021.
- the hull structure condition is periodically assessed, usually at the class renewal survey, using the results of the inspections and thickness measurements performed during the survey. The results of this assessment are made available to the Owner.

2.1.3 The following is to be available on board:

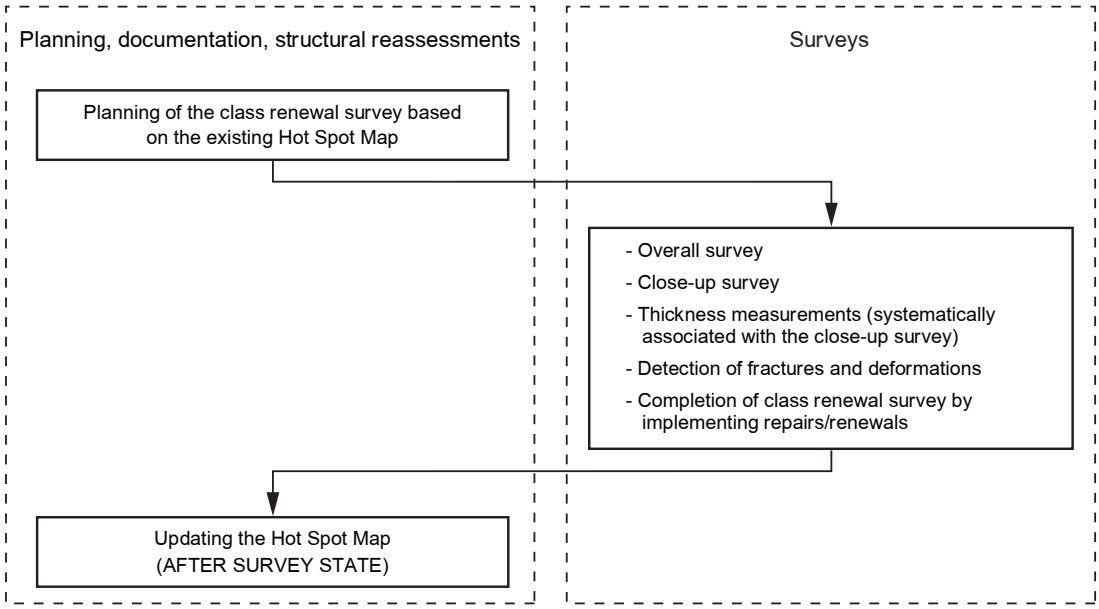
- the class renewal survey report
- the results of the periodical structural reassessments done after each class renewal survey
- the Society's requirements for structural repairs and renewals
- the hot spot map of the structure.

2.2 Class renewal survey

2.2.1 The survey for the renewal of the **VeriSTAR-HULL SIS** notation is to be carried out concurrently with the class renewal survey.

The documentation to be prepared, the surveys to be carried out and the structural reassessment to be done in connection with the class renewal survey are summarized in the flowchart shown in Fig 1.

Figure 1 : Actions to be taken in connection with the class renewal survey (VeriSTAR-HULL SIS)



2.2.2 In addition to the scope of the class renewal survey as required for the ship concerned, additional thickness measurements and surveys may be required by the Society taking into account the surveys, thickness measurements and a specific survey for fatigue fracture detection carried out as a result of the previous hot spot map.

2.2.3 The acceptance criteria for measured thicknesses are given in Ch 2, App 3, or in the edition July 2021 (as amended in January 2022) of NR467 Rules for the Classification of Steel Ships, Pt F, Ch 1, App 2 for items as deemed appropriate by the Society (for example a plating panel or an ordinary stiffener).

When the acceptance criteria are not fulfilled, actions according to [2.2.4] are to be taken.

2.2.4 For each item, thicknesses are measured at several points and the average value of these thicknesses is to satisfy the acceptance criteria for the relevant item.

If the criteria of measured thicknesses are not fulfilled for an item, then this item is to be repaired or replaced.

2.2.5 Once the renewal survey is completed to the Society satisfaction, the "after survey" hot spot map is prepared and submitted to the Society.

3 STAR-HULL

3.1 General

3.1.1 The additional class notation **STAR-HULL** was assigned to a ship in order to reflect the fact that a procedure including periodical and corrective maintenance, as well as periodical and occasional inspections of hull structures and equipment, (hereafter referred to as the Inspection and Maintenance Plan - IMP) are dealt with on board by the crew and at the Owner's offices.

The assignment of the notation implied that a structural tridimensional analysis had been performed for the hull structures, as defined in Pt B, Ch 7, App 1 or Pt B, Ch 7, App 2 or Pt B, Ch 7, App 3, as applicable, of NR 467 Rules for the classification of steel ships, edition July 2021.

The implementation of the Inspection and Maintenance Plan is surveyed by the Society through periodical check of the hull structure, normally at the class renewal survey, against defined acceptance criteria and based on:

- the collected data from actual implementation of the Inspection and Maintenance Plan
- the results of the inspections, thickness measurements and other checks carried out during the class renewal survey.

3.2 Class renewal survey

3.2.1 In addition to the scope of the class renewal survey as required for the ship concerned (see Fig 2), the following is to be carried out:

- the assessment of the condition of coating and anodes
- additional thickness measurements and surveys may be required by the Society
- a specific survey for fatigue fracture detection as a result of the previous hot spot map.

3.2.2 Once the renewal survey is completed to the Society satisfaction, the "after survey" hot spot map is to be prepared and submitted to the Society, as well as the Inspection and Maintenance Plan, updated as needed.

3.3 Suspension and withdrawal of the notation

3.3.1 The maintenance of the **STAR-HULL** notation is subject to the same principles as those for the maintenance of class: surveys are to be carried out by their limit dates and possible conditions of class (related to the notation) are to be dealt with by their limit dates.

The suspension of class automatically causes the suspension of the **STAR-HULL** notation.

3.3.2 Various events may lead either to imposition of a condition of class related to the **STAR-HULL** notation or to suspension of the notation itself. Some cases are given below.

- The condition of the ship is below the minimum level required for class (e.g. scantling of a hull structure below the corrosion margin). The action to be taken is either the immediate repair or the imposition of a condition of class for the class (if acceptable) and suspension of the **STAR-HULL** notation. However, in cases where the condition of class is of a minor nature, the notation may not be suspended.
- The condition of the ship is below the minimum level for the **STAR-HULL** notation, but still above the level for the class (e.g. the scantling of a hull structure is below the corrosion margin acceptable for the notation but is still above the corrosion margin). The action to be taken is either the immediate repair or the imposition of a condition of class for the **STAR-HULL** notation (without condition of class for class).
- The Inspection and Maintenance Plan is not complied with (e.g. delays in performing the operations programmed according to the plan or the scope of inspection and/or maintenance not completely fulfilled).

  The action to be taken is:

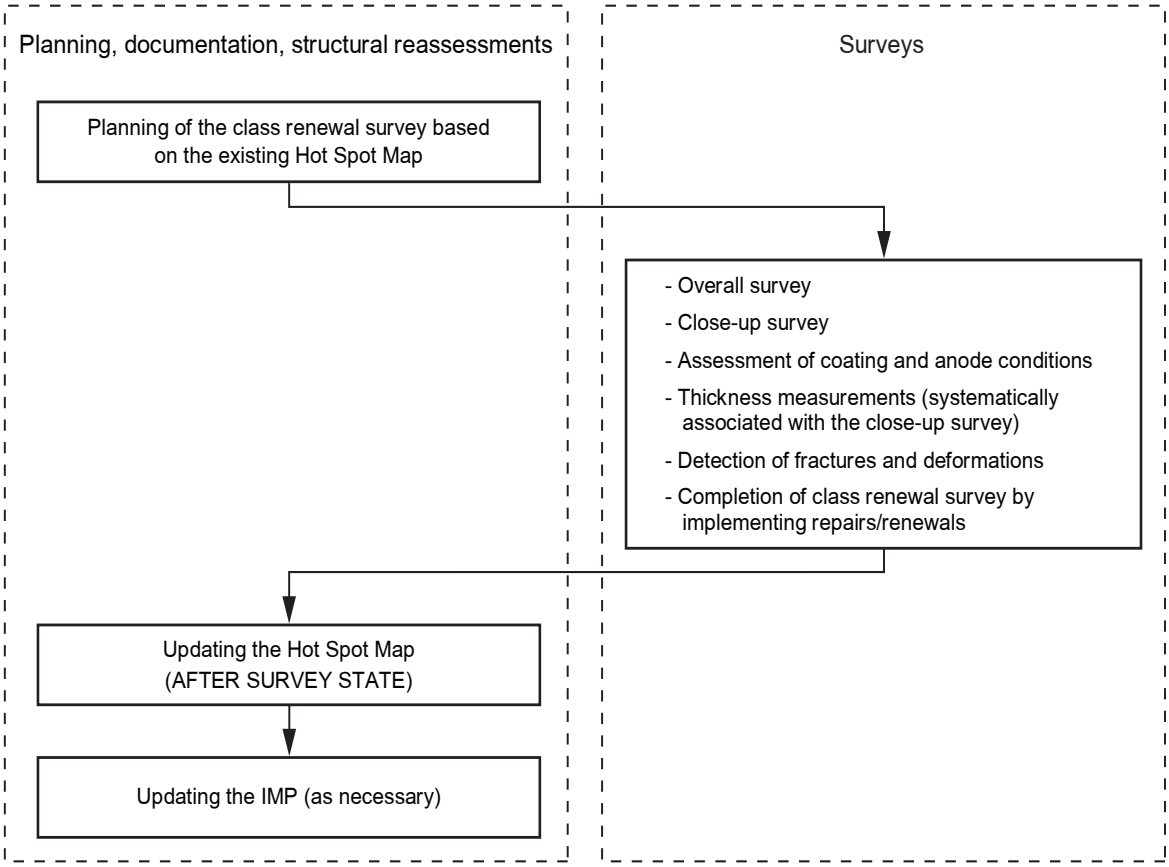
- either the immediate compliance with the requirements or the imposition of a condition of class if the non-conformity is of a minor nature or is an exceptional occurrence
- or the suspension of the **STAR-HULL** notation if the non-conformity is of a major nature or a recurrence.

- A defect or a deficiency is found in applying the IMP. The actions to be taken are the same as stated both for repair of structure/coating/equipment (first two cases above) and for the application of the IMP (third case above).
- An unexpected defect or deficiency is found or an accident occurs, i.e. not as a result of lack of maintenance or failure in the application of the IMP. The actions to be taken are the same as stated for repair of structure/coating/equipment (first two cases above).

3.3.3 The withdrawal of the **STAR-HULL** notation may be decided in different cases, such as:

- recurrent suspension of the **STAR-HULL** notation
- suspension of the **STAR-HULL** notation for more than a given period (i.e. 3 months)
- expiry or withdrawal of class.

Figure 2 : Actions to be taken in connection with the class renewal survey (STAR-HULL)



4 STAR-MACH SIS

4.1 General

4.1.1 The additional class notation **STAR-MACH SIS**, as described in Ch 1, Sec 2, [6.2.5], is assigned as per the requirements of Pt F, Ch 1, Sec 2. The present Article gives requirements for the maintenance of this notation.

4.1.2 The Maintenance Plan based on a risk analysis shall be dynamic and subject to a continuous improvement process. The Operator is to collect, analyse, review and react to equipment historical data throughout the ship operating life in order to tune the Maintenance Plan accordingly.

4.2 Annual audit and confirmatory surveys

4.2.1 The annual shipboard audit and confirmatory surveys are to be carried out in conjunction with the annual survey and in accordance with the requirements of Ch 2, App 1, [5.2].

The scope of this audit and of the confirmatory surveys is to include the ship's items which are covered by the notation in addition to the PMS machinery items.

4.3 Re-approval of the Maintenance Plan

4.3.1 Once in each five year class period, on receipt of the documents listed in [4.3.2], the Society performs a documentation technical review of the elements demonstrating a continuous improvement process of the risk analysis, including the updated maintenance plan, as described in Pt F, Ch 1, Sec 2, [2.2.2], in order to re-approve the maintenance plan.

On a case by case basis, if the risk analysis update is not documented, the Society can update the risk analysis, based on the submitted documentation, in order to re-approve the maintenance plan.

4.3.2 The following documentation is to be submitted to the Society for review:

- Methodology for continuous improvement / tuning of the Reliability Centred Maintenance (RCM) study

Note 1: See Pt F, Ch 1, Sec 2, [1.2] for the definition of RCM.

- Any modification or update in the RCM study documents since the last Maintenance Plan approval, see Pt F, Ch 1, Sec 2, [2.1.1]
- Any modification of the systems design since the last Maintenance Plan approval, see Pt F, Ch 1, Sec 2, [2.1.2]
- Any modification of the ship operation since the last Maintenance Plan approval
- Any modification of the Maintenance Plan since its last approval, including information detailed in Pt F, Ch 1, Sec 2, [2.1.3]
- Available historical data since the last Maintenance Plan approval, see Pt F, Ch 1, Sec 2, [2.1.4].

4.3.3 If the Maintenance Plan is not re-approved in due time in order to maintain the **STAR-MACH SIS** notation for the class certificate renewal, the **STAR-MACH SIS** notation will be converted in **STAR-MACH** notation.

Section 3 Availability of Machinery

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to availability of machinery, as described in Ch 1, Sec 2, [6.3]:

AVM-APS

AVM-DPS

AVM-IPS

AVM-FIRE

2 Annual survey

2.1

2.1.1 At each annual survey the Owner or his representative is to declare to the attending Surveyor that no modifications have been made to the systems affecting the notations without prior approval by the Society.

3 Class renewal survey

3.1

3.1.1 At each class renewal survey a test is to be conducted in order to ascertain that the systems affecting the notations operate satisfactorily. This test is usually to be carried out during sea trials.

Section 4 Automated Machinery Systems

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to automated machinery systems, as described in Ch 1, Sec 2, [6.4]:

AUT-UMS

AUT-CCS

AUT-PORT

AUT-IMS

2 Annual survey

2.1

2.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without prior approval by the Society.

2.1.2 The annual survey is to include:

- an examination of the engineers' log-book to verify the proper operation of automation systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions or failures which have occurred during the same period
- a general examination of the control systems covered by the notation, including a random check of the proper operation and calibration of main measuring, monitoring, alarm, and automatic shut-off devices
- a check of the fire detectors
- a check of the bilge alarms
- in case of flooding alarm provided, a check of the flooding alarms
- a running test which may be also performed by a spot check method.

3 Class renewal survey

3.1

3.1.1 The requirements given in Article [2] for annual survey are to be complied with.

An additional program of examinations, checks and tests is to be devised in agreement with the Owner and based on the operational data and experience of previous surveys. This program is to include verification of the calibration of instruments, testing of control and safety functions of the machinery and black-out test. The Owner is to produce evidence that all these checks and tests have been carried out and this will be verified by the Surveyor at random.

In addition, the proper operation of the control system of propulsion machinery is to be checked during sea trials.

Section 5 Integrated and Digital Systems

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to integrated and digital systems, as described in Ch 1, Sec 2, [6.5]:

SYS-NEQ or **SYS-NEQ-1**

SYS-COM

SYS-IBS or **SYS-IBS-1**

ASYNC-COM or **ASYNC-COM-R**

SYNC-COM or **SYNC-COM-R**

DATA-INFRA or **DATA-INFRA-STAND**

DATA-CENTRIC

2 Annual survey

2.1 All notations

2.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made to the relevant installations without the prior approval by the Society.

An examination of the log-books is to be carried out to verify the proper operation of systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions or failures which have occurred during the same period.

2.2 Notations SYS-NEQ and SYS-NEQ-1

2.2.1 The annual survey is to include:

a) general:
   - general examination of the bridge layout, with regard to the field of vision, window wipe and wash system, wheelhouse lighting and heating/cooling systems, and arrangements for the safety of navigators

b) propulsion and steering controls:
   - test of the steering gear to confirm the proper operation of the various remote controls from the wheelhouse
   - test, as far as practicable, of the propulsion control, including propeller pitch control, where fitted
   - check of the relevant indicators such as rudder angle, ahead/astern position, propeller rpm or pitch

c) navigation aids:
   - test of the satisfactory operating condition of radars
   - test of the functions available at quay side of the ARPA and collision avoidance system
   - test of the position fixing system
   - test of the gyro compass system
   - test of the echo sounding device, using appropriate scale of depth
   - test of other available alarms (sounding equipment, self-checking device, etc.), as far as practicable

d) communications:
   - test of the whistle control device from the relevant workstation
   - check of the different communication systems (internal communication, VHF radiotelephone installation, NAVTEX)

e) bridge safety and alarm system (notation **SYS-NEQ-1**)
   - test, as far as practicable, of the vigilance system and related alarm/warning transfer system.

2.3 Notation SYS-COM

2.3.1 The annual survey is to include a check of the means of transmission (hardware and software) as follows:

a) compliance of the environmental conditions of use of the components (such as temperature, power supply) with those for which they were approved

b) verification of the correct installation on board, including hardware (cabling, location of aerial, layout of console) and software (such as software version, software registry, compatibility of assembled software, man machine interface)

c) verification by means of an appropriate test of the proper function of:
   - the internal communication between the different workstations, checking at random the availability of data
   - the external communication with the shore; consideration may be given to recent records of such external communication from ship to shore and from shore to ship

d) verification of update policies description report, crisis management manual, security risk management process report.

2.4 Notations SYS-IBS and SYS-IBS-1

2.4.1 The annual survey is to include a check of the condition of the different workstations that belong to the IBS system, and a test, as far as practicable, of:

- the main functions of the IBS; in this respect, the examinations and tests given in [2.2.1] are to be carried out, where applicable
- the transitional and emergency sources required for the system and recovery of systems after restoring power
- the alarm and monitoring system in the wheelhouse, at random.

2.5 Notations ASYNC-COM, SYNC-COM, ASYNC-COM-R and SYNC-COM-R

2.5.1 The annual survey includes checking the following items:

- transmission log for the last month to confirm regular data exchanges by connected systems
- subscription validity for the external communication provider for the communication devices in use by onboard connected systems
- visual examination of antennas and cabling of the communication devices.

2.5.2 In addition to the scope defined in [2.5.1], the annual survey for notations **ASYNC-COM-R** and **SYNC-COM-R** is to include the following:

- checking if the connected system has been operated within the geographic area of the redundant coverage by randomly checking the latest passage plans and reports for activities which involve the use of the connected system
- a test of a communication device changeover following a simulated single failure due to a loss of the power supply as per the FMEA test programme for the ship-shore communication system.

2.5.3 In addition to the scope defined in [2.5.1], the annual survey for the notation **SYNC-COM** and **SYNC-COM-R** is to include the following:

- checking if the connected system is operated in the same degree of remote control (RC0, RC1, RC2 or RC3) as defined in the documentation submitted
- checking if the latency observed at the time of the most recent remote operations is below the latency threshold described in Pt F, Ch 4, Sec 3, [4.1.2]
- where the ship-shore communication system is used for remote control over Cat. II or Cat. III systems, a test of the control transfer between Remote Operations Centre and the ship.

2.6 Notations DATA-INFRA and DATA-INFRA-STAND

2.6.1 The Owner has to declare to the Society any major modifications to the data infrastructure.

2.6.2 The annual survey includes checking, the following items:

- general visual examination of the network devices
- ship-shore communication subscription has not been downgraded

Note 1: In case of diminution of the ship-shore subscription, new tests may be carried out at the discretion of the Society.

- record of failures log
- calibration of sensors and equipment, when applicable
- verification that the documentation listed in Pt F, Ch 4, Sec 4, Tab 1, items 9 and 10 is available on board
- check of the Service Level Definition report as defined in Pt F, Ch 4, Sec 4, [10.4]
- personnel for network maintenance is identified and familiar with the dedicated documentation and procedures.

2.7 Notation DATA-CENTRIC

2.7.1 The annual survey includes checking of the following items for DE ODS.

- reports generated by the DE ODS as listed in NR690, Sec 1, [3.2.6], [3.2.7] and [3.2.10], available on board at the time of survey in compliance with the regulations indicated in the Type Approval Certificate
- valid subscription with a DESS
- maintenance records for the entries concerning hardware repair, maintenance or replacement of equipment or components.
- maintenance and calibration records for the measurement instrumentation.

2.7.2 The annual survey includes checking of the following items for DE SDS:

- confirmation that all NC-A registered in NR690, Sec 1, [4.1.10] have been reported to the Society and dealt with.

3 Class renewal survey

3.1 Notations SYS-NEQ, SYS-NEQ-1, SYS-COM, SYS-IBS and SYS-IBS-1

3.1.1 The requirements given in [2] for annual survey are to be complied with. An additional program of examinations, checks and tests is to be devised in agreement with the Owner and based on the operational data and experience of previous surveys. This program is to include verification of the calibration of instruments and testing of control and safety functions of the installation. An additional program of random tests of the systems is to be performed during sea trials.

The Owner is to confirm that any modification to the hardware and software is fully documented and properly recorded.

3.2 Notations ASYNC-COM, SYNC-COM, ASYNC-COM-R and SYNC-COM-R

3.2.1 In addition to the scope defined in [2.1]and [2.5] the class renewal survey includes the following items:

- demonstration of a two-way transmission of the two test data packages between the ship and the shore in the scope of testing the communication management software
- checking the transmission log to confirm that the test data is transferred in an order established by the priority.

3.2.2 In addition to the scope defined in [3.2.1], the class renewal survey for notations **ASYNC-COM-R** and **SYNC-COM-R** includes the following items:

- checking the transmission schedule in the communication management software
- complete testing of the protection, detection and alarms as per the FMEA test programme for the ship-shore communication system.

3.2.3 In addition to the scope defined in [3.2.1], the class renewal survey for notations **SYNC-COM** and **SYNC-COM-R** includes the following items:

- it is to be demonstrated to the Surveyor that during each functional test the latency threshold described in Pt F, Ch 4, Sec 3, [4.1.2] has not been exceeded, unless the test includes degrading the latency intentionally or includes intentionally stopping the ship-shore communication.
- where the ship-shore communication system is used for remote control over Cat. II or Cat. III systems, as defined in Pt C, Ch 3, Sec 3, [3], the following tests are to be witnessed by the Surveyor for the data involved in the control loop between the connected system and the Remote Operations Centre:
  - test for detecting repetition, deletion, insertion and re-sequencing
  - test for detecting a message time out
  - test of the local emergency shut down panel for the ship-shore communication system.
- if directional antennas are used, testing of the automatic azimuth seeking by performing a 360^0 turn.
- where multiple communication devices are used, validation of the traffic balancing in separate tests by:
  - disabling the communication device with the highest outbound traffic allowance, and
  - disabling the communication devices operating on the same radio frequency band, if more than one radio frequency band is used.
- the sea trials are to be performed to validate the functional specification of ship-shore communication modes defined in Pt F, Ch 4, Sec 3, [4.1.3] with either onboard witnessing by a Surveyor, or witnessing by a Surveyor remotely from the Remote Operations Centre.

3.3 Notations DATA-INFRA and DATA-INFRA-STAND

3.3.1 In addition to the scope in [2] the class renewal survey includes the following items:

- on board testing as per Pt F, Ch 4, Sec 4, [11.2].

3.4 Notation DATA-CENTRIC

3.4.1 In addition to the scope of the annual survey as listed in [2.7], the class renewal survey includes the following items:

- carry out each test as per Master Data, confirming that satisfactory results can be obtained
- functional test by synchronising the DE ODS with the DE SDS
- confirmation of access availability for each type of the user categories described in NR690, Sec 1, [4.1.3].

Section 6 Monitoring Equipment

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to hull and tailshaft monitoring equipment, as described in Ch 1, Sec 2, [6.6]:

MON-HULL

MON-SHAFT

MON-ICE L(i)

MON-ICE G

REALTIME ( )

2 MON-HULL

2.1 Annual and class renewal survey

2.1.1 The Owner or his representative is to declare to the attending Surveyor that the hull monitoring equipment has been recently calibrated using a reference loading case.

3 MON-SHAFT

3.1 Tailshaft survey

3.1.1 General

For ships fitted with either oil lubricated or water lubricated tailshaft bearings and assigned with the additional class notation **MON-SHAFT**, in addition to the conditions stated in Ch 2, Sec 2, [5.5.3] and the additional survey requirements stated in [3.1.2] and [3.1.3], the tailshaft need not be withdrawn at both the complete and the modified surveys, provided that all the condition monitoring data are found to be within the permissible limits and the remaining requirements for the respective surveys are complied with.

3.1.2 Requirements for oil lubricated tailshaft bearings

The scope of the requirements for the modified and complete surveys is specified in Ch 2, Sec 2, [5.5.3].

When the records of the tailshaft bearing temperature readings are checked and doubts arise, the Surveyor may require the verification of the accuracy of the gauging devices.

3.1.3 Requirements for water lubricated tailshaft bearings

In the scope of the applicable survey requirements specified in Ch 2, Sec 2, [5.5.3], the following additional requirements are to be fulfilled at modified survey, when applicable:

- verification of the aft bearing clearances
- examination of the endoscopic records and results
- external examination of the water pumping and filtering system and confirmation that such equipment operate satisfactorily
- examination of water analysis records (chloride content and presence of bearing material or other particles)
- verification of alarms (flow etc.) and interlock system.

4 MON-ICE L(i) and MON-ICE G

4.1 Annual survey

4.1.1 The Owner or his representative is to declare to the attending Surveyor that:

- all the components of the ice load monitoring system are able to ensure the main functions
- the ice load monitoring equipment has been calibrated complying with the declaration of the Manufacturer for the period and procedure of calibration.

5 Real-time emissions reporting (REALTIME)

5.1 Annual survey

5.1.1 The annual survey includes checking of the following items for the ODS (Onboard Digital Solution):

- sample of reports generated available on board by the CII ODS for each reporting scheme at the time of survey
- maintenance records for the entries concerning hardware repair, maintenance or replacement of equipment or components
- maintenance and calibration records for the measurement instrumentation for the fuel quantity stored and transferred
- the ODS software version installed, including an ODS Manufacturer's declaration confirming that the software version complies with the up-to-date version of the regulations for the reporting scheme covered.

5.2 Class renewal survey

5.2.1 In addition to the scope of the annual survey as listed in [5.1.1], the class renewal survey includes the following items:

- at the time of survey, checking the ODS and SDS software versions installed
- ODS and SDS Manufacturer's declaration confirming that the software version installed complies with the up-to-date version of the regulations for the reporting scheme covered
- type approval certificate of the software installed
- SDS Manufacturer's declaration of compliance of the software version to the Type approval Certificate.

Section 7 Comfort on Board and Habitability

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.7]:

COMF-NOISE-SIS, **COMF-NOISE-Pax-SIS**, **COMF-NOISE-Crew-SIS**

COMF-VIB-SIS, **COMF-VIB-Pax-SIS**, **COMF-VIB-Crew-SIS**

COMF+-SIS

HABITABILITY

1.1.2 The Owner is to inform the Society in order to submit the ship to a survey so as to maintain the additional class notations after modifications, alterations or repairs which could affect the noise and vibration environment have occurred.

1.2 Annual survey

1.2.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without the prior approval of the Society, in particular with respect to:

- modifications/repairs carried out in crew or passenger accommodations
- HVAC/duct routing modifications
- machinery modifications, main repairs
- list of any alterations, repairs or damages.

1.3 Class renewal survey

1.3.1 The general wear of the ship can induce vibration and noise increase. A survey, including noise and vibration measurements in harbour and sea conditions as well as insulation and impact noise measurements, is to be carried out.

Measurements can be limited in comparison to initial survey measuring points depending on ship's type:

- for cargo ships, 30% of initial survey measuring points
- for passenger ships, 30% of initial survey measuring points (excluding passenger cabins) and 10% of initial survey measuring points in passenger cabins.

In case of additional class notation **HABITABILITY**, noise measurements in harbour and sea conditions, insulation and impact noise measurements are to be carried out only in case of significant modifications, as stated in [1.2.1].

Section 8 Environmental Protection

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to pollution prevention systems, as described in Ch 1, Sec 2, [6.8]:

CLEANSHIP or **CLEANSHIP-CEMS**

CLEANSHIP SUPER( ) or **CLEANSHIP SUPER( )-CEMS**

AWT-A or **AWT-B** or **AWT-A/B**

BWE

BWT

EXGEM

GWT

GWT-B

NDO-x days

OWS-x ppm

NOX-x%

SOX-x%

EGCS-SCRUBBER

SEEMP

ULEV

VCS

2 Prevention of sea pollution

2.1 First annual survey

2.1.1 Confirmation of no discharge period

During the first annual survey, the Surveyor collects the results of tests and measurements undertaken by the Shipowner according to Pt F, Ch 9, Sec 2, [4.2.2]. These results are used to confirm or modify the no discharge numeral appended to the notations **NDO-x days**.

2.1.2 Audit

An onboard audit of the procedures, as required in Part F, Chapter 9, is done by the Surveyor in order to ascertain that the Master and crew are familiar with the ship's onboard procedures for preventing pollution and in order to check that the discharge records mentioned in Part F, Chapter 9 are properly completed.

2.2 Annual survey

2.2.1 General

The survey is to include, as far as practicable:

- confirmation of the installation being in accordance with the plans. If modifications have been made, checking that these modifications are in accordance with approved documentation (for all additional class notations related to pollution prevention systems)
- confirmation that the IOPP certificate is valid (for **CLEANSHIP**, **CLEANSHIP SUPER** and **OWS-x ppm**)
- general examination of the most important components of the sewage treatment plant, the garbage treatment plant, the oil filtering equipment, the incinerators if fitted, the comminuters and grinders, the hazardous wastes recovery unit if fitted (for **CLEANSHIP** and **CLEANSHIP SUPER**)
- general examination of the holding tanks, including examination of a possible corrosion protection of the inside surfaces of the tanks which are to be in good condition (for **CLEANSHIP** and **CLEANSHIP SUPER**)
- verification of the satisfactory condition of the standard discharge connections for oil and wastewater (for **CLEANSHIP**, **CLEANSHIP SUPER**, **AWT-A**, **AWT-B**, **AWT-A/B** and **NDO-x days**)

- external examination and operating tests of the equipment and systems as required in Pt F, Ch 9, Sec 2 to Pt F, Ch 9, Sec 7 (for all additional class notations related to pollution prevention systems).
- confirmation that the hazardous wastes are properly stowed as specified in the garbage management plan (for **CLEANSHIP**, **CLEANSHIP SUPER** and **NDO-x days**).

For some pollution prevention system of [1.1.1], the survey is also to include, as far as practicable:

- ascertainment of the correct concentration of the disinfectant in the effluent (for **CLEANSHIP**, **CLEANSHIP SUPER**, **AWT-A**, **AWT-B**, **AWT-A/B**, **GWT** and **GWT-B**)
- ascertainment of possible concentration of other chemicals in the effluent (for **CLEANSHIP**, **CLEANSHIP SUPER**, **AWT-A**, **AWT-B**, **AWT-A/B**, **GWT** and **GWT-B**).

2.2.2 Review of records

The following records for the preceding 12 months are to be reviewed as necessary:

- oil record book (for **CLEANSHIP**, **CLEANSHIP SUPER** and **OWS-x ppm**)
- garbage record book (for **CLEANSHIP** and **CLEANSHIP SUPER**)
- records of ballast exchanges after international voyages (for **BWE** and **BWT**)
- ballast water record book (for **BWE** and **BWT**)
- sewage and grey water discharge book (for **CLEANSHIP**, **CLEANSHIP SUPER**, **GWT**, **GWT-B** and **AWT-A**, **AWT-B**, **AWT-A/B**)
- emissions record (for **CLEANSHIP SUPER**, **NOX-x%** and **SOX-x%**)
- results of the tests on effluents done by the Shipowner according to Pt F, Ch 9, Sec 2, [4.2.3] for any pollution prevention system of [1.1.1] (for **AWT-A**, **AWT-B**, **AWT-A/B**).

2.3 Class renewal survey

2.3.1 The requirements given in [2.2] for annual surveys are to be complied with. In addition, for all additional class notations related to pollution prevention systems, the following is to be carried out:

- demonstration, under working conditions, of the correct functions of the most important components of the sewage treatment plant or AWT plant if fitted, the garbage treatment plant, the oil filtering equipment, the incinerators if fitted, the comminuters and grinders, the hazardous waste recovery unit if fitted
- ascertainment of the correct function of the alarms.

3 Prevention of air pollution

3.1 Annual survey

3.1.1 Ozone depleting substances (CLEANSHIP, CLEANSHIP SUPER)

a) A procedure for annual verification of the system and equipment condition by an authorised organisation is to be settled. The interval of this verification may be extended in case of predictive maintenance scheme approved by the Society.

b) A procedure for weekly verification and maintenance is to be settled enabling to:
   - check the tightness of the circuits by satisfactory means (such as weighing or vessel pressure monitoring)
   - identify the location of possible leakage
   - carry out necessary corrective actions.

   Record books tracing all the operations carried out on board the ship according to the procedures mentioned in the NOx Technical Code are to be kept on-board and updated after each intervention. They are to include in particular the following records:
   - presence of leak and corrective action
   - volume of substance recovered and indication of the storage location
   - volume of substance recharged
   - volume of substance consumed
   - volume of substance disposed.

   The survey is to include the following items:
   - verification that the above procedures for annual and weekly checking of systems with ozone depleting substances are available on board
   - confirmation that appropriate entries are being made in the record book for ozone depleting substances
   - test of the proper operation of the leak detectors and related audible and visual alarms

c) Review of ozone - depleting substance record book.

3.1.2 NOx emission (CLEANSHIP SUPER, NOX-x%)

- The procedures for demonstrating compliance with NOx emission limits on board are given in the NOx Technical Code.
- During the annual survey, it is to be confirmed that the NOx emission control procedure is available on-board
- NOx emission records.

3.1.3 SOx emission (CLEANSHIP, CLEANSHIP SUPER, SOX-x%)

Procedures are to be established to detail the maximum sulphur content in the fuel oil purchase orders, and to check the actual content of sulphur at the delivery of bunker.

In the case the actual sulphur content is checked by sampling testing and analysis, procedures are to be carried out in accordance with a recognised standard acceptable to the Society.

The fuel management procedures are to be established and followed as part of the certified ship management system of the ship.

Records on purchase orders and on type of checking carried out, including results, are to be kept on-board.

The survey is to include the following items:

- verification that the above procedures for defining, ordering and checking fuel oils for control of SOx emission are available on-board
- confirmation that fuel oil sulphur content records are available on-board
- emission record (when exhaust gas cleaning is provided (EGC)).

3.1.4 Shipboard incineration (CLEANSHIP, CLEANSHIP SUPER)

The annual survey is to include the following items, when fitted:

- external examination of the incinerators and confirmation that such equipment operates satisfactorily
- test of the alarms, exhaust monitoring devices and emergency stop located outside the compartment.

3.1.5 Exhaust Gas Cleaning System-Scrubber (EGCS-SCRUBBER)

The annual survey is to include the following items, when fitted:

- examination of the logbooks with regard to correct functioning of the Exhaust Gas Cleaning Systems, emissions monitoring and washwater monitoring systems
- confirmation that the approved Operating and Maintenance Instruction Manual is onboard
- confirmation that the Instrumentation, Control, Monitoring, and Safety equipment of each system unit are operating satisfactorily
- examination of emergency shutdown or bypass valves, remote operating valves, and machinery and equipment associated with processing or distribution of exhaust gases and, as far as practicable, testing of the emergency shutdown of the system
- examination and functional test of all tanks, piping, hoses, pumps, strainers, separators, filtration units, dosing systems, and equipment associated with processing of washwater, injection of reductant or collection of exhaust residues
- examination of drip trays, overflow arrangements, shielding or insulation installed for the protection of personnel or of the ship
- examination of electrical equipment associated with the operation or monitoring of Exhaust Gas Cleaning Systems
- confirmation that Personal Protective Equipment (PPE) and facilities are available onboard and maintained in good conditions
- external examination of all components including scrubber units, of insulation, etc., including foundations and attachments
- confirmation of correct operation of all rotating and reciprocating components, such as exhaust gas fans, water treatment pumps, dry handling conveyors, ventilation fans
- verification of the correct operation of all remotely operated or automatically controlled valves in the exhaust, water treatment or dry handling systems
- examination of the Exhaust Gas Cleaning System during working condition. Multi-mode SOx scrubbers are to be tested in all operational modes, as far as practicable.

3.2 Class renewal survey

3.2.1 The requirements given in [3.1] for annual surveys are to be complied with. In addition, the following is to be carried out:

- for **CLEANSHIP SUPER**, **NOX-x%** and **SOX-x%**, confirmation of the operation and calibration of the emissions analysers, if fitted

- for the Exhaust Gas Cleaning System (**EGCS-SCRUBBER**), the associated systems and monitoring equipment, the following is also to be carried out:
  - visual inspection of all washwater, water treatment pumps and reductant dosing pumps, including openings, for examination, as deemed necessary by the Surveyor
  - visual inspection of all bypass, mixing, isolating, shut-down or control valves in the exhaust, water treatment and dosing systems
  - visual examination and test of all mechanical, hydraulic and pneumatic control actuators and their power systems, as deemed necessary by the Surveyor
  - dock trials on control systems, in order to verify correct operation of the automatic functions, monitoring and alarms systems, safety systems, including override of system functions if provided, manual control and automatic changeover of designated machinery associated with the Exhaust Gas Cleaning Systems
- external examination and operating tests of the equipment and systems, as required in Pt F, Ch 9, Sec 2 to Pt F, Ch 9, Sec 7 (for all additional class notations related to pollution prevention systems).

3.3 Ultra-low emission vessel (ULEV)

3.3.1 At each annual and class renewal survey, the following is to be checked:

- proper operation of the NOx Control Diagnostic (NCD) and Particulate Control Diagnostic (PCD) systems, when fitted
- proper operation of the recording of the status of the engines related to the operations in the ULEV mode
- confirmation that no modification has been carried out without prior approval of the Society on the engines covered by the **ULEV** additional class notation. In case of replacement or modification of an engine, testing as per Pt F, Ch 9, Sec 8 may be required unless otherwise duly justified and documented by the engine's manufacturer.

3.4 Continuous emission monitoring system (CEMS)

3.4.1 At each annual and class renewal survey, the following is to be checked:

- confirmation that the waste discharge and air emission parameters required to be monitored and recorded are transmitted on a regular basis via a satellite communication system to a shipowner facility ashore
- confirmation that such information is made available to the Surveyor upon request.

3.5 Exhaust Gas Measurement (EXGEM)

3.5.1 At each annual and class renewal survey, it is to be checked that no modification has been carried out without prior approval of the Society on the engines covered by the **EXGEM()** additional class notation.

In case of replacement or modification of an engine, testing as per Pt F, Ch 9, Sec 9 may be required unless otherwise duly justified and documented by the engine's manufacturer.

4 Ship Energy Efficiency Management Plan (SEEMP)

4.1 Intermediate and class renewal surveys

4.1.1 Onboard verification

The onboard survey is to include the following items:

a) verification that the implementation of the energy measures is properly recorded

b) verification by sampling technique that the procedures to measure the data are properly implemented and that the measuring devices are properly maintained and/or calibrated

c) verification that EEOI and other EnPIs defined in the planning phase, if any, are properly calculated from the collected data over the last 6 months of the ship’s operations, and recorded

d) verification that the SEEMP is onboard and that the record books are kept up to date.

5 VCS

5.1 Annual survey

5.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without the prior approval of the Society.

5.1.2 The annual survey is to include:

- an examination of the instruction manual to verify the layout of the complete system and confirm the correspondence to the actual system fitted on board
- a general examination of components of the system such as vapour piping (including manifold and hoses), cargo tank gauging equipment, cargo tank level alarms, vapour pressure alarms and vapour balancing, if any, to verify their satisfactory condition.

5.2 Class renewal survey

5.2.1 The requirements given in [5.1] for annual survey are to be complied with. Additionally, the following is to be carried out:

- a pressure test of the vapour piping, including manifold and hoses
- a check and test of the instrumentation (cargo tank gauging equipment, cargo tank level alarms, vapour pressure alarms)
- an inspection and test of the vapour balancing equipment, if any
- a running test of the system.

Section 9 Refrigerating Installations

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to refrigerating installations, as described in Ch 1, Sec 2, [6.9]:

REF-CARGO

REF-CONT

REF-STORE

as well as the following specific notations:

-PRECOOLING

-QUICKFREEZE

-AIRCONT

2 Annual survey

2.1 General

2.1.1 The annual survey of refrigerating installations (plants and spaces) is to be carried out with the installation in running condition and, whenever possible, during unloading operations or without cargo in refrigerated spaces.

2.1.2 The refrigeration installation log-book (or other similar record) is to be made available to the Surveyor for examination of the records since the last survey, and checking any unusual consumption of refrigerant, breakdown or defective items.

2.1.3 Decks, bulkheads or ship sides adjacent to refrigerated spaces are to be checked as far as practicable in order to verify the absence of cold spots.

2.1.4 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made to the installations that could affect the class notations without the prior approval by the Society.

2.2 Refrigerating plant

2.2.1 Refrigerating machines and related accessories, including compressors, condensers, pumps and piping are to be examined externally and in running condition. Insulation of insulated parts is to be checked for possible signs of humidity or wear. The tightness of the system is to be ascertained.

2.2.2 The electrical installation is to be generally examined, and the insulation resistance of the installation is to be checked as deemed necessary by the Surveyor.

2.2.3 If independent from the electrical installation of the ship, the generators supplying electrical power to the refrigerating installation are to be examined to the same extent as described in Ch 3, Sec 1, [3.3].

2.3 Refrigerated spaces

2.3.1 Refrigerated spaces are to be generally examined to ascertain the condition of:

- insulation lining; removable panels or covers may be dismantled for examination of insulation, as deemed necessary by the Surveyor
- hatch covers, doors, access panels (including gaskets and securing devices) and dampers of ventilation ducts
- air coils, coolers, fans, air ducts, brine piping systems and associated equipment; cleanliness of grids
- bilge wells
- protection of fans and other rotating machinery, battens for air circulation within the space.

2.4 Instrumentation and safety devices

2.4.1 Thermometers used for measurement of temperature in refrigerated spaces, air ducts and other elements of the installation are to be examined and checked for their accuracy. The Surveyor may require the calibration of one or more thermometers and one or more automation devices to be checked in his presence or, failing this, a certificate of calibration is to be presented to him.

2.4.2 The following alarm and safety devices are also to be checked, as required or fitted:

- alarm and emergency shutdown devices
- CO_2 detectors, if any
- refrigerant leakage detectors
- access to spaces, with regard to possibilities of escape and prevention of personnel being trapped within spaces.

2.5 Notation -AIRCONT

2.5.1 The requirements of this item apply to installations assigned the notation **-AIRCONT**. They are additional to the requirements given in [2.1] to [2.4].

2.5.2 The installation is to be visually examined and tested to verify that the controlled atmosphere system remains satisfactory. The survey is to include the following items:

- examination of voyage logs, records of controlled atmosphere zone air-tightness and calibration of instruments
- confirmation that an operating and safety manual is available on board, complete and duly endorsed by the officers responsible
- examination of controlled atmosphere zone sealing arrangements including cleats and hinges, pressure/vacuum valves, door locks, ventilation of adjacent spaces, warning notices
- test to design pressure of controlled atmosphere zones for air-tightness. Tests by ship's staff within one month prior to the survey may be accepted, based on a written report by the Master subject to visual inspection confirming the air-tightness.
- operation and performance test of the gas supply equipment, including controls, alarms, interlocks and safety devices
- examination and test of ventilation arrangements including fans as deemed necessary
- examination of electrical supply arrangements
- check of gas analysers, analysing equipment and calibration
- check of relative humidity sensors and calibration
- check of permanent and portable gas monitoring, including calibration, and of personnel safety equipment.

3 Class renewal survey

3.1 General

3.1.1 The installation is to be surveyed out of operation in order to enable examinations in opened condition of certain items.

3.1.2 After completion of these examinations, the installation is to be checked while cooling down from the ambient temperature to the lowest design temperature for the refrigerated spaces. The plant is to be examined for ability to maintain stable air temperatures and defrosting operation is to be checked.

3.2 Refrigerating plant

3.2.1 The equipment is to be dismantled to a sufficient extent to enable the following examinations:

- reciprocating compressors: examination of cylinders, valves, crankshaft, connecting rods, pistons, bearings and safety devices
- screw compressors, turbo compressors and pumps: parts subject to wear and tear; the equipment may not need to be opened up if log-book records and a running test show proper functioning.

3.2.2 Prime movers of pumps, compressors and fans are to be examined to the same extent as required in Ch 3, Sec 3, [3] for similar equipment for the class renewal survey of machinery.

3.2.3 Condensers and coolers are to be opened up for examination of tube plates, tubes and end covers.

Condensers are to be pressure tested to 1,2 times the rated working pressure.

3.2.4 Insulation of insulated parts (such as piping and pressure vessels) may need to be removed at random, to ascertain the condition of such parts and of the insulation itself.

3.2.5 The electrical installation of the plant is to be examined and insulation tests checked.

3.2.6 If independent from the electrical installation of the ship, the generators supplying electrical power to the refrigerating installation are to be examined to the same extent as described in Ch 3, Sec 3, [3.6].

3.2.7 Sea connections to condenser circulating pumps are to be opened up and piping examined.

3.2.8 Other equipment, such as oil separators on refrigerant systems, filters and dehydrators, are to be examined to the satisfaction of the Surveyor.

3.3 Refrigerated spaces

3.3.1 The lining and insulation in the refrigerated spaces may need to be partly removed for examination of its condition. The condition of the hull part under the insulation is then ascertained, as well as that of girders, meat rails, hooks and coil/cooler supports.

3.3.2 Air coolers and coils are to be examined and pressure tested at the rated working pressure and at 1,2 times such pressure in the case of hydraulic test after repairs.

3.3.3 Air cooler fans are to be examined and their prime movers are to be checked to the same extent as stated in [3.2.2].

3.3.4 The electrical installation in the refrigerated spaces is to be examined and insulation tests checked.

3.3.5 Defrosting and heating systems are to be examined to the satisfaction of the Surveyor.

3.4 Instrumentation and safety devices

3.4.1 Pressure relief valves and safety disks are to be checked. Discharge piping is to be examined with regard to integrity and non-obstructed flow.

3.5 Notation -AIRCONT

3.5.1 The requirements of this item apply to installations assigned the notation **-AIRCONT**. They are additional to the requirements given in [3.1] to [3.4].

3.5.2 Air compressors, pressure vessels and other equipment are to be examined to the same extent as required in Ch 3, Sec 3, [3] for similar equipment for the class renewal survey of machinery.

3.5.3 Each controlled atmosphere zone is to be subjected to an air-tightness test.

Section 10 Navigation in Cold Environment

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.10]:

ICE CLASS IA SUPER, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC**

ICE CLASS ID

YOUNG ICE 1, **YOUNG ICE 2**

ICE

COLD DI

COLD BASIC (H t_{DW}, E t_{DE})

COLD (H t_{DW}, E t_{DE})

COLD CARGO

2 ICE, ICE CLASS and YOUNG ICE notations

2.1

2.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to navigation in an ice environment, as described in Ch 1, Sec 2, [6.10]:

ICE CLASS IA SUPER, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC**

ICE CLASS ID

YOUNG ICE 1, **YOUNG ICE 2**

ICE

2.2 Class renewal survey

2.2.1 Thickness measurements

Additional systematic thickness measurements are required in the areas where strengthening for navigation in an ice environment has been applied in accordance with the requirements in Part F, Chapter 8, as per Tab 1.

2.2.2 Sea chests

During the bottom survey in dry condition which is to be carried out concurrently with the class renewal survey (see Ch 3, Sec 3, [2.1]), the specific arrangements related to sea chests protected against ice blocking, such as heating coil and cooling water discharge piping, are to be checked.

Table 1 :

Age of ship (in years at time of class renewal survey)		
age ≤ 5	5 < age ≤ 10	age > 10
	selected plates	all plates
		selected internal frames, stiffeners and stringers

3 COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

3.1 General

3.1.1 The requirements of this Article apply to ships which have been assigned the following additional class notations defined in Ch 1, Sec 2, [6.10.4]:

COLD DI

COLD BASIC (H t_{DH}, E t_{DE})

COLD (H t_{DH}, E t_{DE})

3.2 Annual survey

3.2.1 The annual survey is to include:

a) Availability on-board of the following documentation:
- when the additional class notation **COLD DI** is assigned:
  - manual for de-icing procedures
- when the additional class notation **COLD BASIC (H t_{DH}, E t_{DE})** or **COLD (H t_{DH}, E t_{DE})** is assigned:
  - manual for de-icing procedures
  - stability manual including loading conditions with ice accretion.

b) Electrical installations (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**):
- general external examination of the arrangements for heated bridge windows and heated cargo control room windows, the de-icing systems for all escape doors and all main doors giving access to the deck area, the heating of bunker lines on deck, the heating of scupper lines, the heating of whistle, the heating of antennas and similar equipment
- general external examination of the socket outlets provided close to each lifeboat to supply the heating system of lifeboat engine
- test of the de-icing systems including indications and alarms, at random
- test, as far as practicable, of the sequence of ventilation in loop in the air inlet compartment on air intakes for HVAC, machinery room and emergency generator room.

c) Machinery installations:
- general external examination and testing at random of the ventilation system for the machinery compartments (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general external examination of de-icing arrangements for:
  - sea inlets, overboard discharges (above the waterline and up to 1 m below the ballast waterline), air vent heads (for **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
  - air pipes and their automatic closing devices where fitted, sounding pipes and overflow pipes (for cooling water recirculation tanks and water ballast tanks), piping systems in exposed areas including ro-ro spaces, spray waterlines, exposed deck scuppers, washing lines and discharge lines (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination, as far as practicable, of the de-icing arrangements provided to the water ballast tanks adjacent to the shell plating and located totally or partly above the ballast waterline (for **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination, as far as practicable of the de-icing arrangements provided to other tanks subject to freezing (such as fresh water, fuel oil tanks) (for **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination of the specific heating arrangements provided for the cargo P/V valves (for **COLD (H t_{DH}, E t_{DE})**)
- test of the de-icing systems including indications and alarms, at random (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**).

d) Other equipment:
- general external examination of the de-icing system on the exposed deck to allow the de-icing of the ship areas where the crew may have access during the normal operation of the ship (manoeuvring area, loading and unloading area, area around the access to the deckhouses, passageways, gangways, walkways) (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination of the specific arrangements for protection of equipment fitted on deck (foam monitors, davits, lifeboats, lifejackets lockers, winches, windlasses, cranes, other deck machinery) and of helideck and its access (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination of personal protection and evacuation equipment which are to be suitable for the design temperature (for **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination of specific protection fitted on cargo valves and associated instrumentation, such as tarpaulins (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination of appropriate gratings and stairs (including escapes, access to lifeboats and to winching areas) for facilitation of circulation on exposed decks and of safety lines where provided (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- general examination of heating arrangement for hydraulic oil system of deck machinery, where provided (for **COLD (H t_{DH}, E t_{DE})**)
- general examination of arrangements made to ensure 20°C in the accommodation and of arrangements made to control humidity, for HVAC plant (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)
- verification that sufficient hand tools or similar equipment for manual de-icing operations are available on-board and stored on the main deck at locations protected from accumulation of ice (for **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**)

- general examination of navigation and communication equipment which are to be suitable for the design temperature (for **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})**).

3.3 Class renewal survey

3.3.1 The requirements given in [3.2] for annual survey are to be complied with. In addition, a test of the de-icing systems, including indications and alarms, is to be carried out.

4 COLD CARGO

4.1 General

4.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **COLD CARGO**, as defined in Ch 1, Sec 2, [6.10.5].

4.2 Annual survey

4.2.1 The annual survey is to include:

- general examination of the heating system
- general examination of steam/thermal oil pipes insulation for the intended heaters
- general examination of the specific heating arrangements and insulation provided for valves serving the heaters
- general examination and verification of the temperature sensing/monitoring devices and alarms
- general examination of the de-icing arrangements provided for the water ballast tanks adjacent to the cargo tanks
- test of the de-icing systems including indications and alarms, at random
- general examination of the circulating arrangements provided for the liquid cargo in the tanks during heating-up.

4.3 Class renewal survey

4.3.1 The requirements given in [4.2] for annual survey are to be complied with. In addition, a test of all the de-icing systems, including indications and alarms, is to be carried out.

Section 11 Protection against Chemical, Biological, Radiological and Nuclear Risk

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.14]:

CBRN

BIORISK MANAGED, **BIORISK SECURED**

2 Chemical, biological, radiological or nuclear hazards

2.1 General

2.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **CBRN** protection as described in Ch 1, Sec 2, [6.14.1], which may be completed by **-WASHDOWN** and/or **-AIR BLAST RESISTANCE**.

2.1.2 At each survey, the Owner or his representative is to declare to the attending surveyor that no significant modifications have been made to the installations that could affect the class notations without prior approval by the Society.

2.2 Annual survey

2.2.1 The CBRN operation manual is to be made available to the Surveyor and may be used as a basis for survey.

An examination of the log-books is to be carried out to verify the proper operation of the systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions and failures which have occurred during the same period.

2.2.2 The annual survey is to include:

- Examination and testing, as feasible, of airlocks, cleansing station(s) and CBRN protection plant(s)
- Examination of CBRN detection system, check number and location of each detector
- Verification that each opening in the citadel and shelter boundaries is provided with a closing appliance in working order and suitably marked
- Verification of remote indication, alarm and control functions at the CBRN control station
- Verification of ventilation non-return devices
- Verification of water traps or equivalent devices against air entrance
- Examination of CBRN ventilation system, including ducts, filters and dampers
- For ships for which the additional class notation **CBRN** is completed by **-WASHDOWN**: Examination of pre-wetting and wash down system, including piping, valves and nozzles
- For ships for which the additional class notation **CBRN** is completed by **-AIR BLAST RESISTANCE**:
  - examination of the protective device
  - checking that the remotely controlled means of closing ventilation openings are in working order.

2.3 Class renewal survey

2.3.1 The CBRN operation manual is to be made available to the Surveyor and may be used as a basis for survey.

An examination of the log-books is to be carried out to verify the proper operation of the systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions and failures which have occurred during the same period.

2.3.2 The class renewal survey is to include:

- Verification of gas tightness of citadel, shelter, airlock and cleansing station boundaries. For this purpose, the tested spaces are to be pressurized with all openings closed, and the air supply is to be isolated. It is then to be checked that the pressure can be maintained for 10 min in the tested space.
- Check of overpressure levels in the citadel with the collective protection ventilation system working. The required overpressure is to be held for at least 30 min. The test may be carried out with dummy filters in lieu of CBRN filters. This test may be carried out with the ventilation system fed by the main power source. Proper functioning the ventilation system when fed by the emergency power source is also to be checked.
- Check of gastightness of engine enclosure and associated supply and exhaust ducts, for engines with dedicated air supply

- Check of air conditioning capability under CBRN condition.
- Functioning test of the CBRN detection system. Each line is to be tested from the level of the detector, with means defined by the system supplier.
- For ships for which the additional class notation **CBRN** is completed by **-WASHDOWN**, functioning test of the pre-wetting and wash down system, including verification that all external surfaces are properly covered, verification of water drainage and verification of section valve remote operation.

3 Biological risk control

3.1 General

3.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **BIORISK MANAGED** or **BIORISK SECURED**, as defined in Ch 1, Sec 2, [6.14.2].

At each survey, the Owner or his representative is to declare to the attending surveyor that no changes or updates of the Outbreak Management Plan have been made since the last version that was submitted to the Society.

3.2 BIORISK MANAGED

3.2.1 Annual and class renewal survey

The annual and class renewal surveys are to include:

- verification that the Outbreak Management Plan is available on board
- verification that there is a register of PPEs and medical supplies required by the Outbreak Management Plan on board
- verification that the posters, signs and markings required by the Outbreak Management Plan are available on board
- verification that the operational records required by the Outbreak Management plan are available.

3.3 BIORISK SECURED

3.3.1 Annual survey

In addition to the requirements for **BIORISK MANAGED** given in [3.2.1], the annual survey is to include:

- verification that a means of monitoring body temperature is available on board
- verification that one totally enclosed stretcher and one totally enclosed wheelchair are available on board
- verification that a means of communication for the quarantine area is available onboard.
- verification that the filters installed in the ventilation systems as required in Pt F, Ch 10, Sec 6, [3.2.2] and Pt F, Ch 10, Sec 6, [3.3] have been replaced in accordance with manufacturer's specifications.

3.3.2 Class renewal survey

In addition to the requirements for annual survey given in [3.3.1], the class renewal survey is to include:

- functional testing of the ventilation arrangements for the quarantine area and for the accommodation spaces and normally manned control stations. It is to be checked that the ventilation system is functioning properly with the air filtration or alternative air disinfection system working
- functional testing of the means of monitoring the access to the quarantine area
- functional testing of the means of monitoring body temperature.

Section 12 Manoeuvring, Mooring, Anchoring and Position Keeping

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.15]:

HEADING CONTROL

SPM

DYNAPOS

2 Heading control

2.1 General

2.1.1 The requirements of this Article apply to ships which have been assigned one of the following additional class notations **HEADING CONTROL-DS** or **HEADING CONTROL-IS** as described in Ch 1, Sec 2, [6.15.2].

2.2 Annual survey

2.2.1 At each annual survey the Owner or his representative is to declare to the attending Surveyor that no modifications have been made to the systems affecting the notations without prior approval by the Society.

2.3 Class renewal survey

2.3.1 At each class renewal survey a test is to be conducted in order to ascertain that the systems affecting the notations operate satisfactorily. This test is usually to be carried out during sea trials, as described in Pt F, Ch 11, Sec 2, [5.2].

3 SPM

3.1 Annual survey

3.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant alterations have been made without the prior approval of the Society.

3.1.2 The annual survey is to include:

- a general examination of all components of the installation (bow chain stoppers, bow fairleads, pedestal roller fairleads, winches and capstans) to verify their satisfactory condition
- an examination of the hull structures supporting and adjacent to the installation to verify that no deformations or fractures have developed.

3.2 Class renewal survey

3.2.1 The class renewal survey is to include:

- a close-up examination of all components of the installation (bow chain stoppers, bow fairleads, pedestal roller fairleads, winches and capstans) to verify their satisfactory condition
- a close-up examination of the hull structures supporting and adjacent to the installation to verify that no deformations or fractures have developed.

Where deemed necessary by the Surveyor, non-destructive tests for measuring thickness deterioration or checking for fractures or other defects may be required.

4 DYNAPOS

4.1 Annual survey

4.1.1 The Owner or its representative is to provide a testing program taking into account the FMEA proving trials to the satisfaction of the attending Surveyor.

The Owner or his representative is to declare to the attending Surveyor that no significant alterations have been made without the prior approval of the Society.

4.1.2 The annual survey is to include:

- an examination of the log-books to verify the proper operation of systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions or failures which have occurred during the same period
- a general examination of visible parts of thrust units, including their prime movers
- a general examination of the electrical power system and switchboards
- a general examination of control, monitoring and alarm devices
- a running test of the installation, including random test by simulation of different alarms and relevant backup systems and switching modes
- confirmation that the DP system has been maintained in accordance with applicable parts of the Rules and is found in good working condition
- for ships granted with the additional class notation **DYNAPOS AM/AT-R** or **DYNAPOS AM/AT-RS**, test of all important systems and components to document the ability of the DP vessel to keep position after single failures associated with the assigned equipment class and to validate the FMEA and operations manual. As a minimum, there should be tests of the failures of position and environmental reference systems, thrusters, power generation and distribution systems, position controls and UPS's. Such tests are to be carried out at sea with the DP system in running condition. The results of these tests are to be recorded and kept on board.

Note 1: For ships granted with the **-DDPS** notation, reference is made to Ch 1, Sec 2, [6.15.5] and Pt F, Ch 11, Sec 5, [11] : tests to be carried out at sea may be performed by ship's crew without attendance of a Surveyor and will be reviewed digitally by a Surveyor.

- verification that DP system tests carried out and results are recorded and kept on board.

4.1.3 Every time a defect is discovered and corrected or an accident occurs which affects the safety of the DP vessel, or whenever significant repairs of alterations are made, a survey is to be carried out.

After such survey, tests are to be carried out to demonstrate full compliance with the applicable provisions of the Rules, as necessary.

The type of tests carried out and results are to be recorded and kept on board.

4.2 Class renewal survey

4.2.1 In general, the class renewal survey consists of the checks detailed in [4.2.3] to [4.2.6]. However, a specific program of the class renewal survey prepared by the Owner and taking into account the maintenance procedures of the Manufacturers of the system is to be submitted to the Society prior to the survey.

4.2.2 The Owner is to confirm that any modification to the software is fully documented and properly recorded.

4.2.3 Prime movers of thrust units, electrical installations and electric power generators are to be surveyed and tested to the same extent as required in Ch 3, Sec 3, [3] for similar equipment for the class renewal survey of machinery.

4.2.4 During the bottom survey in dry condition which is to be carried out concurrently with the class renewal survey (see Ch 3, Sec 3, [2.1]), the thrust units are to be generally examined. Other checks are to be carried out, such as taking clearances, examination of the orientation device or variable pitch system, if any, verifying tightness devices, examination of results of lube oil analysis for detection of possible deterioration of internal gears and bearings. Dismantling of internal parts may be required if the above examinations are not satisfactory.

4.2.5 Sensors and position reference systems are to be tested to check their accuracy. Failure of sensors is to be simulated in order to check the related alarm system and switching logic. Switch over to the different reference systems is to be checked.

4.2.6 A complete test of all systems and components and the ability to keep position after single failures associated with the assigned equipment class is to be carried out. The type of tests carried out and results should be recorded and kept on board. The operational tests are to include:

- test of each thrust unit at different loads, pitches and speeds, and check of monitoring devices
- test of the thrust controls in the different available modes (automatic, semi-automatic, manual), and the switch over between the different modes
- test of the different alarms and safety systems, using simulated conditions as necessary
- test of power supply failure and verification of intended functioning in such cases
- final test to verify the capacity of the system to keep the ship in the intended position and maintain the heading, with related alarm and monitoring devices. The accuracy of the system is to be checked and compared with previous results for evaluation of drift
- test of the power management system.

Section 13 Cargo Operation, Securing and Safety

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.16]:

CARGOCONTROL

EVOC

PaRoll1 and **PaRoll2**

LI-LASHING

2 CARGOCONTROL

2.1 General

2.1.1 The requirements of this Article apply to ships which have been assigned the following additional class notation **CARGOCONTROL** as described in Ch 1, Sec 2, [6.16.5].

2.2 Annual survey

2.2.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without the prior approval of the Society.

2.2.2 The annual survey is to include:

- a general examination of the items of equipment regarding remote control of operations and gauging/alarms provided for all those parameters that are required to be kept under control to verify their satisfactory condition
- a running test which may be also performed by a spot check method.

2.3 Class renewal survey

2.3.1 The requirements given in [2.2] for annual survey are to be complied with. Additionally, the following is to be carried out:

- a check and test of the instrumentation fitted to the components of the system
- an overall running test of the system.

3 EVOC

3.1 General

3.1.1 The requirements of this Article apply to ships which have been assigned the following additional class notation **EVOC** as described in Ch 1, Sec 2, [6.16.12].

3.2 Annual survey

3.2.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without the prior approval of the Society.

3.2.2 The annual survey is to include:

- a general examination of the charging stations with a visual inspection of the safety measures and functions related to the recharging area (e.g. visual check on the charging stations and their cable assemblies, fire safety measures and alarms, ventilation, possibility of disconnection of the charging stations, …)
- verification that the charging equipment, cables and sockets are maintained according to the maintenance plan
- verification of proper working of alarms involving defaults and malfunctions related to the charging stations and cable assemblies
- examination and testing, as feasible at random, of the fixed fire detection and fire alarm system
- checking of portable thermal imaging camera, fire blanket and water fog applicators and confirmation that they are stored in the appropriate location

- in case the recharging area is located on the weather deck, the following items are to be checked with respect to the fixed water monitors covering this area:
  - general examination of all parts of the water monitor system (pumps, piping system, valves and other fittings)
  - checking for proper operation of the system, including local manual control and remote control
  - general examination of foundations of water monitors.

3.3 Class renewal survey

3.3.1 The requirements given in [3.2] for annual survey are to be complied with. In addition, the class renewal survey is to include:

- a comprehensive test of indications and alarms
- verification of the quality of the power supply intended for electric vehicles (EV) charging
- verification if the charging stations maintenance is performed according to the manufacturers' recommendation
- examination of the fire-extinguishing system and fire detection system as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8]
- operational testing and internal examination of the pumps feeding the water monitors covering recharging areas on weather deck, if provided
- testing of the electrical installation to the same extent as required in Ch 3, Sec 3, [3] for similar equipment for the class renewal survey of machinery
- testing of the cooling installation of the charging station.

4 PaRoll1 and PaRoll2

4.1 Annual survey

4.1.1 The annual survey is to include confirmation of the availability onboard of the operation guidance required by NR667, Sec 1, [4].

5 LI-LASHING

5.1 Annual survey

5.1.1 The annual survey is to include:

a) For ships contracted for construction before 1 July 2025:
   - checking of the lashing software for accuracy by the ship's Master by applying the test loading conditions. If the surveyor is not present during the lashing software check, a copy of the test loading condition results obtained by this check is to be retained on board as documentation of satisfactory testing for the surveyor's verification at the next scheduled survey

b) For ships contracted for construction on or after 1 July 2025:
   - survey requirements given in item a)
   - checking that the operation manual for the lashing software is available onboard.

5.2 Class Renewal survey

5.2.1 The class renewal survey is to include:

a) For ships contracted for construction before 1 July 2025:
   - checking of the lashing software for accuracy by the ship's Master by applying the test loading conditions in the presence of the surveyor

b) For ships contracted for construction on or after 1 July 2025:
   - survey requirement given in item a)
   - checking that the operation manual for the lashing software is available onboard.

Section 14 Additional Notations for Hull Structure Assessment

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.18]:

STRENGTHBOTTOM

GRABLOADING

GRAB [X]

2 STRENGTHBOTTOM

2.1 Dry-docking survey

2.1.1 The reinforced area of bottom plating and internal associated structures are to be visually examined for possible deformations, fractures or other damage. If deemed necessary, thickness measurements may be required.

3 GRABLOADING and GRAB[X]

3.1 Class renewal survey

3.1.1 The reinforced area of inner bottom plating, lower part of hopper tank sloping plating and transverse lower stool plating and adjacent associated structures, as applicable, are to be visually examined for possible deformations, fractures or other damage. If deemed necessary, thickness measurements may be required.

Section 15 Electric Propulsion or Electric Power Supply

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.20]:

ELECTRIC HYBRID

HMPS

OPS( )

2 Electric Hybrid

2.1 General

2.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **ELECTRIC HYBRID** as defined in Ch 1, Sec 2, [6.20.1].

2.2 Annual survey

2.2.1 The survey is to include:

- examinations, checks, measurements and tests listed in Ch 4, Sec 13, [1.2.1]
- verification of proper working of monitoring systems
- verification of proper working of alarms and defaults and related functions and/or interfacing to the other ship systems
- disconnection of the ESS in different operating modes, and automatic start of stand by source, as necessary
- test of the fire detection of the battery room
- test of the gas detection system of the battery room
- examination of the fire-extinguishing system of the battery room as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4]
- verification that accessibility for common maintenance and devices for battery overhaul, if any, are maintained.

2.2.2 In addition to the requirements [2.2.1], for **PM** mode, the survey is to include:

- increasing load steps, as far as practicable. The ESS is to deliver power to the grid, to compensate for the load steps. In case of continuous load, the load is to be gradually transferred to the running diesel engine. The load is to be shared equally between the diesel engines (see Pt C, Ch 2, Sec 4, [2.2.5])
- additional increasing load steps, with load dependant start of a stand-by main generating set activated, as far as practicable.

2.2.3 In addition to the requirements of [2.2.1], for **PB** mode, the survey is to include:

- failure of one generator and automatic connection of the ESS
- failure of one generator and ESS autonomy measurement (starting of the stand by generator is blocked)
- automatic start of a stand by source in case of failure of the ESS or low state of charge of the ESS.

2.2.4 In addition to the requirements of [2.2.1], for **ZE MODE**, the survey is to include:

automatic start of a stand by source in case of failure of the ESS or low state of charge of the ESS.

2.3 Class renewal survey

2.3.1 In addition to the requirements given in [2.2.1] for annual survey the following requirements are to be complied with:

- checks and tests as listed in Ch 4, Sec 13, [1.3.1]
- verification of the quality of the power supply in the different modes
- examination of the fire-extinguishing system as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [3.8].

2.3.2 In addition to the requirements of [2.3.1], for **PM** mode, the survey is to include:

confirmation of the capacity of the batteries by verification of the proper operation of the ESS during 6 hours at least in normal working condition; however, where proper record is maintained, consideration may be given to accepting recent records effected by the ship's personnel. The ESS state of charge is not to be less than 80% at the end of the 6 hours period. A load analysis curve corresponding to this period is to be submitted for information. This document is to detail the total electrical production on board, the main generating sets electrical production and the ESS electrical production (with charging and discharging cycles).

2.3.3 In addition to the requirements of [2.3.1], for **ZE MODE**, the survey is to include:

load discharge test with ESS autonomy measurement up to ESS state of charge low level.

2.3.4 In addition to the requirements of [2.3.1], for **PB** and **ZE MODE**, the survey is to include:

ESS charging test, with evaluation of charging current and time for complete charging of the batteries (to reach full charge, just after a full discharge, in the conditions defined by the load balance).

3 Hybrid mechanical propulsion (HMPS)

3.1 General

3.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **HMPS**, as defined in Ch 1, Sec 2, [6.20.3].

3.2 Annual survey

3.2.1 The annual survey is to include:

- confirmation of proper working of alarms and defaults and related functions and/or interfacing to the other ship systems
- test of manual switch from diesel propulsion mode to electric propulsion mode (PTI Fully electric mode and PTI Booster mode, if available)
- test of manual switch from electric propulsion mode to diesel propulsion Mode
- test of transfer of control between the different control positions.

3.3 Class renewal survey

3.3.1 In addition to the requirements of [3.2.1], the class renewal survey is to include:

- test of automatic switch from electric propulsion mode to diesel propulsion.

4 Onshore power supply (OPS)

4.1 General

4.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **OPS( )**, as defined in Ch 1, Sec 2, [6.20.5].

4.2 Annual survey

4.2.1 The electrical equipment related to the shore power system is to be examined and tested following Ch 3, Sec 1, [3.3].

4.3 Class renewal survey

4.3.1 The electrical equipment related to the shore power system is to be examined and tested following Ch 3, Sec 3, [3.6].

Section 16 Additional Notations for Fire Protection

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.19]:

EFP-M, **EFP-AMC**

ECFP-1, **ECFP-2**, **ECFP-3**

COVENT

EVFP-1, **EVFP-2**, **EVFP-3**

2 Enhanced fire protection

2.1 General

2.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **EFP-M** or **EFP-AMC**, as defined in Ch 1, Sec 2, [6.19.1].

2.2 Annual survey

2.2.1 The annual survey is to include a verification that the insulation applied in way of following items is found in satisfactory condition:

- surfaces of engines, boilers, steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers or other equipment where hot surfaces above 220 °C may be expected, with the engines or concerned equipment under normal operating conditions are properly insulated
- surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

In case of doubt the surveyor may require a thermal imaging scanning to be performed in accordance with the requirements of Pt F, Ch 11, Sec 15 [5].

3 Enhanced cargo fire protection on container ships

3.1 General

3.1.1 The requirements of this Article apply to ships which have been assigned the additional class notations **ECFP-1**, **ECFP-2**, or **ECFP-3**, as defined in Ch 1, Sec 2, [6.19.2].

3.2 Annual survey

3.2.1 The annual survey is to include:

a) Checking of fire-fighter's outfits, breathing apparatuses and portable thermal imaging camera and confirmation that they are stored in the appropriate locations

b) Confirmation that the required supply of compressed air for breathing apparatuses is provided and examination of the arrangements for the air compressor(s) and air piping system

3.2.2 In addition to the requirements of [3.2.1], for ships granted with **ECFP-2** or **ECFP-3** notation, the survey is to include:

a) Water monitors covering the cargo stowage area on deck:
   - general examination of all parts of the water monitor system (pumps, piping system, valves and other fittings)
   - checking for proper operation of the system, including local manual control
   - general examination of foundations of water monitors.

b) In the cargo holds covered by the water-spray system below hatch covers, examination of the water-spray system in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.2] item d).

c) In the cargo holds covered by the flooding system for the cargo holds:
   - examination of the system, including piping, nozzles and distribution valves
   - confirmation that cargo hold sea water level sensors are operational and that high and high high level alarms are satisfactory
   - examination of the drainage arrangements

d) General examination of all parts, as far as practicable and visible, of the water-spray system for the protection of the accommodation block, and of scuppers and freeing ports for water drainage from deck surfaces

e) Checking that the means of remotely closing the accommodation block ventilation inlets and the remote controls for the cargo hold power ventilation are in working order.

3.3 Class renewal survey

3.3.1 In addition to the requirements of [3.2.1], the class renewal survey is to include:

a) Examination and test of prime movers of the air compressor for refilling of air bottles of breathing apparatuses.

3.3.2 In addition to the requirements of [3.3.1]and [3.2.2], the class renewal survey for ships granted with **ECFP-2** or **ECFP-3** is to include:

a) Operational testing and internal examination, as required by the Surveyor, of the relevant pumps for the following systems:
   - water monitors covering the cargo stowage area on deck
   - water-spray system below hatch cover
   - flooding system for the cargo holds
   - water-spray system for the protection of the accommodation block

b) Testing of the means of remotely closing the accommodation block ventilation inlets and remote control for the cargo hold power ventilation.

4 COVENT

4.1 Annual survey

4.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without the prior approval of the Society.

4.1.2 The annual survey is to include a general examination of components of the system such as ventilation piping and fans.

4.2 Class renewal survey

4.2.1 The requirements given in [4.1] for annual survey are to be complied with. Additionally, the following is to be carried out:

- an inspection of the components of the system to the same extent as required in Ch 3, Sec 3, [3] for similar equipment for the class renewal survey of machinery
- a running test of the system.

5 Electrical Vehicle Fire Protection

5.1 General

5.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **EVFP-1**, **EVFP-2** or **EVFP-3** as defined in Ch 1, Sec 2, [6.19.4].

5.2 Annual survey

5.2.1 The annual survey is to include:

- checking of fire-fighter's outfits, portable thermal imaging camera, foam extinguishers and portable water curtain nozzles and confirmation that they are stored in the appropriate location
- examination of the deck drainage arrangements in the dedicated EV storage area
- verification of proper working of the video monitoring system
- general examination of the back-up water spray system, including the storage position of the spool pieces.

5.2.2 In addition to the requirements of [5.2.1], for ships assigned the additional class notation **EVFP-2** or **EVFP-3**, the survey is to include:

- checking of the decontamination shower and equipment
- test of the flame recognition software
- test of the fixed gas detection system
- examination and text of the fixed water-based fire-fighting system
- checking of the portable gas detectors and fire blankets and confirmation that they are stored in the appropriate location.

5.2.3 In addition to the requirements of [5.2.1]and [5.2.2], for ships assigned the additional class notation **EVFP-3**, the survey is to include:

- examination and test of the mechanical smoke extraction system
- checking of the upward water-spray system and confirmation that they are stored in the appropriate location.

5.3 Class renewal survey

5.3.1 In addition to the requirements of [5.2], for the ships assigned the additional class notation **EVFP-2** or **EVFP-3**, the class renewal survey is to include:

- operational testing and examination of the relevant pumps of the fixed water-based fire-fighting system.

Section 17 Additional Notations for Computer Based Systems and Cyber Security

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to cyber security as described in Ch 1, Sec 2, [6.21]and smart systems as described in Ch 1, Sec 2, [6.23]:

CYBER MANAGED

CYBER RESILIENT

CYBER SECURE

SMART( )

2 CYBER

2.1 General

2.1.1 The surveys for maintaining the additional class notations **CYBER MANAGED**, **CYBER RESILIENT** and **CYBER SECURE** are to be systematically recorded along with all cyber security events, as set out in the Policy document: date, actors, tests performed, results and conclusions.

2.1.2 The requirements for the maintenance of these notations are provided in [2.2], [2.3] and [2.4], and, in addition, in NR659 Chapter 6.

2.2 Annual surveys

2.2.1 Documents

Confirmation from Cyber Security Responsible, that any modification carried out on the approved documents as listed in NR659 has been declared to the Society.

2.2.2 Surveys

The annual survey is to confirm that:

- the Cyber Handbook present on board is the up to date and approved
- Cyber Security events are logged
- crew cyber training is logged
- up to date and approved Cyber Policy is printed and available on board
- during the interview by the Surveyor, the Person in charge of Cyber is able to answers the questions related to crew training described in the Cyber Policy
- during the interview by the Surveyor, the person in charge of the equipment mentioned in the Cyber Handbook is aware of the monitoring procedures described in the document and knows how to implement the procedures
- during the interview by the Surveyor, the relevant crew demonstrates a complete understanding of the equipment maintenance procedures described in the Cyber Handbook for the equipment they use regularly
- during the interview by the Surveyor, the relevant crew demonstrates that they fully understand the incident response procedures described in the Cyber Handbook for the equipment they use on a daily basis.

2.3 Intermediate surveys

2.3.1 Documents to be updated

Regarding Level 3 equipment only, the following documents are to be updated:

- Cyber Risk Assessment and Criticality Assessment
- Cyber Inventory (system identification part)
- Cyber Handbook, reflecting procedures only for the critical updated systems.

2.3.2 Evidences to be submitted

Evidence of implementation of cyber security rules (from the Policy), crew training (as described in Policy), maintenance procedures (from the Handbook) and incident response procedures (from the Handbook) must be provided.

2.3.3 Surveys

In addition to the requirements given in [2.2.2] for annual surveys, the intermediate survey is to include:

- confirmation that, during the interview, the person in charge of Cyber demonstrates awareness on Cyber Policy and its implementation
- confirmation that, during the interview, the person in charge of Cyber answers the questions related to the responsibilities described in the Policy
- confirmation that any anti-virus usage and update is in accordance with the Cyber Policy
- confirmation that, during the interview, the person in charge of an equipment present in the Handbook is aware of the remote access monitoring procedures described in the Handbook and knows how to implement them.

2.4 Class renewal surveys

2.4.1 Documents to be updated

The following documents are to be updated:

- Cyber Risk Assessment.

Regarding Level 2 and Level 3 equipment only, the following documents are to be updated:

- Cyber Inventory (system identification part).

2.4.2 Evidences to be submitted

Evidence of implementation of cyber security rules (from the Policy), crew training (as described in Policy), maintenance procedures (from the Handbook) and incident response procedures (from the Handbook) must be provided.

2.4.3 Surveys

In addition to the requirements given in [2.2.2] for annual survey and in [2.3.3] for intermediate survey, the class renewal survey is to include:

- confirmation that the password policy present in the Policy is effectively implemented on board
- confirmation that, during the interview, the person in charge of an equipment present in the Handbook is aware of the wireless monitoring procedures described in the Handbook and knows how to implement them
- confirmation that, during the interview, the relevant crew demonstrates their complete understanding of the software maintenance procedures described in the Handbook for the equipment they use on a daily basis.

3 SMART( )

3.1 Application

3.1.1 The present Article defines the requirements for the maintenance of the additional class notation **SMART( )**.

3.1.2 The applicable requirements for the maintenance of the additional class notations which are referred to in NR675 are prerequisites for the maintenance of the notations **SMART(Hx)**, **SMART(Mx)**, **SMART(MH2)**, **SMART(Nx)**, **SMART(EnEx-CII)**, **SMART(EnE2)**, **SMART(X2)** and **SMART(L2)**.

3.1.3 The annual and class renewal surveys applicable to the Computer Based Systems and the Software Registry, in particular, are to be completed as defined in Ch 3, Sec 1, [3.3.3] and in Ch 3, Sec 3, [3.6.12] respectively.

3.1.4 In addition to requirements of [3.1.2] and [3.1.3], the maintenance of **SMART(MHx)**, **SMART(EnEx)**, **SMART(Lx)** and **SMART(Xx)** is to comply with the applicable requirements of [3.2] and [3.3].

3.2 Annual surveys

3.2.1 During the annual survey applicable to smart group **3**, as witnessed by a Surveyor, the SDS (Shore Digital Solution) is to be operated by a representative of the Shipowner to demonstrate:

- transfer of data between the ODS (Onboard Digital Solution) and the SDS, checking the results in the interface of SDS
- visualisation and reporting features as required for ODS, where these features are only available in the SDS
- availability of the visualisation dashboards and/or reports generated by the SDS in its interface based on the data relevant to the operation in the past 12 months

In addition to the functional checks the annual survey for smart group **3** includes checking the following items:

- availability of the valid service agreement between the Shipowner and the smart service supplier
- availability of the user manual and the Type Approval Certificate.

3.2.2 SMART(MHx)

The annual survey for **SMART(MHx)** includes checking the following items:

- reports generated by the smart system during the last 12 months
- maintenance records for the entries concerning hardware repair, maintenance or replacement of equipment or components
- availability of the user manual
- maintenance and calibration records for the connected measurement instrumentation.

3.2.3 SMART(EnEx)

The annual survey for **SMART(EnEx)** includes checking the following items:

- reports defined in NR675, Sec 5, [2.4.1] items a), b) and c) generated during the last 12 months
- maintenance records for the entries concerning hardware repair, maintenance or replacement of equipment or components
- availability of the user manual
- maintenance and calibration records for the connected measurement instrumentation.

Additional requirements for complementary notations **-Em**, **-T**, **-LIT**, **-S**, **-W** and **-CII** are defined in [3.2.4] to [3.2.9].

3.2.4 SMART(EnEx-Em)

In addition to the scope of the annual survey defined in [3.2.3], the annual survey for the complementary class notation **-Em** includes checking, as a minimum the following items:

- reports generated for emission performance indicators during the last 12 months.

3.2.5 SMART(EnEx-T)

In addition to the scope of the annual survey defined in [3.2.3], the annual survey for the complementary class notation **-T** includes checking, as a minimum the following items:

- records of energy consumption assigned to the loading conditions under which the ship sailed in the past 12 months.

3.2.6 SMART(EnEx-LIT)

In addition to the scope of the annual survey defined in [3.2.3], the annual survey for the complementary class notation **-LIT** includes checking, as a minimum the following items:

- records of loading conditions under which the ship sailed in the past 12 months with the corresponding energy efficiency performance indicators.

3.2.7 SMART(EnEx-S)

In addition to the scope of the annual survey defined in [3.2.3], the annual survey for the complementary class notation **-S** includes checking of the following items:

- three latest voyage reports, which are to incorporate the planned and the actual energy efficiency parameters established.

3.2.8 SMART(EnEx-W)

In addition to the scope of the annual survey defined in [3.2.3], the annual survey for the complementary class notation **-W** includes checking of the following items:

- three latest voyage reports by comparing against the relevant surface weather analysis reports.

3.2.9 SMART(EnEx-CII)

In addition to the scope of the annual survey defined in [3.2.3], the annual survey for the complementary class notation **-CII** includes checking of the following items:

- list of alarms generated by the CII ODS for the discrepancies between the manual and automatic entries.

3.2.10 SMART(Lx)

The annual survey for **SMART(Lx)** includes checking the following items:

- confirm that the electronic record keeping covered by the notation is in place
- confirm that the version of the electronic record keeping software corresponds to the Type Approval Certificate
- availability of the user manual
- check that the backup storage is operational, if applicable.

3.2.11 SMART(Xx)

The annual survey for **SMART(Xx)** includes checking of the following items:

- reports generated by the smart system during the last 12 months
- maintenance records for the entries concerning hardware repair, maintenance or replacement of equipment or components
- availability of the user manual.
- maintenance and calibration records for the connected measurement instrumentation

3.3 Class renewal survey

3.3.1 In addition to the scope of the annual survey as defined in [3.2.1], the class renewal survey applicable to Smart group **3** is to include checking the SDS for the visualisation and reporting features as required for ODS, where these features are only available in the SDS. During a test witnessed by a Surveyor, the SDS is to be operated by a representative of the Shipowner.

3.3.2 SMART(MHx)

In addition to the scope of the annual survey defined in [3.2.2], the class renewal survey for **SMART(MHx)** includes the following items:

- consistency check of parameter trends with the recent operation of the equipment. Consistency check is completed by extracting data for a period of 1 to 12 months in a readable format for a review by a Surveyor of the Society. This may include, but not limited to, raw time series, descriptors, diagnostic assessments selected at the discretion of a Surveyor. The preferred format is a report or a non-encrypted delimited text file easily readable on a PC
- functional test by generating a recommended maintenance profile
- functional test by generating a condition report for the list of equipment considered in the scope of the notation
- functional test by generating a condition report in a test mode with a simulated introduction of incipient failures. This condition report is to be used to compare the results to a corresponding pre-calculated test case.

3.3.3 SMART(EnEx)

In addition to the scope of the annual survey defined in [3.2.3], the class renewal survey for **SMART(EnEx)** includes the following items:

- consistency check between the SEEMP and the reports defined in NR675, Sec 5, [2.4.1] items a), b) and c) for a period of 12 months
- general examination of the list of time series with uptime history and source equipment
- functional test by generating recommended performance profile for the latest operational conditions typical for the ship's trade in the last 12 months
- functional test by simulating energy consumption and emissions for a laden voyage and for a port activity and comparing the results to an equivalent profile recorded during the last 12 months.

Additional requirements for complementary notations **-Em**, **-T**, **-LIT**, **-S**, **-W** and **-CII** are defined in [3.3.3] to [3.3.8].

3.3.4 SMART(EnEx-EM)

In addition to the scope of the class renewal survey defined in [3.3.3], the class renewal survey for the complementary class notation **-Em** includes the following items:

- functional test by estimating an emission performance indicator for three last loading conditions under which the ship sailed in the preceding 12 months.

3.3.5 SMART(EnEx-T)

In addition to the scope of the class renewal survey defined in [3.3.3], the class renewal survey for the complementary class notation **-T** includes the following items:

- functional test by estimating the energy consumption for three last loading conditions under which the ship sailed in the preceding 12 months.

3.3.6 SMART(EnEx-LIT)

In addition to the scope of the class renewal survey defined in [3.3.3], the class renewal survey for the complementary class notation **-LIT** includes the following items:

- consistency check of three loading conditions under which the ship sailed in the preceding 12 months with a focus on the corresponding energy efficiency performance indicators and on the compliance to the intact stability and hull girder criteria
- functional test by generating an optimized stowage plan for the last laden voyage.

3.3.7 SMART(EnEx-S)

In addition to the scope of the class renewal survey defined in [3.3.3], the class renewal survey for the complementary class notation **-S** includes the following items:

- consistency check of three latest voyage reports, which is to incorporate the planned and the actual energy efficiency parameters established
- functional test by generating an optimized voyage plan for the last laden voyage
- if the smart system automatically transfers the route to the ship's ECDIS: functional test for the automatic display of the optimized voyage plan in ECDIS in both planning mode and voyage execution mode with a thorough examination of the safety contour alerts produced by the ECDIS in relation to the route

3.3.8 SMART(EnEx-W)

In addition to the scope of the class renewal survey defined in [3.3.3], the class renewal survey for the complementary class notation **-W** includes the following items:

- consistency check of onboard procedures for managing the weather routing information to confirm that the weather routing system is regularly updated with the surface analysis information
- functional test by generating an optimized ocean voyage plan
- if the smart system automatically transfers the route to the ship's ECDIS: functional test for the automatic display of the optimized voyage plan in ECDIS in both planning mode and voyage execution mode with a thorough examination of the safety contour alerts produced by the ECDIS in relation to the route.

3.3.9 SMART(EnEx-CII)

In addition to the scope of the class renewal survey defined in [3.3.3], the class renewal survey for the complementary class notation **-CII** includes the following items:

- items in the scope of the annual survey as per [3.2.9]
- functional test of CII ODS (Onboard Digital Solution) by completion of entries for one day.

3.3.10 SMART(Lx)

In addition to the scope of the annual survey defined in [3.2.10], the class renewal survey for **SMART(Lx)** includes checking that the list of authorised users on board is consistent with the Role Based Access Control defined in the user manual.

3.3.11 SMART(Xx)

In addition to the scope of the annual survey defined in [3.2.11], the class renewal survey for **SMART(Xx)** includes the following items:

- consistency check of the list of time series with uptime history and source equipment
- functional test by generating a report relevant for the onboard process supported by the smart system.

Section 18 Additional Notations for Corrosion Protection

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned the additional service feature **CPS(WBT)**, as defined in Ch 1, Sec 2, [4.16.12] or one of the following additional class notations related to corrosion protection, as described in Ch 1, Sec 2, [6.24]:

CPS(COT)

CPS(MFT)

CPS(VSP)

CPS(WBT)

2 Annual survey

2.1 All notations

2.1.1 The annual survey is to include:

- verification that the coating technical file is kept onboard
- verification that the coating is maintained and repaired in accordance with the coating technical file.

Section 19 Other Notations

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations described in Ch 1, Sec 2, [6.25]:

ACCESS

HEL

OHS

OAS

2 Permanent means of access (ACCESS)

2.1 Annual survey, intermediate survey and class renewal survey

2.1.1 General conditions

Visual examination of following parts of permanent means of access is to be carried out in conjunction with surveys of spaces where the notation **ACCESS** is assigned:

- visual examination for signs of corrosion
- examination for satisfactory condition of the marking (e.g. strip, arrows, non-slip surfaces)
- examination of the location lighting where the permanent mean of access is fitted
- examination for satisfactory condition of rails, stanchions, hand rails and other guard rails.

3 Helideck (HEL)

3.1 Application

3.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **HEL**, as defined in Ch 1, Sec 2, [6.25.3].

3.2 Annual surveys

3.2.1 The Society considers that as a minimum these following issues are to be examined during the periodic surveys to confirm that there has been no alteration or deterioration in the condition of the helicopter landing area:

a) The general examination of the physical characteristics of the helideck is to include:
   - the dimensions as measured
   - the declared D-value
   - the deck shape, and
   - the scale drawings of deck arrangement.

b) The general examination of the preservation of obstacle-protected surfaces is to include:
   - the minimum 210° Obstacle Free Sector (OFS) surface
   - the 150° Limited Obstacle Sector (LOS) surface, and
   - the minimum 180° falling 5:1 gradient surface with respect to significant obstacles.

Note 1: If one or more of these surfaces is/are infringed due, for example, to the proximity of an adjacent installation or vessel, an assessment is to be made to determine any possible negative effect which may lead to operating restrictions.

c) The general examination of the marking and lighting is to include:
   - the adequate helideck perimeter lighting
   - the adequate helideck touchdown marking lighting (“H” and TD/PM Circle lighting) and/or floodlighting
   - the status lights (for day and night operations)
   - the helideck markings
   - the dominant obstacle paint schemes and lighting, and
   - the general installation lighting levels including floodlighting.

Note 2: Where inadequate helideck lighting exists, the Helideck Limitation List (HLL) is to be annotated “daylight only operations”.

d) The general examination of the deck surface is to include:
- the surface friction
- the helideck net (as applicable)
- the drainage system
- the deck edge perimeter safety netting
- the tie-down points, and
- the cleaning of all contaminants (to maintain satisfactory recognition of helideck markings and preservation of the helideck friction surface).

e) The verification of the environment effects is to include:
- foreign object damage
- air quality degradation due to exhaust emissions, hot and cold vented gas emissions and physical turbulence generators
- bird control
- any adjacent helideck/installation having significant environmental effects in any air quality assessment, and
- flares.

f) The general examination of the rescue and fire fighting facilities is to include:
- the primary and complementary media types, quantities, capacity and systems
- the Personal Protective Equipment (PPE), and
- the crash box.

g) The general examination of the communications and navigation system arrangements is to include:
- the aeronautical radio(s)
- the radio/telephone (R/T) call sign to match helideck name and side identification which should be simple and unique
- the Non-Directional Beacon (NDB) or equivalent (as appropriate), and
- the radio log.

h) The general examination of the fuelling facilities is to include:
- the fuel system, ventilation, fire protection and detection
- the pump and aircraft bonding safety systems.

i) The general examination of the additional operational and handling equipment is to include:
- the windsock
- the meteorological information (recorded by an automated means)
- the Helideck Motion System recording and reporting (where applicable)
- the passenger briefing system
- the chocks
- the tie-downs, and
- the weighing scales for passengers, baggage and freight.

4 Offshore Access System (OAS)

4.1 Application

4.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **OAS**, as defined in Ch 1, Sec 2, [6.25.7].

4.2 Periodical surveys

4.2.1 For survey requirements and for periodical surveys, refer to Section 9 of NI 629, Certification of Offshore Access Systems.

5 Offshore handling systems (OHS)

5.1 Application

5.1.1 The requirements of this Article apply to ships which have been assigned the additional class notation **OHS**, as defined in Ch 1, Sec 2, [6.25.6].

5.2 Periodical surveys

5.2.1 For survey requirements and for periodical surveys, refer to Section 4 of NR595 Classification of Offshore Handling Systems.

CHAPTER 6
RETROACTIVE REQUIREMENTS FOR EXISTING SHIPS

Section 1 General

Section 2 Bulk Carriers, Ore Carriers and Combination Carriers

Section 3 Ro-ro Passenger Ships

Section 4 Cargo Ships

Section 5 Ships with Ice Classes

Appendix 1 Technical Retroactive Requirements for Bulk Carriers and Other Types of Ships

Section 1 General

1 General

1.1

1.1.1 The purpose of this Chapter is to deal with the retroactive rule requirements applicable to existing ships which derive from the implementation of SOLAS regulations, IACS Unified Requirements or specific regulations from an Administration.

1.1.2 These requirements are relevant to both construction features and surveyable items. They are laid down in the following Sections according to the service notations assigned to ships.

This Chapter also contains an Appendix for ready reference reproducing the text of the retroactive IACS Unified Requirements relevant to ships assigned the service notation **bulk carrier ESP**.

As a rule, requirements related to additional service features **BC-A**, **BC-B** or **BC-C** are not applicable to ships having the service notation **bulk carrier ESP** contracted for construction before 1st July 2003 or contracted for construction on or after 1st July 2003 but less than 150 m in length.

1.2 List of retroactive rule requirements

1.2.1 Tab 1 summarises these retroactive requirements indicating the service notations to which they are applicable and in which Section they are given.

Table 1 : Summary of retroactive rule requirements

Service notation	Section in Chapter 6	Ship's survey items or features concerned
bulk carrier ESP	Ch 6, Sec 2	- Scantlings of transverse bulkhead between the two foremost cargo holds - Allowable hold loading of the foremost cargo hold - Damage stability - Intermediate survey in lieu of annual survey in the foremost cargo hold - Detection of water ingress into cargo holds - Cargo hatch cover securing arrangements - Renewal criteria for side shell frames and brackets - Restriction from sailing with any hold empty
bulk carrier ESP **ore carrier ESP** **combination carrier/OBO ESP** **combination carrier/OOC ESP**	Ch 6, Sec 2	- Loading conditions, loading manuals and loading instruments - Strength and securing of small hatches on the exposed fore deck - Strength requirements for fore deck fittings and equipment - Hold, ballast and dry space water level detectors - Availability of pumping systems
ro-ro passenger ship	Ch 6, Sec 3	- Increased stability and watertight integrity
general cargo ship **bulk carrier** (without ESP) **refrigerated cargo ship** **livestock carrier** **deck ship**	Ch 6, Sec 4	- Strength and securing of small hatches on the exposed fore deck - Strength requirements for fore deck fittings and equipment
ships with Ice Classes	Ch 6, Sec 5	- Maintenance of additional class notations **ICE CLASS IA SUPER**, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC**

Section 2 Bulk Carriers, Ore Carriers and Combination Carriers

1 Foremost cargo hold requirements

1.1 Application

1.1.1 These retroactive rule requirements apply to ships with service notation **bulk carrier ESP**:

- of single side skin construction see Note 1
- of 150 metres in length and above
- intended to carry solid bulk cargoes having a bulk density of 1,78 t/m^3 or above
- contracted for construction prior to 1st July 1998, and not constructed in compliance with the applicable requirements for new buildings contracted after that date, and given in Pt D, Ch 4, Sec 3.

Note 1: Single side skin bulk carriers means, as defined in SOLAS conf. 4/25 Res.6, where one or more cargo holds are bound by the side shell only or by two watertight boundaries, one of which is the side shell, which are less than 760 mm apart in bulk carriers constructed before 1st January 2000, and less than 1000 mm apart in bulk carriers constructed on or after 1st January 2000. The distance between the watertight boundaries is to be measured perpendicular to the side shell (ref.: IMO MSC Res.89(71)).

1.1.2 They are related to:

- scantlings of the transverse corrugated cargo hold bulkhead between the two foremost cargo holds, as detailed in [1.3]
- allowable hold loading of the foremost cargo hold with the same hold flooded, as detailed in [1.4]
- damage stability with the foremost cargo hold flooded, as detailed in [1.5].

1.2 Schedule for compliance

1.2.1 These requirements are to be complied with by the following limit dates:

- for ships which were 20 years of age or more on 1st July 1998, by the due date of the first intermediate survey or the due date of the first class renewal survey, to be held after 1st July 1998, whichever comes first
- for ships which were 15 years of age or more, but less than 20 years on 1st July 1998, by the due date of the first class renewal survey to be held after 1st July 1998, but not later than 1st July 2002
- for ships which were 10 years of age or more, but less than 15 years on 1st July 1998, by the due date of the next intermediate survey or class renewal survey after the date on which the ship reaches 15 years of age, but not later than the date on which the ship reaches 17 years of age
- for ships which were 5 years of age or more, but less than 10 years on 1st July 1998, by the due date, after 1st July 2003, of the next intermediate survey or class renewal survey after the date on which the ship reaches 10 years of age, whichever occurs first
- for ships which were less than 5 years of age on 1st July 1998, by the date on which the ship reaches 10 years of age.

1.2.2 Completion, prior to 1st July 2003, of an intermediate or class renewal survey with a due date after 1st July 2003, cannot be used to postpone compliance.

However, completion prior to 1st July 2003 of an intermediate survey the window for which straddles 1st July 2003 can be accepted.

1.3 Scantlings of the vertically corrugated transverse watertight bulkhead between the two foremost cargo holds

1.3.1 The net scantlings of the vertically corrugated transverse watertight bulkhead between the two foremost cargo holds are to be assessed in accordance with the method given in Ch 6, App 1, [2].

In these requirements, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for the two foremost cargo holds, does not exceed 1,20, to be corrected for different cargo densities.

1.3.2 Thickness measurements are necessary to determine the general condition of the structure and to define the extent of possible repairs and/or reinforcements of the vertically corrugated transverse watertight bulkhead for verification of the compliance with the requirements given in Ch 6, App 1, [2].

Thickness measurements and assessment of the scantlings are to be carried out for the initial evaluation at the limit date as defined in [1.2.1], and thereafter at each subsequent intermediate survey (for ships over 10 years of age) and each subsequent class renewal survey for purposes of verifying continuing compliance with the above mentioned requirements.

1.3.3 Taking into account the buckling criteria applied in Ch 6, App 1, [2] in the evaluation of strength of the bulkhead, it is essential to determine the thickness diminution at the critical levels shown in Fig 1 and Fig 2.

1.3.4 Thickness measurements are to be carried out at the levels indicated in [1.3.5]. To adequately assess the scantlings of each individual vertical corrugation, each corrugation flange, web, shedder plate (see Ch 6, App 1, Fig 4 and Ch 6, App 1, Fig 5) and gusset plate (see Ch 6, App 1, Fig 6, Ch 6, App 1, Fig 7 and Ch 6, App 1, Fig 8) within each of the levels indicated in [1.3.5] is to be measured.

1.3.5 The locations at which thickness measurements are to be carried out are as follows for each of the prescribed levels a, b and c:

- level a - bulkheads without lower stool (see Fig 1)
  - the mid-breadth of the corrugation flanges and webs at approximately 200 mm above the line of shedder plates
  - the middle of gusset plates between corrugation flanges, where fitted
  - the middle of the shedder plates
- level b - bulkheads with lower stool (see Fig 2)
  - the mid-breadth of the corrugation flanges and webs at approximately 200 mm above the line of shedder plates
  - the middle of gusset plates between corrugation flanges, where fitted
  - the middle of the shedder plates
- level c - bulkheads with or without lower stool (see Fig 1 and Fig 2)
  - the mid-breadth of the corrugation flanges and webs at approximately the mid-height of the corrugation.

Where the thickness changes within the horizontal levels, the thinner plate is to be measured.

1.3.6 Where necessary, steel renewal and/or reinforcements are to meet the requirements given in Ch 6, App 1, [2.6].

Figure 1 : Thickness measurement areas of cargo hold transverse bulkhead without lower stool

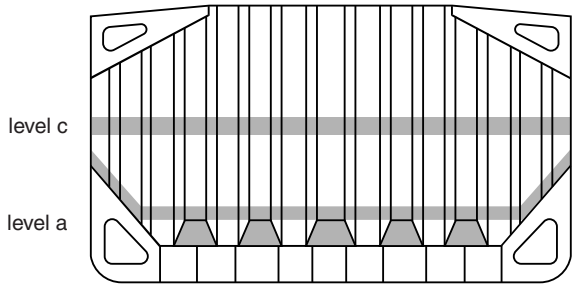
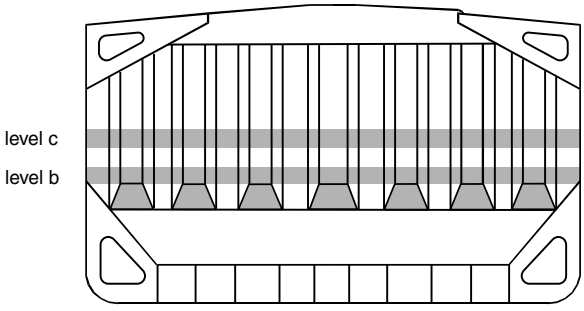


Figure 2 : Thickness measurement areas of cargo hold transverse bulkhead with lower stool



1.4 Allowable hold loading of the foremost cargo hold with the same hold flooded

1.4.1 The loading in the foremost cargo hold is not to exceed the allowable hold loading in the flooded condition. The method of calculation is laid down in Ch 6, App 1, [4].

In no case is the allowable hold loading in the flooding condition to be taken greater than the design hold loading in the intact condition.

1.5 Damage stability

1.5.1 Bulk carriers which are subject to compliance with the requirements laid down in [1.3.1] and [1.4.1] are, when loaded to the summer loadline, to be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in [1.5.2].

1.5.2 The condition of equilibrium after flooding is to satisfy the condition of equilibrium laid down in Pt B, Ch 3, App 4. The assumed flooding need only take into account flooding of the cargo hold. The permeability of a loaded hold is to be assumed as 0,90 and the permeability of an empty hold is to be assumed as 0,95, unless a permeability relevant to a particular cargo is assumed for the volume of a flooded hold occupied by cargo and a permeability of 0,95 is assumed for the remaining empty volume of the hold.

1.5.3 Bulk carriers which have been assigned a reduced freeboard in compliance with the provisions of Pt B, Ch 3, App 4 may be considered as complying with [1.5.1].

2 Loading instruments and loading manuals

2.1 Loading instruments

2.1.1 Bulk carriers, ore carriers and combination carriers, which are assigned one of the following service notations:

- **bulk carrier ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**

of 150 m length and above, which were contracted for construction before 1st July 1998, are to be provided with an approved loading instrument of a type to the satisfaction of the Society not later than their entry into service or 1st January 1999, whichever occurs later.

2.2 Loading manuals

2.2.1 All single side skin bulk carriers which are assigned the service notation **bulk carrier ESP**, of 150 m length and above, which were contracted for construction before 1st July 1998 are to be provided before 1st July 1999, or their entry into service whichever occurs later, with an approved loading manual with typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions, where applicable. Typical unloading sequences for these conditions are also to be included.

Guidance for preparation of such loading/unloading sequences is given in Ch 6, App 1, [7].

3 Strength requirements for fore deck fittings and equipment, strength and securing of small hatches on the exposed fore deck

3.1 Application and requirements

3.1.1 These retroactive rule requirements apply to ships which are assigned one of the following service notations:

- **bulk carrier ESP**
- **bulk carrier BC-A ESP**
- **bulk carrier BC-B ESP**
- **bulk carrier BC-C ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**,

of 100 m in length and above, that are contracted for construction prior to 1st January 2004.

3.1.2 These retroactive rule requirements provide strength requirements to resist green sea forces for the following items located within the forward quarter length: air pipes, ventilator pipes and their closing devices.

They are applicable only for air pipes, ventilator pipes and their closing devices on the exposed deck serving spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards.

The provisions for compliance with these strength requirements for fore deck fittings and equipment are given in Pt C, Ch 1, Sec 10, [9.1.9].

These retroactive rule requirements are also applicable for small hatches on the exposed deck giving access to spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards.

They are related to the strength of, and securing for, such small hatches fitted on the exposed fore deck.

The provisions for compliance with these requirements for strength and securing of small hatches on the exposed fore deck are given in Pt B, Ch 11, Sec 10, [3].

Note 1: For ships contracted for construction prior to 1st July 2007, the following is to be carried out:

- securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are to be provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover,

by the compliance date specified in [3.2.1] or by the due date of the first class renewal survey after 1st July 2007 whichever is later. Completion prior to 1st July 2007 of a class renewal survey with a due date after 1st July 2007 cannot be used to postpone compliance.

Note 2: These requirements do not apply to the cargo tank venting systems and the inert gas systems of tankers.

3.2 Schedule for compliance

3.2.1 Ships referred to in [3.1.1] are to comply with the provisions of Pt B, Ch 11, Sec 10, [3] and of Pt C, Ch 1, Sec 10, [9.1.9] by the following dates:

- for ships which will be 15 years of age or more on 1st January 2004, by the due date of the first intermediate or class renewal survey after that date
- for ships which will be 10 years of age or more on 1st January 2004, by the due date of the first class renewal survey after that date
- for ships which will be less than 10 years of age on 1st January 2004, by the date on which the ship reaches 10 years of age.

3.2.2 Completion, prior to 1st January 2004, of an intermediate or class renewal survey with a due date after 1st January 2004 cannot be used to postpone compliance. However, completion prior to 1st January 2004 of an intermediate survey the window for which straddles 1st January 2004 can be accepted.

4 Cargo hatch cover securing arrangements for bulk carriers

4.1 Application and requirements

4.1.1 These retroactive rule requirements apply to ships which are assigned one of the following service notations:

- **bulk carrier ESP**
- **bulk carrier BC-A ESP**
- **bulk carrier BC-B ESP**
- **bulk carrier BC-C ESP,**

and which were not built in accordance with Pt B, Ch 9, Sec 7, [1] to Pt B, Ch 9, Sec 7, [7] of edition February 2003 of the Rules as amended in accordance with November 2003 amendments or subsequent editions.

4.1.2 They are related to steel hatch cover securing devices and stoppers for cargo hold hatchways No 1 and No 2 which are wholly or partially within 0,25 L of the fore perpendicular, except pontoon type hatch cover.

The provisions for compliance with these requirements for cargo hatch cover securing arrangements are given in Ch 6, App 1, [6].

4.2 Schedule for compliance

4.2.1 Ships referred to in [4.1.1] are to comply with the provisions of Ch 6, App 1, [6] by the following dates:

- for ships which will be 15 years of age or more on 1st January 2004, by the due date of the first intermediate or class renewal survey after that date
- for ships which will be 10 years of age or more on 1st January 2004, by the due date of the first class renewal survey after that date
- for ships which will be less than 10 years of age on 1st January 2004, by the date on which the ship reaches 10 years of age.

4.2.2 Completion, prior to 1st January 2004 of an intermediate or class renewal survey with a due date after 1st January 2004 cannot be used to postpone compliance. However, completion prior to 1st January 2004 of an intermediate survey the window for which straddles 1st January 2004 can be accepted.

5 Renewal criteria for side shell frames and brackets in single side skin bulk carriers and single side skin OBO carriers

5.1 Application and requirements

5.1.1 These retroactive rule requirements apply to:

- the side shell frames and brackets of cargo holds bounded by the single side shell of ships with service notation **bulk carrier ESP** constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk,

- the side shell frames and brackets of cargo holds bounded by the single side shell of ships with service notation **combination carrier/OBO ESP** as defined in Ch 1, Sec 2, [4.3.4] but of single side skin construction,

which were not built in accordance with the applicable requirements of Part II, Chapter 8, Section 8-03 of the 1st April 1998 edition of the Rules or subsequent editions.

In the case a ship as defined above does not satisfy above definition in one or more holds, the retroactive rule requirements do not apply to these individual holds.

5.1.2 These requirements define steel renewal criteria or other measures (reinforcement or coating) to be taken for the webs and flanges of side shell frames and brackets as per the provisions of Ch 6, App 1, [5].

Reinforcing measures of side frames are also defined as per Ch 6, App 1, [5.4.2].

Finite element or other numerical analysis or direct calculation procedures cannot be used as an alternative to compliance with these requirements, except in cases of unusual side structure arrangements or framing to which these requirements cannot be directly applied. In such cases, the analysis criteria and the strength check criteria are to be in accordance with the Rules of the Society.

5.2 Schedule for compliance

5.2.1 Steel renewal, reinforcement or coating, where required in accordance with Ch 6, App 1, [5], is to be carried out in accordance with the following schedule and at subsequent intermediate and class renewal surveys, for ships with service notation **bulk carrier ESP**.

- for ships which will be 15 years of age or more on 1st January 2004, by the due date of the first intermediate or class renewal survey after that date
- for ships which will be 10 years of age or more on 1st January 2004, by the due date of the first class renewal survey after that date
- for ships which will be less than 10 years of age on 1st January 2004, by the date on which the ship reaches 10 years of age.

5.2.2 For ships with service notation **bulk carrier ESP**, completion, prior to 1st January 2004, of an intermediate or class renewal survey with a due date after 1st January 2004 cannot be used to postpone compliance. However, completion prior to 1st January 2004 of an intermediate survey the window for which straddles 1st January 2004 can be accepted.

5.2.3 Steel renewal, reinforcement or coating, where required in accordance with Ch 6, App 1, [5], is to be carried out in accordance with the following schedule and at subsequent intermediate and class renewal surveys, for ships with service notation **combination carrier/OBO ESP**:

- for ships which will be 15 years of age or more on 1st July 2005, by the due date of the first intermediate or class renewal survey after that date
- for ships which will be 10 years of age or more on 1st July 2005, by the due date of the first class renewal survey after that date
- for ships which will be less than 10 years of age on 1st July 2005, by the date on which the ship reaches 10 years of age.

5.2.4 For ships with service notation **combination carrier/OBO ESP**, completion, prior to 1st July 2005 of an intermediate or class renewal survey with a due date after 1st July 2005 cannot be used to postpone compliance. However, completion prior to 1st July 2005 of an intermediate survey the window for which straddles 1st July 2005 can be accepted.

5.3 Requirements for the gauging of side shell frames and brackets

5.3.1 Gauging is required to determine the general condition of the structure and to define the extent of possible steel renewals or other measures for the webs and flanges of side shell frames and brackets for verification of the compliance with the requirements of Ch 6, App 1, [5].

5.3.2 For the purpose of steel renewal, sand blasting and coating, four zones A, B, C and D are defined, as shown in Fig 3.

Zones A and B are considered to be the most critical zones.

5.3.3 Pits can grow in a variety of shapes, some of which would need to be ground before assessment.

Pitting corrosion may be found under coating blisters, which must be removed before inspection.

To measure the remaining thickness of pits or grooving, a miniature transducer (3 to 5 mm diameter) must be used. Alternatively, the gauging firm must use a pit gauge to measure the depth of the pits and grooving and calculate the remaining thickness.

The assessment based upon area is the method specified in Ch 6, App 1, [5.4.4] and is based upon the intensity determined from Fig 4.

If pitting intensity is higher than 15% in an area (see Fig 4), then thickness measurements are to be taken to check the extent of the pitting corrosion. The 15% is based upon pitting or grooving on only one side of the plate.

In cases where pitting is evident as defined above (exceeding 15%), then an area of 300 mm diameter or more (or, where this is impracticable on the frame flange or the side shell, hopper tank plating or topside tank plating attached to the side frame, an equivalent rectangular area), at the most pitted part, is to be cleaned to bare metal, and the thickness measured in way of the five

deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded.

The minimum acceptable remaining thickness in any pit or groove is equal to:

- 75% of the as-built thickness, for pitting or grooving in the cargo hold side frame webs and flanges
- 70% of the as-built thickness, for pitting or grooving in the side shell, hopper tank and topside tank plating attached to the cargo hold side frame, over a width up to 30 mm from each side of it.

5.3.4 Numbers of side frames to be measured are equivalent to those of the class renewal survey or intermediate survey corresponding to the ship's age. Representative thickness measurements are to be taken for each zone as specified below.

Special consideration to the extent of the thickness measurements may be given by the Society, if the structural members show no thickness diminution with respect to the as-built thicknesses and the coating is found in "as-new" condition (i.e without breakdown or rusting).

Figure 3 : Zones of side shell frames and brackets

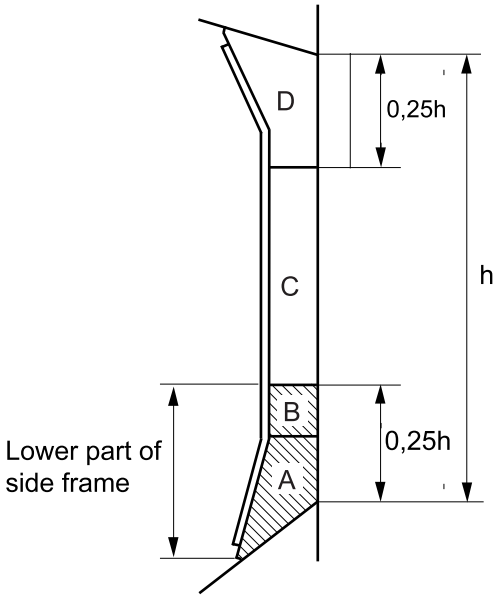
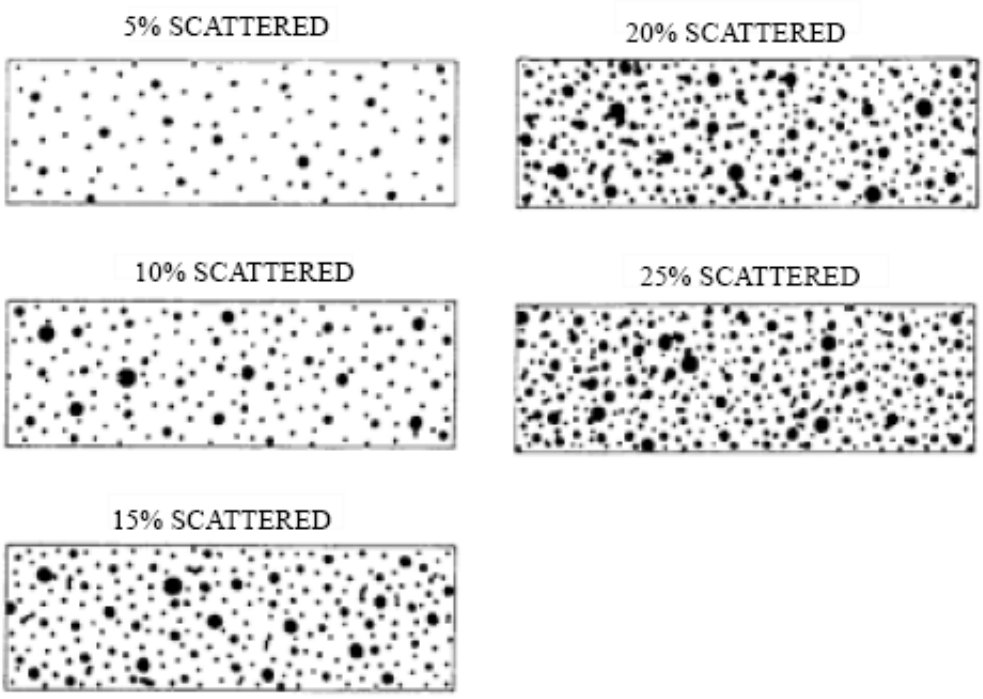


Figure 4 : Pitting intensity diagrams (from 5% to 25% intensity)



If renewal or other measures according to the present Article [5] are to be applied on individual frames in a hold, then all frames in that hold are to be gauged.

Where gauging readings close to the criteria are found, the number of hold frames to be measured is to be increased.

There is a variety of construction methods used for side shell frames in bulk carriers. Some have face plates (T sections) on the side shell frames, some have flanged plates and some have bulb plates. The use of face plates and flanged sections is considered similar for gauging purposes in that both the web and face plate or web and flange plate are to be gauged. If bulb plate has been used, then web of the bulb plate is to be gauged in the normal manner and the sectional modulus has to be specially considered if required.

5.3.5 The gauging pattern for web plating for zones A, B and D are to be a five point pattern (see Fig 5). The 5 point pattern is to be over the depth of the web and the same area vertically. The gauging report is to reflect the average reading.

5.3.6 Depending upon the condition of the web in way of zone C, the web plating for zone C is to be measured by taking 3 readings over the length of zone C and averaging them. The average reading is to be compared with the allowable thickness. If the web plating has general corrosion then this pattern is to be expanded to a five point pattern as noted in [5.3.5].

5.3.7 Where the lower bracket length or depth does not meet the requirements in Pt D, Ch 4, Sec 3, [2.2.5], gaugings are to be taken at sections a) and b) to calculate the actual section modulus required in Ch 6, App 1, [5.5.5] (see Fig 6). At least 2 readings on the flange/face plate are to be taken in way of each section. At least one reading of the attached shell plating is to be taken on each side of the frame (i.e. fore and aft) in way of section a) and section b).

Figure 5 : Typical 5 point pattern on the web plate

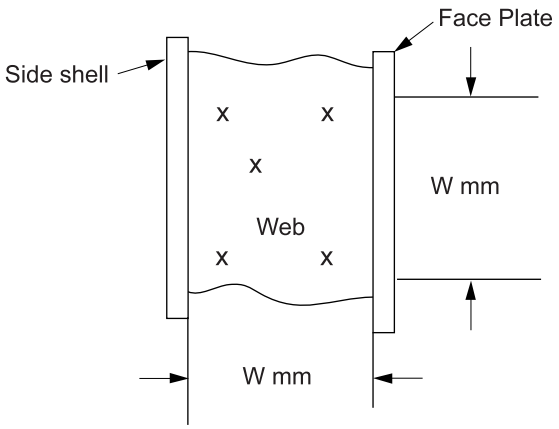
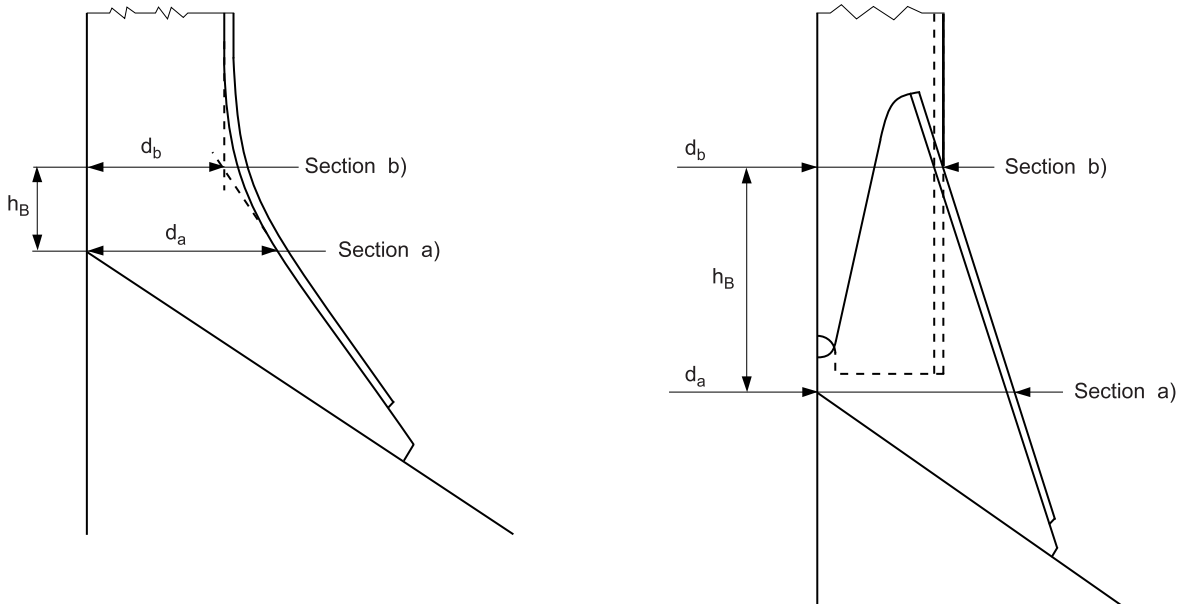


Figure 6 : Sections a) and b)



d_a : Lower bracket web depth for determining $t_{REN, S}$

d_b : Frame web depth

h_B : Lower bracket length.

6 Hold, ballast and dry space water level detectors

6.1 Application and requirements

6.1.1 These retroactive rule requirements apply to ships which are assigned one of the following service notations:

- **bulk carrier ESP**
- **bulk carrier BC-A ESP**
- **bulk carrier BC-B ESP**
- **bulk carrier BC-C ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**,

of 500 GT and above constructed before 1 July 2004.

6.1.2 They are related to the fitting of water level detectors.

The provisions for compliance with these requirements are given in Pt C, Ch 1, Sec 10, [6.12.1] and Pt C, Ch 1, Sec 10, [6.6.3], item d).

6.2 Schedule for compliance

6.2.1 Ships referred to in [6.1.1] are to comply with the provisions of Pt C, Ch 1, Sec 10, [6.12.1] and Pt C, Ch 1, Sec 10, [6.6.3], item d) not later than the date of the annual, intermediate or class renewal survey of the ship to be carried out after 1st July 2004, whichever comes first.

7 Availability of pumping systems

7.1 Application and requirements

7.1.1 These retroactive rule requirements apply to ships which are assigned one of the following service notations:

- **bulk carrier ESP**
- **bulk carrier BC-A ESP**
- **bulk carrier BC-B ESP**
- **bulk carrier BC-C ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**,

of 500 GT and above constructed before 1st July 2004.

7.1.2 They are related to the availability of pumping systems.

The provisions for compliance with these requirements are given in Pt C, Ch 1, Sec 10, [6.6.3], item e).

7.2 Schedule for compliance

7.2.1 Ships referred to in [7.1.1] are to comply with the provisions of Pt C, Ch 1, Sec 10, [6.6.3], item e) not later than the date of the first intermediate or class renewal survey of the ship to be carried out after 1st July 2004, but in no case later than 1st July 2007.

8 Restriction from sailing with any hold empty

8.1 Application and requirements

8.1.1 These retroactive rule requirements apply to ships which are assigned one of the service notations **bulk carrier ESP** or **combination carrier/OBO ESP**:

- of single side skin construction
- of 150 metres in length and above
- intended to carry solid bulk cargoes having a density of 1,78 t/m^3 in alternate hold loading conditions
- contracted for construction prior to 1st July 1998 or constructed before 1st July 1999.

8.1.2 Such ships, if not meeting the requirements for withstanding flooding of any one cargo hold, as specified in Part II, Chapter 8, Section 8-03, 8-032-2, 8-037-3 and 8-033-4 of the 1st April 1998 edition of the Rules or subsequent editions, and the retroactive requirements for side structure of bulk carriers of single-side skin construction, as specified in [5], are not to sail with

any hold loaded to less than 10% of the hold's maximum allowable cargo weight when in the full load condition, after reaching 10 years of age.

The applicable full load condition for this requirement is a load equal to, or greater than, 90% of the ship's deadweight at the relevant assigned freeboard.

8.1.3 Any restrictions imposed on the carriage of solid bulk cargoes having a density of 1,78 t/m^3 and above in accordance with these requirements are to be identified and recorded in the loading manual.

8.1.4 A ship to which the requirements in [8.1.3] apply is to be permanently marked on the side shell amidships, port and starboard, with a solid equilateral triangle having sides of 500 mm and its apex 300 mm below the deck line, and painted a contrasting colour to that of the hull.

Section 3 Ro-ro Passenger Ships

1 General

1.1 Application

1.1.1 Ships which have been assigned the service notation **ro-ro passenger ship** constructed before 1st July 1997 are to comply with all the requirements indicated in [2].

2 Increased stability and watertight integrity

2.1

2.1.1 Ships referred to in [1.1.1] are to comply with the provisions of Pt D, Ch 12, Sec 3, [2.3] not later than the first class renewal survey after the prescribed date of compliance given in Tab 1, according to the value of A/A_{max} as defined in the annex of the Calculation Procedure to assess the survivability characteristics of existing ro-ro passenger ships when using a simplified method based upon resolution A.265(VIII), developed by the Maritime Safety Committee at its fifty-ninth session in June 1991 (MSC/Circ. 574).

Table 1 : Date of compliance according to A/A_{max}

Value of A/A_{max}	Date of compliance
$A/A_{max} < 85\%$	1st October 1998
$85\% \le A/A_{max} < 90\%$	1st October 2000
$90\% \le A/A_{max} < 95\%$	1st October 2002
$95\% \le A/A_{max} < 97,5\%$	1st October 2004
$A/A_{max} \ge 97,5\%$	1st October 2005

2.1.2 Notwithstanding the provisions of [2.1.1], ships referred to in [1.1.1] which are certified to carry 400 persons or more are to comply with the provisions of Pt D, Ch 12, Sec 3, [2.3.12], assuming the damage applied anywhere within the ship's length L, not later than the date of the first class renewal survey after the prescribed date of compliance, which is the one occurring the latest among those given in Tab 2, Tab 3 and item a).

Table 2 : Date of compliance according to A/A_{max}

Value of A/A_{max}	Date of compliance
$A/A_{max} < 85\%$	1st October 1998
$85\% \le A/A_{max} < 90\%$	1st October 2000
$90\% \le A/A_{max} < 95\%$	1st October 2002
$95\% \le A/A_{max} < 97,5\%$	1st October 2004
$A/A_{max} \ge 97,5\%$	1st October 2010

Table 3 : Date of compliance according to the number of persons permitted to be carried

Number of persons (N.)	Date of compliance
$N. \ge 1500$	1st October 2002
$1000 \le N. < 1500$	1st October 2006
$600 \le N. < 1000$	1st October 2008
$400 \le N. < 600$	1st October 2010

a) when the age of the ship is equal to or greater than 20 years, where the age of the ship means the time counted from the date on which the keel was laid, or the date on which it was at a similar stage of construction, or from the date on which the ship was converted to a ro-ro passenger ship.

Section 4 Cargo Ships

1 Strength requirements for fore deck fittings and equipment, strength and securing of small hatches on the exposed fore deck

1.1 Application and requirements

1.1.1 These retroactive rule requirements apply to ships which are assigned one of the following service notations:

- **general cargo ship**
- **bulk carrier** (without ESP additional service feature)
- **refrigerated cargo ship**
- **livestock carrier**
- **deck ship**,

of 100 m in length and above, that are contracted for construction prior to 1st January 2004.

Note 1: The requirements also apply to dedicated forest product carriers (other than woodchip carriers) and to dedicated cement carriers.

1.1.2 These retroactive rule requirements provide strength requirements to resist green sea forces for the following items located within the forward quarter length: air pipes, ventilator pipes and their closing devices.

They are applicable only for air pipes, ventilator pipes and their closing devices on the exposed deck serving spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards.

The provisions for compliance with these strength requirements for fore deck fittings and equipment are given in Pt C, Ch 1, Sec 10, [9.1.9].

These retroactive rule requirements are also applicable for small hatches on the exposed deck giving access to spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards.

They are related to the strength of, and securing for, such small hatches fitted on the exposed fore deck.

The provisions for compliance with these requirements for strength and securing of small hatches on the exposed fore deck are given in Pt B, Ch 11, Sec 10, [3].

Note 1: For ships contracted for construction prior to 1st July 2007, the following is to be carried out:

- securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are to be provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover,

by the compliance date specified in [1.2.1] or by the due date of the first class renewal survey after 1st July 2007 whichever is later. Completion prior to 1st July 2007 of a class renewal survey with a due date after 1st July 2007 cannot be used to postpone compliance.

Note 2: These requirements do not apply to the cargo tank venting systems and the inert gas systems of tankers.

1.2 Schedule for compliance

1.2.1 Ships referred to in [1.1.1] are to comply with the provisions of Pt B, Ch 11, Sec 10, [3] and of Pt C, Ch 1, Sec 10, [9.1.9] by the following dates:

- for ships which will be 15 years of age or more on 1st January 2004, by the due date of the first intermediate or class renewal survey after that date
- for ships which will be 10 years of age or more on 1st January 2004, by the due date of the first class renewal survey after that date
- for ships which will be less than 10 years of age on 1st January 2004, by the date on which the ship reaches 10 years of age.

1.2.2 Completion, prior to 1st January 2004, of an intermediate or class renewal survey with a due date after 1st January 2004 cannot be used to postpone compliance. However, completion prior to 1st January 2004 of an intermediate survey the window for which straddles 1st January 2004 can be accepted.

2 Water level detectors on single hold cargo ships other than bulk carriers

2.1 Application and requirements

2.1.1 These retroactive rule requirements normally apply to ships which are assigned one of the following service notations:

- **general cargo ship** (see Note 1 hereafter)
- **bulk carrier** (without ESP additional service feature)
- **refrigerated cargo ship**

- **container ship**,
- **ro-ro cargo ship** (see Note 2 hereafter)
- **livestock carrier**
- **deck ship** (see Note 2 hereafter)
- **liquefied gas carrier** (of LPG type) (see Note 2 hereafter)
- **supply vessel** (see Note 2 hereafter)

and

- of gross tonnage equal or above 500, and
- constructed before 1st January 2007 with length of less than 80 m, or 100 m if constructed before 1st July 1998, and
- with a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to that deck.

Note 1: The requirements also apply to dedicated cement carriers, dedicated forest product carriers, dedicated woodchip carriers, timber and log carriers with the same conditions.

Note 2: The scope of application for these type of ships is subject to special consideration.

2.1.2 They are related to the fitting of water level detectors in such space or spaces.

2.1.3 The water level detectors required by the present Article need not be fitted in ships complying with Ch 6, Sec 2, [6], or in ships having watertight side compartments each side of the cargo hold length extending vertically at least from inner bottom to freeboard deck.

2.2 Schedule for compliance

2.2.1 Ships referred to in [2.1.1] are to comply with the provisions of Ch 6, App 1, [8] not later than 31st December 2009.

Section 5 Ships with Ice Classes

1 General

1.1 Application

1.1.1 Ships which have been assigned the additional class notations **ICE CLASS IB** or **ICE CLASS IC**, the keel of which has been laid or which has been at a similar stage of construction on 1st November 1986 or thereafter, but before 1st September 2003, are to comply with the requirements indicated in [2.1.1].

1.1.2 Ships which have been assigned the additional class notations **ICE CLASS IA SUPER** or **ICE CLASS IA**, the keel of which has been laid or which has been at a similar stage of construction before 1st September 2003, are to comply with the requirements indicated in [2.1.2].

1.1.3 Ships which have been assigned one of the additional class notations **ICE CLASS IA SUPER** or **ICE CLASS IA** or **ICE CLASS IB** or **ICE CLASS IC** built before 1st July 2007 are to comply with the requirements indicated in [3].

2 Requirements to maintain ice classes

2.1

2.1.1 Ships referred to in [1.1.1] are to comply with the provisions of Pt F, Ch 8, Sec 1, [3.1] of the June 2000 edition of the Rules, in order to maintain their additional class notations **ICE CLASS IB** or **ICE CLASS IC**.

Note 1: In the formula of the BV Rules June 2000 edition, Pt F, Ch 8, Sec 1, [3.1], the displacement restriction is applied only to the part in the formula which is in parenthesis, and not to form factor F_3. The full displacement of the ship is to be used in factor F_3.

2.1.2 Ships referred to in [1.1.2] are to comply with the provisions of Pt F, Ch 8, Sec 1, [3.1.3], in order to maintain their additional class notations **ICE CLASS IA SUPER** or **ICE CLASS IA**, at the following dates:

- 1st January 2005 or
- 1st January in the year when 20 years has elapsed since the year the ship was delivered,

whichever occurs the latest.

When, for an existing ship, values for some of the hull form parameters required for the calculation method in Pt F, Ch 8, Sec 1, [3.1.3] are difficult to obtain, the following alternative formulae can be used:

$$R_{CH} = C_1+C_2+C_3(H_F+H_M)^2(B+0,658H_F)+C_4LH_F^2+C_5\left(\frac{LT}{B^2}\right)^3\frac{B}{4}$$

with $5 \le \left(\frac{LT}{B^2}\right)^3 \le 20$

- for **ICE CLASS IA**

  C_1 and C_2 are to be taken as zero.

- for **ICE CLASS IA SUPER**

  Ship without a bulb, C_1 and C_2 are to be calculated as follows:

$$C_1 = f_1\frac{BL}{2\frac{T}{B}+1}+1,84(f_2B+f_3L+f_4BL)$$

$$C_2 = 3,52(g_1+g_2B)+g_3\left(1+1,2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}$$

- for **ICE CLASS IA SUPER**

  Ship with a bulb, C_1 and C_2 are to be calculated as follows:

$$C_1 = f_1\frac{BL}{2\frac{T}{B}+1}+2,89(f_2B+f_3L+f_4BL)$$

$$C_2 = 6,67(g_1+g_2B)+g_3\left(1+1,2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}$$

Values of f_i and g_i are given in Tab 1.

C_3 = 460 kg/(m²·s²)

C_4 = 18,7 kg/(m²·s²)

C_5 = 825 kg/s²

Table 1 : Values of f_i and g_i

f_1 = 10,3 N/m²	g_1 = 1530 N
f_2 = 45,8 N/m	g_2 = 170 N/m
f_3 = 2,94 N/m	g_3 = 400 N/m^{1,5}
f_4 = 5,8 N/m²	

3 Ice class draught marking

3.1

3.1.1 Ships referred to in [1.1.3] are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships as indicated in Pt F, Ch 8, Sec 1, Fig 2, if the UIWL is below the summer load line, not later than the first scheduled bottom survey in dry-dock after the 1st July 2007.

Note 1: The upper ice waterline (UIWL) shall be the envelope of the highest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

Appendix 1 Technical Retroactive Requirements for Bulk Carriers and Other Types of Ships

1 General

1.1

1.1.1 The present Appendix contains the technical requirements applicable retroactively to existing ships listed in Ch 6, Sec 2.

2 Evaluation of scantlings of the transverse watertight vertically corrugated bulkheads between the two foremost cargo holds

2.1 Application and definitions

2.1.1 These requirements apply to ships indicated in Ch 6, Sec 2, [1.1.1].

2.1.2 In these requirements, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for the two foremost cargo holds, does not exceed 1,20, to be corrected for different cargo densities.

2.1.3 The net scantlings of the transverse bulkhead between the two foremost cargo holds are to be calculated using the loads given in [2.2], the bending moment and shear force given in [2.3] and the strength criteria given in [2.4].

Where necessary, steel renewal and/or reinforcements are required as per [2.6].

2.2 Load model

2.2.1 General

The loads to be considered as acting on the bulkhead are those given by the combination of the cargo loads with those induced by the flooding of the foremost cargo hold.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of the bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions.

Non-homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not be considered according to these requirements.

2.2.2 Bulkhead corrugation flooding head

The flooding head h_f (see Fig 1) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f, in m, from the base line equal to:

- D in general
- 0,95 D for ships less than 50000 t deadweight with type B freeboard,

D being the distance, in m, from the base line to the freeboard deck at side amidships (see Fig 1).

For ships to be operated at an assigned load line draught Tr less than the permissible load line draught T, the flooding head defined for the two cases above may be reduced by (T – Tr).

2.2.3 Pressure in the flooded hold: bulk cargo loaded hold

Two cases are to be considered, depending on the values of d_1 and d_f, d_1 (see Fig 1) being a distance from the base line given, in m, by:

$$d_1 = \frac{M_c}{\rho_c l_c B} + \frac{v_{LS}}{l_c B} + (h_{HT} - h_{DB})\frac{b_{HT}}{B} + h_{DB}$$

where:

M_c : Mass of cargo, in t, in the foremost cargo hold

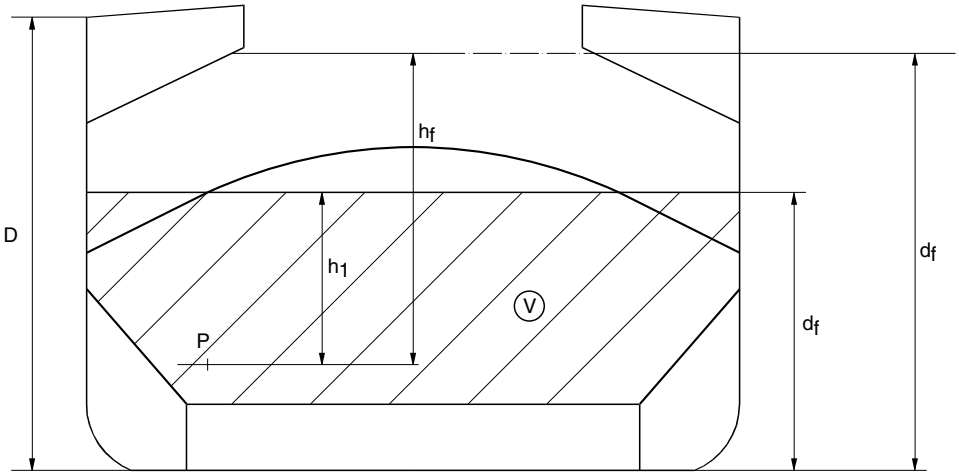
ρ_c : Bulk cargo density, in t/m^3

l_c : Length of the foremost cargo hold, in m

B : Ship's breadth amidships, in m

v_{LS} : Volume, in m^3, of the bottom stool above the inner bottom

Figure 1 : Calculation of pressure on the bulkhead in the flooded cargo hold



V = Volume of cargo

P = Calculation point

h_{HT} : Height of the hopper tanks amidships, in m, from the base line

h_{DB} : Height of the double bottom, in m

b_{HT} : Breadth of the hopper tanks amidships, in m.

a) Case when $d_f \geq d_1$

At each point of the bulkhead located at a distance between d_1 and d_f from the base line, the pressure $p_{c,f}$, in kN/m^2, is given by: $p_{c,f} = \rho\, g\, h_f$

where:

ρ : Sea water density, in t/m^3

g : Gravity acceleration, equal to 9,81 m/s^2

h_f : Flooding head as defined in [2.2.2].

At each point of the bulkhead located at a distance lower than d_1 from the base line, the pressure $p_{c,f}$, in kN/m^2, is given by:

$p_{c,f} = \rho\, g\, h_f + [\rho_c - \rho\,(1 - perm)]\, g\, h_1 \tan^2\gamma$

where:

ρ, g, h_f : As given above

ρ_c : Bulk cargo density, in t/m^3

perm : Permeability of cargo, to be taken as 0,3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3,0 t/m^3)

h_1 : Vertical distance, in m, from the calculation point to a level located at a distance d_1, as defined above, from the base line (see Fig 1)

γ : $\gamma = 45° - (\phi / 2)$

ϕ : Angle of repose of the cargo, in degrees, and may generally be taken as 35° for iron ore.

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1\left[\rho g\frac{(d_f-d_1)^2}{2} + \frac{\rho g(d_f-d_1) + (p_{c,f})_{le}}{2}(d_1-h_{DB}-h_{LS})\right]$$

where:

s_1 : Spacing of corrugations, in m (see Fig 2)

ρ, g, d_1, h_{DB} : As given above

d_f : As given in [2.2.2]

$(p_{c,f})_{le}$: Pressure, in kN/m^2, at the lower end of the corrugation

h_{LS} : Height of the lower stool, in m, from the inner bottom.

b) Case when $d_f < d_1$

At each point of the bulkhead located at a distance between d_f and d_1 from the base line, the pressure $p_{c,f}$, in kN/m^2, is given by: $p_{c,f} = \rho_c\, g\, h_1 \tan^2\gamma$

where:

ρ_c, g, h_1, γ : As given in a) above

At each point of the bulkhead located at a distance lower than d_f from the base line, the pressure $p_{c,f}$, in kN/m^2, is given by:

$p_{c,f} = \rho\, g\, h_f + [\rho_c\, h_1 - \rho\,(1 - perm)\, h_f]\, g \tan^2\gamma$

where:

ρ, g, h_f, ρ_c, h_1, perm, γ: As given in item a) above.

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1\left[\rho_c g\frac{(d_1 - d_f)^2}{2}\tan^2\gamma\right] + s_1\left[\frac{\rho_c g(d_1 - d_f)\tan^2\gamma + (p_{c,f})_{le}}{2}(d_f - h_{DB} - h_{LS})\right]$$

where:

s_1, ρ_c, g, γ, $(p_{c,f})_{le}$, h_{LS} : As given in a) above

d_1, h_{DB} : As given in [2.2.3]

d_f : As given in [2.2.2].

2.2.4 Pressure in the flooded hold: empty hold

At each point of the bulkhead, the hydrostatic pressure p_f induced by the flooding head h_f is to be considered.

The force F_f, in kN, acting on a corrugation is given by:

$$F_f = s_1\rho g\frac{(d_f - h_{DB} - h_{LS})^2}{2}$$

where:

s_1, ρ, g, h_{LS} : As given in [2.2.3], item a)

h_{DB} : As given in [2.2.3]

d_f : As given in [2.2.2].

2.2.5 Pressure in the non-flooded bulk cargo loaded hold

At each point of the bulkhead, the pressure p_c, in kN/m^2, is given by: $p_c = \rho_c\, g\, h_1 \tan^2\gamma$ where:

ρ_c, g, h_1, γ: As given in [2.2.3], item a).

The force F_c, in kN, acting on a corrugation is given by:

$$F_c = s_1\rho_c g\frac{(d_1 - h_{DB} - h_{LS})^2}{2}\tan^2\gamma$$

where:

ρ_c, g, s_1, h_{LS}, γ: As given in [2.2.3], item a)

d_1, h_{DB} : As given in [2.2.3].

2.2.6 Resultant pressure in homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by: $p = p_{c,f} - 0{,}8\, p_c$

The resultant force F, in kN, acting on a corrugation is given by: $F = F_{c,f} - 0{,}8\, F_c$

2.2.7 Resultant pressure in non-homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by: $p = p_{c,f}$

The resultant force F, in kN, acting on a corrugation is given by: $F = F_{c,f}$

Where the foremost cargo hold, in non-homogeneous loading conditions, is not allowed to be loaded, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by: $p = p_f$

and the resultant force F, in kN, acting on a corrugation is given by: $F = F_f$

2.3 Bending moment and shear force in the bulkhead corrugations

2.3.1 General

The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in [2.3.2] and [2.3.3]. The M and Q values are to be used for the checks in [2.4].

2.3.2 Bending moment

The design bending moment M, in kN.m, for the bulkhead corrugations is given by:

$$M = \frac{F\ell}{8}$$

where:

F : Resultant force in kN, as given in [2.2.6] or [2.2.7]

ℓ : Span of the corrugation, in m, to be taken according to Fig 2 and Fig 3.

Figure 2 : Parameters of vertically corrugated bulkhead

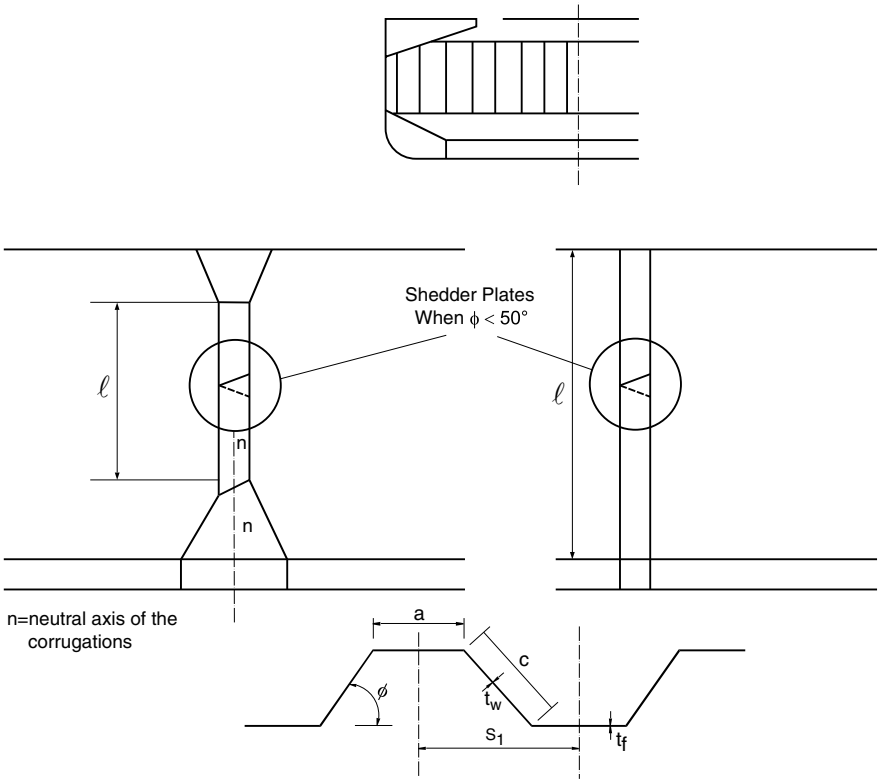
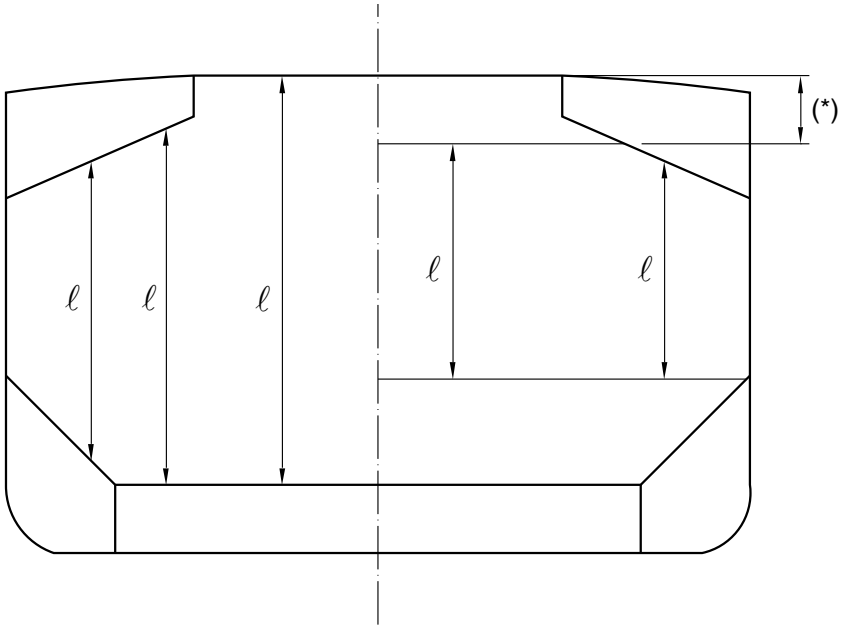


Figure 3 : Definition of the corrugation span



(*): For the definition of ℓ, the internal end of the upper stool is not to be taken more than a distance from the deck at the centreline equal to:

- three times the depth of corrugations, in general
- twice the depth of corrugations, for rectangular stool.

2.3.3 Shear force

The shear force Q, in kN, at the lower end of the bulkhead corrugations is given by:

$Q = 0,8\ F$

where:

F : As given in [2.2.6] or [2.2.7].

2.4 Strength criteria

2.4.1 General

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Fig 2).

Requirements for local net plate thickness are given in [2.4.8].

In addition, the criteria given in [2.4.2] and [2.4.5] are to be complied with.

Where the corrugation angle ϕ shown in Fig 2 is less than 50°, a horizontal row of staggered shedder plates is to be fitted at approximately mid-depth of the corrugations (see Fig 2) to help preserve dimensional stability of the bulkhead under flooding loads. The shedder plates are to be welded to the corrugations by double continuous welding, but they are not to be welded to the side shell.

The thicknesses of the lower part of corrugations considered in the application of [2.4.2] and [2.4.3] are to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than $0,15\ \ell$.

The thicknesses of the middle part of corrugations considered in the application of [2.4.2] and [2.4.4] are to be maintained to a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than $0,3\ \ell$.

2.4.2 Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$10^3 \frac{M}{0,5 Z_{le} \sigma_{a,le} + Z_m \sigma_{a,m}} \leq 1,0$$

where:

M : Bending moment, in kN.m, as given in [2.3.2]

Z_{le} : Section modulus of one half pitch corrugation, in cm^3, at the lower end of corrugations, to be calculated according to [2.4.3]

Z_m : Section modulus of one half pitch corrugation, in cm^3, at the mid-span of corrugations, to be calculated according to [2.4.4]

$\sigma_{a,le}$: Allowable stress, in N/mm^2, as given in [2.4.5], for the lower end of corrugations

$\sigma_{a,m}$: Allowable stress, in N/mm^2, as given in [2.4.5], for the mid-span of corrugations.

In no case is Z_m to be taken greater than the lesser of $1,15Z_{le}$ and $1,15Z'_{le}$ for calculation of the bending capacity, Z'_{le} being defined below.

Where effective shedders plates are fitted which:

- are not knuckled
- are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent
- are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating,

or effective gusset plates are fitted which:

- are fitted in line with the stool side plating
- have material properties at least equal to those provided for the flanges,

the section modulus Z_{le}, in cm^3, is to be taken not larger than the value Z'_{le}, in cm^3, given by:

$$Z'_{le} = Z_g + 10^3 \frac{Q h_g - 0,5 h_g^2 s_1 p_g}{\sigma_a}$$

where:

Z_g : Section modulus of one half pitch corrugation, in cm^3, according to [2.4.4], in way of the upper end of shedder or gusset plates, as applicable

Q : Shear force, in kN, as given in [2.3.3]

h_g : Height, in m, of shedders or gusset plates, as applicable (see Fig 4, Fig 5, Fig 6, Fig 7 and Fig 8)

s_1 : As given in [2.2.3], item a)

p_g : Resultant pressure, in kN/m^2, as defined in [2.2.6] and [2.2.7], calculated in way of the middle of the shedders or gusset plates, as applicable

σ_a : Allowable stress, in N/mm^2, as given in [2.4.5].

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by $(\sin\phi)$, ϕ being the angle between the web and the flange.

When calculating the section moduli and the shear area, the net plate thicknesses are to be used.

The section moduli of corrugations are to be calculated on the basis of the requirements given in [2.4.3] and [2.4.4].

2.4.3 Section modulus at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef}, not larger than as given in [2.4.6].

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

a) Provided that effective shedder plates, as defined in [2.4.2], are fitted (see Fig 4 and Fig 5), when calculating the section modulus of corrugations at the lower end (cross-section 1 in Fig 4 and Fig 5, the area of flange plates, in cm^2, may be increased by the following value (which is not to be taken greater than 2,5 a t_f):

$$2,5\,a\sqrt{t_f t_{sh}}\sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}}$$

where:

a : Width, in m, of the corrugation flange (see Fig 2)

t_{sh} : Net shedder plate thickness, in mm

t_f : Net flange thickness, in mm

σ_{Fsh} : Minimum upper yield stress, in N/mm^2, of the material used for the shedder plate

σ_{Ffl} : Minimum upper yield stress, in N/mm^2, of the material used for the corrugation flanges.

b) Provided that effective gusset plates, as defined in [2.4.2], are fitted (see Fig 6, Fig 7 and Fig 8) when calculating the section modulus of corrugations at the lower end (cross-section 1 in Fig 6, Fig 7 and Fig 8), the area of flange plates, in cm^2, may be increased by 7 h_g t_{gu}, where:

h_g : Height of gusset plate in m, see Fig 6, Fig 7 and Fig 8, not to be taken greater than s_{gu} / 0,7

s_{gu} : Width of the gusset plates, in mm

t_{gu} : Net gusset plate thickness, in mm, not to be taken greater than t_f

t_f : Net flange thickness, in mm, based on the as-built condition.

c) If the corrugation webs are welded to a sloping stool top plate, which is at an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. Where effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in b) above. No credit can be given to shedder plates only.

For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

Figure 4 : Symmetrical shedder plates

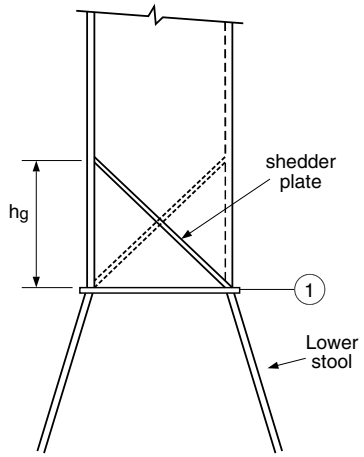


Figure 5 : Asymmetrical shedder plates

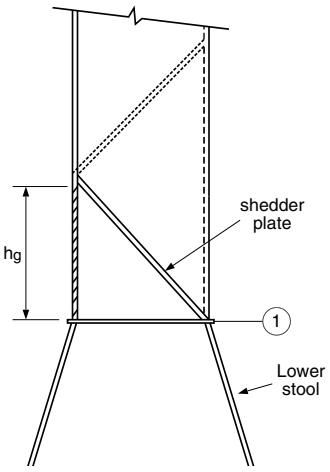


Figure 6 : Symmetrical gusset/shedder plates

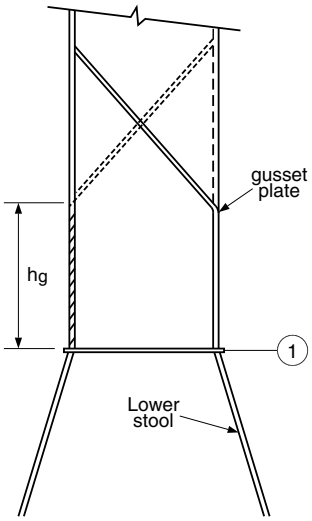


Figure 7 : Asymmetrical gusset/shedder plates

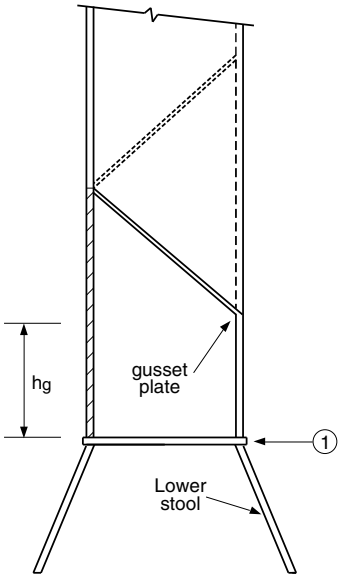
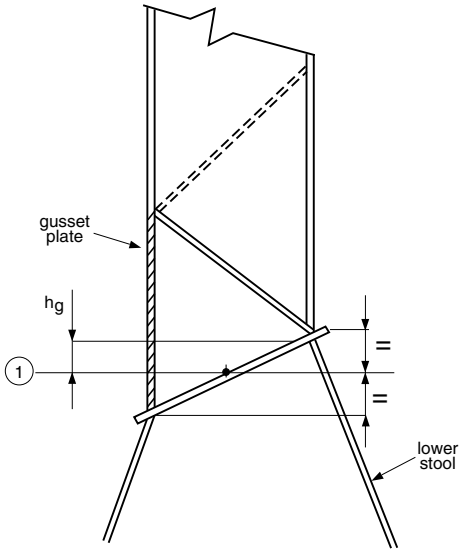


Figure 8 : Asymmetrical gusset/shedder plates - Sloping stool top plate



2.4.4 Section modulus of corrugations at cross-sections other than the lower end

The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width not larger than as given in [2.4.6].

2.4.5 Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a, in N/mm^2, given by:

$\sigma_a = \sigma_F$

$\tau_a = 0,5\ \sigma_F$

where:

σ_F : Minimum upper yield stress, in N/mm^2, of the material.

2.4.6 Effective width of the compression flange of corrugations

The effective width b_{ef}, in m, of the corrugation flange is given by: $b_{ef} = C_e\ a$

where:

$$C_e = \frac{2,25}{\beta} - \frac{1,25}{\beta^2} \qquad \text{for} \quad \beta > 1,25$$

$$C_e = 1 \qquad \text{for} \quad \beta \leq 1,25$$

$$\beta = 10^3 \frac{a}{t_f}\sqrt{\frac{\sigma_F}{E}}$$

t_f : Net flange thickness, in mm

a : As given in [2.4.2]

σ_F : Minimum upper yield stress, in N/mm^2, of the material

E : Modulus of elasticity, in N/mm^2, to be assumed equal to 206000 N/mm^2 for steel.

2.4.7 Shear buckling check

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress τ is not to exceed the critical value τ_C, in N/mm^2, obtained as follows:

$$\tau_C = \tau_E \qquad \text{for} \quad \tau_E \leq \frac{\tau_F}{2}$$

$$\tau_C = \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \qquad \text{for} \quad \tau_E > \frac{\tau_F}{2}$$

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

where:

σ_F : Minimum upper yield stress, in N/mm^2, of the material

$$\tau_E = 0,9 k_t E\left(\frac{t}{1000c}\right)^2$$

$k_t = 6,34$

E : Modulus of elasticity, in N/mm^2, as given in [2.4.6]

t : Net thickness, in mm, of corrugation web

c : Width, in m, of corrugation web (see Fig 2).

2.4.8 Local net plate thickness

The bulkhead local net plate thickness t, in mm, is given by:

$$t = 14,9 s_w \sqrt{\frac{p}{\sigma_F}}$$

where:

s_w : Plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Fig 2)

p : Resultant pressure, in kN/m^2, as defined in [2.2.6] and [2.2.7], at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool or at the inner bottom, if no lower stool is fitted, or at the top of shedders, if shedder or gusset/shedder plates are fitted

σ_F : Minimum upper yield stress, in N/mm^2, of the material.

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different, the net thickness of the narrower plating is to be not less than t_n, in mm, given by:

$$t_n = 14,9 s_n \sqrt{\frac{p}{\sigma_F}}$$

where:

s_n : Width, in m, of the narrower plating.

The net thickness of the wider plating, in mm, is not to be taken less than the maximum of the following values:

$$t_w = 14,9 s_w \sqrt{\frac{p}{\sigma_F}}$$

$$t_w = \sqrt{\frac{440 s_w^2 p}{\sigma_F} - t_{np}^2}$$

where:

t_{np} : Thickness, in mm, less or equal to the actual net thickness of the narrower plating and not to be greater than:

$$14,9 s_w \sqrt{\frac{p}{\sigma_F}}$$

2.5 Local details

2.5.1 General

As applicable, the design of local details is to comply with the Society's requirements for the purpose of transferring the corrugated bulkhead forces and moments to the boundary structures, especially to the double bottom and cross-deck structures.

In particular, the thickness and stiffness of gusset and shedder plates, as defined in [2.4.3], installed for strengthening purposes, are to comply with the Society's requirements on the basis of the load model in [2.2].

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.

2.6 Steel renewal

2.6.1 General

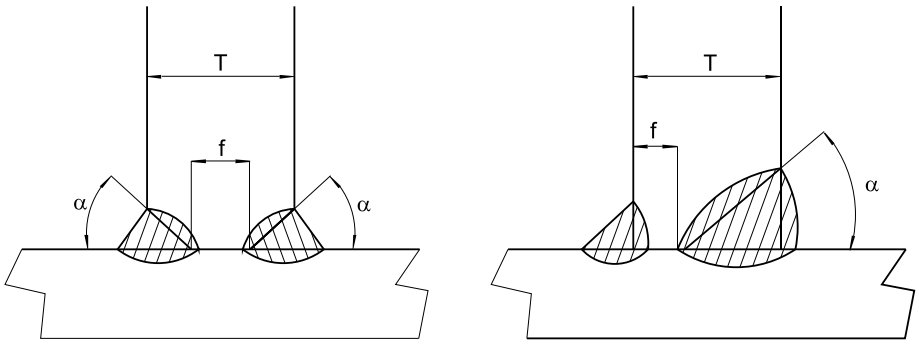
Renewal/reinforcement is to be carried out in accordance with the following requirements and the guidelines contained in [3].

2.6.2 Steel renewal is required where the gauged thickness is less than (t_{net} + 0,5) mm, t_{net} being the thickness used for the calculation of bending capacity and shear stresses as given in [2.4.2] or the local net plate thickness as given in [2.4.8]. Alternatively, reinforcing doubling strips may be used providing the net thickness is not dictated by shear strength requirements for web plates (see [2.4.5] and [2.4.7]) or by local pressure requirements for web and flange plates (see [2.4.8]).

Where steel renewal is required, the bulkhead connections to the lower stool shelf plate (or inner bottom, if no stool is fitted) are to be made at least by deep penetration welds (see Fig 9).

Where the gauged thickness is within the range (t_{net} + 0,5) mm and (t_{net} + 1,0) mm, coating (applied in accordance with the coating Manufacturer's specifications) or annual gauging may be adopted as an alternative to steel renewal.

Figure 9 : Deep penetration welds of shedder and gusset plates



Root face (f): 3 mm to T/3 mm Groove angle (α): 40° to 60°

2.6.3 Where steel renewal or reinforcement is required, a minimum thickness of (t_{net} + 2,5) mm is to be replenished for the renewed or reinforced parts.

2.6.4 Gussets with shedder plates, extending from the lower end of corrugations up to 0,1 ℓ, or reinforcing doubling strips (on bulkhead corrugations and stool side plating) are to be fitted when:

$$\frac{\sigma_{Fs} t_{st}}{\sigma_{Ffl} t_{fl}} \leq 0,8$$

where:

σ_{Ffl} : Minimum upper yield stress, in N/mm², of the material used for the corrugation flanges

σ_{Fs} : Minimum upper yield stress, in N/mm^2, of the material used for the lower stool side plating (or floors, if no stool is fitted)

t_{fl} : Flange thickness, in mm, which is found to be acceptable on the basis of the criteria specified in [2.6.2] or, when steel renewal is required, the replenished thickness according to the criteria specified in [2.6.3]. The above flange thickness dictated by local pressure requirements (see [2.4.8]) need not be considered for this purpose

t_{st} : As-built thickness, in mm, of the lower stool side plating (or floors, if no stool is fitted).

If gusset plates are fitted, their material is to be the same as that of the corrugation flanges. The gusset plates are to be connected to the lower stool shelf plate (or inner bottom, if no lower stool is fitted) by deep penetration welds (see Fig 9).

Where gusset plates are to be fitted or renewed, their connections with the corrugations and the lower stool shelf plate (or inner bottom, if no stool is fitted) are to be made at least by deep penetration welds (see Fig 9).

3 Guidance on renewal/reinforcement of the transverse watertight vertically corrugated bulkhead between the two foremost cargo holds

3.1

3.1.1 The need for renewal or reinforcement of the transverse watertight vertically corrugated bulkhead between the two foremost cargo holds will be determined by the Society on a case-by-case basis using the criteria given in [2] in association with the most recent gaugings and survey findings.

3.1.2 In addition to Rule requirements, the assessment of the transverse corrugated bulkhead based on the criteria given in [2] will take into account the following:

- scantlings of individual vertical corrugations will be assessed for reinforcement/renewal based on thickness measurements obtained in accordance with Ch 6, Sec 2, [1.3] at their lower end, at mid-depth and in way of plate thickness changes in the lower 70%. These considerations will take into account the provision of gussets and shedder plates and the benefits they offer, provided that they comply with [2.4.2] and [2.6].
- taking into account the scantlings and arrangements for each case, permissible levels of diminution will be determined and appropriate measures taken in accordance with [2.6].

3.1.3 Where renewal is required, its extent is to be shown clearly in plans. The vertical distance of each renewal zone is to be determined by considering the criteria given in [2] and is generally to be not less than 15% of the vertical distance between the upper and lower end of the corrugation measured at the ship's centreline.

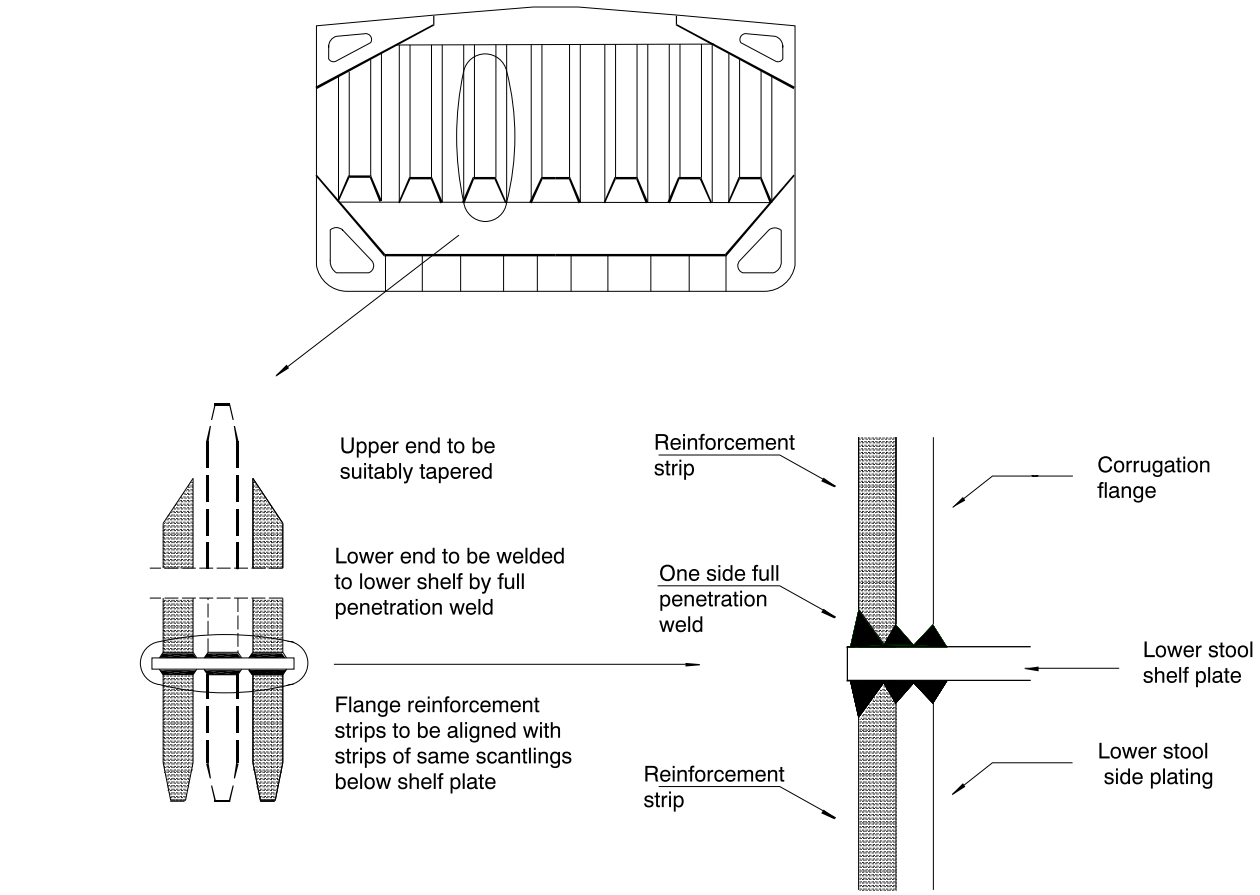
3.1.4 Where the reinforcement is accepted by adding strips, the length of the reinforcing strips is to be sufficient to extend over the whole depth of the diminished plating. In general, the width and thickness of strips are to be sufficient to comply with the criteria given in [2]. The material of the strips is to be the same as that of the corrugation plating. The strips are to be attached to the existing bulkhead plating by continuous fillet welds. The strips are to be suitably tapered or connected at ends in accordance with the usual welding practice to the Surveyor's satisfaction.

3.1.5 Where reinforcing strips are connected to the inner bottom or lower stool shelf plates, one side full penetration welding is to be used. When reinforcing strips are fitted to the corrugation flange and are connected to the lower stool shelf plate, they are normally to be aligned with strips of the same scantlings welded to the stool side plating and having a minimum length equal to the breadth of the corrugation flange.

3.1.6 Fig 10 gives a general arrangement of structural reinforcement. When such reinforcement is carried out, the following applies:

- square or trapezoidal corrugations are to be reinforced with plate strips fitted to each corrugation flange sufficient to meet the requirements given in [2]
- the number of strips fitted to each corrugation flange is to be sufficient to meet the requirements given in [2]
- the shedder plate may be fitted in one piece or prefabricated with a welded knuckle (gusset plate)
- gusset plates, where fitted, are to be welded to the shelf plate in line with the flange of the corrugation, to reduce the stress concentrations at the corrugation corners. Good alignment is to be ensured between gusset plates, corrugation flanges and lower stool sloping plates. Deep penetration welding is to be used at all connections. Start and stop of welding are to be as far away as possible from corners of corrugations
- shedder plates are to be attached by one side full penetration welds onto backing bars
- shedder and gusset plates are to have a thickness equal to or greater than the original bulkhead thickness. Gusset plates are to have a minimum height (on the vertical part) equal to half of the width of the corrugation flange. Shedders and gussets are to be of the same material as that of the flange.

Figure 10 : Reinforcement of vertically corrugated bulkhead



4 Evaluation of allowable hold loading of the foremost cargo hold with the same cargo hold flooded

4.1 Application and definitions

4.1.1 These requirements apply to bulk carriers:

- of single side skin construction
- of 150 metres in length and above
- intended to carry solid bulk cargoes having a bulk density of 1,78 t/m^3 or above
- contracted for construction prior to 1st July 1998, and not constructed in compliance with the applicable requirements for new buildings contracted after that date, and given in Pt D, Ch 4, Sec 3.

4.1.2 The loading in the foremost cargo hold is not to exceed the allowable hold loading in the flooded condition, calculated as per [4.4], using the loads given in [4.2] and the shear capacity of the double bottom given in [4.3].

In no case is the allowable hold loading in flooding condition to be taken greater than the design hold loading in intact condition.

4.2 Load model

4.2.1 General

The loads to be considered as acting on the double bottom of the foremost cargo hold are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the foremost cargo hold itself.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions
- packed cargo conditions, such as steel mill products.

For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold limit.

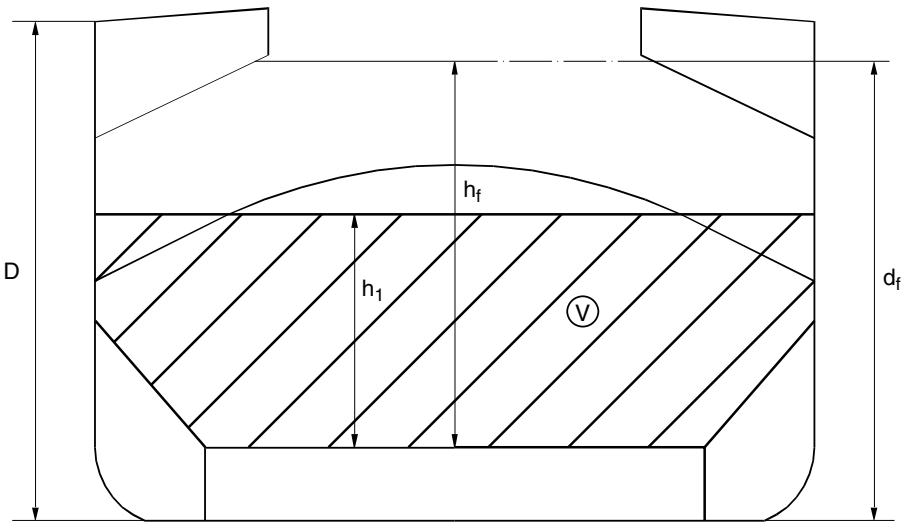
4.2.2 Inner bottom flooding head

The flooding head h_f (see Fig 11) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the base line equal to:

- D in general
- 0,95 D for ships less than 50,000 tonnes deadweight with type B freeboard,

D being the distance, in m, from the base line to the freeboard deck at side amidships (see Fig 11).

Figure 11 : Calculation of pressure on the inner bottom in the flooded cargo hold



V = Volume of cargo

4.3 Shear capacity of the double bottom of the foremost cargo hold

4.3.1 General

The shear capacity C of the double bottom of the foremost cargo hold is defined as the sum of the shear strength at each end of:

- all floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Fig 12)
- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

The strength of girders or floors which run out and are not directly attached to the boundary stool or hopper girder is to be evaluated for the one end only.

Note 1: The floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

Note 2: When the geometry and/or the structural arrangement of the double bottom is such as to make the above assumptions inadequate, at the Society's discretion, the shear capacity C of the double bottom is to be calculated by means of direct calculations to be carried out according to Pt B, Ch 7, Sec 6, as far as applicable.

In calculating the shear strength, the net thicknesses of floors and girders are to be used. The net thickness t_{net}, in mm, is given by:

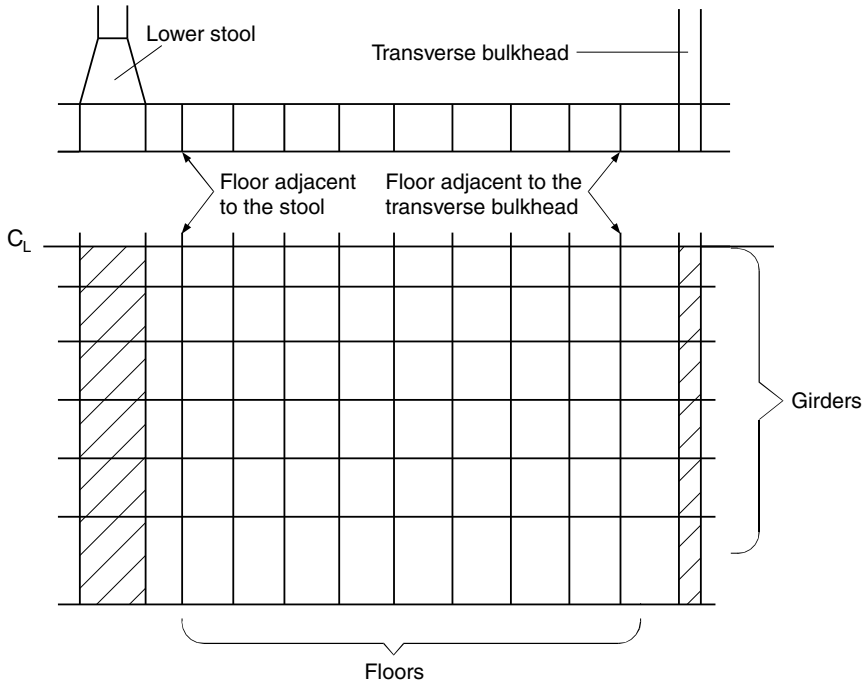
$$t_{net} = t - t_C$$

where:

t : As-built thickness, in mm, of floors and girders

t_C : Corrosion diminution, equal to 2 mm, in general; a lower value of t_C may be adopted, provided that measures are taken, to the Society's satisfaction, to justify the assumption made.

Figure 12 : Double bottom structure



4.3.2 Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1}, in kN, and the floor shear strength in way of the openings in the outermost bay (i.e. that bay which is closest to the hopper) S_{f2}, in kN, are given by the following expressions:

$$S_{f1} = 10^{-3} A_f \frac{\tau_a}{\eta_1}$$

$$S_{f2} = 10^{-3} A_{f,h} \frac{\tau_a}{\eta_2}$$

where:

A_f : Sectional area, in mm^2, of the floor panel adjacent to hoppers

$A_{f,h}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e. that bay which is closest to the hopper)

τ_a : Allowable shear stress, in N/mm^2, to be taken equal to:

$$\tau_a = \frac{\sigma_F}{\sqrt{3}}$$

σ_F : Minimum upper yield stress, in N/mm^2, of the material

η_1 : $\eta_1 = 1,10$

η_2 : $\eta_2 = 1,20$

η_2 may be reduced, at the Society's discretion, down to 1,10 where appropriate reinforcements are fitted to the Society's satisfaction.

4.3.3 Girder shear strength

The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) S_{g1} , in kN, and the girder shear strength in way of the largest opening in the outermost bay (i.e. that bay which is closest to the stool, or transverse bulkhead, if no stool is fitted) S_{g2} , in kN, are given by the following expressions:

$$S_{g1} = 10^{-3} A_g \frac{\tau_a}{\eta_1}$$

$$S_{g2} = 10^{-3} A_{g,h} \frac{\tau_a}{\eta_2}$$

where:

A_g : Minimum sectional area, in mm^2, of the girder panel adjacent to stools (or transverse bulkheads if no stools are fitted)

$A_{g,h}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closest to the stool, or transverse bulkhead, if no stool is fitted)

τ_a : Allowable shear stress, in N/mm^2, as given in [4.3.2]

η_1 : $\eta_1 = 1,10$

η_2 : $\eta_2 = 1,15$

η_2 may be reduced, at the Society's discretion, down to 1,10 where appropriate reinforcements are fitted to the Society's satisfaction.

4.4 Allowable hold loading

4.4.1 The allowable hold loading W, in t, is given by:

$$W = \rho_c V \frac{1}{F}$$

where:

F : Equal to 1,05 in general (for steel mild products, F = 1,0)

ρ_c : Cargo density, in t/m^3; for bulk cargoes see [4.2.1]; for steel products, ρ_c is to be taken as the density of steel

V : Volume, in m^3, occupied by cargo at a level h_1 given by:

$$h_1 = \frac{X}{\rho_c g}$$

where:

X : For bulk cargoes, is the lesser of X_1 and X_2 given by:

$$X_1 = \frac{Z + \rho g(E - h_f)}{1 + \frac{\rho}{\rho_c}(perm - 1)}$$

$$X_2 = Z + \rho g(E - h_f perm)$$

Note 1: For steel products, X may be taken equal to X_1, using perm = 0

ρ : Sea water density, in t/m^3

g : 9,81 m/s^2, gravity acceleration

E : $E = d_f - 0,1\ D$ with d_f and D as given in [4.2.2]

h_f : Flooding head, in m, as defined in [4.2.2]

perm : Permeability of cargo, to be taken as 0,3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3,0 t/m^3)

Z : The lesser of Z_1 and Z_2 given by:

$$Z_1 = \frac{C_h}{A_{DB,h}}$$

$$Z_2 = \frac{C_e}{A_{DB,e}}$$

with:

C_h : Shear capacity of the double bottom, in kN, as defined in [4.3], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see [4.3.2]) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see [4.3.3])

C_e : Shear capacity of the double bottom, in kN, as defined in [4.3], considering, for each floor, the shear strength S_{f1} (see [4.3.2]) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see [4.3.3])

$A_{DB,h}$: $$A_{DB,h} = \sum_{i=1}^{i=n} S_i B_{DB,i}$$

$A_{DB,e}$: $$A_{DB,e} = \sum_{i=1}^{i=n} S_i (B_{DB} - s)$$

where:

n : Number of floors between stools (or transverse bulkheads, if no stools are fitted)

S_i : Space of the ith-floor, in m

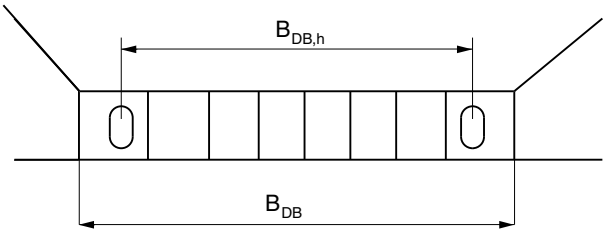
$B_{DB,i}$:
- for floors whose shear strength is given by S_{f1} (see [4.3.2]): $B_{DB,i} = B_{DB} - s$
- for floors whose shear strength is given by S_{f2} (see [4.3.2]): $B_{DB,i} = B_{DB,h}$

where $B_{DB,h}$ is the distance, in m, between the two openings considered (see Fig 13)

B_{DB} : Breadth of double bottom, in m, between hoppers (see Fig 13)

s : Spacing, in m, of double bottom longitudinals adjacent to hoppers.

Figure 13 : Dimensions B_{DB} and $B_{DB,h}$



5 Renewal criteria for side shell frames and brackets in single side skin bulk carriers and single side skin OBO carriers not built in accordance with Part II, Chapter 8, Section 8-03 of the 1st April 1998 edition of the Rules or subsequent editions

5.1 Application and symbols

5.1.1 These retroactive rule requirements apply to:

- the side shell frames and brackets of cargo holds bounded by the single side shell of ships with service notation **bulk carrier ESP** constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk
- the side shell frames and brackets of cargo holds bounded by the single side shell of ships with service notation **combination carrier/OBO ESP** as defined in Ch 1, Sec 2, [4.3.4] but of single side skin construction,

which were not built in accordance with the applicable requirements of Part II, Chapter 8, Section 8-03 of the 1st April 1998 edition of the Rules or subsequent editions.

5.1.2 Symbols

t_M : Thickness as measured, in mm

t_{REN} : Thickness at which renewal is required. Refer to [5.3.1]

$t_{REN,d/t}$: Thickness criteria based on d/t ratio. Refer to [5.3.2]

$t_{REN,S}$: Thickness criteria based on strength. Refer to [5.3.3]

t_{COAT} : $t_{COAT} = 0,75\ t_{S12}$

t_{S12} : Thickness, in mm, as required in Tab 1 for side frame webs and upper and lower end bracket webs

t_{AB} : Thickness as built, in mm

t_C : As defined in Tab 2.

5.2 Ice strengthened ships

5.2.1 Where bulk carriers are reinforced to comply with an ice class notation, the intermediate frames are not to be included when considering compliance with the present Article.

Table 1 : t_{S12} values, in mm

Item	Thickness t_{S12}
Side frame webs	C_L (7,0 + 0,03 L_1)
Lower end brackets	The greater of: • C_L (7,0 + 0,03 L_1) + 2 • as-built thickness of side frame web
Upper end brackets	The greater of: • C_L (7,0 + 0,03 L_1) • as-built thickness of side frame web
Note 1: C_L : Coefficient equal to: • 1,15 for side frames in way of the foremost cargo hold • 1,0 for side frames in way of other cargo holds L_1 : Ship's length, in m, defined in Pt B, Ch 1, Sec 3, Tab 1.	

Table 2 : t_c values, in mm

Ship's length L, in m	Holds other than No.1		Hold No.1	
	Span and upper brackets	Lower brackets	Span and upper brackets	Lower brackets
≤ 100	2,0	2,5	2,0	3,0
150	2,0	3,0	3,0	3,5
≥ 200	2,0	3,0	3,0	4,0
Note: For intermediate ship lengths, t_c is obtained by linear interpolation between the above values.				

5.2.2 The renewal thicknesses for the additional structure required to meet the ice strengthening notation are to be based on the Society's requirements.

5.2.3 If the ice class notation is requested to be withdrawn, the additional ice strengthening structure, with the exception of tripping brackets as required in [5.3.2], item b) and [5.4.2], is not to be considered to contribute to compliance with the present Article.

5.3 Criteria for renewal

5.3.1 General

The webs of side shell frames and brackets are to be renewed when the measured thickness (t_M) is equal to or less than the thickness (t_{REN}) as defined below:

t_{REN} : The greatest of:

- $t_{COAT} - t_C$
- 0,75 t_{AB}
- $t_{REN,d/t}$ (applicable to Zone A and B only) as defined in [5.3.2]
- $t_{REN,S}$ where required by [5.3.3] and as defined in [5.5.4].

The measures are given in [5.3.4] and [5.3.5].

The criteria for frames and brackets are given in [5.3.6].

5.3.2 Thickness criteria based on d/t ratio

Subject to items b) and c) below $t_{REN,d/t}$ is given by the following formula:

$$t_{REN,\,d/t} = \frac{d}{R}$$

where:

d : Web depth, in mm

R : Coefficient given as follows:

- frames:
  65 $k^{0,5}$ for symmetrically flanged frames
  55 $k^{0,5}$ for asymmetrically flanged frames
- lower brackets (see item a) below):

87 $k^{0,5}$ for symmetrically flanged frames

73 $k^{0,5}$ for asymmetrically flanged frames

k : Coefficient given in Pt B, Ch 4, Sec 1, [2.2]

k = 1 for ordinary hull structural steel.

In no instance is $t_{REN,d/t}$ for lower integral brackets to be taken as less than $t_{REN,d/t}$ for the frames they support.

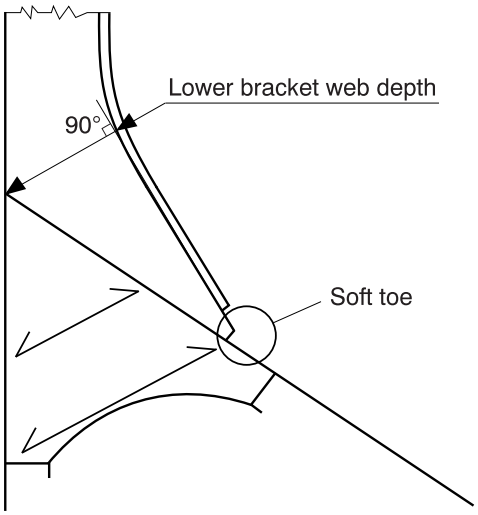
a) Lower brackets

Lower brackets are to be flanged or face plate is to be fitted. Refer to [5.3.6].

In calculating the web depth of the lower brackets, the following items apply:

- The web depth of lower bracket may be measured from the intersection of the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (refer to Fig 14)
- Where stiffeners are fitted on the lower bracket plate, the web depth may be taken as the distance between the side shell and the stiffener, between the stiffeners or between the outermost stiffener and the face plate of the brackets, whichever is the greatest.

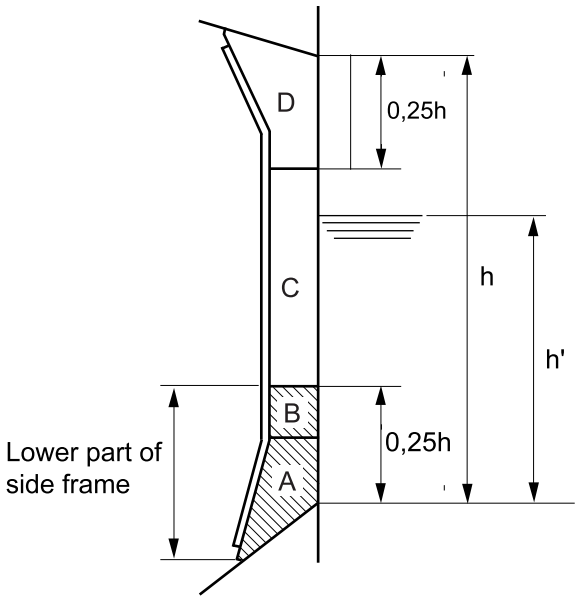
Figure 14 : Definition of the lower bracket web depth for determining $t_{REN,d/t}$



b) Tripping bracket alternative

When t_M is less than $t_{REN,d/t}$ at section b) of the side frames, tripping brackets in accordance with [5.4.2] may be fitted as an alternative to the requirements for the web depth to thickness ratio of side frames, in which case $t_{REN,d/t}$ may be disregarded in the determination of t_{REN} in accordance with [5.3.1]. The value of t_M is to be based on zone B according to Fig 15.

Figure 15 : Lower part and zones of side frames



c) Immediately abaft collision bulkhead

For the side frames, including the lower bracket, located immediately abaft the collision bulkhead, whose scantlings are increased in order that their moment of inertia is such to avoid undesirable flexibility of the side shell, when their web as built thickness t_{AB} is greater than $1,65t_{REN,S}$ the thickness $t_{REN,d/t}$ may be taken as the value $t'_{REN,d/t}$ obtained from the following formula:

$$t'_{REN,d/t} = \sqrt[3]{t^2_{REN,d/t} \cdot t_{REN,S}}$$

where $t_{REN,S}$ is obtained from [5.5.4].

5.3.3 Thickness criteria based on shear strength check

Where t_M in the lower part of side frames, as defined in Fig 15, is equal to or less than t_{COAT}, $t_{REN,S}$ is to be determined in accordance with [5.5.4].

5.3.4 Thickness of renewed webs of frames and lower brackets

Where steel renewal is required, the renewed webs are to be of a thickness not less than t_{AB}, $1,2t_{COAT}$ or $1,2t_{REN}$, whichever is the greatest.

5.3.5 Criteria for other measures

When $t_{REN} < t_M \leq t_{COAT}$, measures are to be taken, consisting of all the following items:

a) sand blasting, or equivalent, and coating (refer to [5.4.1])

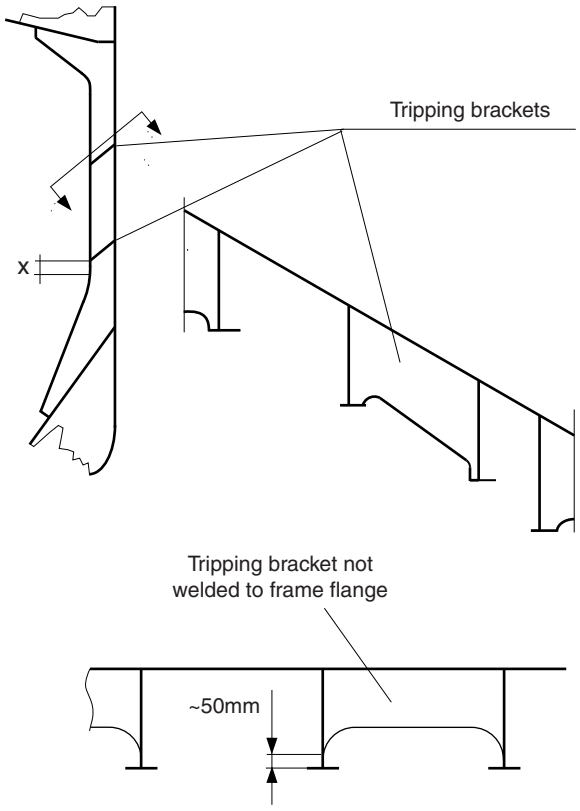
b) Fitting tripping brackets (refer to [5.4.2]), when the above condition occurs for any of the side frame zones A, B, C and D, as shown in Fig 15. Tripping brackets not connected to flanges are to have soft toe, and the distance between the bracket toe and the frame flange is not to be greater than about 50 mm, see Fig 16, and

c) Maintaining the coating in “as-new” condition (i.e. without breakdown or rusting) at class renewal and intermediate surveys.

The above measures may be waived if the structural members show no thickness diminution with respect to the as built thicknesses and coating is in “as-new” condition (i.e. without breakdown or rusting).

When the measured frame webs thickness t_M is such that $t_{REN} < t_M \leq t_{COAT}$ and the coating is in GOOD condition, sand blasting and coating as required in a) above may be waived even if not found in “as-new” condition, as defined above, provided that tripping brackets are fitted and the coating damaged in way of the tripping bracket welding is repaired.

Figure 16 : Tripping brackets



x : Distance from knuckle not greater than 200 mm.

5.3.6 Criteria for frames and brackets (bending check)

When lower end brackets were not fitted with flanges at the design stage, flanges are to be fitted so as to meet the bending strength requirements in [5.5.5]. The full width of the bracket flange is to extend up beyond the point at which the frame flange reaches full width. Adequate back-up structure in the hopper is to be ensured, and the bracket is to be aligned with the back-up structure.

Where the length or depth of the lower bracket does not meet the requirements in Pt D, Ch 4, Sec 3, [2.2.5], a bending strength check in accordance with [5.5.5] is to be carried out and renewals or reinforcements of frames and/or brackets effected as required therein.

The bending check needs not to be carried out in the case the bracket geometry is modified so as to comply with Pt D, Ch 4, Sec 3, [2.2.5] requirements.

5.4 Other measures

5.4.1 Thickness measurements, steel renewal, sand blasting and coating

For the purpose of steel renewal, sand blasting and coating, four zones A, B, C and D are defined, as shown in Fig 15. When renewal is to be carried out, surface preparation and coating are required for the renewed structures as given in Pt D, Ch 4, Sec 3, [6.1] for cargo holds of new buildings.

Representative thickness measurements are to be taken for each zone and are to be assessed against the criteria in [5.3].

When zone B is made up of different plate thicknesses, the lesser thickness is to be used for the application of the requirements in this Article [5].

In case of integral brackets, when the criteria in [5.3] are not satisfied for zone A or B, steel renewal, sand blasting and coating, as applicable, are to be done for both zones A and B.

In case of separate brackets, when the criteria in [5.3] are not satisfied for zone A or B, steel renewal, sand blasting and coating is to be done for each one of these zones, as applicable.

When steel renewal is required for zone C according to [5.3], it is to be done for both zones B and C. When sand blasting and coating is required for zone C according to [5.3], it is to be done for zones B, C and D.

When steel renewal is required for zone D according to [5.3], it needs only to be done for this zone. When sand blasting and coating is required for zone D according to [5.3], it is to be done for both zones C and D.

Special consideration may be given by the Society to zones previously renewed or recoated, if found in “as-new” condition (i.e. without breakdown or rusting).

When adopted, on the basis of the renewal thickness criteria in [5.3], in general coating is to be applied in compliance with the requirements of Ch 4, Sec 2, [1.1.7], as applicable.

Where, according to the requirements in [5.3], a limited number of side frames and brackets are shown to require coating over part of their length, the following criteria apply:

a) The part to be coated includes:
   - the web and the face plate of the side frames and brackets,
   - the hold surface of side shell, hopper tank and topside tank plating, as applicable, over a width not less than 100 mm from the web of the side frame.

b) Epoxy coating or equivalent is to be applied.

In all cases, all the surfaces to be coated are to be sand blasted prior to coating application.

When flanges of frames or brackets are to be renewed according to the retroactive rule requirements, the outstanding breadth to thickness ratio is to comply with Pt D, Ch 4, Sec 3, [2.2.3] and Pt D, Ch 4, Sec 3, [2.2.4].

5.4.2 Reinforcing measures

Reinforcing measures are constituted by tripping brackets, located at the lower part and at midspan of side frames (see Fig 16). Tripping brackets may be located at every two frames, but lower and midspan brackets are to be fitted in line between alternate pairs of frames.

The thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

Double continuous welding is to be adopted for the connections of tripping brackets to the side shell frames and shell plating.

Where side frames and side shell are made of Higher Strength Steel (HSS), Normal Strength Steel (NSS) tripping brackets may be accepted, provided the electrodes used for welding are those required for the particular HSS grade, and the thickness of the tripping brackets is equal to the frame web thickness, regardless of the frame web material.

5.4.3 Weld throat thickness

In case of steel renewal the welded connections are to comply with Pt D, Ch 4, Sec 3, [7].

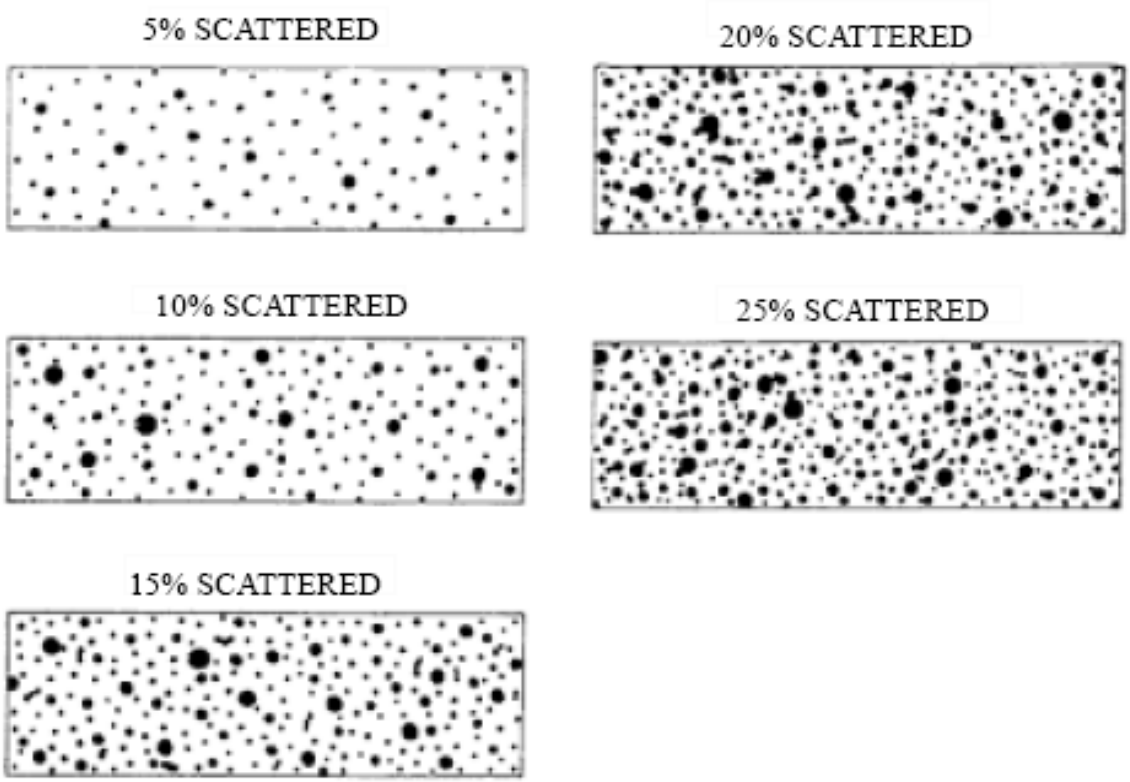
5.4.4 Pitting and grooving

If pitting intensity is higher than 15% in area (see Fig 17), thickness measurement is to be taken to check pitting corrosion.

The minimum acceptable remaining thickness in pits or grooves is equal to:

- 75% of the as built thickness, for pitting or grooving in the frame and brackets webs and flanges
- 70% of the as built thickness, for pitting or grooving in the side shell, hopper tank and topside tank plating attached to the side frame, over a width up to 30 mm from each side of it.

Figure 17 : Pitting intensity diagrams (from 5% to 25% intensity)



5.4.5 Renewal of all frames in one or more cargo holds

When all frames in one or more holds are required to be renewed according to the retroactive rule requirements, the compliance with the applicable requirements of Part II, Chapter 8, Section 8-03 of the first April 1998 edition of the Rules may be accepted in lieu of the compliance with the retroactive rule requirements, provided that:

- It is applied at least to all the frames of the hold(s)
- The coating requirements for side frames of “new ships” are complied with
- The section modulus of side frames is calculated according to the relevant requirements of the Rules.

5.4.6 Renewal of damaged frames

In case of renewal of a damaged frame already complying with this Article [5], the following requirements apply:

- The conditions accepted in compliance with this Article are to be restored as a minimum.
- For localised damages, the extension of the renewal is to be carried out according to the standard practice of the Society.

5.5 Strength check criteria

5.5.1 In general, loads are to be calculated and strength checks are to be carried out for the aft, middle and forward frames of each hold. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the above frames.

When scantlings of side frames vary within a hold, the required scantlings are also to be calculated for the mid frame of each group of frames having the same scantlings. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the calculated frames.

5.5.2 Load model

The following loading conditions are to be considered:

- homogeneous heavy cargo (density > 1.78 t/m^3)
- homogeneous light cargo (density < 1.78 t/m^3)
- non homogeneous heavy cargo, if allowed.

Multi port loading/unloading conditions need not be considered.

a) Forces

The forces $P_{fr,a}$ and $P_{fr,b}$, in kN, to be considered for the strength checks at sections a) and b) of side frames (shown in Fig 18, in the case of separate lower brackets, section b) is at the top of the lower bracket), are given by:

$P_{fr,a} = P_S + \max(P_1, P_2)$

$$P_{fr,b} = P_{fr,a}\frac{h - 2h_b}{h}$$

where:

P_s : Still water force, in kN.

When the upper end of the side frame span h (see Fig 15) is below the load waterline:

$$P_s = sh\left(\frac{p_{s,u} + p_{s,l}}{2}\right)$$

When the upper end of the side frame span h (see Fig 15) is at or above the load waterline:

$$P_s = sh'\left(\frac{p_{s,l}}{2}\right)$$

P_1 : Wave force, in kN, in head sea, given by the following formula:

$$P_1 = sh\left(\frac{p_{1,u} + p_{1,l}}{2}\right)$$

P_2 : Wave force, in kN, in beam sea, given by the following formula:

$$P_2 = sh\left(\frac{p_{2,u} + p_{2,l}}{2}\right)$$

h : Side frame span, in m, defined in Fig 15

h_B : Lower bracket length, in m, defined in Fig 18

h' : Distance, in m, between the lower end of side frame span h (see Fig 15) and the load waterline

s : Frame spacing, in m

$p_{S,U}$: Still water pressure, in kN/m^2, at the upper end of the side frame span h (see Fig 15)

$p_{S,L}$: Still water pressure, in kN/m^2, at the lower end of the side frame span h (see Fig 15)

$p_{1,U}$: Wave pressure, in kN/m^2, as defined in item b) below, for the upper end of the side frame span h and corresponding to force P_1

$p_{1,L}$: Wave pressure, in kN/m^2, as defined in item b) below, for the lower end of the side frame span h and corresponding to force P_1

$p_{2,U}$: Wave pressure, in kN/m^2, as defined in item b) below, for the upper end of the side frame span h and corresponding to force P_2

$p_{2,L}$: Wave pressure, in kN/m^2, as defined in item b) below, for the lower end of the side frame span h and corresponding to force P_2.

b) Wave pressures

- Wave pressure p_1

The wave pressure p_1, in kN/m^2, at and below the waterline is given by:

$$p_1 = 1,50\left[p_{11} + 135\frac{B}{2(B+75)} - (1,2(T-z))\right]$$

where:

$P_{11} = 3\,k_s\,C + k_f$

The wave pressure p_1, in kN/m^2, above the waterline is given by: $p_1 = p_{1wl} - 7,50\,(z - T)$

- Wave pressure p_2

The wave pressure p_2, in kN/m^2, at and below the waterline is given by:

$$p_2 = 13,0\left[0,5B\frac{50c_r}{2(B+75)} + C_B\frac{0,5B + k_f}{14}\left(0,7 + 2\frac{z}{T}\right)\right]$$

The wave pressure p_2, in kN/m^2, above the waterline is given by: $p_2 = p_{2wl} - 5,0\,(z - T)$

where:

p_{1wl} : Wave sea pressure p_1 at the waterline

p_{2wl} : Wave sea pressure p_2 at the waterline

L : Rule length, in m, as given in Pt B, Ch 1, Sec 3, [2.1.1]

B : Greatest moulded breadth, in m, as given in Pt B, Ch 1, Sec 3, [2.1.4]

C_b : Block coefficient, as given in Pt B, Ch 1, Sec 3, [2.1.9]

T : Maximum design draught, in m, as given in Pt B, Ch 1, Sec 3, [2.1.6]

C : Coefficient given as follows:

- for 90 m ≤ L ≤ 300 m

$$C = 10,75 - \left(\frac{300 - L}{100}\right)^{1,5}$$

- for L > 300 m: C = 10,75

C_r : Coefficient given by:

$$C_r = \left(1,25 - \left(0,025\frac{2k_r}{\sqrt{GM}}\right)\right)k$$

k : Coefficient given by:

- for ships without bilge keel k = 1,2
- for ships with bilge keel k = 1,0

k_r : Roll radius of gyration. If the actual value is not available, k_r is taken equal to:

- for ships with even distribution of mass in transverse section (e.g. alternate heavy cargo loading or homogeneous light cargo loading): $k_r = 0,39\ B$
- for ships with uneven distribution of mass in transverse section (e.g. homogeneous heavy cargo distribution): $k_r = 0,25\ B$

GM : If the actual value of GM is not available: GM = 0,12 B

z : Vertical distance, in m, from the baseline to the load point

k_s : Coefficient given as follows:

- at aft end of L:

$$k_s = C_B + \frac{0,83}{\sqrt{C_B}}$$

- between 0,2 L and 0,6 L from aft end of L: $k_s = C_B$
- at forward end of L:

$$k_s = C_B + \frac{1,33}{C_B}$$

Between the above specified points, k_s is to be interpolated linearly

k_f : Coefficient given as follows: $k_f = 0,8\ C$

5.5.3 Allowable stresses

The allowable normal and shear stresses σ_a and τ_a, in N/mm^2, in the side shell frames and brackets are given by:

$\sigma_a = 0,90\ R_{eH}$

$\tau_a = 0,40\ R_{eH}$

where R_{eH} is the minimum yield stress, in N/mm^2, of the material.

5.5.4 Shear strength check

Where t_M in the lower part of side frames, as defined in Fig 15, is equal to or less than t_{COAT}, shear strength check is to be carried out in accordance with the following.

The thickness $t_{REN,S}$, in mm, is the greater of the thicknesses $t_{REN,Sa}$ and $t_{REN,Sb}$ obtained from the shear strength check at sections a) and b) (see Fig 18 and [5.5.2]) given by the following, but need not be taken greater than 0,75 t_{S12}.

- At section a)

$$t_{REN,Sa} = \frac{1000k_sP_{fr,a}}{d_a \sin\phi\tau_a}$$

- At section b)

$$t_{REN,Sb} = \frac{1000k_sP_{fr,b}}{d_b \sin\phi\tau_a}$$

where:

k_S : Shear force distribution factor, to be taken equal to 0,6

$P_{fr,a}$, $P_{fr,b}$: Pressure forces defined in [5.5.2], item a)

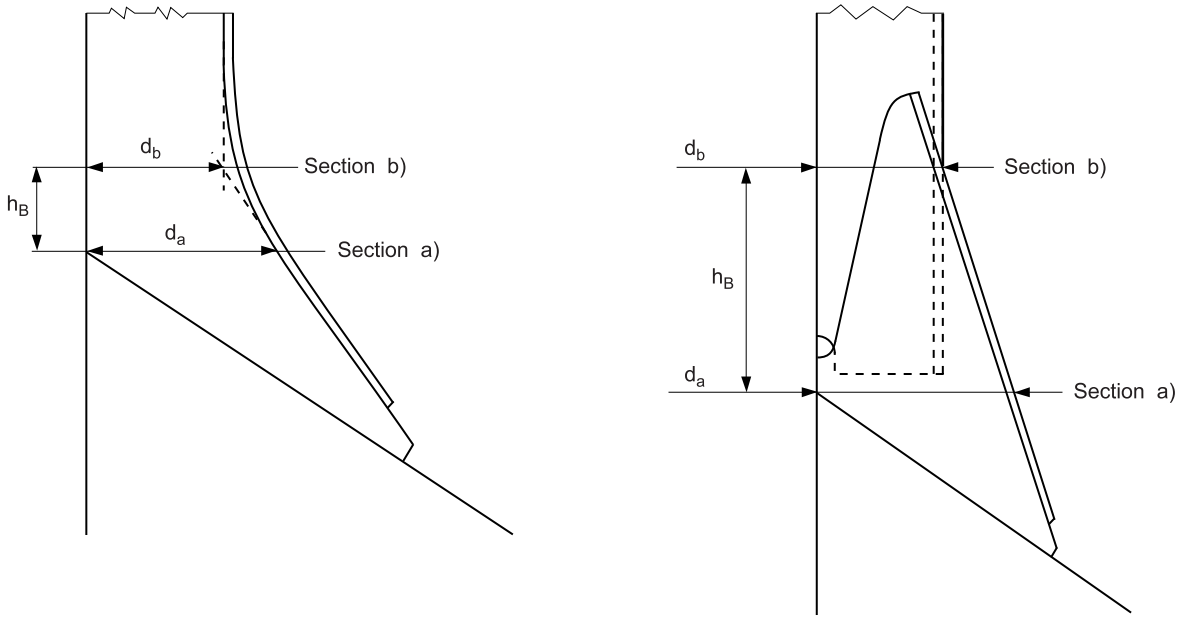
d_a : Bracket web depth, in mm, at section a) (see Fig 18)

d_b : Frame web depth, in mm, at section b) (see Fig 18). In case of separate brackets, d_b is to be taken as the minimum web depth deducing possible scallops

Φ : Angle between frame web and shell plate

τ_a : Allowable shear stress, in N/mm^2, defined in [5.5.3].

Figure 18 : Sections a) and b)



5.5.5 Bending strength check

Where the lower bracket length or depth does not meet the requirements in Pt D, Ch 4, Sec 3, [2.2.5], the actual section modulus, in cm^3, of the brackets and side frames at section a) and b) is to be not less than:

- At section a)

$$Z_a = \frac{1000 P_{fr,a} h}{m_a \sigma_a}$$

- At section b)

$$Z_b = \frac{1000 P_{fr,a} h}{m_b \sigma_a}$$

where:

$P_{fr,a}$: Pressure force defined in [5.5.2], item a)

h : Side frame span, in m, as defined in Fig 15

σ_a : Allowable normal stress, in N/mm^2, as defined in [5.5.3]

m_a, m_b : Bending moment coefficients, as defined in Tab 3.

The actual section modulus of the brackets and side frames is to be calculated about an axis parallel to the attached plate, based on the measured thicknesses. For precalculations, alternative thickness values may be used, provided they are not less than:

- t_{REN} for the web thickness
- the minimum thicknesses allowed by the Society renewal criteria for flange and attached plating.

The attached plate breadth is equal to the frame spacing, measured along the shell at midspan of h.

If the actual section moduli at sections a) and b) are less than the values Z_a and Z_b, the frames and brackets are to be renewed or reinforced in order to obtain actual section moduli not less than 1,2 Z_a and 1,2 Z_b, respectively.

In such a case, renewal or reinforcements of the flange are to be extended over the lower part of side frames, as defined in Fig 15.

Table 3 : Bending moment coefficients m_a and m_b

	m_a	m_b		
		$h_B \le 0,08$ h	$h_B = 0,10$ h	$h_B \ge 0,125$ h
Empty holds of ships approved to operate in non homogeneous loading conditions	10	17	19	22
Other cases	12	20	22	26
Note 1: Non homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, exceeds 1,20 corrected for different cargo densities. Note 2: For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the Table values.				

6 Cargo hatch cover securing arrangements for bulk carriers not built in accordance with edition 2003 of Pt B, Ch 9, Sec 7

6.1 Application

6.1.1 These retroactive rule requirements apply to ships which are assigned one of the following service notations:

- **bulk carrier ESP**
- **bulk carrier BC-A ESP**
- **bulk carrier BC-B ESP**
- **bulk carrier BC-C ESP**,

which were not built in accordance with Pt B, Ch 9, Sec 7, [1] to Pt B, Ch 9, Sec 7, [7] of edition February 2003 of the Rules as amended in accordance with November 2003 amendments or subsequent editions.

6.1.2 They are related to steel hatch cover securing devices and stoppers for cargo hold hatchways No.1 and No.2 which are wholly or partially within 0,25 L of the fore perpendicular, except pontoon type hatch cover.

6.2 Securing devices

6.2.1 The strength of securing devices is to comply with the following items:

a) Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

b) The net cross area of each securing device is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 1,4 S_s \left(\frac{235}{R_{eH}}\right)^f$$

where:

S_s : Spacing, in m, of securing devices, to be taken not less than 2 m

R_{eH} : Minimum yield stress, in N/mm^2, of the steel used for fabrication, defined in Pt B, Ch 4, Sec 1, [2] not to be taken greater than 70% of the minimum ultimate tensile strength R_m defined in Pt B, Ch 4, Sec 1, [2]

f : Coefficient taken equal to:

- 0,75 for $R_{eH} > 235$ N/mm^2
- 1,00 for $R_{eH} \leq 235$ N/mm^2

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

c) Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices.

For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

d) The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia I of edge elements is to be not less than the value obtained, in cm^4, from the following formula:

$$I = 6\, p_L\, S_s^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

S_s : Spacing, in m, of securing devices.

e) Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

f) Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

g) Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

6.3 Stoppers

6.3.1 No.1 and No.2 hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

6.3.2 No.2 hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

6.3.3 No.1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted.

6.3.4 The equivalent stress, in stoppers and their supporting structures and calculated in the throat of the stopper welds is not to exceed the allowable value of 0,8 R_{eH}.

6.4 Materials and welding

6.4.1 Where stoppers or securing devices are fitted to comply with the requirements of this article, they are to be manufactured of materials, including welding electrodes complying with NR216 Materials and Welding.

7 Guidance on loading/unloading sequences

7.1

7.1.1 The minimum acceptable number of typical sequences is:

- one homogeneous full load condition
- one part load condition where relevant, such as block loading or two port unloading
- one full load alternate hold condition, if the ship is approved for alternate hold loading.

7.1.2 The shipowner/operator should select actual loading/ unloading sequences, where possible, which may be port specific or typical.

7.1.3 The sequence may be prepared using the onboard loading instrument. The selected loading conditions should be built up step by step from commencement of cargo loading to reaching full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. The printout from the loading instrument is generally acceptable. This allows the actual bending moments and shear forces to be verified and prevent the permissible values being exceeded. In addition, the local strength of each hold may need to be considered during the loading.

7.1.4 For each loading condition a summary of all steps is to be included. This summary is to highlight the essential information for each step such as:

- how much cargo is filled in each hold during the different steps
- how much ballast is discharged from each ballast tank during the different steps
- the maximum still water bending moment and shear at the end of each step
- the ship's trim and draught at the end of each step.

7.1.5 The approved typical loading/unloading sequences may be included in the approved loading manual or take the form of an addendum. A copy of the approved typical loading/unloading sequences is to be placed onboard the ship.

8 Water level detectors on single hold cargo ships other than bulk carriers

8.1 Application

8.1.1 These retroactive rule requirements apply to ships indicated in Ch 6, Sec 4, [2.1.1].

8.2 Water level detectors

8.2.1 The water level detectors are to:

- give an audible and visual alarm at the navigation bridge when the water level above the inner bottom in the cargo hold reaches a height of not less than 0,3 m, and another when such level reaches not more than 15% of the mean depth of the cargo hold; and
- be fitted at the aft end of the hold, or above its lowest part where the inner bottom is not parallel to the designed waterline. Where webs or partial watertight bulkheads are fitted above the inner bottom, the Society may require the fitting of additional detectors.

8.2.2 For ships not provided with double bottom in cargo hold, the water level detectors are to:

- give an audible and visual alarm at the navigation bridge when the water level above the bottom in the cargo hold reaches a height of not less than 0,3 m or the height of the floors at centerline, whichever is the highest, and another when such level reaches not more than 15% of the mean depth of the cargo hold; and
- be fitted at the aft end of the hold, or above its lowest part where the bottom is not parallel to the designed waterline. Where webs or partial watertight bulkheads are fitted above the bottom, the Society may require the fitting of additional detectors.

NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part B
Hull and Stability

Chapter 1	General
Chapter 2	General Arrangement Design
Chapter 3	Stability
Chapter 4	Structure Design Principles
Chapter 5	Design Loads
Chapter 6	Hull Girder Strength
Chapter 7	Hull Scantlings
Chapter 8	Direct Strength Analysis
Chapter 9	Buckling
Chapter 10	Fatigue
Chapter 11	Other Structures
Chapter 12	Hull Outfitting
Chapter 13	Construction and Testing

July 2025

Table of Content

Chapter 1 General

Section 1 Application

1 Scope of application 31

1.1 General
1.2 Limits of application to lifting appliances

2 Rule application 31

2.1 Ship parts
2.2 Rules applicable to various ship parts
2.3 Rules applicable to other ship items

Section 2 Rules Principles

1 Design basis 33

1.1 General
1.2 Hull form limit
1.3 Design life
1.4 Environmental conditions
1.5 Operating conditions
1.6 Operating draughts
1.7 Maximum service speed
1.8 Owner's extras

2 Design principles 34

2.1 Overall principles
2.2 Loads
2.3 Structural capacity assessment

3 Rule design methods 35

3.1 General
3.2 Minimum requirements
3.3 Load-capacity based requirements
3.4 Acceptance criteria
3.5 Design verification

Section 3 Symbols and Definitions

1 Symbols and units 39

1.1

2 Definitions 42

2.1 Ship's dimensions and main data
2.2 Superstructure and deckhouse
2.3 Type A and Type B ships
2.4 Positions 1 and 2
2.5 Sister ship
2.6 Reference coordinate system
2.7 Arrangement
2.8 Structural components

Section 4 Documentation to be Submitted

1 Documentation to be submitted for all ships 49

1.1 Ships surveyed by the Society during the construction
1.2 Ships for which the Society acts on behalf of the relevant Administration

2 Further documentation to be submitted for ships with certain service notations or additional class notations 51

2.1 General

Table of Content

Section 5 Loading Manual and Loading Instruments

1 Loading manual and loading instrument requirement criteria 52

1.1 Ship categories
1.2 Requirement criteria

2 Loading manual 52

2.1 Definitions
2.2 Conditions of approval

3 Loading instrument 53

3.1 Additional class notations LI
3.2 Definitions
3.3 Conditions of approval
3.4 Approval procedure
3.5 Hull girder forces and moments
3.6 Intact stability
3.7 Grain loading
3.8 Damage stability
3.9 Acceptable tolerances

Appendix 1 Equivalences between Current Revision and July 2021 Edition of the Rules for the Classification of Steel Ships

1 General 61

1.1 Equivalences between current revision and edition July 2021 of NR467, Part B

Chapter 2 General Arrangement Design

Section 1 Subdivision Arrangement

1 General 63

1.1 Application to ships assigned the additional service feature SPxxx or SPxxx-capable
1.2 Application to ships assigned the additional service feature IPxxx or IPxxx-capable

2 Number and arrangement of transverse watertight bulkheads 63

2.1 Number of watertight bulkheads
2.2 Water ingress detection

3 Collision bulkhead 64

3.1

4 After peak, machinery space bulkheads and stern tubes 64

4.1

5 Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkhead 65

5.1

6 Openings in watertight bulkheads and decks for ships having a service notation other than passenger ship or ro-ro passenger ship 65

6.1 Application
6.2 General
6.3 Openings in the watertight bulkheads and internal decks

Section 2 Compartment Arrangement

1 General 68

1.1 Application to ships assigned the additional service feature SPxxx or SPxxx-capable
1.2 Application to ships assigned the additional service feature IPxxx or IPxxx-capable
1.3 Definitions

Table of Content

2 Cofferdams 68

2.1 Cofferdam arrangement

3 Double bottoms 69

3.1 Double bottom arrangement for ships other than tankers

4 Compartments forward of the collision bulkhead 69

4.1 General

5 Minimum bow height 69

5.1 General

6 Shaft tunnels 71

6.1 General

7 Watertight ventilators and trunks 71

7.1 General

8 Fuel oil tanks 72

8.1 General

8.2 Fuel oil tank protection

9 Tanks containing fuel for auxiliary vehicles 72

9.1 General

9.2 Tank protection and segregation

10 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system 72

10.1 Tank protection and segregation

11 Tanks containing solvent for onboard carbon capture systems (ships assigned the additional service feature OCC) 72

11.1 Tank protection and segregation

Section 3 Access Arrangement

1 General 73

1.1

2 Double bottom 73

2.1 Inner bottom manholes

2.2 Floor and girder manholes

3 Access arrangement to and within spaces in, and forward of, the cargo area 73

3.1 General

3.2 Access to tanks

3.3 Access within tanks

3.4 Construction of ladders

4 Shaft tunnels 75

4.1 General

5 Access to steering gear compartment 75

5.1

Chapter 3 Stability

Section 1 General

1 General 77

1.1 Application
1.2 Application to ships assigned the additional service feature SPxxx or SPxxx-capable
1.3 Application to ships assigned the additional service feature IPxxx or IPxxx-capable
1.4 Application to ships assigned the additional class notation STABLIFT
1.5 Alterations

2 Examination procedure 78

2.1 Documents to be submitted
2.2 Inclining test/lightweight check

Section 2 Intact Stability

1 General 80

1.1 Information for the Master
1.2 Permanent ballast

2 Design criteria 80

2.1 General intact stability criteria

3 Severe wind and rolling criterion (weather criterion) 81

3.1 Scope
3.2 Weather criterion

4 Effects of free surfaces of liquids in tanks 84

4.1 General
4.2 Consideration of free surface effects
4.3 Categories of tanks
4.4 Consumable liquids
4.5 Water ballast tanks
4.6 Liquid transfer operations
4.7 GM0 and GZ curve corrections
4.8 Small tanks
4.9 Remainder of liquid

5 Cargo ships carrying timber deck cargoes 86

5.1 Application
5.2 Definitions
5.3 Stability criteria
5.4 Stability booklet
5.5 Calculation of the stability curve
5.6 Loading conditions to be considered
5.7 Assumptions for calculating loading conditions
5.8 Stowage of timber deck cargoes

6 Icing 87

6.1 Application
6.2 Ships carrying timber deck cargoes
6.3 Calculation assumptions
6.4 Guidance relating to ice accretion

Section 3 Damage Stability

1 Application 89

1.1 Ships for which damage stability is required
1.2 Ships assigned the additional class notation SDS and additional service feature SPxxx, SPxxx-capable, IPxxx or IPxxx-capable

Table of Content

2 General 89

2.1 Approaches to be followed for damage stability investigation

3 Documents to be submitted 90

3.1 Damage stability calculations
3.2 Permeabilities
3.3 Progressive flooding
3.4 Bottom damages

4 Damage control documentation 92

4.1 General

5 Specific interpretations 92

5.1 Assumed damage penetration in way of sponsons

Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check 93

1.1 General

Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet 97

1.1 Information to be included in the trim and stability booklet
1.2 Loading conditions
1.3 Stability curve calculation

Appendix 3 Probabilistic Damage Stability Method for Cargo Ships

1 Probabilistic damage stability method for cargo ships 103

1.1 Application
1.2 Definitions
1.3 Required subdivision index R
1.4 Attained subdivision index A
1.5 Calculation of factor pi
1.6 Calculation of factor si
1.7 Permeability
1.8 Stability information

Appendix 4 Damage Stability Calculation for Ships Assigned with a Reduced Freeboard

1 Application 111

1.1 General

2 Initial loading condition 111

2.1 Initial condition of loading

3 Damage assumptions 111

3.1 Damage dimension
3.2 Steps and recesses
3.3 Transverse bulkhead spacing
3.4 Damage assumption
3.5 Condition of equilibrium
3.6 Damage stability criteria

4 Requirements for Type B-60 and B-100 ships 114

4.1 Requirements for Type B-60 ships
4.2 Requirements for Type B-100 ships
4.3 Hatchways closed by weathertight covers of steel or other equivalent material fitted with gaskets and clamping devices
4.4 Doors

Chapter 4 Structure Design Principles

Section 1 Materials

1 General 117

1.1 Standard of material
1.2 Testing of materials
1.3 Manufacturing process

2 Hull structural steel 117

2.1 General
2.2 Material factor k
2.3 Steel grades
2.4 Grades of steel for structures exposed to low air temperatures
2.5 Grades of steel within refrigerated spaces
2.6 Through thickness properties
2.7 Stainless steel

3 Steels for forging and casting 124

3.1 General
3.2 Steels for forging
3.3 Steels for casting

4 Aluminium alloys 125

4.1 General
4.2 Material factor k
4.3 Others

5 Other materials and products 126

5.1 General
5.2 Iron cast parts

Section 2 Net Scantling Approach

1 General 127

1.1 Application
1.2 Gross and net scantling definitions
1.3 Rounding off of scantlings
1.4 Scantling compliance

Section 3 Corrosion Additions

1 General 131

1.1 Applicability
1.2 Corrosion addition determination

Section 4 Protection of Hull Metallic Structures

1 Protection by coating 133

1.1 General
1.2 Structures to be protected

2 Protection against galvanic corrosion in tanks 133

2.1 General

3 Protection of bottom by ceiling 133

3.1 General
3.2 Arrangement
3.3 Scantlings

4 Protection of decks by wood sheathing 134
4.1 General
4.2 Arrangement
4.3 Scantlings
5 Protection of cargo sides by battens 134
5.1 General
5.2 Arrangement

Section 5 Structural Detail Principles

1 Application 135
1.1 General
2 General principles 135
2.1 Structural continuity
2.2 Local reinforcements
2.3 Connection between steel and aluminium
3 Stiffeners 137
3.1 General
3.2 Bracketed end connections of non-continuous stiffeners
3.3 Bracketless connections
3.4 Sniped ends
4 Primary supporting members (PSM) 139
4.1 General
4.2 Web stiffening arrangement
4.3 Tripping bracket arrangement
4.4 Bracketed end connections
4.5 Bracketless end connections
5 Intersection of stiffeners and primary supporting members 143
5.1 Cut-outs
5.2 Connection of stiffeners to PSM
6 Openings 149
6.1 General
6.2 Openings and scallops in stiffeners
6.3 Openings in primary supporting members
6.4 Openings in strength deck
6.5 Corners of hatchways
6.6 Openings in shell plating
7 Bottom structure 156
7.1 General
7.2 Keel plate
7.3 Girders
7.4 Floors
7.5 Open floors
7.6 Bilge keel
7.7 Docking
8 Side structure 160
8.1 Structural arrangement
9 Deck structure 160
9.1 Structural arrangement

10 Bulkhead structure 160
10.1 Application
10.2 Plane bulkheads
10.3 Corrugated bulkheads
10.4 Wash bulkheads
10.5 Watertight bulkheads of trunks and tunnels
10.6 Bulkheads acting as pillars
10.7 Watertight doors
11 Pillars 164
11.1 General
11.2 Connections

Section 6 Structural Idealisation
1 Structural idealisation of stiffeners and primary supporting members 166
1.1 Effective spans
1.2 Spacing and load supporting breadth
1.3 Effective breadth
1.4 Geometrical properties of stiffeners and primary supporting members
2 Plates 180
2.1 Idealisation of EPP
2.2 Load Calculation Point
3 Stiffeners 183
3.1 Reference point
3.2 Load calculation point
4 Primary supporting members 184
4.1 Load calculation point

Chapter 5 Design Loads

Section 1 Introduction
1 General 186
1.1 Definition
1.2 Sign convention

Section 2 Dynamic Load Cases
1 General 188
1.1 Definition of EDW and dynamic load cases
1.2 Application
1.3 Description of dynamic load cases
2 Dynamic load cases for strength assessment 196
2.1 Selection of EDW
2.2 Load combination factors
3 Dynamic load cases for fatigue assessment 199
3.1 Selection of EDW
3.2 Load combination factors

Section 3 Ship Motions and Accelerations
1 General 202
1.1 Definitions

2 Ship motions and accelerations 204
2.1 Ship motions
2.2 Accelerations at the centre of gravity
3 Accelerations at any position 207
3.1 General
3.2 Accelerations for dynamic load cases
3.3 Maximum accelerations for equipment

Section 4 Hull Girder Loads
1 Application 208
1.1 General
2 Still water loads 208
2.1 General
2.2 Vertical still water bending moments
2.3 Vertical still water shear forces
3 Wave loads 210
3.1 Vertical wave bending moments
3.2 Vertical wave shear force
3.3 Horizontal wave bending moment
3.4 Horizontal wave shear force
3.5 Wave torsional moment
3.6 Hull girder loads for dynamic load cases

Section 5 Environmental Loads
1 Sea pressure 218
1.1 Total pressure
1.2 Hydrostatic pressure
1.3 External dynamic pressure for strength assessment
1.4 External dynamic pressure for fatigue assessment
2 Sea chests 233
2.1 Design pressure
3 External pressure on exposed decks 233
3.1 Application
3.2 Green sea loads
3.3 Load carried on exposed deck
4 External impact pressure 234
4.1 Application
4.2 Bottom and stern slamming impact pressures
4.3 Bow flare impact pressure
4.4 Berthing impact pressure
5 External pressure on front, side and aft bulkheads of superstructures and deckhouses 237
5.1 Application
5.2 Definitions
5.3 Superstructures side bulkheads
5.4 Deckhouses side and end bulkheads and superstructures end bulkheads
6 External pressures on hatch covers and coamings 239
6.1 Application
6.2 Green sea loads
7 External pressure on shell doors 241
7.1 Bow doors
7.2 Side and stern doors

8 External loads on containers 244
8.1 Wind forces

Section 6 Internal Loads and Cargo Loads

1 Pressures due to liquids 247
1.1 Application
1.2 Static liquid pressure in intact conditions
1.3 Dynamic liquid pressure in intact conditions
1.4 Static pressure in flooded conditions

2 Partly filled tanks intended for the carriage of liquid or ballast 249
2.1 Application
2.2 Pressure definition
2.3 Static pressure
2.4 Dynamic sloshing pressure
2.5 Dynamic impact pressure
2.6 Alternative methods

3 Pressures and forces due to dry bulk cargo 252
3.1 Application
3.2 Hold definitions
3.3 Dry cargo characteristics
3.4 Dry bulk cargo pressures
3.5 Shear load

4 Pressures and forces due to dry cargoes in flooded conditions 256
4.1 Local loads on vertically corrugated transverse bulkheads in flooded conditions
4.2 Local loads on double bottom in flooded conditions

5 Steel Coil Loads 260
5.1 General
5.2 Total loads
5.3 Static loads
5.4 Dynamic loads

6 Loads on decks and platforms 263
6.1 Pressure due to distributed load
6.2 Concentrated force due to unit cargo

7 Wheeled cargo 265
7.1 Application
7.2 Forces due to wheeled cargo

8 Loads due to containers 266
8.1 Forces applied to containers
8.2 Stacks of containers

9 Loads on hatch covers 268
9.1 Application
9.2 Cargo loads

10 Design pressure for tank testing 270
10.1 Definition

Section 7 Design Load Scenarios

1 General 272
1.1 Application

2 Design load scenarios for strength assessment 273
2.1 Principal design load scenarios
2.2 Design load scenarios for impact and sloshing

3 Design load scenario for fatigue assessment 274
3.1 Design load scenario

Section 8 Loading Conditions
1 Application 275
1.1 Loading conditions for strength assessment
1.2 Loading conditions for fatigue assessment
1.3 Specific loading conditions
2 General 275
2.1 Definitions
3 Standard loading conditions for strength assessment 275
3.1 Seagoing conditions
3.2 Harbour and sheltered water conditions
4 Standard loading conditions for fatigue assessment 276
4.1 General

Chapter 6 Hull Girder Strength

Section 1 Hull Girder Yield and Buckling Strength
1 Strength characteristics of hull girder transverse sections 278
1.1 General
1.2 Hull girder transverse sections
1.3 Structures contributing to the longitudinal strength
1.4 Section modulus
1.5 Moments of inertia
1.6 Ships having large openings in the strength deck
2 Hull girder stresses 283
2.1 Normal stress
2.2 Shear stress
3 Hull girder strength assessment 284
3.1 General
3.2 Longitudinal extent
3.3 Hull girder stiffness
3.4 Hull girder minimum section modulus
3.5 Yield strength assessment
3.6 Extent of higher strength steel
3.7 Buckling strength assessment
4 Structural models for the calculation of normal warping stress and shear stress 286
4.1 Calculation methods

Section 2 Hull Girder Ultimate Strength
1 Application 287
1.1 General
2 Checking criteria 287
2.1 General
2.2 Hull girder ultimate bending loads
2.3 Hull girder ultimate bending moment capacity

Table of Content

Appendix 1 Direct Calculation of Shear Flow

1 Calculation formula 289

1.1 General
1.2 Determinate shear flow qD
1.3 Indeterminate shear flow qI
1.4 Computation of sectional properties

Appendix 2 Hull Girder Ultimate Bending Capacity

1 General 292

1.1 Application
1.2 Methods
1.3 General assumptions

2 Incremental-iterative method 292

2.1 Assumptions
2.2 Procedure
2.3 Load-end shortening curves

3 Alternative methods 301

3.1 General
3.2 Non-linear finite element analysis

Chapter 7 Hull Scantlings

Section 1 General

1 Application 303

1.1 Application
1.2 Acceptance criteria

Section 2 Load Application

1 Load combination 304

1.1 Hull girder
1.2 Pressure combination

2 Design load sets 304

2.1 Application of load components

Section 3 Minimum Thickness

1 Minimum thickness 309

1.1 General requirements

Section 4 Plating

1 Plating subject to lateral pressure 310

1.1 Yielding check
1.2 Plating of corrugated bulkheads
1.3 Buckling check

2 Transverse vertically corrugated bulkheads separating dry bulk cargo holds in flooded condition 312

2.1 Application
2.2 Net thickness of corrugation

3 Strength check of plating supporting wheeled cargo 312

3.1 General
3.2 Load model
3.3 Plating

4 Plating subject to impact loads 314
4.1 General
5 Strength check of plating supporting steel coils on wooden dunnage 315
5.1 General
5.2 Yielding check
6 Special requirements 315
6.1 Minimum thickness of keel plating
6.2 Bilge plating
6.3 Inner bottom of cargo holds intended to carry dry cargo
6.4 Sheer strake
6.5 Deck stringer plating
6.6 Deck plating protected by wood sheathing or deck composition
6.7 Supporting structure in way of corrugated bulkheads
6.8 Aft peak bulkhead

Section 5 Stiffeners
1 General 320
1.1 Yielding check of stiffeners subject to lateral pressure
1.2 Yielding check of stiffeners supporting wheeled cargo
1.3 Net section modulus and net shear sectional area of ordinary stiffeners subject to impact loads
1.4 Yielding check of stiffeners supporting steel coils on wooden dunnage
1.5 Deck stiffeners in way of launching appliances used for survival craft or rescue boat
1.6 Plate and stiffener of different materials
1.7 Beam analysis
1.8 Buckling check

Section 6 Primary Supporting Members and Pillars
1 Application 325
1.1 Application
2 General 326
2.1 Scantling requirements
2.2 Wheeled loads
2.3 Primary members subject to impact loads
2.4 Deck primary members in way of launching appliances used for survival craft or rescue boat
2.5 Buckling check
2.6 Pillars subject to compressive axial load
2.7 Pillars subject to tensile axial load
3 Primary supporting members in holds intended to carry liquid cargo 330
3.1 Floors in double bottom
3.2 Girders in double bottom
3.3 Deck transverses
3.4 Side transverses
3.5 Vertical web frames on longitudinal bulkhead
3.6 Horizontal stringers on transverse bulkheads
3.7 Cross ties
3.8 Vertically corrugated bulkheads separating liquid cargo holds
4 Primary supporting members in holds intended to carry dry bulk cargo 345
4.1 Centre girders and side girders
4.2 Floors
4.3 Stringer of double side structure
4.4 Transverse web in double side structure
4.5 Primary supporting member in bilge hopper tanks and topside tanks
4.6 Transverse vertically corrugated bulkheads separating holds assigned as ballast holds and separating hopper wells on dredgers
4.7 Transverse vertically corrugated bulkheads in flooded conditions
4.8 Double bottom capacity in flooded conditions

5 Grillage structure 356
5.1 General

Appendix 1 Analyses of Primary Supporting Members Subject to Wheeled Loads
1 General 358
1.1 Scope
1.2 Application
1.3 Information required
1.4 Lashing of vehicles
2 Analysis criteria 358
2.1 Finite element model analyses
2.2 Beam model analyses
3 Primary supporting members structural modelling 359
3.1 Model construction
3.2 Model extension
3.3 Boundary conditions of the three dimensional model
4 Load model 360
4.1 General
4.2 Local loads
5 Stress calculation 361
5.1 Normal stress induced by hull girder loads
5.2 Analyses based on beam models
6 Grillage analysis of primary supporting members of decks 361
6.1 Application
6.2 Structural model
6.3 Boundary conditions
6.4 Load model
6.5 Stress calculation

Chapter 8 Direct Strength Analysis
Section 1 Direct Strength Assessment
1 General 364
1.1 Application
2 Net scantling 364
2.1 Net scantling application
3 Finite element types 364
3.1 Finite element types to be used
4 Acceptance criteria 365
4.1 Definition
5 Submission of results 365
5.1 Detailed report
6 Computer programs 365
6.1 Use of computer programs

Appendix 1 Cargo Hold Structural Strength Analysis
1 Objective and scope 366
1.1 General
1.2 Cargo hold structural strength analysis procedure

2 Structural model 367
2.1 Members to be modeled
2.2 Extent of model
2.3 Finite element types
2.4 Structural modeling
2.5 Boundary conditions
3 FE load combinations 377
3.1 Design load combinations
4 Load application 377
4.1 General
4.2 External and internal loads
4.3 Hull girder loads
4.4 Procedure to adjust hull girder shear forces and bending moments
4.5 Procedure to adjust hull girder torsional moments
4.6 Summary of hull girder load adjustments
5 Analysis criteria 392
5.1 General
5.2 Yield strength assessment
5.3 Buckling strength assessment

Appendix 2 Local Structural Strength Analysis

1 Objective and scope 394
1.1 General
1.2 Structural details to be assessed by fine mesh analysis
2 Structural modeling 395
2.1 General
2.2 Extent of model
2.3 Mesh size
2.4 Elements
2.5 Transverse web frames
2.6 Transverse bulkhead stringers, buttress and adjacent web frame
2.7 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners
2.8 Corrugated bulkheads
3 FE load combinations 400
3.1 General
3.2 Application of loads and boundary conditions
4 Analysis criteria 400
4.1 Yield strength assessment

Appendix 3 Full Length Structural Strength Analysis

1 Objective and scope 401
1.1 General
1.2 Full length structural strength analysis procedure
2 Structural model 401
2.1 Model construction
2.2 Extent of model
2.3 Finite element types
2.4 Structural modeling
2.5 Boundary conditions of the model
3 Load combinations 402
3.1 General
4 Load application 402
4.1 General
4.2 Procedure for the selection of design waves

5 Analysis criteria 404
5.1 Yield strength assessment
5.2 Buckling strength assessment
6 Refined analysis 404
6.1 Application
6.2 Structural modeling
6.3 Loading conditions and load cases
6.4 Load application
6.5 Analysis criteria

Chapter 9 Buckling

Section 1 Buckling
1 General 407
1.1 Application
1.2 Allowable buckling utilisation factor
2 Slenderness requirements 407
2.1 Application
3 Prescriptive buckling requirements 408
3.1 Application
3.2 Design load sets
3.3 Hull girder stress

Chapter 10 Fatigue

Section 1 Fatigue
1 General 410
1.1 Application
1.2 Reference
1.3 Fatigue due to loading and unloading
2 Loading conditions 410
2.1 Design loading conditions for fatigue assessment
3 Corrosion model 411
3.1 General
4 Fatigue assessment based on a deterministic approach 411
4.1 Longitudinal stiffener connections
4.2 Other structural details
5 Fatigue assessment based on spectral fatigue analysis 412
5.1 General
6 Acceptance criteria 413
6.1 Fatigue life and acceptance criteria

Chapter 11 Other Structures

Section 1 Fore Part

1 General 415

1.1 Application

2 Structural arrangement 416

2.1 Bottom Structure
2.2 Centreline wash bulkheads
2.3 Side shell structure
2.4 Tripping brackets
2.5 Decks
2.6 Platforms
2.7 Bulbous bow
2.8 Stems
2.9 Thruster tunnel

3 Structures subject to impact loads 420

3.1 General
3.2 Bottom slamming
3.3 Bow impact

Section 2 Machinery Space

1 General 424

1.1 Application

2 Machinery space arrangement 424

2.1 Structural arrangement
2.2 Double bottom
2.3 Single bottom

3 Machinery foundations 427

3.1 General
3.2 Scantlings
3.3 Foundations for internal combustion engines and thrust bearings
3.4 Auxiliary machinery foundations

Section 3 Aft Part

1 General 429

1.1 Application

2 Aft peak 429

2.1 Structural arrangement
2.2 Scantlings
2.3 Stiffening of floors and girders

3 Connection of hull structures with the rudder horn 431

3.1 Connection of after peak structures with the rudder horn
3.2 Structural arrangement above the after peak

4 Stern frames 431

4.1 General
4.2 Propeller posts
4.3 Connections
4.4 Rudder gudgeons
4.5 Sterntubes

5 Structure subject to stern impact loads 433

5.1 General

Table of Content

Section 4 Tanks subject to Sloshing

1 Application 435

1.1 General
1.2 Liquefied gas carriers
1.3 Sloshing loads
1.4 Impact loads
1.5 Evaluation of the risk of resonance

2 Scantling of elements subject to sloshing loads 438

2.1 Plating
2.2 Stiffeners
2.3 Primary supporting members

3 Scantling of elements subject to impact loads 440

3.1 Plating
3.2 Ordinary stiffeners
3.3 Primary supporting members

Section 5 Superstructures and Deckhouses

1 General 442

1.1 Application
1.2 Net scantlings
1.3 Definitions
1.4 Connections of superstructures and deckhouses with the hull structure
1.5 Structural arrangement of superstructures and deckhouses

2 Superstructures side bulkheads 443

2.1 Plating
2.2 Stiffeners
2.3 Primary supporting members

3 Fore and aft bulkheads of superstructures and deckhouses, side bulkheads of deckhouses 444

3.1 Application
3.2 Plating
3.3 Stiffeners
3.4 Primary supporting members

4 Decks 445

4.1 Plating
4.2 Stiffeners
4.3 Primary supporting members

5 Additional requirements applicable to movable wheelhouses 445

5.1 General
5.2 Supports and guides, connections with the deck, under deck reinforcements, locking devices

Section 6 Bow Doors and Inner Doors

1 General 446

1.1 Application
1.2 Gross scantlings
1.3 Arrangement
1.4 Definitions

2 Design loads 447

2.1 Bow doors
2.2 Inner doors

3 Scantlings of bow doors 447

3.1 General
3.2 Plating and ordinary stiffeners
3.3 Primary supporting members

4 Scantlings of inner doors 448

4.1 General

5 Securing and supporting of bow doors 448

5.1 General
5.2 Scantlings

6 Strength criteria 449

6.1 Primary supporting members and securing and supporting devices

7 Securing and locking arrangement 450

7.1 Systems for operation
7.2 Systems for indication/monitoring

8 Operating and Maintenance Manual 452

8.1 General

Section 7 Side Doors and Stern Doors

1 General 453

1.1 Application
1.2 Gross scantlings
1.3 Arrangement
1.4 Definitions

2 Design loads 453

2.1 Side and stern doors

3 Scantlings of side doors and stern doors 453

3.1 General
3.2 Plating and ordinary stiffeners
3.3 Primary supporting members

4 Securing and supporting of doors 454

4.1 General
4.2 Scantlings

5 Strength criteria 455

5.1 Primary supporting members and securing and supporting devices

6 Securing and locking arrangement 455

6.1 Systems for operation
6.2 Systems for indication / monitoring

7 Operating and Maintenance Manual 456

7.1 General

Section 8 Watertight and Weathertight Doors

1 General 458

1.1 Application
1.2 Definitions

2 Design loads 458

2.1 General
2.2 Side shell doors
2.3 Internal bulkheads doors
2.4 Superstructure doors

3 Door leaf scantling 458
3.1 Plating
3.2 Stiffeners
3.3 Glass
4 Securing and supporting 459
4.1 General
4.2 Scantlings
5 Inspection and testing 459
5.1 General
5.2 Hydrostatic pressure testing
5.3 Hose testing
6 Type approval procedure 460
6.1 General
6.2 Documents and information to be submitted
6.3 Prototype test

Section 9 Large Hatch Covers
1 General 462
1.1 Application
1.2 Definitions
1.3 Materials
1.4 Net scantlings
1.5 Corrosion additions
1.6 Allowable stresses
2 Arrangements 464
2.1 Height of hatch coamings
2.2 Hatch covers
2.3 Hatch coamings
3 Width of Attached Plating 465
3.1 Stiffeners
4 Load Model 465
4.1 Lateral pressures and forces
4.2 Load point
5 Strength Check 466
5.1 General
5.2 Plating
5.3 Stiffeners
5.4 Primary supporting members
5.5 Buckling
6 Hatch Coamings 469
6.1 Stiffening
6.2 Load model
6.3 Scantlings
7 Container foundations on hatch covers 471
7.1 Strength requirements
8 Weathertightness, closing arrangement, securing devices, stoppers and supports 471
8.1 Weathertightness
8.2 Gaskets
8.3 Closing arrangement, securing devices and stoppers
8.4 Cleats
8.5 Tarpaulins
8.6 Wedges, battens and locking bars
8.7 Hatch covers supports

9 Drainage 475
9.1 Arrangement
10 Testing 476
10.1 Initial test of watertight hatches
10.2 Prototype test

Section 10 Small Hatches
1 General 477
1.1 Definition
1.2 Application
1.3 Materials
2 Small hatches fitted on exposed decks 477
2.1 General
2.2 Gaskets
3 Small hatches fitted on the exposed fore deck 478
3.1 Application
3.2 Strength
3.3 Weathertightness
3.4 Primary securing devices
3.5 Secondary securing devices
4 Small hatch covers fitted on non-exposed decks 480
4.1 General
5 Testing 480
5.1 Initial test of watertight hatches
5.2 Prototype test

Section 11 Movable Decks, Inner Ramps and External Ramps
1 Movable decks and inner ramps 481
1.1 Application
1.2 Materials
1.3 Plating
1.4 Ordinary stiffeners
1.5 Primary supporting members
1.6 Supports, suspensions and locking devices
1.7 Tests and trials
2 External ramps 482
2.1 General
2.2 Plating
2.3 Ordinary stiffeners
2.4 Primary supporting members

Section 12 Arrangement of Hull and Superstructure Openings
1 General 484
1.1 Application
1.2 Definitions
2 External openings 484
2.1 General
3 Sidescuttles, windows and skylights 484
3.1 General
3.2 Opening arrangement
3.3 Glasses
3.4 Deadlight arrangement

4 Discharges 490
4.1 Arrangement of discharges
4.2 Arrangement of garbage chutes
4.3 Scantlings of garbage chutes
5 Transducers 491
5.1 General
5.2 Protection of transducers in ballast and main compartment
5.3 Fitting of hull boss and transducer receiver
5.4 Fitting of transducer in heavily stressed areas
6 Freeing ports 492
6.1 General provisions
6.2 Freeing port area in a well not adjacent to a trunk or hatchways
6.3 Freeing port area in a well contiguous to a trunk or hatchways
6.4 Freeing port area in an open space within superstructures
6.5 Freeing port area in bulwarks of the freeboard deck for ships of types A, B-100 and B-60
7 Machinery space openings 495
7.1 Engine room skylights
7.2 Closing devices
7.3 Coamings
8 Companionway 496
8.1 General
8.2 Scantlings
8.3 Closing devices
9 Ventilators 496
9.1 Closing appliances
9.2 Coamings
10 Tank cleaning openings 497
10.1 General

Section 13 Helicopter Decks and Platforms

1 Application 498
1.1 General
2 Definition 498
2.1 Landing gear
3 General arrangement 498
3.1 Landing area and approach sector
3.2 Sheathing of the landing area
3.3 Safety net
3.4 Drainage system
4 Design principle 498
4.1 General
5 Design loads 499
5.1 Emergency landing load
5.2 Garage load
5.3 Specific loads for helicopter platforms
6 Scantlings 499
6.1 General
6.2 Plating
6.3 Ordinary stiffeners
6.4 Primary supporting members

Chapter 12 Hull Outfitting

Section 1 Rudders

1 General 503

1.1 Application
1.2 Gross scantlings
1.3 Arrangements
1.4 Materials
1.5 Welding and non-destructive testing

2 Force and torque acting on the rudder 504

2.1 Rudder blade without cut-outs
2.2 Rudder blade with cut-outs (semi-spade rudders)

3 Rudder types and relevant loads acting on the rudder structure 508

3.1 General

4 Rudder stock scantlings 510

4.1 Rudder stock diameter
4.2 Deformation criterion
4.3 Service notations - Navigation in ice

5 Rudder stock couplings 511

5.1 Horizontal flange couplings
5.2 Couplings between rudder stocks and tillers
5.3 Cone couplings between rudder stocks and rudder blades
5.4 Vertical flange couplings
5.5 Couplings by continuous rudder stock welded to the rudder blade
5.6 Rudder trunks

6 Rudder stock and pintle bearings 518

6.1 Forces on rudder stock and pintle bearings
6.2 Rudder stock bearing
6.3 Pintle bearings
6.4 Pintles

7 Rudder blade scantlings 521

7.1 General
7.2 Strength checks
7.3 Rudder blade plating
7.4 Connections of rudder blade structure with solid parts in forged or cast steel
7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges
7.6 Single plate rudders

8 Rudder horn and solepiece scantlings 527

8.1 General
8.2 Rudder horn
8.3 Connection of after peak structures with the rudder horn
8.4 Solepieces

9 Simplex rudder shaft 529

9.1 Scantlings
9.2 Connections

10 Nozzles 530

10.1 General
10.2 Nozzle plating and internal diaphragms
10.3 Nozzle stock
10.4 Pintles
10.5 Nozzle coupling

Table of Content

11 Azimuth propulsion system 533

11.1 General
11.2 Arrangement
11.3 Design loads
11.4 Plating
11.5 Ordinary stiffeners
11.6 Primary supporting members
11.7 Hull supports of the azimuth propulsion system

Section 2 Bulwarks and Guard Rails

1 General 536

1.1 Application
1.2 General requirements

2 Bulwarks 536

2.1 Construction of bulwarks
2.2 Scantlings

3 Guard rails 537

3.1 General
3.2 Construction of guard rails

Section 3 Propeller Shaft Brackets

1 Propeller shaft brackets 539

1.1 General
1.2 Double arm propeller shaft brackets
1.3 Single arm propeller shaft brackets
1.4 Bossed propeller shaft brackets

Section 4 Equipment

1 General 542

1.1 Application
1.2 Equipment number

2 Anchoring equipment 546

2.1 Anchors
2.2 Chain cables for bower anchors
2.3 Attachment pieces
2.4 Hawse pipes
2.5 Windlass
2.6 Chain stopper
2.7 Chain locker

3 Emergency towing arrangement 550

3.1 Definitions
3.2 Application
3.3 Documentation
3.4 General
3.5 Emergency towing arrangement approval
3.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strongpoints
3.7 Towing pennant
3.8 Chafing gear
3.9 Fairleads
3.10 Strongpoint
3.11 Hull structures in way of fairleads or strongpoints
3.12 Rapid deployment of towing arrangement
3.13 Type approval

4 Towing and mooring arrangement 558

4.1 General
4.2 Shipboard fittings and supporting hull structures associated with towing and mooring

Table of Content

Appendix 1 Criteria for Direct Calculation of Rudder Loads

1 Criteria for direct calculation of the loads acting on the rudder structure 563

1.1 General
1.2 Required data
1.3 Calculation of support stiffness properties
1.4 Calculation of the main structure of the rudder system
1.5 Calculation of the solepiece
1.6 Rudder horn calculation (case of 1-elastic support)
1.7 Rudder horn calculation (case of 2-conjugate elastic supports)
1.8 Calculation of the rudder trunk

Appendix 2 Towing and Mooring Arrangement

1 General 577

1.1 Application
1.2 Definition
1.3 Mooring arrangement
1.4 Towing arrangement

2 Tow lines and mooring lines 578

2.1 General
2.2 Materials
2.3 Steel wires
2.4 Length of mooring lines
2.5 Synthetic fibre ropes
2.6 Additional mooring lines
2.7 Mooring lines for ships with EN > 2000

Chapter 13 Construction and Testing

Section 1 Construction and Fabrication

1 General 584

1.1 Workmanship
1.2 Fabrication standard

2 Cut-outs, plate edges 585

2.1 General

3 Cold forming 585

3.1 Special structural members
3.2 Corrugated bulkheads and hopper knuckles
3.3 Low bending radius

4 Hot forming 585

4.1 Temperature requirements
4.2 Line or spot heating

5 Modifications and repairs during construction 586

5.1 General
5.2 Gap and weld deformations
5.3 Defects
5.4 Repairs on structures already welded

Section 2 Fabrication by Welding

1 General 587

1.1 Application
1.2 Base material
1.3 Documentation to be submitted
1.4 Personnel and equipment

2 Welding 588
2.1 General
2.2 Welding consumables and procedures
2.3 Welding operations
2.4 Crossing of structural elements
2.5 Hatch coaming
3 Inspections and checks 591
3.1 General
3.2 Hatch coaming

Section 3 Design of Weld Joints
1 General 593
1.1 Application
1.2 Arrangement
2 Butt joint 594
2.1 General
3 Tee or cross joint 595
3.1 Application
3.2 Fillet welding
3.3 Partial or full penetration welds
4 Other types of joints 604
4.1 Lapped joints
4.2 Slot welds
4.3 Stud and lifting lug welds
4.4 Plug welding
5 Specific weld connections 605
5.1 Bilge keels
5.2 End connections of pillars
5.3 Abutting plates with small angles
5.4 Struts connecting ordinary stiffeners
5.5 Connection between propeller post and propeller shaft bossing
5.6 Bar stem connections
5.7 Deck subjected to wheeled loads

Section 4 Non-Destructive Testing
1 General 608
1.1 Scope
1.2 General requirements
1.3 Requirements for the entity carrying out NDT
1.4 Terms and definitions
2 Application 609
2.1 Base metals
2.2 Welding processes
2.3 Weld joints
2.4 Timing of NDT
2.5 Applicable methods for testing of weld joints
3 Qualification of personnel involved in NDT 610
3.1 Requirements
4 Surface condition 610
4.1 General
5 General plan of testing 610
5.1 Extent of testing and selection of NDT method

6 Testing 611

6.1 General
6.2 Visual testing (VT)
6.3 Liquid penetrant testing (PT)
6.4 Magnetic particle testing (MT)
6.5 Radiographic testing (RT)
6.6 Ultrasonic testing (UT)

7 Acceptance Levels (criteria) 612

7.1 General
7.2 Quality Levels
7.3 Testing Levels
7.4 Acceptance Levels
7.5 Visual testing (VT)
7.6 Penetrant testing (PT)
7.7 Magnetic Particle testing (MT)
7.8 Radiographic testing (RT)
7.9 Ultrasonic testing (UT)

8 Reporting 615

8.1 General

9 Unacceptable indications and repairs 616

9.1 General

Section 5 Special Structural Details

1 General 617

1.1 Application
1.2 Design requirements
1.3 Constructional requirements
1.4 Material requirements
1.5 Welding requirements
1.6 Survey requirements

2 List and characteristics of special structural details 618

2.1 General
2.2 All types of ships with longitudinally framed sides
2.3 Ships carrying liquid cargo in bulk, except liquefied gas carriers
2.4 Liquefied gas carriers
2.5 Container ships
2.6 Bulk, ore and combination carriers
2.7 Ro-ro ships
2.8 Passenger ships

Section 6 Testing

1 Testing procedures of watertight compartments 626

1.1 Application
1.2 General
1.3 Definitions
1.4 Structural test procedures
1.5 Leak test procedures
1.6 Test methods
1.7 Application of coating
1.8 Safe access to joints
1.9 Hydrostatic or hydropneumatic tightness test
1.10 SOLAS Exempt / Equivalent Ships
1.11 Non-SOLAS Ships

2 Miscellaneous 633

2.1 Watertight decks, trunks, etc.
2.2 Steering nozzles

Table of Content

Appendix 1 Welding Details

1 Contents 634

1.1 General
1.2 Butt welding edge preparation
1.3 Partial of full penetration edge preparation
1.4 Lap-joint, slot and plug welding

Appendix 2 Reference Sheets for Special Structural Details

1 Contents 636

1.1 General

Part B
Hull and Stability

CHAPTER 1
GENERAL

Section 1	Application
Section 2	Rules Principles
Section 3	Symbols and Definitions
Section 4	Documentation to be Submitted
Section 5	Loading Manual and Loading Instruments
Appendix 1	Equivalences between Current Revision and July 2021 Edition of the Rules for the Classification of Steel Ships

Section 1 Application

1 Scope of application

1.1 General

1.1.1 These Rules contain the requirements for the determination of the minimum hull scantlings, applicable to all types of seagoing monohull displacement ships of conventional shape, speed and proportions, made in welded steel construction.

Other types of ships will be considered by the Society on a case by case basis.

These requirements are to be integrated with those specified in Part D and Part E, for any individual ship type, and in Part F, as applicable, depending on the additional class notations assigned to the ships.

1.1.2 Ships covered by NR600 "Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m" are not covered in these Rules.

Note 1: NR600 is applicable for:

- cargo ships with length less than 65 m, and
- non cargo ships with length less than 90 m.

The wording "cargo ships" and "non-cargo ships" used in NR600 means:

- Cargo ships: ships liable to carry cargoes and having a deadweight greater than 30% of the total displacement. As a general rule, these ships are fitted with cargo holds, tanks and lateral ballast tanks (i.e bulk or ore carriers, oil or chemical tanker, container ship, general cargo ship) and the value of the block coefficient is greater than 0,75
- Non-cargo ships: type of ships other than cargo ships defined here above or ships having a deadweight greater than 30% of the total displacement and not fitted with lateral ballast tanks used in non loaded navigation condition.

Note 2: NR600 is not applicable for liquefied gas carriers and any cargo ships with alternate light and heavy cargo loading conditions.

1.1.3 These Rules apply to welded hull structures made of steel having characteristics complying with requirements in Ch 4, Sec 1. These Rules applies also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in Ch 4, Sec 1.

Ships whose hull materials are different than those given in the first paragraph are to be individually considered by the Society, on the basis of the principles and criteria adopted in these Rules.

1.1.4 The strength of ships constructed and maintained according to the Rules is sufficient for the draught corresponding to the assigned freeboard. The scantling draught considered when applying the Rules is to be not less than that corresponding to the assigned freeboard.

1.1.5 Where scantlings are obtained from direct calculation procedures which are different from those specified in Part B, Chapter 7, adequate supporting documentation is to be submitted to the Society, as detailed in Ch 1, Sec 4.

1.2 Limits of application to lifting appliances

1.2.1 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2 The fixed parts of lifting appliances and their connections to the ship's structure are covered by the Rules, even when the certification (especially the issuance of the Cargo Gear Register) of lifting appliances is not required.

1.2.3 The foundations of lifting appliances intended to be used at sea are to comply with the requirements of Part E, Chapter 8.

2 Rule application

2.1 Ship parts

2.1.1 General

For the purpose of application of these Rules, the ship is considered as divided into the following three parts:

- fore part
- central part
- aft part.

2.1.2 Fore part

The fore part is the part of the ship located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stem.

2.1.3 Central part

The central part includes the structures located between the collision bulkhead (included) and the after peak bulkhead.

Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part

The aft part includes the structures located aft of the aft peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1 The various Chapters and Sections of Part B are to be applied for the scantling and arrangement of ship parts according to Tab 1.

Table 1 : Part B Chapters and Sections applicable for the scantling of ship parts

Applicable Chapters and Sections		
All ship parts	Specific ship parts	
Part B, Chapter 1 Part B, Chapter 2 Part B, Chapter 3 Part B, Chapter 4 Part B, Chapter 5 Part B, Chapter 6		
Part B, Chapter 7	Central part	Part B, Chapter 7
Part B, Chapter 8 Part B, Chapter 9 Part B, Chapter 10		
Part B, Chapter 11 **(1) (2)**	Fore part	Ch 11, Sec 1
	Aft part	Ch 11, Sec 3
Part B, Chapter 13		
(1) See also [2.3]. **(2)** excluding Ch 11, Sec 1 and Ch 11, Sec 3		

2.3 Rules applicable to other ship items

2.3.1 The various Chapters and Sections of Part B are to be applied for the scantling and arrangement of other ship items according to Tab 2.

Table 2 : Part B Chapters and Sections applicable for the scantling of other items

Item	Applicable Chapters and Sections	Item	Applicable Chapters and Sections
Machinery space	Ch 11, Sec 2	Rudders	Ch 12, Sec 1
Tanks subject to sloshing	Ch 11, Sec 4	Other hull outfitting	Ch 12, Sec 2 Ch 12, Sec 3 Ch 12, Sec 4
Superstructures and deckhouses	Ch 11, Sec 5		
Bow doors and inner doors	Ch 11, Sec 6		
Side shell doors and stern doors	Ch 11, Sec 7		
Watertight and weathertight doors	Ch 11, Sec 8		
Large hatch covers	Ch 11, Sec 9		
Small hatches	Ch 11, Sec 10		
Movable decks and inner ramp External ramps	Ch 11, Sec 11		
Arrangement of hull and superstructures openings	Ch 11, Sec 12		
Helicopter decks	Ch 11, Sec 13		

Section 2 Rules Principles

1 Design basis

1.1 General

1.1.1 Ships are to be designed to withstand, in intact condition, the environmental conditions as defined in [1.4] anticipated during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations must include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

1.1.2 Ships are to be designed to have sufficient reserve strength to withstand loads in damaged conditions, e.g. flooded scenarios.

1.1.3 Finite element analysis

Scantlings of structural members within the cargo hold region of ships having a length L of 150 m or above are to be assessed according to the requirements specified in Part B, Chapter 8.

1.1.4 Fatigue life

Ships having a length L of 150 m or above are to be assessed according to the design fatigue life for structural details specified in Part B, Chapter 10.

1.2 Hull form limit

1.2.1 Loads applying to the ship hull, as described in these Rules, are based on hull forms within the following limits:

- $L < 500$ m
- $C_B > 0,6$
- $L/B > 5$
- $B/D < 2,5$

with the Rule length L, the block coefficient C_B, the moulded breadth B and the moulded depth D defined in Ch 1, Sec 3.

Specific consideration will be given by the Society to ships with different hull forms.

1.3 Design life

1.3.1 Rule loads and scantling criteria are based on a target design life of 25 years. The design life is the period during which the ship is assumed to be exposed to operating conditions.

1.4 Environmental conditions

1.4.1 Wave environment

Unless otherwise specified, the rule requirements are based on north atlantic wave environment for the strength and fatigue assessments.

1.4.2 Wind and current

The effects of current are not considered with regard to the strength of the structure.

The effects of wind are only considered for defining the minimum external pressure acting on the hull, superstructures and deckhouses.

1.4.3 Design temperatures

The structural assessment of hull strength members is assumed to be valid for the following design temperatures:

- lowest mean daily average temperature in air: –10°C
- lowest mean daily average temperature in seawater: 0°C.

Ships intended to operate in areas with lower mean daily average temperature, e.g. regular service during winter seasons to Arctic or Antarctic waters, are subject to specific requirements.

In the above, the following definitions apply:

daily average : Average during one day and one night

mean : Statistical mean over an observation period (at least 20 years)

lowest : The lowest value during one year.

For seasonally restricted service, the lowest value within the period of operation applies.

1.5 Operating conditions

1.5.1 The Rules specify the minimum loading conditions that are to be assessed for compliance.

Specification of loading conditions other than those required by the Rules is the responsibility of the Owner. These other loading conditions are to be documented and assessed for compliance.

1.6 Operating draughts

1.6.1 The design operating draughts are to be specified by the builder/designer, subject to acceptance by the Owner, and are to be used to derive the appropriate structural scantlings.

All operational loading conditions in the loading manual are to comply with the specified design operating draughts. The following design operating draughts are, as a minimum, to be considered:

- scantling draught for the assessment of structure
- minimum ballast draught at midship for the assessment of structure
- minimum forward draught, T_F, for the assessment of bottom structure forward subjected to slamming loads, as defined in Ch 5, Sec 5, [4.2.1].

1.7 Maximum service speed

1.7.1 The maximum service speed is to be specified. Although the hull structure assessment accounts for the service speed, this does not relieve the responsibilities of the Owner and personnel to properly handle the ship.

1.8 Owner's extras

1.8.1 The Owner's specification above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:

- vibration analysis
- maximum percentage of high strength steel
- additional scantlings above those required by the Rules
- additional design margin on the loads specified by the Rules, etc
- improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent.

Owner's extras are not specified in these Rules. Owner's extras, if any, that may affect the structural design are to be clearly specified in the design documentation.

2 Design principles

2.1 Overall principles

2.1.1 These Rules are based on the following principles:

- the safety of the structure can be assessed by addressing the potential structural failure mode(s) when the ship is subject to operational loads and environmental loads/conditions
- the structural requirements are based on consistent design load sets which cover the appropriate operating modes of ships complying with Ch 1, Sec 1, [1].

2.1.2 The ship structure is so designed that:

- it has a degree of redundancy. The ship structure should work in a hierarchical manner and, in principle, failure of structural elements lower down in the hierarchy does not result in immediate consequential failure of elements higher up in the hierarchy
- it has sufficient reserve strength to withstand the wave and internal loads in damaged conditions that are reasonably foreseeable, e.g. flooding scenarios
- the incidence of in-service cracking is minimised, particularly in locations which affect the structural integrity or containment integrity, affect the performance of structural or other systems, or are difficult to inspect and repair
- it has adequate structural redundancy to survive in the event that the structure is accidentally damaged by a minor impact leading to flooding of any compartment.

2.2 Loads

2.2.1 Design load scenarios

The structural assessment is based on the design load scenarios encountered by the ship, as defined in Ch 5, Sec 7 and reminded below:

N : Seagoing conditions with extrem sea loads

H : Harbour and sheltered water conditions

T : Tank testing operations
I : Application of impact loads such as bottom slamming and bow impact encountered during seagoing operations
SL : Application of sloshing loads encountered during seagoing operations
F : Fatigue design load scenario
A : Accidental scenarios with loads not occurring during normal operations
BWE : Ballast water exchange scenario.

2.2.2 Load categories

The design load scenarios given in [2.2.1] may be associated to one of the following load categories:

- S when the associated load components result only from static effects
- S+D when the associated load components result from both static and dynamic effects.

2.3 Structural capacity assessment

2.3.1 General

The basic principle in structural design is to apply the defined design loads, identify failure modes and use appropriate capacity models to obtain the required structural scantlings.

2.3.2 Capacity models for strength assessment

The capacity models for strength assessment are to be able to analyse the failure mode with regards to the required degree of accuracy.

The capacity models are either in a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

The formulae used to determine stress, deformations and capacity are deemed appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

2.3.3 Capacity models for fatigue assessment

The capacity models for fatigue assessment:

- provide rule requirements to assess structural details against fatigue failure
- are based on a linear cumulative damage summation (Palmgren-Miner rule) in combination with a design S-N curve, a reference stress range and an assumed long-term stress distribution curve, and
- are either in a prescriptive format or require the use of more advanced calculations, such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

2.3.4 Net scantling approach

The objective of the net scantling approach is to:

- provide a relationship between the thickness used for strength calculations during the newbuilding stage and the minimum thickness accepted during the operational phase
- enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

The net scantling approach distinguishes between local corrosion and global corrosion:

- local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener
- global corrosion is defined as the overall average corrosion of larger areas, such as primary supporting members and the hull girder.

Both the local corrosion and the global corrosion are used as a basis for the newbuilding review and are to be assessed during operation of the ship.

No credit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

The application of the net thickness approach to assess the structural capacity is specified in Ch 4, Sec 2.

3 Rule design methods

3.1 General

3.1.1 Design methods

Scantling requirements are specified to cover the relevant failure modes, as necessary, for various structural parts.

The criteria for the assessment of scantlings are based on one of the following design methods:

- Working Stress Design (WSD) method, also known as the permissible or allowable stress method
- Partial Safety Factor (PSF) method, also known as Load and Resistance Factor Design (LRFD).

For both WSD and PSF, two design assessment conditions are given, as well as the corresponding acceptance criteria. These conditions are associated with the probability level of the combined loads, A and B.

a) Composition of the WSD method

- for condition A:

$$W_{stat} \leq \eta_1 R$$

- for condition B:

$$W_{stat} + W_{dyn} \leq \eta_2 R$$

where:

W_{stat} : Simultaneously occurring static loads (or load effects in terms of stresses)

W_{dyn} : Simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components

R : Characteristic structural capacity (e.g. specified minimum yield stress or buckling capacity)

η_i : Permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure.

b) Composition of the PSF method

- for condition A:

$$\gamma_{stat\text{-}1}\, W_{stat} + \gamma_{dyn\text{-}1}\, W_{dyn} \leq \frac{R}{\gamma_R}$$

- for condition B:

$$\gamma_{stat\text{-}2} W_{stat} + \gamma_{dyn\text{-}2} W_{dyn} \leq \frac{R}{\gamma_R}$$

where:

$\gamma_{stat\text{-}i}$: Partial safety factor that accounts for the uncertainties related to static loads in condition A or B

$\gamma_{dyn\text{-}i}$: Partial safety factor that accounts for the uncertainties related to dynamic loads in condition A or B

γ_R : Partial safety factor that accounts for the uncertainties related to structural capacity.

The acceptance criteria for both the WSD method and the PSF method are calibrated for the various requirements such that consistent and acceptable safety levels for all combinations of static and dynamic load effects are derived.

3.2 Minimum requirements

3.2.1 The minimum requirements specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum is not allowed.

The minimum requirements are usually in one of the following forms:

- minimum thickness, which is independent of the specified minimum yield stress
- minimum stiffness and proportion, which are based on buckling failure modes.

3.3 Load-capacity based requirements

3.3.1 General

In general, the working stress design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria, where the partial safety factor (PSF) method is applied for its highly critical failure mode, in order to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set.

Load-capacity based prescriptive requirements provide scantling requirements for all plating, local support members, most primary supporting members and the hull girder and cover all structural elements including deckhouses and foundations for deck equipment.

In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

3.3.2 Design loads for strength assessment

The structural assessment of the compartment boundaries, e.g. the bulkheads, is based on the loading condition deemed relevant for the type of ship and the operation the ship is intended for.

To provide consistency of approach, standardised rule values for parameters, such as GM and C_B, are applied to calculate the rule load values.

The design load scenarios for structural verification combine the applicable and simultaneously acting local and global load components. The relevant design load scenarios are given in Ch 5, Sec 7.

The simultaneously occurring dynamic loads are obtained by applying a dynamic load combination factor to the dynamic load values given in Part B, Chapter 5. The dynamic load combination factors for each dynamic load case are given in Ch 5, Sec 2.

Design load conditions for the hull girder ultimate strength are given in Ch 6, Sec 2.

3.3.3 Design loads for fatigue assessment

For the fatigue requirements given in Part B, Chapter 10, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-2} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

The considered wave induced loads include:

- hull girder loads (i.e. vertical and horizontal bending moments)
- dynamic wave pressures
- dynamic pressure from cargo, if any.

The load values are based on rule parameters corresponding to the loading conditions, e.g. GM, C_B and the applicable draughts amidships.

The simultaneously occurring dynamic loads are accounted for, combining the stresses due to the various dynamic load components. The stress combination procedure is given in Part B, Chapter 10.

3.3.4 Structural response analysis

The following approaches are used for the determination of the structural response to the applied design load combinations:

a) beam theory is used for prescriptive requirements

b) finite element analysis is used for:
   - standard mesh for cargo hold model
   - fine mesh for local models
   - very fine mesh for fatigue assessment.

3.4 Acceptance criteria

3.4.1 General

The acceptance criteria are categorised into four sets. The specific acceptance criteria sets applied in the rule requirements depend on the probability level of the characteristic combined load.

a) The acceptance criteria set AC-1- is typically applied for the static design load scenarios (S) and for the sloshing design loads. The allowable stress for such loads is lower than for an extreme load to take into account effects of:
   - repeated yield
   - allowance for some dynamics
   - margins for some selected limited operational mistakes.

b) the acceptance criteria set AC-2 is typically applied for the static + dynamic design load scenarios (S+D), where the considered loads are extreme loads with a low probability of occurrence.

c) the acceptance criteria set AC-3 is typically applied for exceptional static conditions load scenarios (A: S and T: S), such as flooding or tank testing loads.

d) the acceptance criteria set AC-4 is typically applied for impact design load scenarios (I), such as bottom slamming and bow impact loads.

3.4.2 Criteria

A general overview of the acceptance criteria is provided in Tab 1 and Tab 2 for the different design load scenarios covered by these Rules for the yield and buckling failure modes:

- for the yield criteria, the permissible stress is proportional to the specified minimum yield stress of the material
- for the buckling failure mode, the acceptance criteria are based on the control of stiffness and proportions as well as on the buckling utilisation factor.

3.5 Design verification

3.5.1 Design verification - Hull girder ultimate strength

The requirements for the ultimate strength of the hull girder are based on a partial safety factor (PSF) method. A safety factor is assigned to each of the basic variables, the still water bending moment, the wave bending moment and the ultimate capacity. The safety factors are determined using a structural reliability assessment approach, the long-term load history distribution of the wave bending moment is derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

The purpose of the hull girder ultimate strength verification is to demonstrate that one of the most critical failure modes of the ship is controlled.

3.5.2 Design verification - Finite element analysis

The finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements to better consider the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy.

A linear elastic three dimensional finite element analysis of the cargo region, if any, or of the full length model is carried out to assess and verify the structural response of the actual hull girder and primary supporting members and to provide the scantling requirements for the primary supporting members. The purpose of the finite element analysis is to verify that the stresses and buckling capability of the primary supporting members are within acceptable limits for the applied design loads.

3.5.3 Design verification - Fatigue assessment

The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A simplified fatigue requirement is applied to details such as end connections of longitudinal stiffeners using stress concentration factors (SCF) to account the actual detail geometry. A fatigue assessment procedure using finite element analysis for determining the actual hot spot stress of the geometric detail is applied to selected details. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

3.5.4 Relationship between prescriptive scantling requirements and finite element analysis

The scantlings defined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as finite element analysis, unless explicitly stated.

Table 1 : Acceptance criteria - Prescriptive requirements

Acceptance criteria	Plate panels and local supporting members **(1)**		Primary supporting members **(1)**		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-1 AC-2 AC-3	Permissible stress: Ch 7, Sec 4 Ch 7, Sec 5	Control of stiffness and proportions: Ch 9, Sec 1	Permissible stress: Ch 7, Sec 6	Control of stiffness and proportions: Ch 9, Sec 1	Permissible stress: Ch 6, Sec 1	Allowable buckling utilisation factor: Ch 9, Sec 1
AC-4	Plastic criteria: Ch 11, Sec 1, [3] Ch 11, Sec 3, [5] Ch 11, Sec 4, [3]	Control of stiffness and proportions: Ch 9, Sec 1	Plastic criteria: Ch 11, Sec 1, [3] Ch 11, Sec 3, [5] Ch 11, Sec 4, [3]	Control of stiffness and proportions: Ch 9, Sec 1	N/A	N/A
(1) Refer to Part B, Chapter 11 for other structures and to Ch 11, Sec 5 for superstructures, deckhouses and hull outfitting.						

Table 2 : Acceptance criteria - Finite Element Analysis

Acceptance criteria	Cargo hold analysis		Fine mesh analysis
	Yield	Buckling	Yield
AC-1 AC-2 AC-3	Permissible stress: refer to Ch 8, App 1, [5]	Allowable buckling utilisation factor: refer to Ch 9, Sec 1	Permissible stress: refer to Ch 8, App 2, [4] Screening criteria: refer to Ch 8, App 2, [1.2.2]

Section 3 Symbols and Definitions

1 Symbols and units

1.1

1.1.1 Ship's dimensions and main data

Unless otherwise specified, symbols regarding ship's main data and their units used in these Rules are those defined in Tab 1.

1.1.2 Materials

Unless otherwise specified, symbols regarding materials and their units used in these Rules are those defined in Tab 2.

Table 1 : Ship's dimensions and main data

Symbol	Meaning				Unit	Reference
B	Moulded breadth of the ship				m	[2.1.4]
C_B	Block coefficient at draught T_{SC}				–	[2.1.9]
$C_{B\text{-}BAL}$	Block coefficient at draught T_{BAL}				–	[2.1.9]
C_W	Waterplane coefficient at draught T_{SC}				–	[2.1.10]
$C_{W\text{-}BAL}$	Waterplane coefficient at draught T_{BAL}				–	[2.1.10]
D	Moulded depth of the ship				m	[2.1.5]
Δ	Moulded displacement at draught T_{SC}				t	[2.1.7]
L	Rule length				m	[2.1.1]
	L_0 = min (L; 120)	L_1 = min (L; 200)	L_2 = min (L; 250)	L_3 = min (L; 300)		
L_{LL}	Load line length				m	[2.1.2]
L_S	Subdivision length				m	[2.1.3]
T	Moulded draught				m	[2.1.6]
T_{BAL}	Minimum draught amidships among ballast conditions				m	[2.1.6]
$T_{BAL\text{-}H}$	Minimum draught amidships among heavy ballast conditions				m	[2.1.6]
T_{LC}	Draught amidships at the considered loading condition				m	[2.1.6]
T_{SC}	Scantling draught				m	[2.1.6]
V	Maximum service speed				knots	[2.1.8]
x, y, z	Coordinates of the calculation point with respect to the reference coordinate system				m	[2.6]

Table 2 : Materials

Symbol	Meaning	Unit	Reference
E	Young's modulus	N/mm²	Ch 4, Sec 1, [2]
G	Shear modulus: $G = \frac{E}{2(1+\nu)}$	N/mm²	–
k	Material factor	–	Ch 4, Sec 1, [2]
ν	Poisson's ratio	–	Ch 4, Sec 1, [2]
R_{eH}	Specified minimum yield stress	N/mm²	Ch 4, Sec 1, [2]
R_m	Specified minimum tensile strength	N/mm²	Ch 4, Sec 1, [2]
R_Y	Nominal yield stress, taken equal to 235/k	N/mm²	–
τ_{eH}	Specified shear yield stress: $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm²	–

1.1.3 Loads

Unless otherwise specified, symbols regarding loads and their units used in these Rules are those defined in Tab 3.

1.1.4 Scantlings

Unless otherwise specified, symbols regarding scantlings and their units used in these Rules are those defined in Tab 4.

1.1.5 Gravity acceleration

The gravity acceleration g is taken equal to 9,81 m/s^2.

1.1.6 Density of seawater

The density of seawater ρ is taken equal to 1,025 t/m^3.

Table 3 : Loads

Symbol	Meaning	Unit	Reference
T_θ	Roll period	s	Ch 5, Sec 3, [2.1.1]
θ	Roll angle	deg	Ch 5, Sec 3, [2.1.1]
T_φ	Pitch period	s	Ch 5, Sec 3, [2.1.2]
φ	Pitch angle	deg	Ch 5, Sec 3, [2.1.2]
a_x	Longitudinal acceleration	m/s^2	Ch 5, Sec 3, [3]
a_y	Transverse acceleration	m/s^2	Ch 5, Sec 3, [3]
a_z	Vertical acceleration	m/s^2	Ch 5, Sec 3, [3]
k_r	Roll radius of gyration	m	Ch 5, Sec 3, Tab 4
GM	Metacentric height	m	Ch 5, Sec 3, Tab 4
S	Static load scenario	–	–
S+D	Dynamic load scenario	–	–
P_{ex}	Total sea pressure	kN/m^2	Ch 5, Sec 5, [1]
P_{in}	Total internal pressure due to liquid	kN/m^2	Ch 5, Sec 6, [1]
P_s	Static sea pressure	kN/m^2	Ch 5, Sec 5, [1.2]
P_{ls}	Static tank pressure	kN/m^2	Ch 5, Sec 6, [1.2]
P_w	Dynamic wave pressure	kN/m^2	Ch 5, Sec 5, [1.3] and Ch 5, Sec 5, [1.4]
P_{ld}	Dynamic tank pressure	kN/m^2	Ch 5, Sec 6, [1.3]
P_d	Green sea deck pressure	kN/m^2	Ch 5, Sec 5, [3.2]
P_{sl}	Sloshing pressure	kN/m^2	Ch 5, Sec 6, [2.2.1]
P_{dl}	Total pressure due to uniform cargo	kN/m^2	Ch 5, Sec 6, [6.1]
P_{SLI}	Bottom and stern slamming pressure	kN/m^2	Ch 5, Sec 5, [4.2]
P_{FI}	Bow impact pressure	kN/m^2	Ch 5, Sec 5, [4.3]
P_{fs}	Static pressure in flooded conditions	kN/m^2	Ch 5, Sec 6, [1.4.1]
P_{ST}	Tank testing pressure	kN/m^2	Ch 5, Sec 6, [10.1.1]
F_{u-s}	Force due to unit cargo in static (S) design load scenario	kN	Ch 5, Sec 6, [6.2.1]
F_{u-d}	Force due to unit cargo in static plus dynamic (S+D) design load scenario	kN	Ch 5, Sec 6, [6.2.1]
M_{sw}	Vertical still water bending moment	kN·m	Ch 5, Sec 4, [2.1.1]
Q_{sw}	Vertical still water shear force	kN	Ch 5, Sec 4, [2.3.1]
M_{wv}	Vertical wave bending moment	kN·m	Ch 5, Sec 4, [3.1]
Q_{wv}	Vertical wave shear force	kN	Ch 5, Sec 4, [3.2]
M_{wt}	Torsional wave moment	kN·m	Ch 5, Sec 4, [3.5]
M_{wh}	Horizontal wave bending moment	kN·m	Ch 5, Sec 4, [3.3]
Q_{wh}	Horizontal wave shear force	kN	Ch 5, Sec 4, [3.4]

Table 4 : Scantlings

Symbol	Meaning	Unit	Reference
$I_{y\text{-}n50}$	Net vertical moment of inertia of hull girder, calculated with half corrosion reduction	m^4	–
$I_{z\text{-}n50}$	Net horizontal moment of inertia of hull girder, calculated with half corrosion reduction	m^4	–
$Z_{D\text{-}n50}$	Net vertical hull girder section moduli, at deck, calculated with half corrosion reduction	m^3	–
$Z_{B\text{-}n50}$	Net vertical hull girder section moduli, at bottom, calculated with half corrosion reduction	m^3	–
z_n	Vertical distance from BL to horizontal neutral axis	m	–
a	Length of an elementary plate panel (EPP)	mm	Ch 4, Sec 6, [2.1.1]
b	Breadth of an elementary plate panel (EPP)	mm	Ch 4, Sec 6, [2.1.1]
s	Stiffener spacing	mm	Ch 4, Sec 6, [1.2.1]
S	Primary supporting member spacing	m	Ch 4, Sec 6, [1.2.2]
ℓ	Span of stiffeners or primary supporting members	m	Ch 4, Sec 6, [1]
ℓ_b	Bracket arm length	m	–
t	Net thickness with full corrosion reduction	mm	–
t_{n50}	Net thickness with half corrosion reduction	mm	–
t_c	Corrosion addition	mm	–
t_{gr}	Gross thickness	mm	–
t_{as_built}	As-built thickness taken as the actual thickness provided at the newbuilding stage	mm	–
t_{gr_off}	Gross thickness offered	mm	–
t_{gr_req}	Gross thickness required	mm	–
t_{off}	Net thickness offered	mm	–
t_{req}	Net thickness required	mm	–
t_{vol_add}	Thickness for voluntary addition	mm	–
t_{res}	Reserve thickness, taken equal to 0,5	mm	–
t_{c1}, t_{c2}	Corrosion addition on each side of structural member	mm	–
h_w	Web height of stiffener or primary supporting member	mm	–
t_w	Web thickness of stiffener or primary supporting member	mm	–
b_f	Face plate width of stiffener or primary supporting member	mm	–
h_{stf}	Height of stiffener or primary supporting member	mm	–
t_f	Face plate/flange thickness of stiffener or primary supporting member	mm	–
t_p	Thickness of the plating attached to a stiffener or a primary supporting member	mm	–
b_{eff}	Effective breadth of attached plating, in bending, for yield and fatigue	mm	–
A_{eff}	Net sectional area of stiffener or primary supporting member, with attached plating of width s, calculated with full corrosion reduction	cm^2	–
$A_{eff\text{-}n50}$	Net sectional area of stiffener or primary supporting member, with attached plating of width s, calculated with half corrosion reduction	cm^2	–
A_{shr}	Net shear sectional area of stiffener or primary supporting member, calculated with full corrosion reduction	cm^2	–
$A_{shr\text{-}n50}$	Net shear sectional area of stiffener or primary supporting member, calculated with half corrosion reduction	cm^2	–
I_p	Net polar moment of inertia of a stiffener about its connection to plating	cm^4	–
I	Net moment of inertia of a stiffener, with attached plating, about its neutral axis parallel to the plating	cm^4	–
Z	Net section modulus of a stiffener or primary supporting member, with attached plating of breadth b_{eff} , calculated with full corrosion reduction	cm^3	–
Z_{n50}	Net section modulus of a stiffener or primary supporting member, with attached plating of breadth b_{eff} , calculated with half corrosion reduction	cm^3	–

2 Definitions

2.1 Ship's dimensions and main data

2.1.1 Rule length

The rule length L is the distance, in m, measured on the waterline at the scantling draught T_{SC}, from the fore-side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post. L is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the rule length L is to be taken equal to 97% of the extreme length on the waterline at the scantling draught T_{SC}.

In ships with unusual stem or stern arrangements, the rule length is considered on a case-by-case basis.

2.1.2 Load line length

The load line length L_{LL} shall be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.

For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.

Where the stem contour is concave above the waterline at 85% of the least moulded depth, both the forward terminal of the total length and the fore-side of the stem is taken at the vertical projection to that waterline of the aftermost point of the stem contour (see Fig 1).

In ship design with a rake of keel, the waterline on which this length is measured is parallel to the designed waterline at 85% of the least moulded depth D_{min} found by drawing a line parallel to the keel line of the ship (including skeg) tangent to the moulded sheer line of the freeboard deck.The least moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side at the point of tangency (see Fig 2).

Figure 1 : Concave stem contour

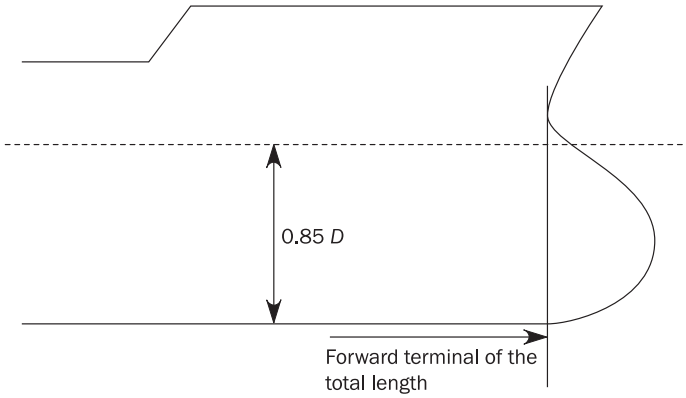
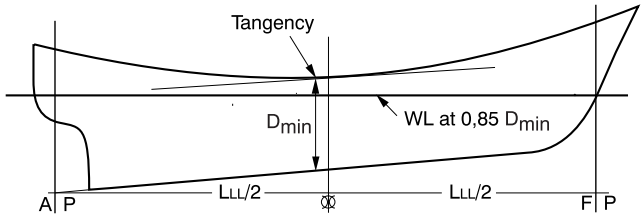


Figure 2 : Length of ships with a rake of keel



2.1.3 Subdivision length

The subdivision length L_S of the ship is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

2.1.4 Moulded breadth

The moulded breadth B is the greatest moulded breadth, in m, measured amidships at the scantling draught T_{SC}.

2.1.5 Moulded depth

The moulded depth D is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. Where the form at the lower part of the midship section is of a hollow character or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel.

In ships having rounded gunwales, the moulded depth is to be measured to the point of intersection of the moulded lines of deck and sides, the lines extending as though the gunwales were of angular design.

Where the freeboard deck is stepped and the raised part of the deck extends over the point at which the moulded depth is to be determined, the moulded depth is to be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

2.1.6 Draught

The draught T, in m, is the summer load line draught for the ship in operation, measured from the moulded baseline at midship.

Note 1: This may be less than the maximum permissible summer load waterline draught.

In the case of ships with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating with the solid bar keel at the middle of the length L.

T_{SC} is the scantling draught, in m, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught T_{SC} is to be not less than that corresponding to the assigned freeboard. The draught of ships to which timber freeboards are assigned corresponds to the loading condition of timber, and the requirements of the Society are to be applied to this draught.

T_{LC} is the draught, in m, amidships for a considered load case

T_{BAL} is the minimum design normal ballast draught amidships, in m, at which the strength requirements for the scantlings of the ship are met. This normal ballast draught is the minimum draught of ballast conditions including ballast water exchange operation, if any, for any ballast conditions in the loading manual including both departure and arrival conditions.

T_{BAL-H} is the minimum design heavy ballast draught, in m, at which the strength requirements for the scantlings of the ship are met. This heavy ballast draught is to be considered for ships having heavy ballast condition.

2.1.7 Moulded displacement

The moulded displacement Δ, in t, corresponds to the underwater volume of the ship, at draught T_{SC}, in seawater with a density of 1,025 t/m^3.

The moulded displacement Δ_{LC}, in t, at a considered load case, corresponds to the underwater volume of the ship, at draught T_{LC}, in seawater with a density of 1,025 t/m^3.

2.1.8 Maximum service speed

The maximum ahead service speed V, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM (revolution per minute) and corresponding engine MCR (maximum continuous rating).

2.1.9 Block coefficient

The block coefficient C_B, at scantling draught T_{SC}, is defined by:

$$C_B = \frac{\Delta}{1,025\ L\ B\ T_{SC}}$$

The block coefficient $C_{B\text{-}LC}$, at a considered load case, is defined by:

$$C_{B-LC} = \frac{\Delta_{LC}}{1,025\ L\ B\ T_{LC}}$$

2.1.10 Waterplane coefficient

The waterplane coefficient C_W, at scantling draught T_{SC}, is defined by:

$$C_W = \frac{A_{WP}}{L\ B}$$

where:

A_{WP} : Waterplane area at scantling draught T_{SC}, in m^2.

The waterplane coefficient $C_{W\text{-}LC}$, at a considered load case, is defined by:

$$C_{W-LC} = \frac{A_{WP-LC}}{L\ B}$$

where:

$A_{WP\text{-}LC}$: Waterplane area at draught T_{LC}, in m^2.

2.1.11 Lightweight

The lightweight is the ship displacement, in t, complete in all respects, but without cargo, consumable, stores, passengers and crew and their effects, and without any liquids on board except the machinery and piping fluids, such as lubricants and hydraulics, which are at operating levels.

2.1.12 Deadweight

The deadweight DWT is the difference, in t, between the displacement, at the summer draught in seawater of density ρ = 1,025 t/m^3, and the lightweight.

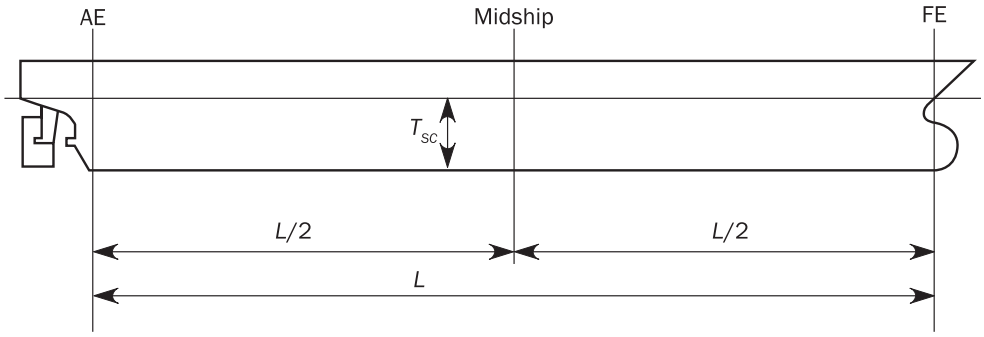
2.1.13 Fore end or forward perpendicular

The fore end (FE) of the rule length L is the perpendicular to the scantling draught waterline at the forward side of the stem. See Fig 3.

2.1.14 Aft end

The aft end (AE) of the rule length L is the perpendicular to the scantling draught waterline at a distance L aft of the fore end. See Fig 3.

Figure 3 : Fore end, Aft end and midship part



2.1.15 After perpendicular

The after perpendicular is the perpendicular to the waterline at the after side of the rudder post on the summer load waterline. For ships without rudder post, the after perpendicular is the perpendicular to the waterline at the centre of the rudder stock on the summer load waterline.

2.1.16 Midship

The midship is the perpendicular to the scantling draught waterline at a distance 0,5 L aft of the fore end.

2.1.17 Midship part

The midship part of a ship is the part extending 0,4 L amidships, unless otherwise specified.

2.2 Superstructure and deckhouse

2.2.1 Superstructure

A superstructure is a decked structure on the freeboard deck extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0,04 B.

2.2.2 Deckhouse

A deckhouse is a decked structure on the freeboard or superstructure deck which does not comply with the definition of a superstructure.

2.2.3 Bridge

A bridge is an elevated superstructure having a clear view forward and at each side, and from which a ship is steered.

2.2.4 Enclosed/open superstructure

Enclosed superstructure means a superstructure with bulkheads forward and/or aft fitted with weathertight doors and closing appliances.

An open superstructure is a superstructure which does not comply with the definition of a enclosed superstructure.

2.2.5 Forecastle

A forecastle is a short superstructure situated at the bow.

2.2.6 Poop

The poop is the superstructure located at the extreme aft end of the ship.

2.2.7 Raised quarterdeck

A raised quarterdeck is a partial superstructure of reduced height as defined in [2.2.9].

It extends forward from the after perpendicular and has an intact front bulkhead (sidescuttles of the non-opening type fitted with efficient deadlights and bolted man hole covers).

Where the forward bulkhead is not intact due to doors and access openings, the superstructure is then to be considered as a poop.

2.2.8 Trunk

A trunk is a decked structure similar to a deckhouse but not provided with a lower deck.

2.2.9 Standard height of superstructure

The standard height of superstructure is defined in Tab 5.

Table 5 : Standard height of superstructure

Load line length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$L_{LL} \leq 30$	0,90	1,80
$30 < L_{LL} < 75$	$0,9 + 0,00667\ (L_{LL} - 30)$	1,80
$75 \leq L_{LL} < 125$	$1,2 + 0,012\ (L_{LL} - 75)$	$1,8 + 0,01\ (L_{LL} - 75)$
$L_{LL} \geq 125$	1,80	2,30

2.2.10 Tiers of superstructure

A tier is extending over one standard height of superstructure as defined in [2.2.9].

The lowest tier is the tier located immediately above the freeboard deck.

When the freeboard exceeds one standard superstructure height, as defined in [2.2.9] for "all other superstructures", the lowest tier may be considered as an upper tier when calculating the scantlings of superstructures and deckhouses.

The second tier is the tier located immediately above the lowest tier, and so on.

2.3 Type A and Type B ships

2.3.1 Type A ship

A Type A ship is one which:

- *is designed to carry only liquid cargoes in bulk;*
- *has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material; and*
- *has low permeability of loaded cargo compartments.*

A Type A ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

2.3.2 Type B ship

All ships which do not come within the provisions regarding Type A ships stated in [2.3.1] are to be considered as Type B ships.

A Type B ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

2.3.3 Type B-60 ship

A Type B-60 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements *reported in Ch 3, App 4, [4.4], is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.*

2.3.4 Type B-100 ships

A Type B-100 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements *reported in Ch 3, App 4, [4.4], is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.*

2.4 Positions 1 and 2

2.4.1 Position 1

Position 1 includes:

- *exposed freeboard and raised quarter decks,*
- *exposed superstructure decks situated forward of 0,25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel.*

2.4.2 Position 2

Position 2 includes:

- *exposed superstructure decks situated aft of 0,25 L from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least one standard height of superstructure above the freeboard deck,*

- *exposed superstructure decks situated forward of 0,25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least two standard heights of superstructure above the freeboard deck.*

2.5 Sister ship

2.5.1 A sister ship is a ship built by the same yard from the same plans.

2.6 Reference coordinate system

2.6.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system (see Fig 4):

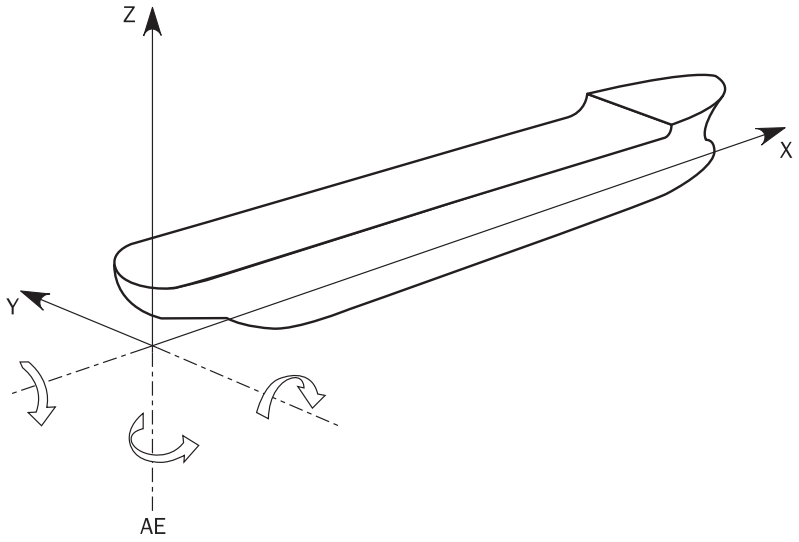
Origin : At the intersection of the longitudinal plane of symmetry of ship, the aft end of L, and the baseline

X axis : Longitudinal axis, positive forwards

Y axis : Transverse axis, positive towards portside

Z axis : Vertical axis, positive upwards.

Figure 4 : Reference coordinate system



2.7 Arrangement

2.7.1 Aft peak

The aft peak is the area aft of the aft peak bulkhead.

The aft peak bulkhead is the first main transverse watertight bulkhead forward of the stern.

The aft peak tank is the compartment in the narrow part of the stern, aft of the aft peak bulkhead.

2.7.2 Bow

The bow is the structural arrangement and form of the forward end of the ship.

2.7.3 Bulkhead

A bulkhead is a structural partition wall subdividing the interior of the ship into compartments.

In a cargo ship the freeboard deck may be taken as the bulkhead deck.

An engine room bulkhead is a transverse bulkhead located either directly forward or aft of the engine room.

2.7.4 Compartment

A compartment is an internal space bounded by bulkheads or plating.

2.7.5 Deck

A deck is the horizontal structure element defining the upper or lower boundary of a compartment.

The freeboard deck is the deck designated as such by the designer, in accordance with International Convention on Load Lines (ICLL), generally the uppermost complete deck exposed to weather and sea, with permanent means of closing for all the exposed openings.

The strength deck is the uppermost continuous deck.

The superstructure deck is the deck forming the upper boundary of a superstructure.

2.7.6 Fore peak

The fore peak is the area of the ship forward of the collision bulkhead.

2.7.7 Stern

The stern is the after end of the vessel.

2.7.8 Tank

Tank is a generic term for space intended to carry liquid such as seawater, fresh water, oil, liquid cargoes, fuel oil, water ballast, etc.

2.7.9 Well

Well means any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on two or more sides by deck structures.

2.8 Structural components

2.8.1 Bilge plating

The bilge plating is the curved plating between the bottom shell and the side shell, to be taken as follows:

- Within the cylindrical part of the ship: from the start of the curvature at the lower turn of bilge on the bottom to the end of the curvature at the upper turn of the bilge
- Outside the cylindrical part of the ship: from the start of the curvature at the lower turn of the bilge on the bottom to the lesser of:
  - a point on the side shell located 0,2D above the baseline/local centreline elevation
  - the end of the curvature at the upper turn of the bilge

2.8.2 Bottom shell

The bottom shell is the shell envelope plating forming the predominantly flat bottom portion of the shell envelope, including the keel plate.

2.8.3 Bracket

A bracket is an extra structural component used to increase the strength of a joint between two structural members

2.8.4 Double skin member

A double skin member is a structural member where the idealised beam comprises the web with top and bottom flanges formed by the attached plating.

2.8.5 Elementary plate panel (EPP)

An elementary plate panel is the smallest plate element surrounded by structural members such as stiffeners, PSM, bulkheads, etc.

2.8.6 Flange

A flange is a section of a stiffening member attached to the web, or sometimes formed by bending the web over. It is usually parallel to the plated surface.

2.8.7 Girder

Girder is a collective term for primary supporting structural members.

2.8.8 Keel

The keel is the main structural member or backbone of a ship running longitudinally along the centreline of the bottom, usually a flat plate stiffened by a vertical plate on its centreline inside the shell.

2.8.9 Plating

A plating is a sheet of steel supported by stiffeners, primary supporting members or bulkheads.

2.8.10 Primary supporting member (PSM)

A primary supporting member is a member of the beam, girder or stringer type, which provide the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads.

2.8.11 Shelf plate

A shelf plate is an horizontal plate located on the top of a bulkhead stool.

2.8.12 Shell envelope plating

The shell envelope plating is the shell plating forming the effective hull girder exclusive of the strength deck plating.

2.8.13 Side shell

The side shell is the shell envelope plating forming the side portion of the shell envelope above the bilge plating.

2.8.14 Single skin member

A single skin member is a structural member where the idealised beam comprises a web, a top flange formed by an attached plating and a bottom flange formed by a face plate.

2.8.15 Stiffener

Stiffener is a collective term for secondary supporting structural members.

2.8.16 Strake

Strake means course or row of shell, deck, bulkhead, or other plating.

2.8.17 Stringer

A stringer is an horizontal girder linking vertical web frames.

A stringer plate is the outside strake of deck plating.

2.8.18 Web

A web is a section of a stiffening member attached to the plated surface, usually perpendicular.

Web frame means a transverse primary supporting member, including deck transverse

Section 4 Documentation to be Submitted

1 Documentation to be submitted for all ships

1.1 Ships surveyed by the Society during the construction

1.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1.

The above plans and documents are to be supplemented by further documentation which depends on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, as specified in [2].

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welded procedures and heat treatments. See also Ch 13, Sec 1.

The structural drawings are to indicate for each structural element the as-built scantling and the renewal thickness as specified in Pt A, Ch 2, App 3, [4.5.3]. If thickness for voluntary addition, as defined in Ch 4, Sec 2, is included in the as-built thickness, this is to be clearly mentioned and identified on the drawings.

An alternative means for reporting the renewal thicknesses may be accepted by the Society on a case-by-case basis.

Table 1 : Plans and documents to be submitted for approval for all ships

Plan or document	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Maximum ahead service speed Density of cargoes Design loads on decks and double bottom, including details of unitary loads, if any, as vehicles, steel coils, containers, etc. Steel grades Areas subjected to low temperatures Location and height of air vent outlets of various compartments Corrosion protection Welding details Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures Overpressure due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow through ballast water exchange Relief valve setting pressure Design still water bending moments and shear forces at midship
Loading manual and loading instruments	See Ch 1, Sec 5, [2]
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	Location and height of air vent outlets of various compartments
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Aft part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers **(1)** Details, including SWL, of travelling gantry cranes, if any
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)

Plan or document	Containing also information on
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Bow or stern ramps, elevators for cargo handling and movable decks, if any	Structural arrangements of ramps, elevators and movable decks with their masses Arrangement of vehicles on ramps and movable decks and vehicles characteristics Arrangements of securing and locking devices Connection of ramps, lifting and/or hoisting appliances to the hull structures, with indication of design loads (amplitude and direction) Wire ropes and hoisting devices in working and stowed position Hydraulic jacks Loose gear (blocks, shackles, etc.) indicating the safe working loads and the testing loads Test conditions
Windows and side scuttles, arrangements and details	Type of material (glass, PMMA, PC) and its mechanical properties
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Helicopter decks, if any	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between landing gears or landing skids, print area of wheels or skids, distribution of landing gear loads
Rudder and rudder horn **(1)**	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	Overpressure due to the inlet grating cleaning system
Hawse pipes	
Plan of outer doors and hatchways	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Freeboard calculations	
Stability documentation	See Ch 3, Sec 1, [2.1]
Calculations relevant to intact stability and, where required, damage stability	
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Emergency towing arrangement	See Ch 12, Sec 4

(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 12, Sec 1, [11].

1.1.2 Plans and documents to be submitted for information

In addition to those in [1.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution
- towing and mooring arrangement plan as defined in Ch 12, Sec 4, [4.2.10]
- technical specification of the mooring lines supplied with the ship.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society.

1.2 Ships for which the Society acts on behalf of the relevant Administration

1.2.1 Plans and documents to be submitted for approval

The plans required by the National Regulations concerned are to be submitted to the Society for approval, in addition to those in [1.1].

2 Further documentation to be submitted for ships with certain service notations or additional class notations

2.1 General

2.1.1 Depending on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1]. They are listed in the relevant parts of the Rules applicable to these notations as defined in Pt A, Ch 1, Sec 2.

Section 5 Loading Manual and Loading Instruments

1 Loading manual and loading instrument requirement criteria

1.1 Ship categories

1.1.1 Category I ships

- ships having large openings in the strength decks where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads need to be considered
- ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed; exception is made for ships less than 120 metres in length, when their design takes into account uneven distribution of cargo or ballast: such ships belong to Category II
- ships having the service notation **chemical tanker ESP** or **liquefied gas carrier**.

1.1.2 Category II ships

- ships whose arrangement provides small possibilities for variation in the distribution of cargo and ballast
- ships on a regular and fixed trading pattern where the loading manual gives sufficient guidance
- the exception given under Category I.

1.2 Requirement criteria

1.2.1 All ships

An approved loading manual is to be supplied for all ships equal to or greater than 65 m in length, except those of Category II less than 90 m in length in which the deadweight does not exceed 30% of the displacement at the summer loadline draught.

In addition, an approved loading instrument is to be supplied for all ships of Category I of 65 m in length and above.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

1.2.2 In any case, when a loading instrument is present onboard, it is to be approved by the Society.

1.2.3 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

Ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, are to be provided with an approved loading manual and an approved computer-based loading instrument, in accordance with the applicable requirements of this Section.

1.2.4 Bulk carriers, ore carriers or combination carriers less than 150 m in length

Ships with one of the service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and less than 150 m in length, are to be provided with an approved computer-based loading instrument in accordance with the applicable requirements of this Section. The approved loading instrument is to be capable of providing information on the ship's stability in the intact condition.

1.2.5 Oil tankers and chemical tankers

Ships with one of the service notation **oil tanker ESP**, or **chemical tanker**, are to be provided with an approved computer-based loading instrument in accordance with the applicable requirements of this Section.The approved loading instrument is to be capable of verifying compliance with the intact and applicable damage stability requirements. Exemptions may be granted on a case by case basis.

2 Loading manual

2.1 Definitions

2.1.1 All ships

A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force
- the results of the calculations of still water bending moments, shear forces and, where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

2.1.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition to [2.1.1], for ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the loading manual is also to describe:

- for cargo holds of ships with the service notation **bulk carrier** or **bulk carrier ESP**: the envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition
- the cargo hold(s) or combination of cargo holds which might be empty at full draught
- hold mass curves for each single hold in the relevant loading conditions listed in Pt D, Ch 4, Sec 3, [3.1], showing the maximum allowable and the minimum required masses of cargo and double bottom contents of each hold as a function of the draught at mid-hold position (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2)
- hold mass curves for any two adjacent holds in the relevant loading conditions listed in Pt D, Ch 4, Sec 3, [3.1], showing the maximum allowable and the minimum required masses of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2)
- maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes
- maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual
- the maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.2 Conditions of approval

2.2.1 All ships

The approved loading manual is to be based on the final data of the ship. The manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, defined in Ch 5, Sec 8, [3.1.1].

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

2.2.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition to [2.2.1], for ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the following loading conditions, subdivided into departure and arrival conditions as appropriate, are also to be included in the loading manual:

- alternate light and heavy cargo loading conditions at maximum draught, where applicable
- homogeneous light and heavy cargo loading conditions at maximum draught
- ballast conditions

  For ships with ballast holds adjacent to topside wing, hopper and double bottom tanks, it may be acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty
- short voyage conditions where the ship is to be loaded to maximum draught but with a limited amount of bunkers
- Multi-port (MP) loading/unloading conditions
- deck cargo conditions, where applicable
- typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included

  The typical loading/unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to the loading rate and deballasting capability
- typical sequences for change of ballast at sea, where applicable.

2.2.3 Language

The loading manual is to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

3 Loading instrument

3.1 Additional class notations LI

3.1.1 The additional class notations **LI-HG**, **LI-S1**, **LI-S2**, **LI-S3**, **LI-S4**, **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** and **LI-LASHING** may be assigned in accordance with Pt A, Ch 1, Sec 2, [6.16.1] to ships equipped with a loading instrument, as defined in [3.1.2].

3.1.2 When the ship is equipped with a loading instrument performing:

- only hull girder calculations, the additional class notation **LI-HG** is assigned
- only intact stability calculations (when the ship is not required to meet damage stability requirements), the additional class notation **LI-S1** is assigned

- intact stability calculations and damage stability on a basis of a limit curve, the additional class notation **LI-S2** is assigned
- intact stability calculations and direct damage stability calculations based on pre-programmed damage cases, the additional class notation **LI-S3** is assigned.
- damage stability calculations associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for Safe Return to Port (SRtP), the additional class notation **LI-S4** is assigned.
- lashing calculations, the additional class notation **LI-LASHING** is assigned.

When the loading instrument performs hull girder and stability calculations, the additional class notation **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** is assigned, as applicable.

3.2 Definitions

3.2.1 All ships

A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces and still water torsional moments and lateral loads, where applicable, in any load or ballast condition, do not exceed the specified permissible values.

An operational manual is always to be provided for the loading instrument.

Single point loading instruments are not acceptable.

The approval of a loading instrument for lashing calculation is to be performed according to the approval of lashing software as applicable in Pt F, Ch 12, Sec 5.

3.2.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

For ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the loading instrument is an approved digital system as defined in [3.2.1]. In addition to [3.2.1], it is also to ascertain as applicable that:

- the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position
- the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds
- the still water bending moment and shear forces in the hold flooded conditions, where required,

do not exceed the specified permissible values.

3.3 Conditions of approval

3.3.1 All ships

The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

3.3.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition, for ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the approval is also to include, as applicable:

- acceptance of hull girder bending moment limits for all read-out points
- acceptance of hull girder shear force limits for all read-out points
- acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2)
- acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2).

3.3.3 In the case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

3.3.4 The operation manual and the instrument output are to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

3.3.5 The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

3.3.6 When the loading instrument also performs stability calculations, it is to be approved for stability purposes in accordance with the procedures indicated in [3.6], [3.7] and [3.8], as applicable.

3.4 Approval procedure

3.4.1 General

The loading instrument approval process includes the following procedures for each ship:

- data verification which results in endorsed test conditions
- approval of computer hardware, where necessary, as specified in Pt C, Ch 3, Sec 6, [2.4.1]
- installation testing which results in an Installation Test Report.

3.4.2 Data verification approval - Endorsed test conditions

The Society is to verify the results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

Upon application for data verification, the Society is to advise the applicant of a minimum of four loading conditions, taken from the ship's approved loading manual, which are to be used as the test conditions. Within the range of these test conditions, each compartment is to be loaded at least once. The test conditions normally cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition. In addition, the lightship test condition is to be submitted.

When the additional class notation **LI-S4** is assigned, at least three damage cases are to be examined, each of them associated with at least three loading conditions taken from the ship's approved stability information. Output of the software is to be compared with results of corresponding load / damage case in the approved damage stability booklet or an alternative independent software source.

When the loading instrument also performs stability calculations, it is to cover all the stability requirements applicable to the ship. The test conditions are to be taken from the ship's approved trim and stability booklet.

The data indicated in [3.4.3] and contained in the loading program are to be consistent with the data specified in the approved loading manual. Particular attention is drawn to the final lightship weight and centres of gravity derived from the inclining experiment or lightweight check.

The approval of the computer application software is based on the acceptance of the results of the test conditions according to [3.5], [3.6], [3.7], and [3.8], as applicable.

When the requested information has been submitted and the results of the test conditions are considered satisfactory, the Society endorses the test conditions, a copy of which is to be available on board.

3.4.3 Data to be submitted

The following data, submitted by the applicant, are to be consistent with the as-built ship:

- identification of the calculation program including the version number
- main dimensions, hydrostatic particulars and, if applicable, ship profile
- position of the forward and after perpendiculars and, if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks
- ship lightweight and lightweight distribution along the ship's length
- lines plans and/or offset tables
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- deadweight definitions for each loading condition.

3.4.4 Installation testing

During the installation test, one of the ship's senior officers is to operate the loading instrument and calculate the test conditions. This operation is to be witnessed by a Surveyor of the Society. The results obtained from the loading instrument are to be identical to those stated in the endorsed test conditions. If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.4.1], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and the date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

3.4.5 Operational manual

A uniquely identified ship specific operational manual is to be submitted to the Society for documentation.

The operational manual is to be written in a concise and unambiguous manner. The use of illustrations and flowcharts is recommended.

The operational manual is to contain:

- a general description of the program denoting identification of the program and its stated version number
- details of the hardware specification needed to run the loading program
- a description of error messages and warnings likely to be encountered, and unambiguous instructions for subsequent actions to be taken by the user in each case
- where applicable, the shear force correction factors
- where applicable, the local permissible limits for single and two adjacent hold loadings as a function of the appropriate draught and the maximum weight for each hold
- where applicable, the Society's restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks)
- example of a calculation procedure supported by illustrations and sample computer output
- example computer output of each screen display, complete with explanatory text.

3.4.6 Calculation program specifications

The software is to be written so as to ensure that the user cannot alter the critical ship data files containing the following information:

- lightship weight and lightship weight distribution and associated centres of gravity
- the Society's structural limitations or restrictions
- geometric hull form data
- hydrostatic data and cross curves, where applicable
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- when intact stability criteria are given, a listing of all calculated stability criteria with the obtained values and the conclusions (criteria fulfilled or not fulfilled), the down-flooding angle and the corresponding down-flooding opening.

Any changes in the software are to be made by the manufacturer or his appointed representative and the Society is to be informed immediately of such changes. Failure to advise of any modifications to the calculation program may invalidate the approval issued. In cases where the approval is considered invalid by the Society, the modified calculation program is to be re-assessed in accordance with the approval procedure.

3.4.7 Functional specification

The calculation program is to be user-friendly and designed such that it limits possible input errors by the user.

The forward, midship and after draughts, at the respective perpendiculars, are to be calculated and presented to the user on screen and hardcopy output in a clear and unambiguous manner.

It is recommended that the forward, midship and after draughts, at the actual position of the ship's draught marks are calculated and presented to the user on screen and hard copy output in a clear and unambiguous manner.

The displacement is to be calculated for the specified loading condition and corresponding draught readings and presented to the user on screen and hardcopy output.

The loading instrument is to be capable of producing print-outs of the results in both numerical and graphical forms. The numerical values are to be given in both forms, as absolute values and as the percentage of the permissible values. This print-out is to include a description of the corresponding loading condition.

All screen and hardcopy output data is to be presented in a clear and unambiguous manner with an identification of the calculation program (the version number is to be stated).

When the additional class notation **LI-S3** is assigned, the software is to include pre-defined relevant damage cases for both sides of the ship according to the applicable rules for automatic check of a given loading condition.

When the additional class notation **LI-S3** or **LI-S4** is assigned, the damage stability is to be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model. In addition, the system shall be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

When the additional class notation **LI-S1** or **LI-S2** is assigned, in case a full three dimensional model is used for stability calculations, the requirements of the computer model for the additional class notation **LI-S3** or **LI-S4** are applicable.

For ships engaged in anchor handling operations, planning tools are to be provided in compliance with operational manual requirements. Information such as ballasting and consumables sequences, permissible tension, working sectors, heeling angles and use of roll-reduction devices are to be stated.

3.4.8 Specific functional requirements for LI-S4

The software used for damage stability for SRtP need not to be totally separated from other software used for normal stability.

When the software for damage stability for SRtP is not separated:

- the function of switching between normal software and SRtP software is to be provided
- the actual intact loading condition is to be the same for both functions (normal operation and SRtP)
- the SRtP module needs only to be activated in case of an incident.

For passenger ships which are subject to SRtP and have an onboard stability computer and shore-based support, such software need not be identical.

Each internal space is to be assigned its permeability as given in Tab 1, unless a more accurate permeability has been reflected in the approved stability information.

The system is to be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

The system is to take into account for the effect of wind by using the method in SOLAS regulation II-1/7-2.4.1.2 as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different ($P = 120$ N/m^2 equates to Beaufort 6; approximately 13,8 m/s or 27 knots).

The system is to be capable of assessing the impact of open main watertight doors on stability (e.g. for each damage case provided for verification, additional damage stability calculation shall be done and presented, taking into account any watertight door located within the damaged compartment(s)).

The system is to utilize the latest approved lightship weight and centre of gravity information.

The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the ship.

When the actual loading condition is input in the software, in addition to the information required in [3.4.6] and in [3.4.7], the following output corresponding to intact stability are to be available:

- free surfaces
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- GM/KG limiting curve according to SOLAS, Ch II-1, Regulation 5-1

When the actual loading condition is associated to the actual damage case(s) due to the casualty, in addition to the information required in [3.4.6] and in [3.4.7], the following output corresponding to the damage stability are to be available:

- progressive flooding angle and corresponding progressive flooding openings
- GM value
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- the survivability criteria are left to the discretion of the Society
- relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point
- list of all flooded compartments with the permeability considered
- amount of water in each flooded compartment
- escape route immersion angles
- a profile view, deck views and cross-sections of the ship indicating the flooded waterplane and the damaged compartments.

For Ro-Ro Passenger ships subject to the Stockholm Agreement (IMO Circular Letter No. 1891), the software is to include algorithms for estimating the effect of water accumulation on deck (WOD). For example, in addition to the predefined significant wave height taken from the approved stability document, the software allows the crew to input manually the significant wave height of the ship navigation area. For checking the correctness of the algorithms for estimating the effect of WOD, the calculations with two additional significant wave heights are to be submitted.

Table 1 : Permeability for internal spaces

Spaces	Default	Full	Partially filled	Empty
Container spaces	0,95	0,70	0,80	0,95
Dry cargo spaces	0,95	0,70	0,80	0,95
Ro-Ro spaces	0,95	0,90	0,90	0,95
Cargo liquids	0,95	0,70	0,80	0,95
Intended for consumable liquids	0,95	0,95	0,95	0,95
Stores	0,95	0,60	0,60	0,95
Occupied by machinery	0,85			
Void spaces	0,95			
Occupied by accommodation	0,95			

3.5 Hull girder forces and moments

3.5.1 General

The loading program is to be capable of calculating the following hull girder forces and moments in accordance with Ch 5, Sec 4, [2]:

- Still Water Shear Force (SWSF) including the shear force correction, where applicable
- Still Water Bending Moment (SWBM)
- Still Water Torsion Moment (SWTM), where applicable
- for ships with relatively large openings in the strength deck, additional considerations such as torsional loads are to be considered.

The data which are to be provided to, or accepted by, the Society are specified in Tab 3.

Read-out points are usually to be selected at the position of the transverse bulkheads or other obvious boundaries. Additional read-out points may be required between bulkheads of long holds or tanks, or between container stacks.

Where the still water torsion moments are required to be calculated, one test condition is to demonstrate such a calculation.

The calculated forces and moments are to be displayed in both graphical and tabular formats, including the percentage of permissible values. The screen and hardcopy output is to display the calculated forces or moments, and the corresponding permissible limits, at each specified read-out point. Alternative limits may be considered by the Society on a case by case basis.

3.5.2 Acceptable tolerances

The accuracy of the calculation program is to be within the acceptable tolerance band, specified in Tab 2, of the results at each read-out point obtained by the Society, using an independent program or the approved loading manual with identical input.

3.5.3 Permissible limits and restrictions

The user is to be able to view the following Society structural limitations in a clear and unambiguous manner:

- all permissible still water shear forces and still water bending moments
- where applicable, the permissible still water torsion moments
- where applicable, all local loading limits both for one hold and for adjacent hold loadings
- cargo hold weight
- ballast tank/hold capacities
- filling restrictions.

It is to be readily apparent to the user when any of the structural limits has been exceeded.

Table 2 : Tolerance band for the comparison of computational accuracy

Computation	Tolerance (percentage of the permissible values)
Still Water Shear Force	± 5%
Still Water Bending Moment	± 5%
Still Water Torsion Moment, where applicable	± 5%

Table 3 : Data to be provided to, or to be accepted by, the Society

Calculation	Data to be provided to, or accepted by, the Society
Still Water Shear Force (SWSF)	• The read-out points (frame locations) for the SWSF calculations. These points are normally selected at the position of the transverse bulkhead or other obvious boundaries. Additional read-out points may be specified between the bulkheads of long holds or tanks or between container stacks. • Shear force correction factors and method of application. • The permissible seagoing and harbour SWSF limits at the read-out points. Where appropriate, additional sets of permissible SWSF values may be specified.
Still Water Bending Moment (SWBM)	• The read-out points (frame locations) for the SWBM calculations. These points are normally selected at the position of the transverse bulkhead, mid-hold or other obvious boundaries. • The permissible seagoing and harbour SWBM limits at the read-out points. Where appropriate, additional sets of permissible SWBM values may be specified.
Still Water Torsion Moment (SWTM), where applicable	• The read-out points (frame locations) for the SWTM calculations, where applicable. • The permissible limits at the read-out points.

3.6 Intact stability

3.6.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs stability calculations, as stated in [3.3.6].

3.6.2 Data verification approval - Endorsed test conditions

The requirements in [3.4.2] apply. In addition, at least one of the four loading conditions required is to show the compartments, intended for liquid loads in which the free surface effect is considerable, filled in order to have the maximum free surface moment.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [3.6.3].

In order to obtain the approval of the loading instrument, all the intact stability requirements (and relevant criteria) applicable to the ship, reported in Ch 4, Sec 2 as well as in Part D or Part E, are to be available in the computer output; the lack of any one of them is sufficient to prevent the endorsement of the test conditions.

3.6.3 Additional data to be submitted

In addition to the data required in [3.4.3], the following are to be submitted:

- cross curves of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- capacity tables indicating, for each compartment or space, the values of the co-ordinates X_G, Y_G and Z_G of the centre of gravity, as well as the inertia, corresponding to an adequate number of filling percentages
- list of all the openings (location, tightness, means of closure), pipes or other sources which may lead to progressive flooding
- deadweight definitions for each loading condition in which, for any load taken into account, the following information is to be specified:
  - weight and centre of gravity co-ordinates
  - percentage of filling (if liquid load)
  - free surface moment (if liquid load)
- information on loading restrictions (maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria), when applicable
- all the intact stability criteria applicable to the ship concerned.

3.7 Grain loading

3.7.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs grain loading stability calculations, as stated in [3.3.6].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [3.6].

Additional requirements relevant to grain stability are provided in [3.7.2] and [3.7.3].

3.7.2 Data verification approval - Endorsed test conditions

The requirements stated in [3.6.2] apply. In addition, when the ship is allowed to carry grain in slack hold, at least one of the four loading conditions required is to include partially filled holds.

The additional data necessary for the approval of the loading instrument for grain stability purposes are specified in [3.7.3].

In order to obtain the approval of the loading instrument, all the grain stability requirements and relevant criteria specified in NR 467 Pt D, Ch 4, Sec 3, [1.2] are to be available in the computer output.

In addition, the outputs are to include:

- the reference to the type of calculation (trimmed or untrimmed ends)
- the value of the actual grain heeling moment for each hold
- the value of the maximum permissible grain heeling moment for each hold
- the total value of the actual grain heeling moment
- the total value of the maximum permissible grain heeling moment.

The lack of any of the above is sufficient to prevent the endorsement of the test conditions.

3.7.3 Additional data to be submitted

In addition to the data required in [3.6.3], the following are to be submitted:

- calculation of the total grain heeling moment
- calculation of the maximum permissible total grain heeling moment as a function of the draught (or displacement) and maximum KG

- curves or tables of volume, centre of volume and volumetric heeling moment for partially filled compartments (if applicable)
- for filled holds: volumetric heeling moment for trimmed and/or untrimmed ends, as applicable, including temporary bulkheads, if any.

3.8 Damage stability

3.8.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs damage stability calculations, as stated in [3.3.6].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [3.6].

Additional requirements relevant to damage stability are given in [3.8.2] and [3.8.3].

3.8.2 Data verification approval - Endorsed test conditions

The requirements specified in [3.6.2] apply.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [3.8.3].

The approval of damage stability calculations performed by a loading instrument is limited to those relevant to deterministic damage stability rules specified in Part D applicable to ships with one of the service notations **passenger ship**, **oil tanker ESP**, **chemical tanker ESP** or **liquefied gas carrier**. In order to obtain the approval of the loading instrument, all the damage stability requirements (and relevant criteria) applicable to the ship are to be available in the computer output. The lack of any one of them is sufficient to prevent the endorsement of the test conditions.

3.8.3 Additional data to be submitted

In addition to the data required in [3.6.3], the following are to be submitted:

- List of all the damage cases which are to be considered in accordance with the relevant deterministic damage stability rules. Each damage case is to clearly indicate all the compartments or spaces taken into account, as well as the permeability associated with each compartment or space.

  This information is to be taken from the approved damage stability documentation, and the source details are to be clearly indicated; in the case of unavailability of such documentation, the above-mentioned information may be requested from the Society
- All the damage stability criteria applicable to the ship concerned.

3.9 Acceptable tolerances

3.9.1 General

The acceptable tolerances for the stability particulars are to be in agreement with the requirements of IACS Unified Requirements UR L5 as amended.

Appendix 1 Equivalences between Current Revision and July 2021 Edition of the Rules for the Classification of Steel Ships

1 General

1.1 Equivalences between current revision and edition July 2021 of NR467, Part B

1.1.1 Tab 1 provides equivalences between the provisions of the current revision of the Rules and former revision (Editon July 2021 amended in January 2022).

Table 1 : Equivalences between curent revision and edition July 2021 of NR467, Part B

Reference in Current revision of Part B	Reference in July 2021 edition of Part B	Reference in Current revision of Part B	Reference in July 2021 edition of Part B	Reference in Current revision of Part B	Reference in July 2021 edition of Part B
Ch 1, Sec 1	Ch 1, Sec 1	Ch 5, Sec 5	Ch 5, Sec 5	Ch 11, Sec 3	Ch 8, Sec 2 Ch 9, Sec 3
Ch 1, Sec 2	–	Ch 5, Sec 6	Ch 5, Sec 6 Ch 5, App 1		
Ch 1, Sec 3	Ch 1, Sec 2			Ch 11, Sec 4	Ch 5, Sec 6, [2] Ch 7, Sec 1 Ch 7, Sec 2
Ch 1, Sec 4	Ch 1, Sec 3	Ch 5, Sec 7	–		
–	Ch 1, Sec 4	Ch 5, Sec 8	Ch 5, Sec 1, [2.5.2] Ch 5, Sec 2, [2.1.2]		
Ch 1, Sec 5	Ch 10, Sec 2			Ch 11, Sec 5	Ch 8, Sec 4
Ch 2, Sec 1	Ch 2, Sec 1	Ch 6, Sec 1	Ch 6, Sec 1 Ch 6, Sec 2	Ch 11, Sec 6	Ch 8, Sec 5
Ch 2, Sec 2	Ch 2, Sec 2			Ch 11, Sec 7	Ch 8, Sec 6
Ch 2, Sec 3	Ch 2, Sec 3	Ch 6, Sec 2	Ch 6, Sec 3	Ch 11, Sec 8	Ch 8, Sec 12
Ch 3, Sec 1	Ch 3, Sec 1	Ch 6, App 1	Ch 6, Sec 1, [2.6] Ch 6, Sec 2, [2.3] Ch 6, Sec 2, [2.4]	Ch 11, Sec 9	Ch 8, Sec 7
Ch 3, Sec 2	Ch 3, Sec 2			Ch 11, Sec 10	Ch 8, Sec 8
Ch 3, Sec 3	Ch 3, Sec 3			Ch 11, Sec 11	Ch 8, Sec 9
Ch 3, App 1	Ch 3, App 1	Ch 6, App 2	Ch 6, App 1	Ch 11, Sec 12	Ch 8, Sec 10
Ch 3, App 2	Ch 3, App 2	Ch 7, Sec 1	–	Ch 11, Sec 13	Ch 8, Sec 11
Ch 3, App 3	Ch 3, App 3	Ch 7, Sec 2	–	Ch 12, Sec 1	Ch 9, Sec 1
Ch 3, App 4	Ch 3, App 4	Ch 7, Sec 3	Chapter 7	Ch 12, Sec 2	Ch 9, Sec 2
Ch 4, Sec 1	Ch 4, Sec 1	Ch 7, Sec 4	Ch 7, Sec 1	Ch 12, Sec 3	Ch 9, Sec 3
Ch 4, Sec 2	Ch 4, Sec 2, [1] Ch 4, Sec 2, [2]	Ch 7, Sec 5	Ch 7, Sec 2	Ch 12, Sec 4	Ch 9, Sec 4
		Ch 7, Sec 6	Ch 7, Sec 3	Ch 12, App 1	Ch 9, App 1
Ch 4, Sec 3	Ch 4, Sec 2, [3]	Ch 7, App 1	Ch 7, App 2	Ch 12, App 2	Ch 9, App 2
Ch 4, Sec 4	Ch 10, Sec 1	Ch 8, Sec 1 Ch 8, App 1 Ch 8, App 2	Ch 7, App 1	– **(1)**	Ch 10, App 1
Ch 4, Sec 5	Ch 4, Sec 3			Ch 13, Sec 1 Ch 13, Sec 2 Ch 13, Sec 3	Ch 11, Sec 1
Ch 4, Sec 6	Ch 4, Sec 4 Ch 4, Sec 5 Ch 4, Sec 6 Ch 4, Sec 7	Ch 8, App 3	Ch 7, App 3		
		Ch 9, Sec 1	Ch 7, Sec 1 Ch 7, Sec 2 Ch 7, Sec 3	Ch 13, Sec 4	Ch 11, Sec 2
				Ch 13, Sec 5	Ch 11, Sec 3
Ch 5, Sec 1	Ch 5, Sec 1			Ch 13, Sec 6	Ch 11, Sec 4
Ch 5, Sec 2	Ch 5, Sec 4	Ch 10, Sec 1	Ch 7, Sec 4	Ch 13, App 1	Ch 11, App 1
Ch 5, Sec 3	Ch 5, Sec 3	Ch 11, Sec 1	Ch 8, Sec 1	Ch 13, App 2	Ch 11, App 2
Ch 5, Sec 4	Ch 5, Sec 2	Ch 11, Sec 2	Ch 8, Sec 3		

(1) See Pt D, Ch 4, App 2

CHAPTER 2
GENERAL ARRANGEMENT DESIGN

Section 1 Subdivision Arrangement

Section 2 Compartment Arrangement

Section 3 Access Arrangement

Section 1 Subdivision Arrangement

1 General

1.1 Application to ships assigned the additional service feature SPxxx or SPxxx-capable

1.1.1 Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 2, considering the special personnel as passengers.

1.1.2 Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the special personnel as crew.

1.2 Application to ships assigned the additional service feature IPxxx or IPxxx-capable

1.2.1 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 2, considering the industrial personnel as passengers.

1.2.2 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the industrial personnel as crew.

2 Number and arrangement of transverse watertight bulkheads

2.1 Number of watertight bulkheads

2.1.1 General

All ships, in addition to complying with the requirements of [2.1.2], are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

2.1.2 Additional bulkheads

For ships not required to comply with subdivision regulations, transverse bulkheads adequately spaced and in general not less in number than indicated in Tab 1 are to be fitted.

Additional bulkheads may be required for ships having to comply with subdivision or damage stability criteria (see Part D or Part E for the different types of ships).

2.2 Water ingress detection

2.2.1 A water ingress detection system is to be fitted according to Pt C, Ch 1, Sec 10, [6.12].

Table 1 : Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery **(1)**	Number of bulkheads for other ships
L < 65	3	4
65 ≤ L < 85	4	5
85 ≤ L < 105	4	5
105 ≤ L < 120	5	6
120 ≤ L < 145	6	7
145 ≤ L < 165	7	8
165 ≤ L < 190	8	9
L ≥ 190	to be defined on a case by case basis	

(1) After peak bulkhead and aft machinery bulkhead are the same.

3 Collision bulkhead

3.1

3.1.1 *A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. This bulkhead is to be located at a distance from the forward perpendicular* FP_{LL} *of not less than 5 per cent of the length* L_{LL} *of the ship or 10 m, whichever is the less, and, except as may be permitted by the Society, not more than 8 per cent of* L_{LL} *or 5 per cent of the* L_{LL} *+ 3 m, whichever is the greater.*

For ships not covered by the SOLAS Convention, the length L_{LL} need not be taken less than 50 m, unless required by the National Authorities.

3.1.2 *Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [3.1.1] are to be measured from a point either:*

- *at the mid-length of such extension, or*
- *at a distance 1,5 per cent of the length* L_{LL} *of the ship forward of the forward perpendicular, or*
- *at a distance 3 metres forward of the forward perpendicular; whichever gives the smallest measurement.*

3.1.3 *The bulkhead may have steps or recesses provided they are within the limits prescribed in [3.1.1] or [3.1.2].*

No door, manhole, ventilation duct or any other opening is to be fitted in the collision bulkhead below the bulkhead deck of passenger ships and the freeboard deck of cargo ships.

3.1.4 At Owner request and subject to the agreement of the flag Administration, the Society may, on a case by case basis, accept a distance from the collision bulkhead to the forward perpendicular FP_{LL} greater than the maximum specified in [3.1.1] and [3.1.2], provided that subdivision and stability calculations show that, when the ship is in upright condition on full load summer waterline, flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or in any unacceptable loss of stability.

In such a case, the attention of the Owner and the Shipyard is drawn to the fact that the flag Administration may impose additional requirements and that such an arrangement is, in principle, formalised by the issuance of a certificate of exemption under the SOLAS Convention provisions. Moreover, in case of change of flag, the taking Administration may not accept the exemption.

3.1.5 *Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the next deck above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The extension need not be fitted directly above the bulkhead below provided that all parts of the extension, including any part of the ramps attached to it, are located within the limits prescribed in [3.1.1] or [3.1.2] with the exemption permitted by [3.1.6] and the part of the deck which forms the step is made effectively weathertight. The extension is to be so arranged as to preclude the possibility of the bow door or ramp, where fitted, causing damage to it in the case of damage to, or detachment of, a bow door or any part of the ramp.*

3.1.6 *Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the ramp is to be weathertight over its complete length. In cargo ships, the part of the ramp which is more than 2,3 m above the freeboard deck may extend forward of the limit specified in [3.1.1] or [3.1.2]. Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.*

3.1.7 *The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.*

4 After peak, machinery space bulkheads and stern tubes

4.1

4.1.1 General

Bulkheads are to be fitted separating the machinery space from cargo and accommodation spaces forward and aft and made watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. An after peak bulkhead is also to be fitted and made watertight up to the bulkhead deck or the freeboard deck. The after peak bulkhead may, however, be stepped below the bulkhead deck or the freeboard deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

4.1.2 Sterntubes

In all cases, sterntubes are to be enclosed in watertight spaces of moderate volume. In passenger ships, the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the sterntube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society.

For ships less than 65 m, where the after peak bulkhead in way of the sterntube stuffing box is not provided, sterntubes are to be enclosed in watertight spaces of moderate volume.

5 Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkhead

5.1

5.1.1 Transverse watertight bulkheads are to extend watertight up to the bulkhead deck. In exceptional cases at the request of the Owner, the Society may allow transverse watertight bulkheads to terminate at a deck below that from which freeboard is measured, provided that this deck is at an adequate distance above the full load waterline.

5.1.2 Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

6 Openings in watertight bulkheads and decks for ships having a service notation other than passenger ship or ro-ro passenger ship

6.1 Application

6.1.1 The requirements in [6.2] and [6.3] are not applicable to ships having a service notation **passenger ship** or **ro-ro passenger ship**.

Openings in watertight bulkheads below the bulkhead deck for ships with service notation **passenger ship** or **ro-ro passenger ship** are to comply with Part D, Chapter 11 or Part D, Chapter 12, respectively.

6.1.2 Ships assigned the additional service feature SPxxx or SPxxx-capable

The requirements in [6.2] and [6.3] are not applicable to ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240.

Openings in watertight bulkheads below the bulkhead deck for ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with Part D, Chapter 11.

6.1.3 Ships assigned the additional service feature IPxxx or IPxxx-capable

The requirements in [6.2] and [6.3] are not applicable to ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx less than 240.

Openings in watertight bulkheads below the bulkhead deck for ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx less than 240 are to comply with Part D, Chapter 11.

6.2 General

6.2.1 *The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Society may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.*

6.2.2 No door, manhole ventilation duct or any other opening is permitted in the collision bulkhead below the subdivision deck.

6.2.3 Lead or other heat sensitive materials may not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

6.2.4 Valves not forming part of a piping system are not permitted in watertight subdivision bulkheads.

6.2.5 The requirements relevant to the operating systems for doors complying with the provisions in [6.3] are specified in:

- Tab 2 for doors of internal watertight bulkheads, and
- Tab 3 for doors of external watertight boundaries below equilibrium or intermediate waterplane.

6.2.6 A diagram showing the location of the door and an indication to show its position is to be provided at the central operating console located at the navigation bridge. A red light is to indicate that the door is in the open position and a green light is to indicate that the door is in the closed position. The red light is to flash when the door is in an intermediate position.

6.2.7 Signboard/instructions are to be placed in way of the door advising how to act when the door is closed.

6.2.8 For watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or an independent hydraulic unit for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located at the navigation bridge.

Table 2 : Doors in internal watertight bulkheads of cargo ships

Position relative to freeboard deck	Frequency of use while at sea	Type **(1)**	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Used	POS	X	X	X (local)	
	Normally closed **(2) (3)**	S, H		X		X
	Permanently closed	S, H				X
At or above	Used	POS	X	X	X (local)	
	Normally closed **(2) (3) (4)**	S, H		X		X
	Permanently closed	S, H				X

(1) POS : Power operated, sliding or rolling
S : Sliding or rolling
H : Hinged

(2) If hinged, this door is to be of single action type.

(3) Under ICLL66, hinged doors separating a main machinery space from a steering gear compartment must have the lower sill above the Summer Load Line.

(4) Under MARPOL I/28.4.3, hinged watertight doors may be acceptable in watertight bulkhead in the superstructure.

Table 3 : Doors in external watertight boundaries below equilibrium or intermediate waterplane of cargo ships

Position relative to freeboard deck	Frequency of use while at sea	Type **(1)**	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Permanently closed	S, H		X		X
At or above	Normally closed **(2)**	S, H		X		X
	Permanently closed	S, H		X		X

(1) POS : Power operated, sliding or rolling
S : Sliding or rolling
H : Hinged

(2) If hinged, this door is to be of single action type.

6.3 Openings in the watertight bulkheads and internal decks

6.3.1 Openings used while at sea

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead.

These doors may be opened during navigation to permit the passage of passengers or crew, or when work in the immediate vicinity of the door necessitates it being opened as per SOLAS II-1/22.3 and are to be closed immediately after use.

For cargo ships, the angle of list at which operation by hand is to be possible is 30 degrees.

Position indicators are to be provided at all remote operating positions for all ships and locally on both sides of the internal doors for cargo ships. An audible alarm is also to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

Failure of the normal power supply of the required alarms is to be indicated by an audible and visual alarm at the navigation bridge.

6.3.2 Openings normally closed at sea

Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with position indicators on the bridge for all ships, and locally on both sides of the internal doors for cargo ships, showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open.

They may be used if authorized by the master and closed again after use.

6.3.3 Doors or ramps in large cargo spaces

Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely controlled. Such doors are to be closed before the voyage commences and are to be kept closed during navigation. *Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.*

The word “satisfactory” means that scantlings and sealing requirements for such doors or ramps are to be sufficient to withstand the maximum head of the water at the flooded waterline.

6.3.4 Openings permanently kept closed at sea

Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

The time of opening such appliances in port and of closing them before the ship leaves port is to be authorized by the Master and entered in the logbook. Should such appliances be accessible during the voyage, they are to be fitted with a device to prevent unauthorized opening.

Section 2 Compartment Arrangement

1 General

1.1 Application to ships assigned the additional service feature SPxxx or SPxxx-capable

1.1.1 Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 2, considering the special personnel as passengers.

1.1.2 Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the special personnel as crew.

1.2 Application to ships assigned the additional service feature IPxxx or IPxxx-capable

1.2.1 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 2, considering the industrial personnel as passengers.

1.2.2 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the industrial personnel as crew.

1.3 Definitions

1.3.1 Cofferdam

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow for inspection.

2 Cofferdams

2.1 Cofferdam arrangement

2.1.1 Cofferdams are to be provided between:

- fuel oil tanks and lubricating oil tanks
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and compartments intended for fresh water (drinking water, water for propelling machinery and boilers, water for fire-fighting purposes)
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2 Cofferdams separating:

- fuel oil tanks and lubricating oil tanks
- lubricating oil tanks from compartments intended for fresh water
- lubricating oil tanks from those intended for the carriage of liquid foam for fire extinguishing
- fuel oil tanks from tanks intended for the carriage of liquid foam for fire extinguishing on ships having the service notation **fire-fighting**

need not to be required when agreed by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch 7, Sec 4, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
- the structural test is carried out with a head increased by 1 m with respect to Ch 13, Sec 6, [1.4].

2.1.3 Vented cofferdam may be required to separate heated oil fuel tanks from enclosed spaces located directly above (see Pt C, Ch 1, Sec 10, [11.7.2], item a)).

3 Double bottoms

3.1 Double bottom arrangement for ships other than tankers

3.1.1 *A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.*

3.1.2 *Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection is to be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:*

h = B/20

However, in no case is the value of h to be less than 760 mm, and need not to be taken as more than 2 m.

3.1.3 *Small wells constructed in the double bottom in connection with drainage arrangement are not to extend downward more than necessary. The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than h/2 or 500 mm, whichever is greater, or compliance with requirement defined in Ch 3, Sec 3, [3.4.3] is to be shown for that part of the ship.*

Other wells (e.g. for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation.

Proof of equivalent protection is to be shown by demonstrating that the ship is capable of withstanding bottom damages as specified in Ch 3, Sec 3, [3.4.3]. Alternatively, wells for lubricating oil below main engines may protrude into the double bottom below the boundary line defined by the distance h provided that the vertical distance between the well bottom and a plane coinciding with the keel line is not less than h/2 or 500 mm, whichever is the greater.

For a cargo ship of less than 80 m in length, the arrangements are to provide a level of safety to the satisfaction of the Society.

3.1.4 *A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage as defined in Ch 3, Sec 3, [3.4].*

3.1.5 *Any part of a ship that is not fitted with a double bottom in accordance with [3.1.1] or [3.1.4] is to be capable of withstanding bottom damages, as specified in Ch 3, Sec 3, [3.4.3]. For cargo ships of less than 80 m in length, the alternative arrangements are to provide a level of safety to the satisfaction of the Society.*

3.1.6 *In the case of unusual bottom arrangements, it is to be demonstrated that the ship is capable of withstanding bottom damages as specified in Ch 3, Sec 3, [3.4.3]. For cargo ships of less than 80 m in length, the alternative arrangements are to provide a level of safety to the satisfaction of the Society.*

4 Compartments forward of the collision bulkhead

4.1 General

4.1.1 The fore peak and other compartments located forward of the collision bulkhead are not to be used for the carriage of fuel oil or other flammable products.

This requirement does not apply to ships of less than 400 gross tonnage, except for those where the fore peak is the forward cofferdam of tanks arranged for the carriage of flammable liquid products having a flashpoint not exceeding 60°C.

5 Minimum bow height

5.1 General

5.1.1 *The bow height F_b defined as the vertical distance at the forward perpendicular between the waterline corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side, is to be not less than:*

$F_b = [6075(L_{LL}/100) - 1875(L_{LL}/100)^2 + 200(L_{LL}/100)^3] \times [2{,}08 + 0{,}609C_b - 1{,}603C_{wf} - 0{,}0129(L_{LL}/T_1)]$

where:

F_b : *Calculated minimum bow height, in mm*

T_1 : *Draught at 85% of the least moulded depth, in m, as defined in Ch 1, Sec 3, [2.1.6]*

C_{wf} : *Waterplane area coefficient forward of $L_{LL}/2$:*

$$C_{wf} = \frac{A_{wf}}{\frac{L_{LL}}{2}B}$$

A_{wf} : *Waterplane area forward of $L_{LL}/2$ at draught T_1, in m^2.*

For ships to which timber freeboards are assigned, the summer freeboard (and not the timber summer freeboard) is to be assumed when applying the formula above.

5.1.2 *Where the bow height required in [5.1.1] is obtained by sheer, the sheer is to extend for at least 15% of L_{LL} of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least $0,07L_{LL}$ abaft the forward perpendicular and is to be enclosed as defined in Ch 11, Sec 5.*

5.1.3 *Ships which, to suit exceptional operational requirements, cannot meet the requirements in [5.1.1] and [5.1.2] will be considered by the Society on a case by case basis.*

5.1.4 *The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than $0,15L_{LL}$, but greater than $0,07L_{LL}$, provided that the forecastle height is not less than one half of standard height of superstructure between $0,07L_{LL}$ and the forward perpendicular.*

5.1.5 *Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows:*

a) *Where the freeboard deck has sheer extending from abaft $0,15L_{LL}$, by a parabolic curve having its origin at $0,15L_{LL}$ abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (see Fig 1). However, if the value of the height denoted h_t in Fig 1 is smaller than the value of the height denoted h_b then h_t may be replaced by h_b in the available bow height, where:*

$$h_t = Z_b\left(\frac{0,15L_{LL}}{x_b}\right)^2 - Z_t$$

Z_b, Z_t : *As defined in Fig 1*

h_f : *Half standard height of superstructure.*

b) *Where the freeboard deck has sheer extending for less than $0,15L_{LL}$ or has no sheer, by a line from the forecastle deck at side at $0,07L_{LL}$ extended parallel to the base line to the forward perpendicular (see Fig 2).*

Figure 1 : Credited bow height where the freeboard deck has sheer extending from abaft 0,15 L

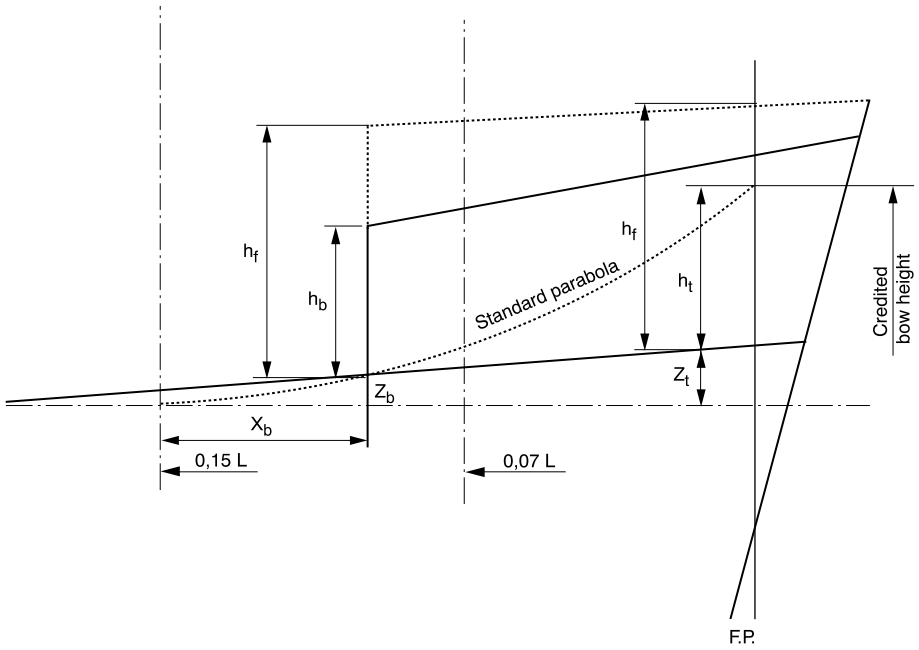
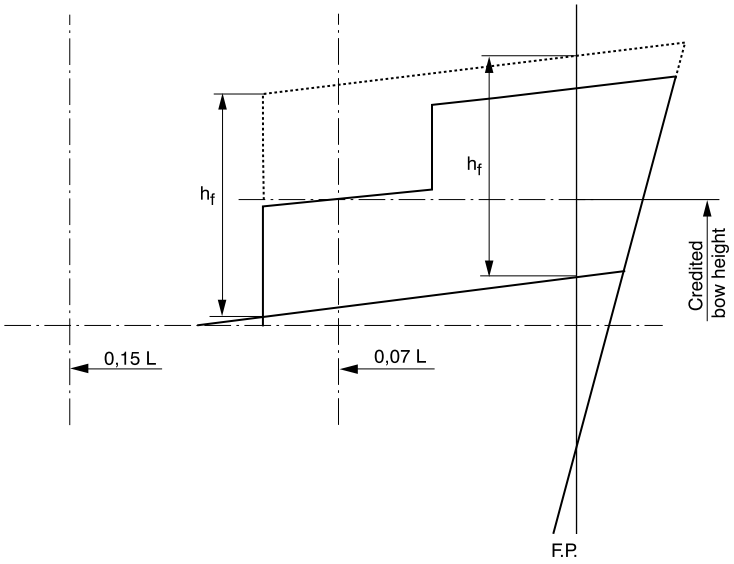


Figure 2 : Credited bow height where the freeboard deck has sheer extending for less than 0,15 L



5.1.6 *All ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carriers, are to have additional reserve buoyancy in the fore end. Within the range of $0,15L_{LL}$ abaft of the forward perpendicular, the sum of the projected area between the summer load waterline and the deck at side (A1 and A2 in Fig 3) and the projected area of an enclosed superstructure, if fitted, is, in m^2, to be not less than:*

$A3 = (0,15\ F_{min} + 4\ (L_{LL}/3 + 10))\ L_{LL}/1000$

where:

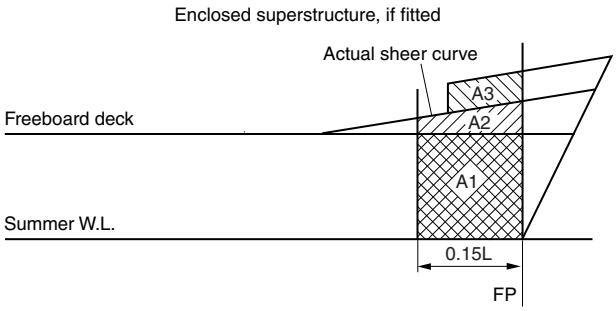
F_{min} : $F_{min} = (F_0 \cdot f_1) + f_2$

F_0 : *Tabular freeboard, in mm, taken from the International Convention on Load Lines, as amended, Table 28.2, corrected for regulation 27(9) or 27(10), as applicable*

f_1 : *Correction for block coefficient given in the International Convention on Load Lines, as amended, regulation 30*

f_2 : *Correction for depth, in mm, given in the International Convention on Load Lines, as amended, regulation 31.*

Figure 3 : Areas A1, A2 and A3



6 Shaft tunnels

6.1 General

6.1.1 Shaft tunnels are to be watertight.

7 Watertight ventilators and trunks

7.1 General

7.1.1 *Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in ships other than passenger ships.*

8 Fuel oil tanks

8.1 General

8.1.1 *The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.*

8.1.2 *As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A.*

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint of less than 60°C.

Note 1: Machinery spaces of category A are defined in Pt C, Ch 4, Sec 1, [2.30].

8.1.3 *Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.*

Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

8.1.4 Where a compartment intended for goods or coal is situated in proximity of a heated liquid container, suitable thermal insulation is to be provided.

8.2 Fuel oil tank protection

8.2.1 All ships with an aggregate oil fuel capacity of 600 m^3 are to comply with the requirements of the Regulation 12 A of Annex I to Marpol Convention, as amended.

9 Tanks containing fuel for auxiliary vehicles

9.1 General

9.1.1 Tanks containing fuel for auxiliary vehicles are to comply with the requirements of Pt C, Ch 4, Sec 11, [3.1].

9.2 Tank protection and segregation

9.2.1 Tanks containing fuel for auxiliary vehicles are to be located in accordance with the requirements of Pt C, Ch 4, Sec 11, [3.2].

10 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system

10.1 Tank protection and segregation

10.1.1 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system are to comply with requirements of:

- Pt C, Ch 1, Sec 11, [3.2] for tank containing urea
- Pt C, Ch 1, Sec 11, [4.2] for tank containing sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$
- Pt C, Ch 1, Sec 11, [4.9] for tank residues
- Pt C, Ch 1, Sec 11, [5.4] for tanks containing other chemicals.

11 Tanks containing solvent for onboard carbon capture systems (ships assigned the additional service feature OCC)

11.1 Tank protection and segregation

11.1.1 Tanks containing solvent (as defined in Pt C, Ch 1, Sec 12, [1.3.6]) for OCC are to comply with the requirements of Pt C, Ch 1, Sec 12, [2.4.4].

Section 3 Access Arrangement

1 General

1.1

1.1.1 The number and size of small hatchways for trimming and access openings to tanks or other enclosed spaces, are to be kept to the minimum consistent with access and maintenance of the space.

2 Double bottom

2.1 Inner bottom manholes

2.1.1 Inner bottom manholes are to be not less than 400 mm x 400 mm. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

2.1.2 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage by the cargo.

2.2 Floor and girder manholes

2.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to all parts of the double bottom.

2.2.2 The size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

2.2.3 Manholes may not be cut into the continuous centreline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

3 Access arrangement to and within spaces in, and forward of, the cargo area

3.1 General

3.1.1 The requirements in [3.2] to [3.4] are not applicable to ships with service notations **bulk carrier**, **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP**, **self-unloading bulk carrier ESP, ore carrier ESP**, **combination carrier ESP**, of 20,000 gross tonnage and over, and to ships with service notation **oil tanker ESP** of 500 gross tonnage and over. For such ships, refer to the applicable requirements of Part D.

3.1.2 The requirements in [3.2] to [3.4] are not applicable to spaces in double bottom and double side tanks.

3.2 Access to tanks

3.2.1 Tanks with a length equal to or greater than 35 m

Tanks and subdivisions of tanks having lengths of 35 m and above are to be fitted with at least two access hatchways and ladders, as far apart as practicable longitudinally.

3.2.2 Tanks with a length less than 35 m

Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.

3.2.3 Dimensions of access hatchways

The dimensions of any access hatchway are to be sufficient to allow a person wearing a self-contained breathing apparatus to ascend or descend the ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the tank. In no case is the clear opening to be less than 600 mm x 600 mm.

3.2.4 Tanks subdivided by wash bulkheads

When a tank is subdivided by one or more wash bulkheads, at least two hatchways are to be fitted, and these hatchways are to be so located that the associated ladders effectively serve all subdivisions of the tank.

3.3 Access within tanks

3.3.1 Wash bulkheads in tanks

Where one or more wash bulkheads are fitted in a tank, they are to be provided with openings not less than 600 x 800 mm and so arranged as to facilitate the access of persons wearing breathing apparatus or carrying a stretcher with a patient.

3.3.2 Passage on the tank bottom

To provide ease of movement on the tank bottom throughout the length and breadth of the tank, a passageway is to be fitted on the upper part of the bottom structure of each tank, or alternatively, manholes having at least the dimensions of 600 mm x 800 mm are to be arranged in the floors at a height of not more than 600 mm from the bottom shell plating.

3.3.3 Passageways in the tanks

a) Passageways in the tanks are to have a minimum width of 600 mm considering the requirement for the possibility of carrying an unconscious person. Elevated passageways are to be provided with guard rails over their entire length. Where guard rails are provided on one side only, foot rails are to be fitted on the opposite side. Shelves and platforms forming a part of the access to the tanks are to be of non-skid construction where practicable and be fitted with guard rails. Guard rails are to be fitted to bulkhead and side stringers when such structures are being used for recognised access

b) Access to elevated passageways from the ship's bottom is to be provided by means of easily accessible passageways, ladders or treads. Treads are to provide lateral support for the foot. Where rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to that surface is to be at least 150 mm

c) When the height of the bottom structure does not exceed 1,50 m, the passageways required in a) may be replaced by alternative arrangements having regard to the bottom structure and requirement for ease of access of a person wearing a self-contained breathing apparatus or carrying a stretcher with a patient.

3.3.4 Manholes

Where manholes are fitted, as indicated in [2.2.2], access is to be facilitated by means of steps and hand grips with platform landings on each side.

3.3.5 Guard rails

Guard rails are to be 900 mm in height and consist of a rail and intermediate bar. These guard rails are to be of substantial construction.

3.4 Construction of ladders

3.4.1 General

In general, the ladders are not to be inclined at an angle exceeding 70°. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

3.4.2 Construction

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

3.4.3 Corrosive effect of the cargo

Provision is to be made for maintaining the structural strength of the ladders and railings taking into account the corrosive effect of the cargo.

3.4.4 Width of ladders

The width of ladders is not to be less than:

- *350 mm for vertical ladders*
- *400 mm for inclined ladders.*

3.4.5 Treads

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 22 mm by 22 mm in section fitted to form a horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be carried through the side stringers and attached thereto by double continuous welding.

3.4.6 Sloping ladders

All sloping ladders are to be provided with handrails of substantial construction on both sides fitted at a convenient distance above the treads.

4 Shaft tunnels

4.1 General

4.1.1 Tunnels are to be large enough to ensure easy access to shafting.

4.1.2 Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with Ch 2, Sec 1, [6].

5 Access to steering gear compartment

5.1

5.1.1 The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

5.1.2 Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided.

These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

CHAPTER 3
STABILITY

Section 1 General

Section 2 Intact Stability

Section 3 Damage Stability

Appendix 1 Inclining Test and Lightweight Check

Appendix 2 Trim and Stability Booklet

Appendix 3 Probabilistic Damage Stability Method for Cargo Ships

Appendix 4 Damage Stability Calculation for Ships Assigned with a Reduced Freeboard

Section 1 General

1 General

1.1 Application

1.1.1 General

All ships equal to or greater than 24 m in length may be assigned class only after it has been demonstrated that their intact stability is adequate. Adequate intact stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Chapter taking into account the ship's size and type. In any case, the level of intact stability is not to be less than that provided by the Rules.

1.1.2 Ships less than 24 m in length

The Rules also apply to ships less than 24 m in length. In this case, the requirements concerned may be partially omitted when deemed appropriate by the Society.

1.1.3 Approval of the Administration

Evidence of approval by the Administration concerned may be accepted for the purpose of classification.

1.2 Application to ships assigned the additional service feature SPxxx or SPxxx-capable

1.2.1 Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt D, Ch 11, Sec 3, considering the special personnel as passengers.

1.2.2 Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Chapter, unless otherwise specified, considering the special personnel as crew.

1.3 Application to ships assigned the additional service feature IPxxx or IPxxx-capable

1.3.1 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt D, Ch 11, Sec 3 with the exemption of Pt D, Ch 11, Sec 3, [2.2.2], considering the industrial personnel as passengers.

1.3.2 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** with xxx less than 240 are to comply with the requirements of this Chapter, unless otherwise specified, considering the industrial personnel as crew.

1.4 Application to ships assigned the additional class notation STABLIFT

1.4.1 Ships assigned the additional class notation **STABLIFT** are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt E, Ch 8, Sec 3.

1.5 Alterations

1.5.1 When alterations are made to a ship in service that result in calculable differences in the lightship properties, a detailed weights and centres of gravity calculation to adjust the lightship properties is to be carried out.

The ship is to be re-inclined if any of the following deviations from the approved values are exceeded:

- 2% of the lightship displacement; or
- 1% of L for the longitudinal centre of gravity; or
- 1% of the vertical centre of gravity.

The lightship transverse centre of gravity is not subject to a deviation limit.

1.5.2 When a ship does not exceed the deviation limits specified in [1.5.1], amended stability information should be provided to the master using the new calculated lightship properties if any of the following deviations from the approved values are exceeded:

- 1% of the lightship displacement; or
- 0,5% of L for the longitudinal centre of gravity; or
- 0,5% of the vertical centre of gravity.

However, in cases when these deviation limits are not exceeded, it is not necessary to amend the stability information supplied to the master.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of documents

For the purpose of the examination of the stability, the documentation listed in Ch 1, Sec 4, [1.1.2] is to be submitted for information.

The stability documentation to be submitted for approval, as indicated in Ch 1, Sec 4, [1.2.1], is as follows:

- inclining test report for the ship, as required in [2.2] or:
  - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question; or
  - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along with a summary of the method used to determine those particulars as indicated in [2.2.4].
- trim and stability booklet, as required in Ch 3, Sec 2, [1.1.1]
- and, as applicable:
  - grain loading manual, as required in Pt D, Ch 4, Sec 3, [1.2.2]
  - damage stability calculations, as required in Ch 3, Sec 3, [3.1]
  - damage control documentation, as required in Ch 3, Sec 3, [4]
  - loading computer documentation, as required in Ch 3, Sec 2, [1.1.2] and in Ch 3, Sec 3, [3.1.3].

  A copy of the trim and stability booklet and, if applicable, the grain stability booklet, the damage control documentation or the loading computer documentation is to be available on board for the attention of the Master.

2.1.2 Provisional documentation

The Society reserves the right to accept or demand the submission of provisional stability documentation for examination.

Provisional stability documentation includes loading conditions based on estimated lightship values.

2.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

When provisional stability documentation has already been submitted and the difference between the estimated values of the lightship and those obtained after completion of the test is less than:

- 2% for the displacement, and
- 1% of the length between perpendiculars for the longitudinal position of the centre of gravity

and the determined vertical position of the centre of gravity is not greater than the estimated vertical position of the centre of gravity, the provisional stability documentation may be accepted as the final stability documentation.

2.2 Inclining test/lightweight check

2.2.1 Definitions

a) Lightship

The lightship is a ship complete in all respects, but without consumables, stores, cargo, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricants and hydraulics, at operating levels, and mediums required for the fixed fire-extinguishing systems, such as fresh water, CO_2, dry chemical powder, foam concentrate, etc.

b) Inclining test

The inclining test is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The lightship displacement and longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the ship at the time of the inclining test as determined by measuring the freeboard or verified draught marks of the ship, the ship's hydrostatic data and the sea water density.

2.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subjected to an inclining test permitting the evaluation of the position of the lightship centre of gravity, or a lightweight check of the lightship displacement, so that the stability data can be determined. Cases for which the inclining test is required and those for which the lightweight check is accepted in its place are listed in [2.2.4] and [2.2.5].

A detailed procedure of the test is to be submitted to the Society prior to the test. This procedure is to include:

a) *Identification of the ship by name and shipyard hull number, if applicable*

b) *Date, time and location of the test*

c) *Inclining weight data:*
   - *type*
   - *amount (number of units and weight of each)*
   - *certification*
   - *method of handling (i.e. sliding rail or crane)*
   - *anticipated maximum angle of heel to each side*

d) *Measuring devices:*
   - *pendulums - approximate location and length*
   - *U-tubes - approximate location and length*
   - *inclinometers - Location and details of approvals and calibrations*

e) *Approximate trim*

f) *Condition of tanks*

g) *Estimate weights to deduct, to complete, and to relocate in order to place the ship in its true lightship condition.*

The inclining test or lightweight check is to be attended by a Surveyor of the Society. The Society may accept inclining tests or lightweight checks attended by a member of the flag Administration.

The inclining test is adaptable to ships less than 24 m in length, provided that precautions are taken, on a case by case basis, to ensure the accuracy of the test procedure.

The inclining test or lightweight test report is to be signed by the Surveyor to confirm the information witnessed during the test. In addition, for ships performing regular adjustments of equipment such as for example supply vessels, the report is to include the detailed list of the major equipment on the decks, if they are included in the lightship particulars.

2.2.3 Inclining test

The inclining test is required in the following cases:

- any new ship, after its completion, except for the cases specified in [2.2.4]
- any ship, where any alterations are made so as to materially affect the stability (see [1.5]).

Note 1: Due attention is to be paid to SOLAS Ch.II.1 Reg.22 (if applicable) whereby it is stipulated that such allowance is subject to the agreement of the Flag Administration (refer to Pt A, Ch 1, Sec 1, [3.1.1]).

2.2.4 Lightweight check

The Society may allow a lightweight check to be carried out in lieu of an inclining test in the case of:

- *Stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of the Society that reliable stability information for the exempted ship can be obtained from such basic data. A lightweight survey shall be carried out upon completion and the ship shall be inclined whenever in comparison with the data derived from the sister ship, a deviation from the lightship displacement exceeding 1% for ships of 160 m or more in length and 2% for ships of 50 m or less in length and as determined by linear interpolation for intermediate lengths or a deviation from the lightship longitudinal centre of gravity exceeding 0.5% of L_{LL} is found.*
- Special types of ship, such as pontoons, provided that the vertical centre of gravity is considered at the level of the deck.
- Special types of ship provided that:
  - a detailed list of weights and the positions of their centres of gravity is submitted
  - a lightweight check is carried out, showing accordance between the estimated values and those determined
  - adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

2.2.5 Detailed procedure

A detailed procedure for conducting an inclining test is included in Ch 3, App 1. For the lightweight check, the same procedure applies except as provided for in Ch 3, App 1, [1.1.9].

Section 2 Intact Stability

1 General

1.1 Information for the Master

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the working language of the ship and any other language the Society may require. reference is also made to the International Safety Management (ISM) Code, adopted by IMO by resolution A.741(18). All translations of the stability booklet are to be approved.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.1.2 Loading instrument

As a supplement to the approved stability booklet, a loading instrument, approved by the Society, may be used to facilitate the stability calculations mentioned in Ch 3, App 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 1, Sec 5, [3].

1.1.3 Operating booklets for certain ships

Ships with innovative design are to be provided with additional information in the stability booklet such as design limitations, maximum speed, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship.

1.2 Permanent ballast

1.2.1 *If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship's stability booklet.*

1.2.2 Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in [2.1.2], [2.1.3], [2.1.4],and [2.1.5] are to be complied with for the loading conditions mentioned in Ch 3, App 2, [1.2].

However, the lightship condition not being an operational loading case, the Society may accept that part of the above-mentioned criteria are not fulfilled.

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and to safe carriage of the cargo.

2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0,055 m·rad up to θ = 30° angle of heel and not less than 0,09 m·rad up to θ = 40° or the angle of down flooding θ_f if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_f, if this angle is less than 40°, is to be not less than 0,03 m·rad.

Note 1: Note 1: θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge.

In applying this criterion, openings which cannot be closed weathertight include ventilators that have to remain open to supply air to the engine room, to the emergency generator room or to closed ro-ro and vehicle spaces for the effective operation of the ship, but exclude small openings through which progressive flooding cannot take place. This interpretation is not intended to be applied to existing ships.

The means of closing air pipes are to be weathertight and of an automatic type if the openings of the air pipes to which the devices are fitted would be submerged at an angle of less than 40 degrees (or any lesser angle which may be needed to suit stability requirements) when the ship is floating at its summer load line draught. Pressure/vacuum valves (P.V. valves) may be accepted on tankers. Wooden plugs and trailing canvas hoses may not be accepted in positions 1 and 2 as defined in Ch 1, Sec 3, [2.4].

2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of ships with a particular design and subject to the prior agreement of the flag Administration, the Society may accept an angle of heel θ_{max} less than 25° but in no case less than 15°, provided that the area "A" below the righting lever curve up to the angle of θ_{max} is not less than the value obtained, in m.rad, from the following formula:

$A = 0,055 + 0,001\ (30° - \theta_{max})$

where θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.1.5 Initial metacentric height

The initial metacentric height GM_0 is not to be less than 0,15 m.

2.1.6 Elements affecting stability

A number of influences such as beam wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, following seas, etc., which adversely affect stability, are to be taken into account.

2.1.7 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in [6]) and to losses of weight such as those due to consumption of fuel and stores.

3 Severe wind and rolling criterion (weather criterion)

3.1 Scope

3.1.1 *This criterion supplements the stability criteria given in [2.1] for ships of 24 m in length and over. The more stringent criteria of [2.1] and the weather criterion are to govern the minimum requirements.*

3.2 Weather criterion

3.2.1 Assumptions

The ability of a ship to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig 1 as follows:

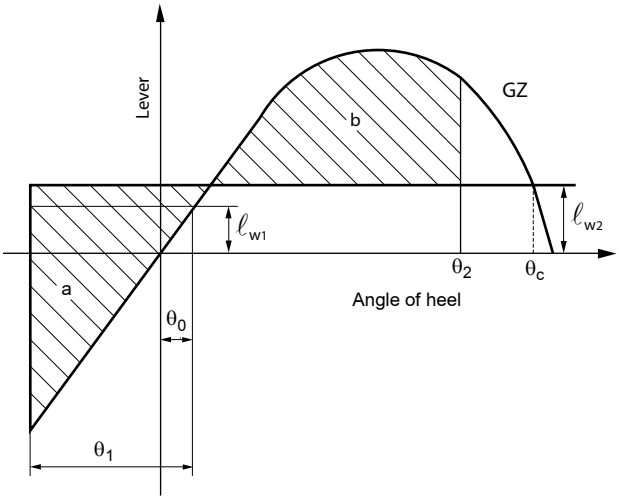
- *the ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (ℓ_{w1})*
- *from the resultant angle of equilibrium (θ_0), the ship is assumed to roll owing to wave action to an angle of roll (θ_1) to windward*
- *the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓ_{w2})*
- *free surface effects, as described in [4], are to be accounted for in the standard conditions of loading as set out in Ch 3, App 2, [1.2].*

3.2.2 Criteria

Under the assumptions of [3.2.1], the following criteria are to be complied with:

- *the area "b" is to be equal to or greater than area "a", where:*
  - *a* : Area above the GZ curve and below ℓ_{w2}, between θ_R and the intersection of ℓ_{w2} with the GZ curve
  - *b* : *Area above the heeling lever ℓ_{w2} and below the GZ curve, between the intersection of ℓ_{w2} with the GZ curve and θ_2*
- *the angle of heel under action of steady wind (θ_0) is to be limited to 16° or 80% of the angle of deck edge immersion, whichever is less.*

Figure 1 : Severe wind and rolling



3.2.3 Heeling levers

The wind heeling levers ℓ_{w1} and ℓ_{w2}, in m, referred to in [3.2.2], are constant values at all angles of inclination and are to be calculated as follows:

$$\ell_{W1} = \frac{PAZ}{1000g\Delta}$$

and

$$\ell_{W2} = 1{,}5\,\ell_{W1}$$

where:

P : *504 N/m² for unrestricted navigation notation. The value of P used for ships with restricted navigation notation may be reduced subject to the approval of the Society*

A : *Projected lateral area in m², of the portion of the ship and deck cargo above the waterline*

Z : *Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught*

Δ : *Displacement in t*

g = 9,81 m/s².

3.2.4 Angles of heel

For the purpose of calculating the criteria of [3.2.2], the angles in Fig 1 are defined as follows:

θ_0 : *Angle of heel, in degrees, under action of steady wind*

θ_1 : *Angle of roll, in degrees, to windward due to wave action, calculated as follows:*

$$\theta_1 = 109kX_1X_2\sqrt{rs}$$

θ_2 : *Angle of downflooding (θ_f) in degrees, or 50° or θ_c , whichever is less*

θ_f : *Angle of heel in degrees, at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, openings which cannot be closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship, but exclude small openings through which progressive flooding cannot take place.*

θ_c : *Angle in degrees, of second intercept between wind heeling lever ℓ_{w2} and GZ curves*

$\theta_R = \theta_0 - \theta_1$

X_1 : *Coefficient defined in Tab 1*

X_2 : *Coefficient defined in Tab 2*

k : *Coefficient equal to:*

k = 1,0 for a round-bilged ship having no bilge or bar keels

k = 0,7 for a ship having sharp bilge

For a ship having bilge keels, a bar keel or both, k is defined in Tab 3.

$r = 0{,}73 \pm 0{,}6\ (OG)/T_1$

OG : *Distance in m, between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)*

T_1 : *Mean moulded draught in m, of the ship*

s : *Factor defined in Tab 4.*

Note 1: The angle of roll θ_1 for ships with anti-rolling devices is to be determined without taking into account the operations of these devices.

Note 2: The angle of roll θ_1 may be obtained, in lieu of the above formula, from model tests or full scale measurements.

The rolling period T_R, in s, is calculated as follows:

$$T_R = \frac{2CB}{\sqrt{GM}}$$

where:

$$C = 0{,}373 + 0{,}023\frac{B}{T_1} - 0{,}043\frac{L_W}{100}$$

The symbols in the tables and formula for the rolling period are defined as follows:

L_W : *Length in m, of the ship at the waterline*

T_1 : *Mean moulded draught in m, of the ship*

A_K : *Total overall area in m^2 of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas,* or area of the lateral projection of any hull appendages generating added mass during ship roll

GM : *Metacentric height in m, corrected for free surface effect.*

3.2.5 *Tab 1 to Tab 4 and formulae described in [3.2.4] are based on data from ships having:*

- *B/T_1 smaller than 3,5*
- *$(KG/T_1–1)$ between – 0,3 and 0,5*
- *T_R smaller than 20 s.*

For ships with parameters outside of the above limits the angle of roll (θ_1) may be determined with model experiments of a subject ship with the procedure described in IMO MSC.1/Circ. 1200 as the alternative. In addition, the Society may accept such alternative determinations for any ship, if deemed appropriate.

Table 1 : Values of coefficient X_1

B/T_1	X_1
≤ 2,4	1,00
2,5	0,98
2,6	0,96
2,7	0,95
2,8	0,93
2,9	0,91
3,0	0,90
3,1	0,88
3,2	0,86
3,4	0,82
≥ 3,5	0,80
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

Table 2 : Values of coefficient X_2

C_B	X_2
≤ 0,45	0,75
0,50	0,82
0,55	0,89
0,60	0,95
0,65	0,97
≥ 0,70	1,00
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

Table 3 : Values of coefficient k

$\frac{A_K \times 100}{L \times B}$	k
0,0	1,00
1,0	0,98
1,5	0,95
2,0	0,88
2,5	0,79
3,0	0,74
3,5	0,72
≥ 4,0	0,70
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

Table 4 : Values of factor s

T_R	s
≤ 6	0,100
7	0,098
8	0,093
12	0,065
14	0,053
16	0,044
18	0,038
≥ 20	0,035
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

3.2.6 *Alternative means for determining the wind heeling lever (ℓ_{W1}) may be accepted, to the satisfaction of the Society as an equivalent to the calculation in [3.2.3]. When such alternative tests are carried out, reference shall be made based on the Interim Guidelines for alternative assessment of the weather criterion (IMO MSC.1/Circ.1200). the wind velocity used in the tests shall be 26 m/s in full scale with uniform velocity profile. the value of wind velocity used for ships in restricted services may be reduced to the satisfaction of the Society.*

4 Effects of free surfaces of liquids in tanks

4.1 General

4.1.1 *For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.*

4.2 Consideration of free surface effects

4.2.1 *Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in [4.8.1].*

4.2.2 *Nominally full cargo tanks should be corrected for free surface effects at 98% filling level. In doing so, the correction to initial metacentric height should be based on the inertia moment of liquid surface at 5° of the heeling angle divided by displacement, and the correction to righting lever is suggested to be on the basis of real shifting moment of cargo liquids.*

4.3 Categories of tanks

4.3.1 *Tanks which are taken into consideration when determining the free surface correction may be one of two categories:*

- *tanks with fixed filling level (e.g. liquid cargo, water ballast). The free surface correction is to be defined for the actual filling level to be used in each tank.*
- *tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water, and also liquid cargo and water ballast during liquid transfer operations). Except as permitted in [4.5.1] and [4.6.1], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.*

4.4 Consumable liquids

4.4.1 *In calculating the free surfaces effect in tanks containing consumable liquids, it is to be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account are to be those where the effect of free surface is the greatest.*

4.5 Water ballast tanks

4.5.1 *Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operations.*

4.6 Liquid transfer operations

4.6.1 *For ships engaged in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations may be determined in accordance with the filling level in each tank at the stage of the transfer operation.*

4.7 GM_0 and GZ curve corrections

4.7.1 *The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in [4.7.2] and [4.7.3].*

4.7.2 *In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel according to the categories indicated in [4.3.1].*

4.7.3 *The righting lever curve may be corrected by any of the following methods:*

- *correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]*
- *correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1].*

4.7.4 *Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.*

4.8 Small tanks

4.8.1 *Small tanks which satisfy the following condition corresponding to an angle of inclination of 30° need not be included in the correction:*

$$\frac{M_{fs}}{\Delta_{min}} < 0,01$$

where:

M_{fs} : *free surface moment, in t.m, of the tank*

Δ_{min} : *Minimum ship displacement, in t, calculated at* d_{min}

d_{min} : *Minimum mean service draught, in m, of ship without cargo, with 10% stores and minimum water ballast, if required.*

When more than one tank are intended to be excluded from the correction, the following condition is to be satisfied :

where:

$$\sum_{i}^{n} \frac{M_{fs,\,i}}{\Delta_{min}} < 0,01$$

$M_{fs,i}$: free surface moment, in t.m, of the tank i

n : total number of tanks intended to be excluded from the correction.

4.9 Remainder of liquid

4.9.1 *The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.*

5 Cargo ships carrying timber deck cargoes

5.1 Application

5.1.1 *The provisions given hereunder apply to ships engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended.*

5.2 Definitions

5.2.1 Timber

Timber means sawn wood or lumber, cants, logs, poles, pulpwood and all other types of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

5.2.2 Timber deck cargo

Timber deck cargo means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

5.2.3 Timber load line

Timber load line means a special load line assigned to ships complying with certain conditions related to their construction set out in the International Convention on Load Lines 1966, as amended, and used when the cargo complies with the stowage and securing conditions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (Resolution A.715(17)).

5.3 Stability criteria

5.3.1 *For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship after due allowance for a rounded gunwale not exceeding 4% of the breadth of the ship and/or securing the supporting uprights and which remains securely fixed at large angles of heel, the Society may apply the* criteria given in [5.3.2] to [5.3.5]*, which substitute those given in [2.1.2], [2.1.3], [2.1.4] and [2.1.5] and in [3.2].*

5.3.2 *The area under the righting lever curve (GZ curve) is to be not less than 0,08 m·rad up to* $\theta = 40°$ *or the angle of flooding if this angle is less than 40°.*

5.3.3 *The maximum value of the righting lever (GZ) is to be at least 0,25 m.*

5.3.4 *At all times during a voyage, the metacentric height* GM_0 *is to be not less than 0,10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces. (Details regarding ice accretion are given in [6]).*

5.3.5 *When determining the ability of the ship to withstand the combined effect of beam wind and rolling according to [3.2], the 16° limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of 80% of the angle of deck edge immersion may be ignored.*

5.4 Stability booklet

5.4.1 *The ship is to be supplied with comprehensive stability information which takes into account timber deck cargo. Such information is to enable the Master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service. Comprehensive rolling period tables or diagrams have proved to be very useful aids in verifying the actual stability conditions.*

5.4.2 *For ships carrying timber deck cargoes, the Society may deem it necessary that the Master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from 25% (see [5.5.1]).*

5.4.3 *For ships carrying timber deck cargoes, conditions are to be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.*

5.5 Calculation of the stability curve

5.5.1 *In addition to the provisions given in Ch 3, App 2, [1.3], the Society may allow account to be taken of the buoyancy of the deck cargo assuming that such cargo has a permeability of 25% of the volume occupied by the cargo. Additional curves of stability may be required if the Society considers it necessary to investigate the influence of different permeabilities and/or assumed effective height of the deck cargo.*

5.6 Loading conditions to be considered

5.6.1 *The loading conditions which are to be considered for ships carrying timber deck cargoes are specified in Ch 3, App 2, [1.2.2]. For the purpose of these loading conditions, the ship is assumed to be loaded to the summer timber load line with water ballast tanks empty.*

5.7 Assumptions for calculating loading conditions

5.7.1 *The following assumptions are to be made for calculating the loading conditions referred to in Ch 3, App 2, [1.2.2]:*

- *the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in [2.1.2], [2.1.3], [2.1.4] and [2.1.5], or the optional criteria given in [5.3], are met*
- *in the arrival condition, it is to be assumed that the weight of the deck cargo has increased by 10% due to water absorption.*

5.7.2 *The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, is to be positive and* in compliance with the stability criteria of [5.3]. *It is to be calculated having regard to:*

- *the increased weight of the timber deck cargo due to:*
  - *absorption of water in dried or seasoned timber, and*
  - *ice accretion, if applicable (as reported in [6])*
- *variations in consumable*
- *the free surface effect of liquid in tanks, and*
- *the weight of water trapped in broken spaces within the timber deck cargo and especially logs.*

5.7.3 *Excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings.* Unless otherwise stated in the stability booklet, *the metacentric height is* generally *not to exceed 3% of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in [5.3] are satisfied.*

5.8 Stowage of timber deck cargoes

5.8.1 *The stowage of timber deck cargoes is to comply with the provisions of chapter 3 of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (resolution A.715(17)).*

6 Icing

6.1 Application

6.1.1 *For any ship having an ice class notation or operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.*

6.2 Ships carrying timber deck cargoes

6.2.1 *The Master is to establish or verify the stability of his ship for the worst service condition, having regard to the increased weight of deck cargo due to water absorption and/or ice accretion and to variations in consumable.*

6.2.2 *When timber deck cargoes are carried and it is anticipated that some formation of ice will take place, an allowance is to be made in the arrival condition for the additional weight.*

6.2.3 Allowance for ice accretion

The ice accretion weight, w, in kg/m^2, is to be taken as follows:

$$w = 30 \cdot \frac{2{,}3\ (15{,}2\ L - 351{,}8)}{l_{FB}} \cdot f_{TL} \cdot \frac{l_{bow}}{0{,}16\ L}$$

where:

f_{TL} : *Timber and lashing factor:*

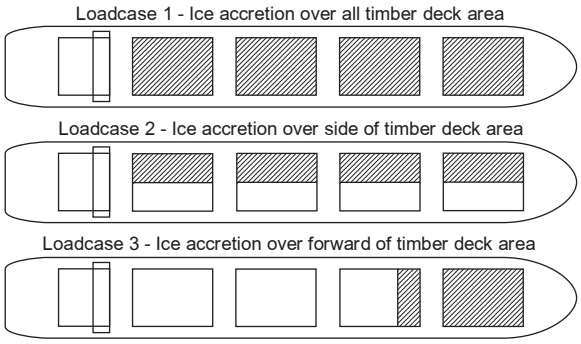
$f_{TL} = 1{,}2$

l_{FB} : *Freeboard height, in mm*

l_{bow} : *Length of bow flare region, in m, to be taken as the distance from the longitudinal position at which the maximum breadth occurs on a water line located 0,5 m below the freeboard deck at side to the foremost point of the bow at that waterline.*

The ice accretion weight w over the timber deck region is to be applied to each of the load cases as illustrated in Fig 2.

Figure 2 : Ice accretion load case for timber deck cargoes



Load cases are to be applied in stability calculations.

6.3 Calculation assumptions

6.3.1 *For ships operating in areas where ice accretion is likely to occur, the following icing allowance is to be made in the stability calculations:*

- *30 kg per square metre on exposed weather decks and gangways*
- *7,5 kg per square metre for the projected lateral area of each side of the ship above the water plane*
- *the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.*

6.3.2 *Ships intended for operation in areas where ice is known to occur are to be:*

- *designed to minimise the accretion of ice, and*
- *equipped with such means for removing ice as, for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.*

6.4 Guidance relating to ice accretion

6.4.1 *The following icing areas are to be considered:*

a) The area north of latitude 65°30'N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea

b) The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W

c) All sea areas north of the North American Continent, west of the areas defined in a) and b)

d) The Bering and Okhotsk Seas and the Tartary Strait during the icing season, and

e) South of latitude 60°S.

6.4.2 *For ships operating where ice accretion may be expected:*

- *within the areas defined in a), c), d) and e)* of [6.4.1] *known to having icing conditions significantly different from those described in [6.3], ice accretion requirements of one half to twice the required allowance may be applied*
- *within the area defined in b), where ice accretion in excess of twice the allowance required by [6.3] may be expected, more severe requirements than those given in [6.3] may be applied.*

Section 3 Damage Stability

1 Application

1.1 Ships for which damage stability is required

1.1.1 Damage stability calculation is required for ships which are assigned with the additional class notation **SDS**.

1.1.2 The damage stability criteria to be applied depend on the ship type as described by its service notation and corresponding rules defined in Pt A, Ch 1, Sec 2.

1.1.3 For tankers assigned with a tropical freeboard and granted with **SDS** additional class notation, the corresponding loading conditions and damage stability calculations are to be submitted into the damage stability booklet.

1.2 Ships assigned the additional class notation SDS and additional service feature SPxxx, SPxxx-capable, IPxxx or IPxxx-capable

1.2.1 Ships assigned the additional class notation **SDS** and the additional service feature **SPxxx**, **SPxxx-capable**, **IPxxx** or **IPxxx-capable** are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 3, [2.3], considering the special personnel, or industrial personnel as applicable, as passengers, where the attained subdivision index A (defined in Pt D, Ch 11, Sec 3, [2.3.3]) is not to be less than:

- R, where the ship is carrying 240 persons or more
- 0,8 R, where the ship is carrying not more than 60 persons
- R value to be calculated by linear interpolation between 0,8 R and R, where the ship is carrying more than 60 (but not more than 240) persons.

where:

$$R = 1 - \frac{5000}{L_S + 2{,}5N + 15225}$$

$N = N_1 + 2\ N_2$

N_1 : Number of persons for whom lifeboats are provided

N_2 : Number of persons (including officers and crew) the ship is permitted to carry in excess of N_1

L_S : Subdivision length of the ship, as defined in Pt D, Ch 11, Sec 3, [2.1.4]

Where the conditions of service are such that compliance with Pt D, Ch 11, Sec 3, [2.3] on the basis of $N = N_1 + 2\ N_2$ is impracticable and where the Society considers that a suitably reduced degree of hazard exists, a lesser value of N may be taken but in no case less than $N = N_1 + N_2$.

1.2.2 However, for ships assigned the additional class notation **SDS** and additional service feature **SPxxx**, **SPxxx-capable**, **IPxxx** or **IPxxx-capable** with xxx less than 240 persons, Pt D, Ch 11, Sec 3, [2.3.12] is not applicable.

2 General

2.1 Approaches to be followed for damage stability investigation

2.1.1 General

The purpose of damage stability calculations is to assess the equilibrium position and reserve stability of the ship after flooding.

In order to assess the behaviour of the ship after damage, two approaches have been developed: the deterministic and the probabilistic, which are to be applied depending on the ship type.

The metacentric heights (GM), stability levers (GZ) and centre of gravity positions for judging the final conditions are to be calculated by the constant displacement (lost buoyancy) method.

2.1.2 Deterministic approach

The deterministic approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The consequence of such standard of damage is the creation of a group of damage cases, the number of which, as well as the number of compartments involved in each case, depend on the ship's dimensions and internal subdivision.

For each loading condition, each damage case is to be considered, and the applicable criteria are to be complied with.

Different deterministic methods in damage stability have been developed depending on ship type, on freeboard reduction, and on the kind of cargo carried.

The deterministic methods to be applied in the case of freeboard reduction are specified in Ch 3, App 4.

2.1.3 Probabilistic approach

The probabilistic concept takes the probability of survival after collision as a measure of ship safety in the damaged condition, referred to as the attained subdivision index A.

The damage stability calculations are performed for a limited number of draughts and relevant GM values in order to draw a minimum GM curve where the attained subdivision index A achieves the minimum required level of safety R. For cargo ships, each case of damage is not required to comply with the applicable criteria, but the attained index A, which is the sum of the contribution of all damage cases, is to be equal to or greater than R.

The probabilistic method developed on the basis of the above-mentioned concepts is detailed in Ch 3, App 3.

As a general rule, the probabilistic method applies to cargo ships of a length not less than 80 m, and for which no deterministic methods apply.

3 Documents to be submitted

3.1 Damage stability calculations

3.1.1 Damage stability documentation

For all ships to which damage stability requirements apply, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

- list of the characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged
- a table of openings in bulkheads, decks and side shell reporting all the information about:
  - identification of the opening
  - vertical, transverse and horizontal location
  - type of closure: sliding, hinged or rolling for doors
  - type of tightness: watertight, weathertight, semi-watertight or unprotected
  - operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable
  - foreseen utilization: open at sea, normally closed at sea, kept closed at sea
- list of all damage cases corresponding to the applicable requirements
- detailed results of damage stability calculations for all the loading conditions foreseen in the applicable requirements
- the limiting GM/KG curve, if foreseen in the applicable requirements
- capacity plan
- cross and down flooding devices and the calculations thereof according to Pt D, Ch 11, App 1 with information about diameter, valves, pipe lengths and coordinates of inlet/outlet
- watertight and weathertight door plan with pressure calculation
- side contour and wind profile
- pipes and damaged area when the destruction of these pipes results in progressive flooding.

3.1.2 Additional information for the probabilistic approach

In addition to the information listed in [3.1.1], the following is to be provided:

- *subdivision length L_S*
- *initial draughts and the corresponding GM-values*
- *required subdivision index R*
- *attained subdivision index A with a summary table for all contributions for all damaged zones.*
- *draught, trim, GM in damaged condition*
- *damage extension and definition of damage cases with probabilistic values p, v and r*
- *righting lever curve (including GZmax and range) with factor of survivability s*
- *critical weathertight and unprotected openings with their angle of immersion*
- *details of sub-compartments with amount of in-flooded water/lost buoyancy with their centres of gravity.*

3.1.3 Loading instrument

As a supplement to the approved damage stability documentation, a loading instrument, approved by the Society, may be used to facilitate the damage stability calculations mentioned in [3.1.1].

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 1, Sec 5, [3.7].

3.2 Permeabilities

3.2.1 Definition

The permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

3.2.2 General

The permeabilities relevant to the type of spaces which can be flooded depend on the applicable requirements. Such permeabilities are indicated in Part D or Part E for each type of ship.

3.3 Progressive flooding

3.3.1 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings or pipes as indicated in [3.3.2] and [3.3.3].

3.3.2 Openings

The openings may be listed in the following categories, depending on their means of closure:

- Unprotected

  Unprotected openings may lead to progressive flooding if they are situated within the range of the positive righting lever curve or if they are located below the waterline after damage (at any stage of flooding). Unprotected openings are openings which are not fitted with at least weathertight means of closure, or ventilators that have to remain open to supply air to the engine room, to the emergency generator room or to closed ro-ro and vehicle spaces for the effective operation of the ship.

- Weathertight

  Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.

  Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).

- Semi-watertight

  Internal openings fitted with semi-watertight means of closure are able to sustain a constant head of water corresponding to the immersion relevant to the highest waterline after damage at the equilibrium of the intermediate stages of flooding.

  Semi-watertight openings may lead to progressive flooding if they are located below the final equilibrium waterline after damage.

- Watertight

  Internal openings fitted with watertight means of closure are able to sustain a constant head of water corresponding to the distance between the lowest edge of this opening and the bulkhead/freeboard deck.

  Air pipe closing devices complying with Pt C, Ch 1, Sec 10, [9.1.6] may not be considered watertight, unless additional arrangements are fitted in order to demonstrate that such closing devices are effectively watertight.

  The pressure/vacuum valves (PV valves) currently installed on tankers do not theoretically provide complete watertightness.

  Manhole covers may be considered watertight provided the cover is fitted with bolts located such that the distance between their axes is less than five times the bolt's diameter.

  Access hatch covers leading to tanks may be considered watertight.

  Watertight openings do not lead to progressive flooding.

3.3.3 Pipes

Progressive flooding through pipes may occur when:

- the pipes and connected valves are located within the assumed damage, and no valves are fitted outside the damage
- the pipes, even if located outside the damage, satisfy all of the following conditions:
  - the pipe connects a damaged space to one or more spaces located outside the damage
  - the highest vertical position of the pipe is below the waterline, and
  - no valves are fitted.

The possibility of progressive flooding through ballast piping passing through the assumed extent of damage, where positive action valves are not fitted to the ballast system at the open ends of the pipes in the tanks served, is to be considered. Where remote control systems are fitted to ballast valves and these controls pass through the assumed extent of damage, then the effect of damage to the system is to be considered to ensure that the valves would remain closed in that event.

If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that the additional flooding of those compartments cannot lead to the capsizing or the sinking of the ship.

Requirements relative to the prevention of progressive flooding are specified in Pt C, Ch 1, Sec 10, [5.5].

3.4 Bottom damages

3.4.1 General

Ships which are not fitted with a double bottom as required by Ch 2, Sec 2, [3.1.2] or which are fitted with unusual bottom arrangements as defined in Ch 2, Sec 2, [3.1.6], are to comply with [3.4.2] and [3.4.3].

3.4.2 Bottom damage description

The assumed extent of damage is described in Tab 1.

If any damage of a lesser extent than the maximum damage specified in Tab 1 would result in a more severe condition, such damage should be considered.

Table 1 : Assumed extent of damage

	For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 $L^{2/3}$ or 14,5 m, whichever is less	1/3 $L^{2/3}$ or 14,5 m, whichever is less
Transverse extent	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	B/20, to be taken not less than 0,76 m and not more than 2 m	B/20, to be taken not less than 0,76 m and not more than 2 m

3.4.3 Stability criteria

Compliance with the requirements of Ch 2, Sec 2, [3.1.5] or Ch 2, Sec 2, [3.1.6] is to be achieved by demonstrating that s_i, when calculated in accordance with Ch 3, App 3, [1.6], is not less than 1 for all service conditions when subject to a bottom damage with an extent specified in [3.4.2] for any position in the affected part of the ship.

Flooding of such spaces shall not render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship.

4 Damage control documentation

4.1 General

4.1.1 Application

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmentation and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control, and is to be provided in the language or languages of the ship's officers. If the languages used in the preparation of the documentation are not English or French, a translation into one of these languages is to be included.

The use of a loading instrument performing damage stability calculations may be accepted as a supplement to the damage control documentation. This instrument is to be approved by the Society according to the requirements of Ch 1, Sec 5, [3.8].

The damage control plan is required for the following ships:

- ships carrying passengers
- cargo ships of 500 GT and over.

4.1.2 Application to ships assigned the additional service feature SPxxx, SPxxx-capable, IPxxx or IPxxx-capable

The damage control documentation of ships assigned the additional service feature **SPxxx**, **SPxxx-capable**, **IPxxx** or **IPxxx-capable** is to comply with Pt D, Ch 11, Sec 3, [2.3.14].

5 Specific interpretations

5.1 Assumed damage penetration in way of sponsons

5.1.1 *If sponsons are fitted, it is necessary to establish the maximum assumed damage penetration (B/5) to be used when deciding on the various damage cases. For this purpose, the breadth B in the way of such sponsons is to be measured to the outside of the sponsons.*

Clear of any suck sponsons, the breadth B is to be the midship breadth measured to the outside of the original shell. In other words, the assumed penetration of B/5 is the same as that which applied before the fitting of sponsons.

Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

The following conditions are to be met, as far as practicable:

- the weather conditions are to be favourable
- the ship should be moored in a quiet, sheltered area free from extraneous forces such as propeller wash from passing vessels, or sudden discharges from shore side pumps. The tide conditions and the trim of the ship during the test should be considered. Prior to the test, the depth of water should be measured and recorded in as many locations as are necessary to ensure that the ship will not contact the bottom. The specific gravity of water should be accurately recorded. The ship should be moored in a manner to allow unrestricted heeling. The access ramps should be removed. Power lines, hoses, etc., connected to shore should be at a minimum, and kept slack at all times
- the ship should be as upright as possible; with inclining weights in the initial position, up to one-half degree of list is acceptable. The actual trim and deflection of keel, if practical, should be considered in the hydrostatic data. In order to avoid excessive errors caused by significant changes in the water plane area during heeling, hydrostatic data for the actual trim and the maximum anticipated heeling angles should be checked beforehand
- cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured
- main and auxiliary boilers, pipes and any other system containing liquids are to be filled
- the bilge and the decks are to be thoroughly dried
- the anticipated liquid loading for the test should be included in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. The number of slack tanks should be kept to an absolute minimum. The viscosity of the fluid, the depth of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined
- the weights necessary for the inclination are to be already on board, located in the correct place. Their certificates are to be presented to the Surveyor witnessing the inclining test and are also to be included into the inclining test report.
- all work on board is to be suspended and crew or personnel not directly involved in the incline test are to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum
- decks should be free of water. Water trapped on deck may shift and pocket in a fashion similar to liquids in a tank. Any rain, snow or ice accumulated on the ship should be removed prior to the test.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.4] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast transfer may be carried out, when it is impractical to incline using solid weights and subject to requirement of [1.1.3].

Weights, such as porous concrete, that can absorb significant amounts of moisture should only be used if they are weighed just prior to the inclining test or if recent weight certificates are presented. Each weight should be marked with an identification number and its weight. For small ships, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control. In such cases, the weight of the drums should be verified in the presence of a surveyor of the Society using a recently calibrated scale.

Precautions should be taken to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then a structural analysis should be performed to determine if existing framing can support the weight.

Generally, the test weights should be positioned as far outboard as possible on the upper deck. The test weights should be on board and in place prior to the scheduled time of the inclining test.

1.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is deemed to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets

- tanks are to be directly opposite to maintain ship's trim
- specific gravity of ballast water is to be measured and recorded
- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control must be maintained during the test
- all inclining tanks must be manually sounded before and after each shift
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 15 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

1.1.5 Free surface and slack tanks

The number of slack tanks should normally be limited to one port/starboard pair or one centreline tank of the following:

- fresh water reserve feed tanks
- fuel/diesel oil storage tanks
- fuel/diesel oil day tanks
- lube oil tanks
- sanitary tanks
- potable water tanks.

To avoid pocketing, slack tanks are normally to be of regular (i.e. rectangular, trapezoidal, etc.) cross section and be 20% to 80% full if they are deep tanks and 40% to 60% full if they are double-bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the inclining test. If the trim changes as the ship is inclined, then consideration are also to be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the ship is inclined (such as bunker at low temperature), are to be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks is not to be used unless the tanks are heated to reduce viscosity. Communication between tanks are never to be allowed. Cross-connections, including those via manifolds, are to be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross connection closures.

1.1.6 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test.

1.1.7 Documentation

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- *lines plan*
- *hydrostatic curves or hydrostatic data*
- *general arrangement plan of decks, holds, inner bottoms, etc.*
- *capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc. When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, must be available*
- *tank sounding tables*
- *draught mark locations, and*
- *docking drawing with keel profile and draught mark corrections (if available).*

1.1.8 Determination of the displacement

The operations necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below, are to be carried out:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard reading) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/ draughts are to be retaken
- the specific gravity of the sea water is to be determined. Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary.

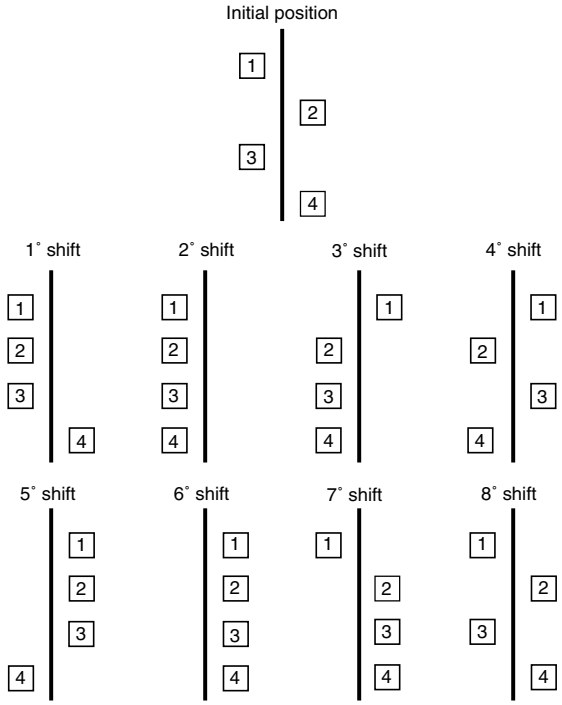
  A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve
- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of [1.1.1]
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the ship to the lightship condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.
- normally, the total value of missing weights is not to exceed 2% and surplus weights, excluding liquid ballast, not exceed 4% of the lightship displacement. For smaller vessels, higher percentages may be allowed.

1.1.9 The incline

The standard test generally employs eight distinct weight movements as shown in Fig 1.

Movement No.8, a recheck of the zero point, may be omitted if a straight line plot is achieved after movement No.7. If a straight line plot is achieved after the initial zero and six weight movements, the inclining test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did not yield acceptable plotted points should be repeated or explained.

Figure 1 : Weight shift procedure



The weights are to be transversely shifted, so as not to modify the ship's trim and vertical position of the centre of gravity.

After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig 2.

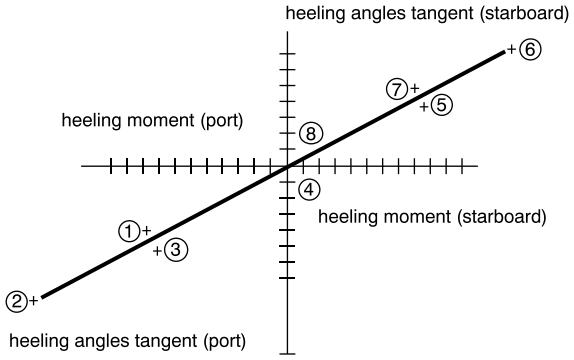
The plot is to be run during the test to ensure that acceptable data are being obtained.

The pendulum deflection is to be read when the ship has reached a final position after each weight shifting.

During the reading, no movements of personnel are allowed.

For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 2 : Graph of resultant tangents



Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain information to enable the Master to operate the ship in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the ship type and operation.

Additional information may be required depending on the type of the ship as specified in Part D and Part E.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- A general description of the ship, including:
  - the ship's name and the Society classification number
  - the ship type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the Flag, the port of registry, the international call sign and the IMO number
  - the moulded dimensions
  - the draught corresponding to the assigned summer load line, the draught corresponding to the assigned summer timber load line and the draught corresponding to the tropical load line, if applicable
  - the displacement corresponding to the above-mentioned draughts.
- Instructions on the use of the booklet.
- General arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, passenger, stores, accommodation, etc.).
- A sketch indicating the position of the draught marks referred to the ship's perpendiculars.
- Hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A reference relevant to the sea density, in t/m^3, is to be included as well as the draught measure (from keel or underkeel).
- Cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves.
- Tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank.
- Lightship data from the inclining test, as indicated in Ch 3, Sec 1, [2.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included.

  Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included.
- Standard loading conditions as indicated in [1.2] and examples for developing other acceptable loading conditions using the information contained in the booklet.
- Intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 2, [2] and Ch 3, Sec 2, [3] as well as possible additional criteria specified in Part D or Part E when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.3].
- Information on loading restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable.
- Information about openings (location, tightness, means of closure), pipes or other progressive flooding sources.
- Information concerning the use of any special cross-flooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable.
- Any other guidance deemed appropriate for the operation of the ship.
- A table of contents and index for each booklet.

1.2 Loading conditions

1.2.1 General

The standard loading conditions to be included in the trim and stability booklet are:

- lightship condition
- ship in ballast in the departure condition, without cargo but with full stores and fuel
- ship in ballast in the arrival condition, without cargo and with 10% stores and fuel remaining.

Further loading cases may be included when deemed necessary or useful.

The heel at the equilibrium of any sailing condition is not to be greater than 1°.

1.2.2 Ships carrying cargo on deck

In addition to the loading conditions indicated in [1.2.1] to [1.2.14], in the case of cargo carried on deck the following cases are to be considered:

- ship in the fully loaded departure condition having cargo homogeneously distributed in the holds and a cargo specified in extension and weight on deck, with full stores and fuel
- ship in the fully loaded arrival condition having cargo homogeneously distributed in holds and a cargo specified in extension and weight on deck, with 10% stores and fuel.

1.2.3 General cargo ships

In addition to the standard loading conditions reported in [1.2.1], the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.

For ships with service notation **general cargo ship** completed by the additional feature **nonhomload**, the following loading cases are also to be included in the trim and stability booklet:

- Ship in the departure condition, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables.

  Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded
- Same conditions as above, but with 10% stores and consumables.

1.2.4 Container ships

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **container ship** the following loading cases are to be included in the trim and stability booklet:

- ship with a number of containers having a weight corresponding to the maximum permissible weight for each container at the summer load waterline when loaded with full stores and consumables
- same loading condition as above, but with 10% stores and consumables

The vertical location of the centre of gravity for each container is generally to be taken at one half of the container height. Different locations of the vertical centre of gravity may be accepted in specific cases, if documented.

1.2.5 Bulk carriers, ore carriers and combination carriers

Dry cargo is intended to mean grain, as well as any other type of solid bulk cargo.

The term grain covers wheat, maize (corn), oats, rye, barley, rice, pulses, seeds and processed forms thereof, whose behaviour is similar to that of grain in its natural state.

The term solid bulk cargo covers any material, other than liquid or gas, consisting of a combination of particles, granules or any larger pieces of material, generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier ESP** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure conditions at the summer load waterline, with cargo homogeneously distributed throughout all cargo holds and with full stores and consumables, for at least three specific gravities, one of which is relevant to the complete filling of all cargo holds
- same conditions as above, but with 10% stores and consumables
- ship in the departure condition, with cargo holds not entirely filled, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables
- same conditions as above, but with 10% stores and consumables.

For ships with one of the service notations **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier ESP** and for ships with the service notation **bulk carrier** or **bulk carrier ESP** completed by the additional feature **nonhomload**, the following loading cases are also to be included in the trim and stability booklet:

- Ship in the departure conditions, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline, and with full stores and consumables.

  Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded.
- Same conditions as above, but with 10% stores and consumables.

1.2.6 Oil tankers and FLS tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 7, Sec 3, [2].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with the requirements in Pt D, Ch 7, Sec 3, [2] may be used.

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **oil tanker ESP** or **FLS tanker** the following loading cases are to be included in the trim and stability booklet:

- Ship in the fully loaded departure condition at the summer load waterline, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables.
- Same condition as above, but with 10% stores and consumables.
- Ship in the departure condition loaded with a cargo having a density in order to fill all cargo tanks, with full stores and consumables, but immersed at a draught less than the summer load waterline.
- Same condition as above, but with 10% stores and consumables.
- Ship in the fully loaded departure condition at the summer load waterline, with cargo tanks not entirely filled and with full stores and consumables.
- Same condition as above, but with 10% stores and consumables.
- Two loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables.

  When it is impossible to have segregations, these conditions are to be replaced by loading conditions with the same specific gravity and with slack cargo tanks.
- Same loading condition as above, but with 10% stores and consumables.
- For oil tankers having segregated ballast tanks as defined in Pt D, Ch 7, Sec 2, [2], the lightship condition with segregated ballast only is also to be included in the trim and stability booklet for examination.
- If a tropical load line is assigned in accordance with the International Load Line Convention:
  - ship in the fully loaded departure condition at the tropical load line, with cargo homogeneously distributed throughout all cargo tanks and see water density taken equal to 1,025 t/m^3
  - same loading condition as above, but with 10% store and consumables.

1.2.7 Chemical tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 8, Sec 2, [6].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with Pt D, Ch 8, Sec 2, [6] may be used.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **chemical tanker ESP** the following loading cases are to be included in the trim and stability booklet:

- Ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables.
- Same loading condition as above, but with 10% stores and consumables.
- Three loading conditions corresponding to different specific gravities with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables.
- Same loading conditions as above, but with 10% stores and consumables.
- Four loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables. Cargo segregation is intended to mean loading conditions with liquids of different specific gravities.

  When it is impossible to have segregations, these conditions are to be replaced by loading conditions corresponding to different specific gravities with slack cargo tanks.
- Same loading conditions as above, but with 10% stores and consumables.

  When it is impossible to have segregations, these conditions may be replaced by cases corresponding to different specific gravities with slack cargo tanks.

- If a tropical load line is assigned in accordance with the International Load Line Convention:
  - ship in the fully loaded departure condition at the tropical load line, with cargo homogeneously distributed throughout all cargo tanks and see water density taken equal to 1,025 t/m^3
  - same loading condition as above, but with 10% store and consumables.

1.2.8 Liquefied gas carriers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 9, Sec 2, [7.1.2].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with Pt D, Ch 9, Sec 2, [7.1.2] may be used.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **liquefied gas carrier** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.
- If a tropical load line is assigned in accordance with the International Load Line Convention:
  - ship in the fully loaded departure condition at the tropical load line, with cargo homogeneously distributed throughout all cargo tanks and see water density taken equal to 1,025 t/m^3
  - same loading condition as above, but with 10% store and consumables.

1.2.9 Passenger ships

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **passenger ship** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition with full stores and fuel and with the full number of passengers with their luggage
- ship in the fully loaded arrival condition, with the full number of passengers and their luggage but with only 10% stores and fuel remaining
- ship without cargo, but with full stores and fuel and the full number of passengers and their luggage
- ship in the same condition as above, but with only 10% stores and fuel remaining.

1.2.10 Dredgers

For ships with one of the service notations **dredger**, **hopper dredger**, **hopper unit**, **split hopper dredger** and **split hopper unit**, the loading conditions described in a) and b) are to replace the standard loading conditions defined in [1.2.1].

a) State of cargo: liquid
   - Ship loaded to the dredging draught with cargo considered as a liquid.
   - Hopper(s) fully loaded with a homogeneous cargo having density ρ_m, up to the spill out edge of the hopper coaming:

     $\rho_m = M_1 / V_1$

     M_1 : Mass of cargo, in t, in the hopper when loaded at the dredging draught

     V_1 : Volume, in m^3, of the hopper at the spill out edge of the hopper coaming.

     The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more critical than both 100% and 10%.
   - Hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1000, 1200, 1400, 1600, 1800 and 2000 kg/m^3.

     When the dredging draught cannot be reached due to the density of the cargo, the hopper is to be considered filled up to the spill out edge of the hopper coaming.

     The conditions of stores and fuel are to be the most conservative obtained from the stability calculations with the density ρ_m.

b) State of the cargo: solid
   - Ship loaded to the dredging draught with cargo considered as a solid.
   - Hopper(s) fully loaded with a homogeneous cargo having density ρ_m up to the spill out edge of the hopper coaming, as calculated in a).

     The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more conservative than both 100% and 10%.
   - Hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1400, 1600, 1800, 2000 and 2200 kg/m^3 if greater than ρ_m.

c) Without cargo:
- Ship without cargo in the hopper
- Hopper(s) in open communication to the sea (bottom doors open or split condition)
- Stores and consumables:
  - ship with 10% stores and consumables
  - ship with 100% stores and consumables.

1.2.11 Tugs and fire-fighting ships

In addition to the standard loading conditions defined in [1.2.1], for ships with one of the service notations **tug** and **fire-fighting**, the following loading cases are to be included in the trim and stability booklet:

- ship in the departure condition at the waterline corresponding to the maximum assigned immersion, with full stores, provisions and consumables
- same conditions as above, but with 10% stores and consumables
- same conditions as above, but with 50% stores and consumables.

1.2.12 Anchor handling vessels

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **anchor handling**, the following loading cases are to be included in the trim and stability booklet:

- service loading condition at the maximum draught at which anchor handling operations may occur with the heeling levers as defined in Pt E, Ch 2, Sec 3, [1.3] for the line tension the ship is capable of with a minimum of 67% stores and fuel, in which all the relevant stability criteria defined in Pt E, Ch 2, Sec 3 are met.
- service loading condition at the minimum draught at which anchor handling operations may occur with the heeling levers as defined in Pt E, Ch 2, Sec 3, [1.3] for the line tension the ship is capable of with 10% stores and fuel, in which all the relevant stability criteria as defined in Pt E, Ch 2, Sec 3 are met.

1.2.13 Supply vessels

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **supply** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition having under deck cargo, if any, and cargo specified by position and weight on deck, with full stores and fuel, corresponding to the worst service condition in which all the relevant stability criteria are met
- ship in the fully loaded arrival condition with cargo as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.14 Fishing vessels

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **fishing vessel** the following loading cases are to be included in the trim and stability booklet:

- departure conditions for the fishing grounds with full fuel stores, ice, fishing gear, etc.
- departure from the fishing grounds with full catch
- arrival at home port with 10% stores, fuel, etc. remaining and full catch
- arrival at home port with 10% stores, fuel, etc. and a minimum catch, which is normally to be 20% of the full catch but may be up to 40% if documented.

1.2.15 Oil recovery ships

For oil recovery ships, additional information to be included in stability booklet are specified in Pt E, Ch 5, Sec 2.

1.2.16 Lifting units

For lifting units, additional information to be included in stability booklet are specified in Pt E, Ch 8, Sec 3.

1.2.17 Semi-submersible cargo ships

For semi-submersible cargo ships, additional information to be included in stability booklet are specified in Pt E, Ch 9, Sec 3.

1.2.18 Ships assigned the additional service feature SPxxx or SPxxx-capable

In addition to the loading conditions specified in [1.2.1] to [1.2.17] as applicable, for ships assigned the additional service feature **SPxxx** or **SPxxx-capable**, the following cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, having cargo specified by position and weight, with full stores and fuel, and with the total number of persons on board, including crew, special personnel and passengers
- ship in the fully loaded arrival condition, with cargo and total number of persons as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.19 Ships assigned the additional service feature IPxxx or IPxxx-capable

In addition to the loading conditions specified in [1.2.1] to [1.2.17] as applicable, for ships assigned the additional service feature **IPxxx** or **IPxxx-capable**, the following cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, having cargo specified by position and weight, with full stores and fuel, and with the total number of persons on board, including crew, industrial personnel and passengers
- ship in the fully loaded arrival condition, with cargo and total number of persons as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.20 Ships assigned the additional service feature OCC (ships fitted with onboard carbon capture and storage system)

For ships assigned the additional service feature **OCC**, the arrival conditions specified in [1.2.1] and [1.2.2] to [1.2.18] as applicable, are to include the CO_2 storage tank filled at its maximum allowable filling level.

1.3 Stability curve calculation

1.3.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the ship are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

The calculations are to take into account the volume to the upper surface of the deck sheathing.

1.3.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures complying with Ch 1, Sec 3, [2.2] may be taken into account.

The second tier of similarly enclosed superstructures may also be taken into account.

Deckhouses on the freeboard deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in Ch 1, Sec 3, [2.2.2].

Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided.

Deckhouses, the doors of which do not comply with the requirements of Ch 11, Sec 5, [1.5.4], are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of Ch 11, Sec 9, [8.3] or Ch 11, Sec 10, as relevant.

Deckhouses on decks above the freeboard deck are not to be taken into account, but openings within them may be regarded as closed.

Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to show one or more steps, and in subsequent computations the flooded space are to be considered non-existent).

Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

1.3.3 Angle of flooding

In cases where the ship would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the ship is to be considered to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

Appendix 3 Probabilistic Damage Stability Method for Cargo Ships

1 Probabilistic damage stability method for cargo ships

1.1 Application

1.1.1 *The requirements included in this Appendix are to be applied to cargo ships over 80 m in length L_{LL} as defined in* Ch 1, Sec 3, [2.1.2], *but are not to be applied to those ships which are shown to comply with subdivision and damage stability regulations* already required in Part D or Part E.

Any reference hereinafter to regulations refers to the set of regulations contained in this Appendix.

The Society may, for a particular ship or group of ships, accept alternative arrangements, if it is satisfied that at least the same degree of safety as represented by these regulations is achieved.

This includes, for example, the following:

- ships constructed in accordance with a standard of damage stability with a set of damage criteria agreed by the Society
- ships of a multi-hull design, where the subdivision arrangements need to be evaluated against the basic principles of the probabilistic method since the regulations have been written specifically for mono-hulls.

1.1.2 The requirements of this Appendix are to be applied in conjunction with the explanatory notes as set out by the IMO Resolution MSC.429 (98)/Rev.2.

1.2 Definitions

1.2.1 Deepest subdivision draught

The deepest subdivision draught (d_S) is the waterline which corresponds to the summer load line draught of the ship.

1.2.2 Light service draught

Light service draught (d_L) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

1.2.3 Partial subdivision draught

The partial subdivision draught (d_P) is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

1.2.4 Subdivision length L_s

The subdivision length L_s is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

1.2.5 Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, the Society may define the limits of the machinery spaces.

1.2.6 Other definitions

Mid-length is the mid point of the subdivision length of the ship.

Aft terminal is the aft limit of the subdivision length.

Forward terminal is the forward limit of the subdivision length.

Breadth B is the greatest moulded breadth, in m, of the ship at or below the deepest subdivision draught.

Draught d is the vertical distance, in m, from the moulded baseline at mid-length to the waterline in question.

Permeability μ of a space is the proportion of the immersed volume of that space which can be occupied by water.

Note 1: In determining the permeability of a space, the volume of a space is to be taken as the moulded volume, i.e. the immersed volume of a space shall be the underwater moulded volume of that space multiplied by the permeability.

1.3 Required subdivision index R

1.3.1 *These regulations are intended to provide ships with a minimum standard of subdivision.*

The degree of subdivision to be provided is to be determined by the required subdivision index R, as follows:

- *for ships greater than 100 m in length L_S:*

$$R = 1 - \frac{128}{L_S + 152}$$

- *for ships of 80 m in length L_S and upwards, but not greater than 100 m in length L_S:*

$$R = 1 - \frac{1}{\left(1 + \frac{L_S}{100}\frac{R_0}{(1 - R_0)}\right)}$$

where R_0 is the value of R as calculated in accordance with the formula given for ships greater than 100 m in length L_S.

1.4 Attained subdivision index A

1.4.1 *The attained subdivision index A is obtained by the summation of the partial indices A_S, A_P and A_L (weighed as shown), calculated for the draughts d_S, d_P and d_L defined in [1.2.1], [1.2.2] and [1.2.3], in accordance with the following formula:*

$A = 0,4\ A_S + 0,4\ A_P + 0,2\ A_L$

The attained subdivision index A is not to be less than the required subdivision index R. In addition, the partial indices A_S, A_P and A_L are not to be less than 0,5 R.

1.4.2 *Each partial index is a summation of contributions from all damage cases taken in consideration, using the following formula:*

$A = \Sigma\ p_i\ s_i$

where:

i : *Represents each compartment or group of compartments under consideration*

p_i : *Accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision, as defined in [1.5]*

s_i : *Accounts for the probability of survival after flooding the compartment or group of compartments under consideration, and includes the effects of any horizontal subdivision, as defined in [1.6].*

1.4.3 *As a minimum, the calculation of A is to be carried out at the level trim for the deepest subdivision draught d_s and the partial subdivision draught d_p. The estimated service trim may be used for the light service draught d_l. If, in any anticipated service condition within the draught range from d_s to d_l, the trim variation in comparison with the calculated trim is greater than 0,005 L, one or more additional calculations of A are to be performed for the same draughts but including sufficient trims to ensure that, for all intended service conditions, the difference in trim in comparison with the reference trim used for one calculation will be not more than 0,005L. Each additional calculation of A is to comply with [1.3].*

When determining the positive righting lever (GZ) of the residual stability curve in the intermediate and final equilibrium stages of flooding, the displacement used should be that of the intact loading condition. All calculations should be done with the ship freely trimming.

The summation indicated by the formula in [1.4.2] is to be taken over the ship's subdivision length (L_s) for all cases of flooding in which a single compartment or two or more adjacent compartments are involved. In the case of unsymmetrical arrangements, the calculated A value is to be the mean value obtained from calculations involving both sides. Alternatively, it is to be taken as that corresponding to the side which evidently gives the least favourable result.

1.4.4 *Wherever wing compartments are fitted, contribution to the summation indicated by the formula is to be taken for all cases of flooding in which wing compartments are involved. Additionally, cases of simultaneous flooding of a wing compartment or group of compartments and the adjacent inboard compartment or group of compartments, but excluding damage of transverse extent greater than one half of the ship breadth B, may be added. For the purpose of this regulation, transverse extent is measured inboard from ship's side, at right angle to the centreline at the level of the deepest subdivision draught.*

1.4.5 *In the flooding calculations carried out according to the regulations, only one breach of the hull and only one free surface need to be assumed. The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent of damage gives a more severe result, such extent is to be assumed.*

1.4.6 *If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.*

1.5 Calculation of factor p_i

1.5.1 *The factor p_i for a compartment or group of compartments is to be calculated in accordance with [1.5.2] to [1.5.6] using the following notations:*

j : *The aftmost damage zone number involved in the damage starting with no.1 at the stern*

n : *The number of adjacent damage zones involved in the damage*

k : *The number of a particular longitudinal bulkhead as barrier for transverse penetration in a damage zone, counted from shell towards the centreline. The shell has k = 0*

x_1 : *The distance from the aft terminal of L_s to the aft end of the zone in question*

x_2 : *The distance from the aft terminal of L_s to the forward end of the zone in question*

b : *The mean transverse distance in metres measured at right angles to the centreline at the deepest subdivision draught between the shell and an assumed vertical plane extended between the longitudinal limits used in calculating the factor p_i and which is a tangent to, or common with, all or part of the outermost portion of the longitudinal bulkhead under consideration. This vertical plane shall be so orientated that the mean transverse distance to the shell is a maximum, but not more than twice the least distance between the plane and the shell. If the upper part of a longitudinal bulkhead is below the deepest subdivision draught, the vertical plane used for the determination of b is assumed to extend upwards to the deepest subdivision waterline. In any case, b is not to be taken greater than B/2.*

If the damage involves a single zone only:

$$p_i = p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})]$$

If the damage involves two adjacent zones:

$$p_i = p(x_{1(j)}, x_{2(j+1)}) \cdot [r(x_{1(j)}, x_{2(j+1)}, b_k) - r(x_{1(j)}, x_{2(j+1)}, b_{(k-1)})] - p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})] - p(x_{1(j+1)}, x_{2(j+1)}) \cdot [r(x_{1(j+1)}, x_{2(j+1)}, b_k) - r(x_{1(j+1)}, x_{2(j+1)}, b_{(k-1)})]$$

If the damage involves three or more adjacent zones:

$$p_i = p(x_{1(j)}, x_{2(j+n-1)}) \cdot [r(x_{1(j)}, x_{2(j+n-1)}, b_k) - r(x_{1(j)}, x_{2(j+n-1)}, b_{(k-1)})] - p(x_{1(j)}, x_{2(j+n-2)}) \cdot [r(x_{1(j)}, x_{2(j+n-2)}, b_k) - r(x_{1(j)}, x_{2(j+n-2)}, b_{(k-1)})] - p(x_{1(j+1)}, x_{2(j+n-1)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-1)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-1)}, b_{(k-1)})] + p(x_{1(j+1)}, x_{2(j+n-2)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-2)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-2)}, b_{(k-1)})]$$

and where $r(x_1, x_2, b_0) = 0$

1.5.2 *The factor $p(x_1, x_2)$ is to be calculated according to the formulae given in [1.5.3] to [1.5.5], with:*

J_{max} : *Overall normalized max damage length*

$J_{max} = 10 / 33$

J_{kn} : *Knuckle point in the distribution*

$J_{kn} = 5 / 33$

p_k : *Cumulative probability at J_{kn}*

$p_k = 11 / 12$

ℓ_{max} : *Maximum absolute damage length*

$\ell_{max} = 60$ m

L^* : *Length where normalized distribution ends*

$L^* = 260$ m

b_0 : *Probability density at J = 0*

$$b_0 = 2\left(\frac{p_k}{J_{kn}} - \frac{1 - p_k}{J_{max} - J_{kn}}\right)$$

- *when $L_s \leq L^*$:*

$$J_m = \min\left\{J_{max}, \frac{\ell_{max}}{L_s}\right\}$$

$$J_k = \frac{J_m}{2} + \frac{1 - \sqrt{1 + (1 - 2p_k) b_0 \cdot J_m + \frac{1}{4} {b_0}^2 \cdot {J_m}^2}}{b_0}$$

$$b_{12} = b_0$$

- *when $L_s > L^*$:*

$$J_m^* = \min\left\{J_{max}, \frac{\ell_{max}}{L^*}\right\}$$

$$J_k^* = \frac{J_m^*}{2} + \frac{1 - \sqrt{1 + (1 - 2p_k)b_0 \cdot J_m^* + \frac{1}{4}b_0^2 \cdot J_m^{*2}}}{b_0}$$

$$J_m = \frac{J_m^* \cdot L^*}{L_s}$$

$$J_k = \frac{J_k^* \cdot L^*}{L_s}$$

$$b_{12} = 2\left(\frac{p_k}{J_k} - \frac{1 - p_k}{J_m - J_k}\right)$$

$$b_{11} = 4\frac{1 - p_k}{(J_m - J_k)J_k} - 2\frac{p_k}{J_k^2}$$

$$b_{21} = -2\frac{1 - p_k}{(J_m - J_k)^2}$$

$$b_{22} = -b_{21} \cdot J_m$$

J : *Non-dimensional damage length:*

$$J = \frac{x_2 - x_1}{L_s}$$

J_n : *Normalized length of a compartment or group of compartments, to be taken as the lesser of J and J_m.*

1.5.3 *Where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:*

- *$J \le J_k$:*

$$p(x_1, x_2) = p_1 = \frac{1}{6}J^2(b_{11} \cdot J + 3b_{12})$$

- *$J > J_k$:*

$$p(x_1, x_2) = p_2 = -\frac{b_{11} \cdot J_k^3}{3} + \frac{(b_{11} \cdot J - b_{12})J_k^2}{2} + b_{12} \cdot J \cdot J_k - \frac{b_{21}(J_n^3 - J_k^3)}{3} + \frac{(b_{21} \cdot J - b_{22})(J_n^2 - J_k^2)}{2} + b_{22} \cdot J(J_n - J_k)$$

1.5.4 *Where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:*

- *$J \le J_k$:*

$$p(x_1, x_2) = \frac{1}{2}(p_1 + J)$$

- *$J > J_k$:*

$$p(x_1, x_2) = \frac{1}{2}(p_2 + J)$$

1.5.5 *Where the compartment or group of compartments considered extends over the entire subdivision length (L_s):*

$$p(x_1, x_2) = 1$$

1.5.6 *The factor $r(x_1, x_2, b)$ is to be determined by the following formula:*

$$r(x_1, x_2, b) = 1 - (1 - C) \cdot \left[1 - \frac{G}{p(x_1, x_2)}\right]$$

where:

$$C = 12J_b(-45J_b + 4)$$

with $J_b = b / (15\ B)$

- *where the compartment or group of compartments considered extends over the entire subdivision length (L_s):*

$$G = G_1 = \frac{1}{2}b_{11} \cdot J_b^2 + b_{12} \cdot J_b$$

- *where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:*

$$G = G_2 = -\frac{1}{3}b_{11} \cdot J_0^3 + \frac{1}{2}(b_{11} \cdot J - b_{12})J_0^2 + b_{12} \cdot J \cdot J_0$$

with $J_0 = min\ (J, J_b)$

- *where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:*

$$G = \frac{1}{2}(G_2 + G_1 \cdot J)$$

1.6 Calculation of factor s_i

1.6.1 *The factor s_i is to be determined for each case of assumed flooding involving a compartment or group of compartments according to the requirement indicated in [1.6.2] to [1.6.12] and the following notations:*

θ_e : *Equilibrium heel angle in any stage of flooding, in degrees*

θ_v : *Angle, in any stage of flooding, where the righting lever becomes negative, or the angle at which an opening incapable of being closed weathertight becomes submerged*

GZ_{max} : *Maximum positive righting lever, in metres, up to the angle θ_v*

Range : *Range of positive righting levers, in degrees, measured from the angle θ_e. The positive range is to be taken up to the angle θ_v*

Flooding stage is any discrete step during the flooding process, including the stage before equalization (if any) until final equilibrium has been reached.

1.6.2 *The factor s_i, for any damage case at any initial loading condition, d_i, shall be obtained from the formula:*

$$s_i = \min[s_{intermediate,i}, s_{final,i}]$$

where:

$s_{intermediate,i}$: *The probability to survive all intermediate flooding stages until the final equilibrium stage, calculated in accordance with [1.6.3]*

$s_{final,i}$: *The probability to survive in the final equilibrium stage of flooding, calculated in accordance with [1.6.4].*

1.6.3 Calculation of $s_{intermediate}$

- For cargo ships fitted with cross-flooding devices, the factor $s_{intermediate,i}$ is to be taken as the least of the s-factors obtained from all flooding stages including the stage before equalization, if any, and is to be calculated as follows:

$$s_{intermediate,i} = \left(\frac{GZ_{max}}{0,05} \cdot \frac{Range}{7}\right)^{\frac{1}{4}}$$

where GZ_{max} is not to be taken as more than 0,05 m and Range as not more than 7°.

$s_{intermediate} = 0$, if the intermediate heel angle exceeds 30°.

- For cargo ships not fitted with cross-flooding devices the factor $s_{intermediate,i}$ is taken as unity, except if the Society considers that the stability in intermediate stages of flooding may be insufficient. It should require further investigation thereof.

Where cross-flooding fittings are required, the time for equalization is not to exceed 10 min. The time for equalization is to be calculated in accordance with Pt D, Ch 11, App 1.

1.6.4 Calculation of s_{final}

The factor $s_{final,i}$ is to be obtained from the formula:

$$s_{final,i} = K\left(\frac{GZ_{max}}{TGZ_{max}} \cdot \frac{Range}{TRange}\right)^{\frac{1}{4}}$$

where:

GZ_{max} is not to be taken as more than TGZ_{max}

Range is not to be taken as more than TRange.

TGZ_{max} = 0,12 m

TRange = 16°

K is to be taken equal to:

- $K = 1$ if $\theta_e \leq \theta_{min}$
- $K = 0$ if $\theta_e \geq \theta_{max}$
- $K = \sqrt{\frac{\theta_{max} - \theta_e}{\theta_{max} - \theta_{min}}}$ otherwise

θ_{min} is equal to 25°

θ_{max} is equal to 30°.

1.6.5 Cases where s_i is taken as zero

a) The factor s_i is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:

- *the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor s_i Such openings are to include air-pipes, ventilators and openings that are closed by means of weathertight doors or hatch covers, but the openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, hinged watertight access doors with open/closed indication locally and at the navigation bridge, of the quick-acting or single-action type that are normally closed at sea, hinged watertight doors that are permanently closed at sea, side scuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.*
- *any part of the bulkhead deck considered a horizontal evacuation route.*

b) The factor s_i is to be taken as zero if, taking into account sinkage, heel and trim, any of the following occur in any intermediate stage or in the final stage of flooding:

- *immersion of any vertical escape hatch in the freeboard deck of cargo ships intended for compliance with the applicable requirements of Pt C, Ch 4, Sec 8*
- *any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the freeboard deck of cargo ships become inaccessible or inoperable*
- *immersion of any part of piping or ventilation ducts located within the assumed extent of damage and carried through a watertight boundary if this can lead to the progressive flooding of compartment not assumed as flooded.*

1.6.6 *The ship is to be so designed that s_i calculated in accordance with [1.6.1] will not be less than 1 at the deepest subdivision draught loading condition, level trim or any forward trim loading conditions, if any part of the ship forward of the collision bulkhead is flooded without vertical limits.*

1.6.7 *Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted are, where practicable, to be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the freeboard deck of cargo ships. These fittings, together with their controls, are to be acceptable to the Society. Suitable information concerning the use of equalization devices are to be supplied to the master of the ship.*

1.6.8 *Tanks and compartments taking part in such equalization are to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.*

1.6.9 *Where horizontal watertight boundaries are fitted above the waterline under consideration, the s-value calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in [1.6.2] by the reduction factor v_m according to [1.6.10], which represents the probability that the spaces above the horizontal subdivision will not be flooded.*

1.6.10 *The factor v_m is to be obtained from the following formula:*

$$v_m = v(H_{j,n,m}, d) - v(H_{j,n,m-1}, d)$$

where:

$H_{j,n,m}$: *Least height above the baseline, in metres, within the longitudinal range of $x_1(j)...x_2(j+n-1)$ of the m^{th} horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration*

$H_{j,n,m-1}$: *Least height above the baseline, in metres, within the longitudinal range of $x_1(j)...x_2(j+n-1)$ of the $(m-1)^{th}$ horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration*

j : *The aft terminal of the damaged compartments under consideration*

m : *Each horizontal boundary counted upwards from the waterline under consideration*

d : *Draught in question, as defined in [1.2]*

x_1, x_2 : *Terminals of the compartment or group of compartments considered in [1.5.1].*

1.6.11 *The factors $\nu(H_{j,n,m}, d)$ and $\nu(H_{j,n,m-1}, d)$ are to be obtained from the following formulae:*

- *if $(H_m - d) \leq 7,8$ m:*

$$\nu(H, d) = 0,8\frac{(H-d)}{7,8}$$

- *in all other cases:*

$$\nu(H, d) = 0,8 + 0,2\left[\frac{(H-d)-7,8}{4,7}\right]$$

where:

- *$\nu(H_{j,n,m}, d)$ is to be taken as 1, if H_m coincides with the uppermost watertight boundary of the ship within the range $(x_{1(j)} \ldots x_{2(j+n-1)})$*
- *$\nu(H_{j,n,0}, d)$ is to be taken as 0.*

In no case is ν_m to be taken as less than zero or more than 1.

1.6.12 *In general, each contribution dA to the index A in the case of horizontal subdivisions is obtained from the following formula:*

$$dA = p_i \cdot [\nu_1 \cdot s_{min1} + (\nu_2 - \nu_1) \cdot s_{min2} + \ldots + (1 - \nu_{m-1}) \cdot s_{min\,m}]$$

where:

ν_m : *The ν-value calculated in accordance with [1.6.10] and [1.6.11]*

s_{min} : *The least s-factor for all combinations of damages obtained when the assumed damage extends from the assumed damage height H_m downwards.*

1.7 Permeability

1.7.1 *For the purpose of the subdivision and damage stability calculations* reported in this Appendix*, the permeability of each space or part of a space is to be as per Tab 1.*

Table 1 : Permeability

Spaces	Permeability
Appropriated to stores	0,60
Occupied by accommodations	0,95
Occupied by machinery	0,85
Void spaces	0,95
Intended for liquids	0 or 0,95 **(1)**
(1) whichever results in the more severe requirements	

1.7.2 *For the purpose of the subdivision and damage stability calculations reported in this Appendix, the permeability of each cargo compartment is to be as per Tab 2.*

Other figures for permeability may be used if substantiated by calculations.

Table 2 : Permeability of cargo compartments

Spaces	Permeability at draught		
	d_S	d_P	d_L
Dry cargo spaces	0,70	0,80	0,95
Container spaces	0,70	0,80	0,95
Ro-ro spaces	0,90	0,90	0,95
Cargo liquids	0,70	0,80	0,95

1.8 Stability information

1.8.1 *The master is to be supplied with such information satisfactory to the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information is to be furnished to the Society.*

1.8.2 Information to be submitted

The information is to include:

- *curves or tables of minimum operational metacentric height (GM) versus draught which assures compliance with the relevant intact and damage stability requirements, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity (KG) versus draught, or with the equivalents of either of these curves*
- *instructions concerning the operation of cross-flooding arrangements, and*
- *all other data and aids which might be necessary to maintain the required intact stability and stability after damage.*

1.8.3 *The stability information is to show the influence of various trims in cases where the operational trim range exceeds ± 0,5% of L_s.*

1.8.4 *For ships which have to fulfil the stability requirements of this Annex, information referred to in [1.8.2] is determined from considerations related to the subdivision index, in the following manner: Minimum required GM (or maximum permissible vertical position of centre of gravity KG) for the three draughts d_S, d_P and d_L are equal to the GM (or KG values) of corresponding loading cases used for the calculation of survival factor s_i. For intermediate draughts, values to be used are to be obtained by linear interpolation applied to the GM value only between the deepest subdivision draught and the partial subdivision draught and between the partial load line and the light service draught respectively. Intact stability criteria are also to be taken into account by retaining for each draught the maximum among minimum required GM values or the minimum of maximum permissible KG values for both criteria. If the subdivision index is calculated for different trims, several required GM curves are to be established in the same way.*

1.8.5 *When curves or tables of minimum operational metacentric height (GM) versus draught are not appropriate, the master is to ensure that the operating condition does not deviate from a studied loading condition, or verify by calculation that the stability criteria are satisfied for this loading condition.*

Appendix 4 Damage Stability Calculation for Ships Assigned with a Reduced Freeboard

1 Application

1.1 General

1.1.1 The requirements of this Appendix apply to:

- Type A ships having a length greater than 150 m, and
- Type B-60 ships and Type B-100 ships having a length greater than 100 m.

Any reference hereafter to regulations refers to the set of regulations contained in this Appendix.

2 Initial loading condition

2.1 Initial condition of loading

2.1.1 *The initial condition of loading before flooding is to be determined* according to [2.1.2] and [2.1.3].

2.1.2 *The ship is loaded to its summer load waterline on an imaginary even keel.*

2.1.3 *When calculating the vertical centre of gravity, the following principles apply:*

a) Homogeneous cargo is carried.

b) All cargo compartments, except those referred to under c), but including compartments intended to be partially filled, are to be considered fully loaded except that in the case of fluid cargoes each compartment is to be treated as 98 per cent full.

c) If the ship is intended to operate at its summer load waterline with empty compartments, such compartments are to be considered empty provided the height of the centre of gravity so calculated is not less than as calculated under b).

d) Fifty per cent of the individual total capacity of all tanks and spaces fitted to contain consumable liquids and stores is allowed for. It is to be assumed that for each type of liquid, at least one transverse pair or a single centre line tank has maximum free surface, and the tank or combination of tanks to be taken into account are to be those where the effect of free surfaces is the greatest; in each tank the centre of gravity of the contents is to be taken at the centre of volume of the tank. The remaining tanks are to be assumed either completely empty or completely filled, and the distribution of consumable liquids between these tanks is to be effected so as to obtain the greatest possible height above the keel for the centre of gravity.

e) At an angle of heel of not more than 5 degrees in each compartment containing liquids, as prescribed in b) except that in the case of compartments containing consumable fluids, as prescribed in d), the maximum free surface effect is to be taken into account.

Alternatively, the actual free surface effects may be used, provided the methods of calculation are acceptable to the Society.

f) Weights are to be calculated on the basis of Tab 1.

Table 1 : Specific gravities

Weight item	Specific gravity, in t/m^3
Salt water	1,025
Fresh water	1,000
Fuel oil	0,950
Diesel oil	0,900
Lubricating oil	0,900

3 Damage assumptions

3.1 Damage dimension

3.1.1 *The principles* indicated in [3.1.2] to [3.1.5] *regarding the character of the assumed damage apply.*

3.1.2 *The vertical extent of damage in all cases is assumed to be from the base line upwards without limit.*

3.1.3 *The transverse extent of damage is equal to B/5 or 11,5 metres, whichever is the lesser, measured inboard from the side of the ship perpendicularly to the centre line at the level of the summer load waterline.*

3.1.4 *If damage of a lesser extent than specified in* [3.1.2] and [3.1.3] *results in a more severe condition, such lesser extent is to be assumed.*

3.1.5 *Except where otherwise required in [3.4.3], the flooding is to be confined to a single compartment between adjacent transverse bulkheads provided the inner longitudinal boundary of the compartment is not in a position within the transverse extent of assumed damage. Transverse boundary bulkheads of wing tanks, which do not extend over the full breadth of the ship are to be assumed not to be damaged, provided they extend beyond the transverse extent of assumed damage prescribed in [3.1.3].*

3.2 Steps and recesses

3.2.1 *If in a transverse bulkhead there are steps or recesses of not more than 3,05 metres in length located within the transverse extent of assumed damage as defined in [3.1.3], such transverse bulkhead may be considered intact and the adjacent compartment may be floodable singly. If, however, within the transverse extent of assumed damage there is a step or recess of more than 3,05 metres in length in a transverse bulkhead, the two compartments adjacent to this bulkhead are to be considered as flooded. The step formed by the after peak bulkhead and the after peak tank top is not to be regarded as a step for the purpose of this regulation.*

3.2.2 *Where a main transverse bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3,05 metres, the double bottom or side tanks adjacent to the stepped portion of the main transverse bulkhead are to be considered as flooded simultaneously. If this side tank has openings into one or several holds, such as grain feeding holes, such hold or holds are to be considered as flooded simultaneously. Similarly, in a ship designed for the carriage of fluid cargoes, if a side tank has openings into adjacent compartments, such adjacent compartments are to be considered as empty and flooded simultaneously. This provision is applicable even where such openings are fitted with closing appliances, except in the case of sluice valves fitted in bulkheads between tanks and where the valves are controlled from the deck. Manhole covers with closely spaced bolts are considered equivalent to the unpierced bulkhead except in the case of openings in topside tanks making the topside tanks common to the holds.*

3.2.3 Where a transverse bulkhead forming the forward or aft limit of a wing tank or double bottom tank is not in line with the main transverse bulkhead of the adjacent inboard compartment, it is considered to form a step or recess in the main transverse bulkhead.

Such a step or recess may be assumed not to be damaged provided that, either:

- the longitudinal extent of the step or recess, measured from the plan of the main transverse bulkhead, is not more than 3,05 metres, or
- any longitudinal surface forming the step or recess is located inboard of the assumed damage.

3.2.4 Where, otherwise, the transverse and longitudinal bulkheads bounding a main inboard compartment are entirely inboard of the assumed damage position, damage is assumed to occur between the transverse bulkheads and the adjacent wing compartment. Any step or recess in such wing tank is to be treated as indicated above.

Examples are shown in Fig 1 to Fig 2:

- Fig 1: refer to [3.2.2]
- Fig 2: refer to [3.2.1] and [3.2.2].

Figure 1 : Step and recesses - Examples 1 and 2

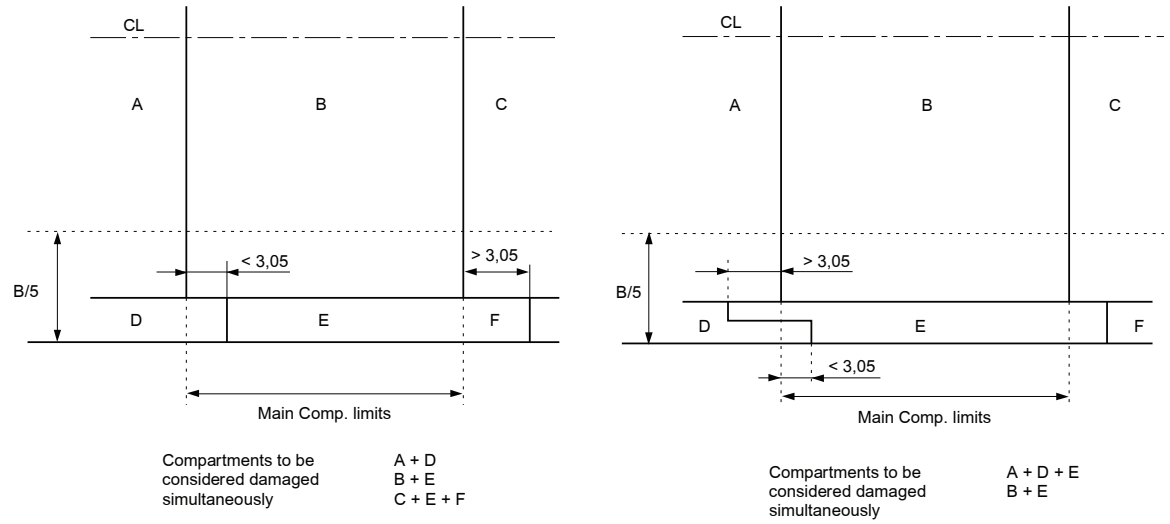
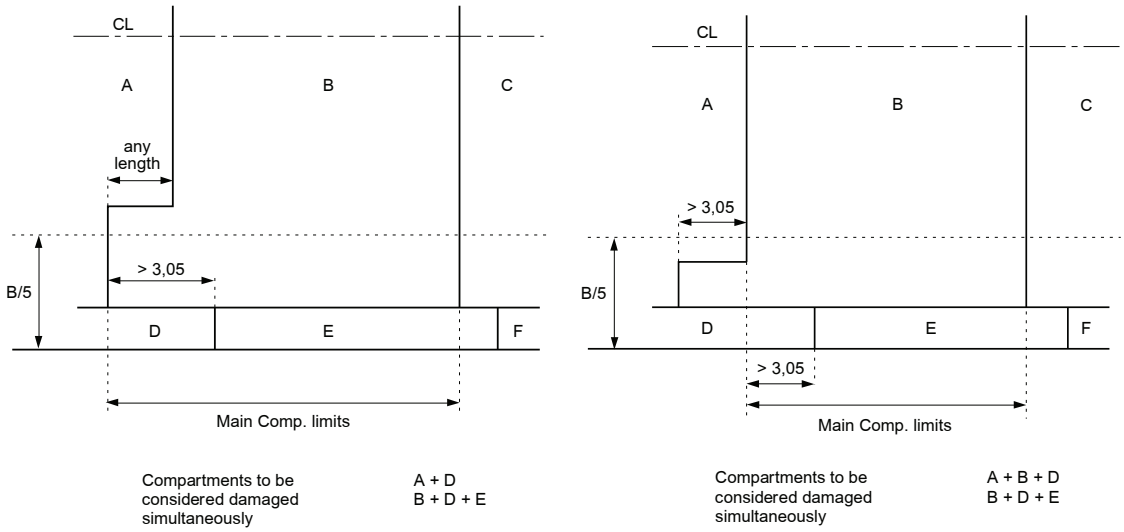


Figure 2 : Step and recesses - Examples 3 and 4



3.3 Transverse bulkhead spacing

3.3.1 *Where the flooding of any two adjacent fore and aft compartments is envisaged, main transverse watertight bulkheads are to be spaced at least* $1/3(L)^{2/3}$ *or 14,5 metres, whichever is the lesser, in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads are to be assumed as non-existent in order to achieve the minimum spacing between bulkheads.*

3.4 Damage assumption

3.4.1 *A Type A ship, if over 150 metres in length to which a freeboard less than Type B has been assigned, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. In such a ship, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85.* See Tab 2.

3.4.2 *A Type B-60 ship, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85.* See Tab 2.

3.4.3 *A Type B-100 ship, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. Furthermore all the requirements stated in [4.1] are to be complied with, provided that throughout the length of the ship any one transverse bulkhead will be assumed to be damaged, such that two adjacent fore and aft compartments are to be flooded simultaneously, except that such damage will not apply to the boundary bulkheads of a machinery space. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85.* See Tab 2.

Table 2 : Damage assumption

Type	L, in m	Standard of flooding **(1)**
A	≥ 150	one compartment
B - 60	≥ 100	one compartment
B -100	≥ 100	two adjacent compartments (exemption for machinery space which is to be flooded alone)
(1) except where otherwise required by [4.2].		

3.5 Condition of equilibrium

3.5.1 *The condition of equilibrium after flooding is to be regarded as satisfactory* according to [3.5.2] and [3.5.3].

3.5.2 *The final waterline after flooding, taking into account sinkage, heel and trim, is below the lower edge of any opening through which progressive downflooding may take place. Such openings are to include air pipes, ventilators and openings that are closed by means of weathertight doors or hatch covers, unless closed by watertight gasketed covers of steel or equivalent material, and may exclude those openings closed by means of manhole covers and flush scuttles, cargo hatch covers, remotely operated sliding watertight doors, hinged watertight access doors with open/closed indication locally and at the navigation*

bridge, of the quick-acting or single-action type that are normally closed at sea, hinged watertight doors that are permanently closed at sea, and side scuttles of the non-opening type. However, in the case of doors separating a main machinery space from a steering gear compartment, watertight doors may be of a hinged, quick acting type kept closed at sea, whilst not in use, provided also that the lower sill of such doors is above the summer load waterline.

3.5.3 *If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in [3.1.3], arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.*

3.6 Damage stability criteria

3.6.1 *The angle of heel due to unsymmetrical flooding does not exceed 15 degrees. If no part of the deck is immersed, an angle of heel of up to 17 degrees may be accepted.*

3.6.2 *The metacentric height in the flooded condition is positive.*

3.6.3 *When any part of the deck outside the compartment assumed flooded in a particular case of damage is immersed, or in any case where the margin of stability in the flooded condition may be considered doubtful, the residual stability is to be investigated. It may be regarded as sufficient if the righting lever curve has a minimum range of 20 degrees beyond the position of equilibrium with a maximum righting lever of at least 0,1 metre within this range. The area under the righting lever curve within this range is to be not less than 0,0175 metre-radians. The Society is to give consideration to the potential hazard presented by protected or unprotected openings which may become temporarily immersed within the range of residual stability.*

3.6.4 *The Society is satisfied that the stability is sufficient during intermediate stages of flooding.* In this regard, the Society will apply the same criteria relevant to the final stage, also during the intermediate stages of flooding.

4 Requirements for Type B-60 and B-100 ships

4.1 Requirements for Type B-60 ships

4.1.1 *Any Type B ships of over 100 metres, having hatchways closed by weathertight covers as specified in [4.3], may be assigned freeboards less than those required for Type B, provided that, in relation to the amount of reduction granted, the* requirements in [4.1.2] to [4.1.4] are considered satisfactory by the Society.

In addition, the requirements stated in [3.4.2] are to be complied with.

4.1.2 *The measures provided for the protection of the crew are to be adequate.*

4.1.3 *The freeing arrangements are* to comply with the provisions of Ch 11, Sec 12.

4.1.4 *The covers in positions 1 and 2 comply with the provisions of [4.3] and have strength complying with Ch 11, Sec 9, special care being given to their sealing and securing arrangements.*

4.2 Requirements for Type B-100 ships

4.2.1 In addition to the requirements specified in [4.1], not taking into account the prescription stated in [3.4.2], the requirements in [4.2.2] to [4.2.4] are to be complied with.

In addition, the provisions of [3.4.3] are to be complied with.

4.2.2 Machinery casings

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of [4.4] may, however, be permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

4.2.3 Gangway and access

An efficiently constructed fore and aft permanent gangway of sufficient strength is to be fitted on Type A ships at the level of the superstructure deck between the poop and the midship bridge or deckhouse where fitted, or equivalent means of access is to be provided to carry out the purpose of the gangway, such as passages below deck. Elsewhere, and on Type A ships without a midship bridge, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

Safe and satisfactory access from the gangway level is to be available between separate crew accommodation spaces and also between crew accommodation spaces and the machinery space.

4.2.4 Freeing arrangements

Type A ships with bulwarks are to be provided with open rails fitted for at least half the length of the exposed parts of the weather deck or other effective freeing arrangements. The upper edge of the sheer strake is to be kept as low as practicable.

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

4.3 Hatchways closed by weathertight covers of steel or other equivalent material fitted with gaskets and clamping devices

4.3.1 At positions 1 and 2 the height above the deck of hatchway coamings fitted with weathertight hatch covers of steel or other equivalent material fitted with gaskets and clamping devices is to be:

- 600 millimetres if in position 1
- 450 millimetres if in position 2.

The height of these coamings may be reduced, or the coamings omitted entirely, upon proper justification. Where coamings are provided they are to be of substantial construction.

4.3.2 *Where weathertight covers are of mild steel the strength is to be calculated with assumed loads not less than those specified in Ch 11, Sec 9.*

4.3.3 *The strength and stiffness of covers made of materials other than mild steel are to be equivalent to those of mild steel to the satisfaction of the Society.*

4.3.4 *The means for securing and maintaining weathertightness are to be to the satisfaction of the Society. The arrangements are to ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness are required at the initial survey, and may be required at periodical surveys and at annual inspections or at more frequent intervals.*

4.4 Doors

4.4.1 *All access openings in bulkheads at ends of enclosed superstructures are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The means for securing these doors weathertight are to consist of gaskets and clamping devices or other equivalent means and are to be permanently attached to the bulkhead or to the doors themselves, and the doors are to be so arranged that they can be operated from both sides of the bulkhead.*

4.4.2 *Except as otherwise provided, the height of the sills of access openings in bulkheads at ends of enclosed superstructures is to be at least 380 millimetres above the deck.*

CHAPTER 4
STRUCTURE DESIGN PRINCIPLES

Section 1 Materials

Section 2 Net Scantling Approach

Section 3 Corrosion Additions

Section 4 Protection of Hull Metallic Structures

Section 5 Structural Detail Principles

Section 6 Structural Idealisation

Section 1 Materials

1 General

1.1 Standard of material

1.1.1 Materials used during construction are to comply with the applicable requirements of NR216 Materials and Welding.

1.1.2 Materials other than those covered in [1.1.1] may be accepted, provided their specification (e.g. manufacture, chemical composition, mechanical properties, welding) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1 Materials are to be tested in compliance with the applicable requirements of NR216 Materials and Welding.

1.3 Manufacturing process

1.3.1 The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and with the applicable requirements of NR216 Materials and Welding.

In particular:

- parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2 Hull structural steel

2.1 General

2.1.1 Young's modulus and Poisson's ratio

For carbon steel materials, Young's modulus is equal to 206000 N/mm^2 and Poisson's ratio is equal to 0,3.

In case of steel used at a temperature θ between 90°C and 300°C, and when no other information is available, the minimum specified yield stress R_{eH} and the Young's modulus E of the steel at the temperature θ may be taken respectively equal to:

$$R_{eH} = R_{eH0}\left(1,04 - \frac{0,75}{1000}\theta\right)$$

$$E = E_0\left(1,03 - \frac{0,5}{1000}\theta\right)$$

where:

R_{eH0} : Value of the minimum specified yield stress at ambient temperature, in N/mm^2

E_0 : Value of the Young's modulus at ambient temperature, in N/mm^2

θ : Temperature of use of the steel, in °C.

2.1.2 Steel material grades and mechanical properties

Steel having a specified minimum yield stress equal to 235 N/mm^2 is regarded as normal strength steel and is denoted 'NSS'. Steel having a higher specified minimum yield stress is regarded as higher strength steel and is denoted 'HSS'.

Steel grades are referred to as follows:

- A, B, D and E denote normal strength steel grades
- AH, DH and EH denote higher strength steel grades.

Tab 1 gives the mechanical characteristics of steels generally used in the construction of ships.

Higher strength steels other than those indicated in Tab 1 are considered by the Society on a case-by-case basis.

2.1.3 Steels with through thickness properties

Characteristics of steels with specified through thickness properties are given in NR216 Materials and Welding, Ch 3, Sec 1, [1].

2.1.4 Onboard documents

It is advised to keep onboard a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Tab 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available onboard together with the above plan.

Table 1 : Mechanical properties of hull steels

Steel grades for plates with $t_{as_built} \leq 100$ mm	Specified minimum yield stress R_{eH} in N/mm²	Specified minimum tensile strength R_m in N/mm²
A-B-D-E	235	400 - 520
AH32-DH32 EH32-FH32	315	440 - 570
AH36-DH36 EH36-FH36 EH36CAS1-EH36CAS2 FH36CAS1-FH36CAS2	355	490 - 630
AH40-DH40 EH40-FH40 EH40CAS1-EH40CAS2 FH40CAS1-FH40CAS2	390	510 - 660
EH47 EH47CAS1-FH47CAS2	460	570 - 720
Note 1: Refer to NR216 Materials and Welding, Ch 3, Sec 2		

2.2 Material factor k

2.2.1 Unless otherwise specified, the material factor k of normal and higher strength steels for hull girder strength and scantling purposes is to be taken as given in Tab 2, as a function of the specified minimum yield stress R_{eH}.

For intermediate values of R_{eH}, k is obtained by linear interpolation.

Steels with a yield stress lower than 235 N/mm² or greater than 460 N/mm² are considered on a case by case basis by the Society.

Table 2 : Material factor k

R_{eH}, in N/mm²	k
235	1,00
315	0,78
355	0,72
390	0,68 **(1)**
460	0,62
(1) k may be taken equal to 0,66 for steels with a minimum yield stress R_{eH} equal to 390 N/mm², provided the hull structure is additionally verified for compliance with finite element analysis and spectral fatigue assessment according to NI611.	

2.3 Steel grades

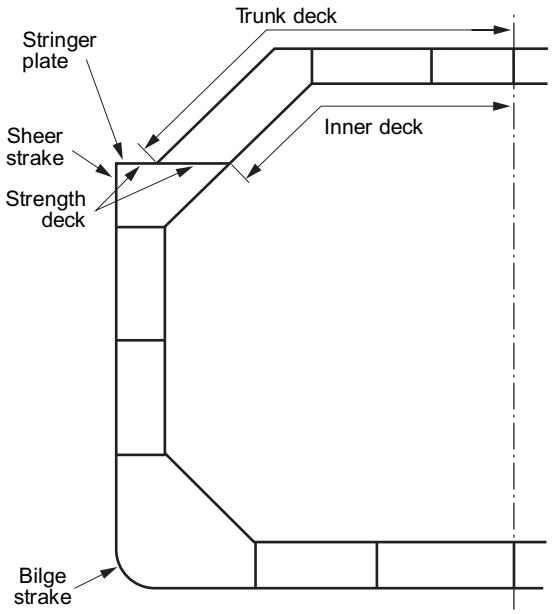
2.3.1 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Tab 3 to Tab 9.

General requirements are given in Tab 3. Additional minimum requirements are given in:

- Tab 4 for ships, excluding membrane-type liquefied gas carriers, greater than 150 m in length and having a single strength deck
- Tab 5 for membrane type liquefied gas carriers greater than 150 m in length and having a deck arrangement as shown in Fig 1. Tab 5 may apply to similar ships with a double deck arrangement above the strength deck.
- Tab 6 for ships greater than 250 m in length
- Tab 7 for single-side **bulk carriers**, **bulk carriers ESP**, **self-unloading bulk carriers ESP**, **ore carrier ESP** and **combination carrier / OBO ESP**
- Tab 8 for ships with ice strengthening.

2.3.2 Materials are to be of a grade not lower than that indicated in Tab 9 depending on the material class and structural member gross thickness (see [2.3.5]).

Figure 1 : Typical deck arrangement for membrane-type liquefied natural gas carriers



2.3.3 For strength members not mentioned in Tab 3, Tab 4, Tab 5, Tab 6, Tab 7 and Tab 8, grade A/AH may generally be used.

2.3.4 Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are generally to be of grades not lower than those corresponding to Class II.

For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders), Class III is to be applied.

2.3.5 The steel grade is to correspond to the as fitted gross thickness when this is greater than the gross thickness obtained from the net thickness required by the Rules, according to Ch 4, Sec 2, [1].

2.3.6 Steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Tab 9 are considered by the Society on a case by case basis.

2.3.7 In specific cases, such as [2.3.8], with regard to stress distribution along the hull girder, the classes required within 0,4L amidships may be extended beyond that zone, on a case by case basis.

2.3.8 The material classes required for the strength deck plating, the sheer strake and the upper strake of longitudinal bulkheads within 0,4L amidships are to be maintained for an adequate length across the poop front and at the ends of the bridge, where fitted.

2.3.9 Rolled products used for welded attachments on hull plating, such as gutter bars are to be of the same grade as that used for the hull plating in way.

Where it is necessary to weld attachments to the sheer strake or stringer plate, attention is to be given to the appropriate choice of material and design, the workmanship and welding and the absence of prejudicial undercuts and notches, with particular regard to any free edges of the material.

2.3.10 In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case by case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to minimize the risk of lamellar tearing (Z type steel, see NR216 Materials and Welding).

2.3.11 In highly stressed areas, the Society may require that plates of gross thickness greater than 20 mm are of grade D/DH or E/EH.

2.4 Grades of steel for structures exposed to low air temperatures

2.4.1 For ships intended to operate in areas with low air temperatures (–10°C or below), e.g. regular service during winter seasons to Arctic or Antarctic waters (known as the Polar Regions), the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in [2.4.2].

Table 3 : Material classes and grades for ships in general

Structural member category		Material class or grade	
		Within 0,4L amidships	Outside 0,4L amidships
SECONDARY	• Longitudinal bulkhead strakes, other than that belonging to the primary category • Deck plating exposed to weather, other than that belonging to the primary or special category • Side plating	I	A / AH
PRIMARY	• Bottom plating, including keel plate • Strength deck plating, excluding that belonging to the special category • Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings, for ships equal to or greater than 90 m in length • Uppermost strake in longitudinal bulkhead • Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	II	A / AH
SPECIAL	• Sheer strake at strength deck **(1)** • Stringer plate in strength deck **(1)** • Deck strake at longitudinal bulkhead excluding deck plating in way of inner-skin bulkhead of double hull ships **(1)**	III	II I outside 0,6L amidships
	• Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch openings configurations	III	II I outside 0,6L amidships Min. class III within cargo region
	• Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configurations • Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	III	III within 0,6L amidships II within the rest of cargo region
	• Bilge strake in ships with double bottom over the full breadth and length less than 150 m	II	II within 0,6L amidships I outside 0,6L amidships
	• Bilge strake in other ships **(1)**	III	II I outside 0,6L amidships
	• Longitudinal hatch coamings of length greater than 0,15 L, including top plate and flange, for ships equal to or greater than 90 m in length • End brackets and deck house transition of longitudinal cargo hatch coamings	III Not to be less than grade D/DH	II I outside 0,6L amidships Not to be less than grade D/DH

(1) Single strakes required to be of class III within 0.4L amidships are to have breadths not less than (800 + 5 L) mm, need not to be greater than 1800 mm, unless limited by the geometry of the ship's design.

Table 4 : Minimum material grades for ships greater than 150 m in length

Structural member category	Material grade
• Longitudinal plating of strength deck where contributing to the longitudinal strength • Continuous longitudinal plating of strength members above strength deck	B/AH within 0,4 L amidships
• Single side strakes for ships without inner continuous longitudinal bulkhead(s) between the bottom and the strength deck	B/AH within cargo region

Table 5 : Material classes and grades for membrane-type liquefied gas carriers, greater than 150 m in length

Structural member category		Material class or grade
Longitudinal plating of strength deck where contributing to the longitudinal strength		B/AH within 0,4 L amidships
Continuous longitudinal plating of strength members above the strength deck	Trunk deck plating	II within 0,4L amidships
	• Inner deck plating • Longitudinal strength member plating between the trunk deck and the inner deck	B/AH within 0,4 L amidships

Table 6 : Minimum material grades for ships greater than 250 m in length

Structural member category **(1)**	Material grade within 0,4 L amidships
• Sheer strake at strength deck • Stringer plate in strength deck	E/EH
• Bilge strake	D/DH
(1) Single strakes required to be of grade D/DH or grade E/EH and within 0,4 L amidships are to have breadths not less than (800 + 5 L) mm, but need not be greater than 1800 mm, unless limited by the geometry of the ship's design.	

Table 7 : Material classes and grades for single-side bulk carrier, bulk carrier ESP, self-unloading bulk carrier, ore carrier ESP and combination carrier / OBO ESP

Structural member category	Material grade
Lower bracket of ordinary side frame **(1) (2)**	D/DH
Side shell strakes included totally or partially between the two points located to 0,125 ℓ above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate **(2)**	D/DH
(1) the term "lower bracket" means web of lower bracket and web of the lower part of side frames up the point of 0,125 ℓ above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. **(2)** the span of the side frame, ℓ, is defined as the distance between the supporting structures.	

Table 8 : Material classes and grades for ships with ice strengthening

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	B/AH

Table 9 : Material grade requirements for classes I, II and III

As-built thickness, in mm	Class I		Class II		Class III	
	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 15	A	AH	A	AH	A	AH
15 < t ≤ 20	A	AH	A	AH	B	AH
20 < t ≤ 25	A	AH	B	AH	D	DH
25 < t ≤ 30	A	AH	D	DH	D	DH
30 < t ≤ 35	B	AH	D	DH	E	EH
35 < t ≤ 40	B	AH	D	DH	E	EH
40 < t ≤ 50	D	DH	E	EH	E	EH

2.4.2 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean : Statistical mean over observation period

Average : Average during one day and night

Lowest : Lowest during one year.

Fig 2 illustrates the temperature definition for Arctic waters.

For seasonally restricted service, the lowest value within the period of operation applies.

For the purpose of issuing a Polar Ship Certificate in accordance with the Polar Code, the design temperature t_D shall be no more than 13°C above the Polar Service Temperature (PST) of the ship.

In the Polar Regions, the statistical mean over observation period is to be determined for a period of, at least, 10 years.

2.4.3 For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 10.

Tab 10 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members. Class I is to be considered for superstructures and deckhouses structural members exposed to air.

For non-exposed structures (except bulkhead strakes as mentioned in footnote **(5)** of Tab 10) and structures below the lowest ballast waterline, see [2.3].

Figure 2 : Commonly used definitions of temperatures

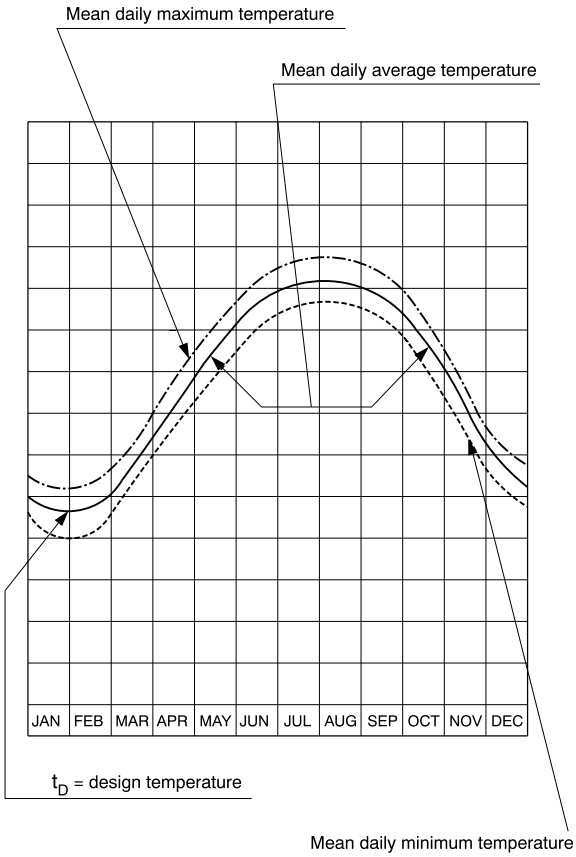


Table 10 : Material classes and grades - Structures exposed to low air temperatures

Structural member category		Material class	
		Within 0,4L amidships	Outside 0,4L amidships
SECONDARY	Deck plating exposed to weather (in general) Side plating above T_{BAL} Transverse bulkheads above T_{BAL} **(5)**	I	I
PRIMARY	Strength deck plating **(1)** Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length) Longitudinal bulkhead above T_{BAL} **(5)** Topside tank bulkhead above T_{BAL} **(5)**	II	I
SPECIAL	Sheer strake at strength deck **(2)** Stringer plate in strength deck **(2)** Deck strake at longitudinal bulkhead **(3)** Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(4)**	III	II

(1) Plating at corners of large hatch openings to be considered on a case by case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur.

(2) To be not less than grade E/EH within 0,4 L amidships in ships with length exceeding 250 m.

(3) In ships with breadth exceeding 70 metres at least three deck strakes to be class III.

(4) To be not less than grade D/DH.

(5) Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered as exposed plating over a width of not less than 600 mm.

Note 1: Plating materials for sternframes, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.3].

2.4.4 Materials may not be of a lower grade than that indicated in Tab 11 to Tab 13 depending on the material class, structural member gross thickness and design temperature t_D.

For design temperatures $t_D < -55°C$, materials will be specially considered by the Society on a case by case basis.

2.4.5 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than (800+5L) mm, but not necessarily greater than 1800 mm.

2.5 Grades of steel within refrigerated spaces

2.5.1 For structural members within or adjacent to refrigerated spaces, when the design temperatures is below 0°C, the materials are to be of grade not lower than those indicated in Tab 14, depending on the design temperature, the structural member gross thickness and its category (as defined in Tab 3).

Table 11 : Material grade requirements for class I at low temperatures

Gross thickness, in mm	−11°C / −15°C		−16°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	A	AH	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	A	AH	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	B	AH	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	B	AH	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	D	DH	E	EH	E	EH	N.A.	FH
45 < t ≤ 50	D	DH	E	EH	E	EH	N.A.	FH	N.A.	FH

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 12 : Material grade requirements for class II at low temperatures

Gross thickness, in mm	−11°C / −15°C		−16°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	B	AH	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	D	DH	E	EH	E	EH	N.A.	FH
30 < t ≤ 40	D	DH	E	EH	E	EH	N.A.	FH	N.A.	FH
40 < t ≤ 45	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
45 < t ≤ 50	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 13 : Material grade requirements for class III at low temperatures

Gross thickness, in mm	−11°C / −15°C		−16°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH	N.A.	FH
20 < t ≤ 25	D	DH	E	EH	E	EH	E	FH	N.A.	FH
25 < t ≤ 30	D	DH	E	EH	E	EH	N.A.	FH	N.A.	FH
30 < t ≤ 35	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
35 < t ≤ 40	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
40 < t ≤ 50	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.	N.A.	N.A.

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 14 : Material grade requirements for members within or adjacent to refrigerated spaces

Design temperature, in °C	Gross thickness, in mm	Structural member category	
		Secondary	Primary or Special
$-10 \le t_D < 0$	$t \le 20$	B / AH	B / AH
	$20 < t \le 25$	B / AH	D / DH
	$t > 25$	D / DH	E / EH
$-25 \le t_D < -10$	$t \le 15$	B / AH	D / DH
	$15 < t \le 25$	D / DH	E / EH
	$t > 25$	E / EH	E / EH
$-40 \le t_D < -25$	$t \le 25$	D / DH	E / EH
	$t > 25$	E / EH	E / EH

2.5.2 Unless a temperature gradient calculation is carried out to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the design temperatures to be considered are specified below:

a) For members within refrigerated spaces:
- temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
- mean value of temperatures in the adjacent spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is generally not greater than 10 °C (when the temperature difference between the adjacent spaces is greater than 10°C, the temperature value is established by the Society on a case by case basis)

b) For members adjacent to refrigerated spaces:

temperature of the non-refrigerated space, conventionally taken equal to 0°C (in such case, the steel grades are to be considered as per [2.3]).

2.5.3 Situations other than those mentioned in [2.5.1] and [2.5.2] or special arrangements will be considered by the Society on a case by case basis.

2.5.4 Irrespective of the provisions of [2.5.1], [2.5.2] and Tab 14, steel having grades lower than those required in [2.3], Tab 3 and Tab 9, in relation to the class and gross thickness of the structural member considered, may not be used.

2.6 Through thickness properties

2.6.1 Where normal tensile loads induce out-of-plane stress greater than 0,5 R_Y in steel plates:
- for plates with t < 15 mm, ultrasonic testing is to be performed
- for plates with t ≥ 15 mm, Z-quality steel is to be used or ultrasonic testing is to be performed,

in order to prevent laminar tearing.

The above mentioned ultrasonic testing is to be performed, before and after welding, on the area of the plate located within 50 mm or t, whichever is the greater, around the weld, in accordance with NR216 Materials and Welding, Ch 3, Sec 12.

2.7 Stainless steel

2.7.1 The reduction of strength of stainless steel with increasing temperature is to be taken into account in the calculation of the material factor k and in the material Young's modulus E.

Stainless steels are considered by the Society on a case-by-case basis.

3 Steels for forging and casting

3.1 General

3.1.1 Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of NR216 Materials and Welding.

3.1.2 Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

3.1.3 The steels used are to be tested in accordance with the applicable requirements of NR216 Materials and Welding.

3.2 Steels for forging

3.2.1 Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis. In such case, compliance with the applicable requirements of NR216 Materials and Welding, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1 Cast parts intended for stems and stern frames in general may be made of C and C-Mn weldable steels, having a specified minimum tensile strength R_m equal to 400 N/mm^2, in accordance with the applicable requirements of NR216 Materials and Welding.

Items which may be subjected to high stresses may be required to be of quality 2 steels of the above types.

3.3.2 The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

3.3.3 Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to surface and volumetric non-destructive examination to check their internal structure.

4 Aluminium alloys

4.1 General

4.1.1 The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components is to be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

4.1.2 The characteristics of aluminium alloys to be used in the construction and their testing and manufacturing process are to comply with the applicable requirements of the following Rules:

- NR216 Materials and Welding
- NR561 Aluminium Ships, Section 2.

Aluminium alloys with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding,...) is submitted to the Society for approval.

4.1.3 Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

4.2 Material factor k

4.2.1 The material factor k used for the scantling criteria of structural members made of aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{lim}}$$

where:

R'_{lim} : Minimum yield stress of the aluminium alloys considered, to be taken equal to the minimum value, in welded condition, between $R'_{p0,2}$ (proof stress) and 0,7 R'_m (tensile strength), where $R'_{p0,2}$ and R'_m are defined in NR561 Aluminium Ships.

4.3 Others

4.3.1 Aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided.

4.3.2 The underside of heavy portable aluminium structures such as gangways, is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

5 Other materials and products

5.1 General

5.1.1 Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of NR216 Materials and Welding.

5.1.2 The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

5.1.3 Materials used in welding processes are to comply with the applicable requirements of NR216 Materials and Welding.

5.2 Iron cast parts

5.2.1 As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2 Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

Section 2 Net Scantling Approach

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

d_f : Distance in mm, for the extension of flange for L1 profiles, see Fig 3.

t_{dm} : Design production margin, in mm, taken as the thickness difference between offered gross thickness and required gross thickness (equal also to the difference between offered net and required net thickness) as a result of scantlings applied by the designer or builder to suit design or production situation. This difference in thickness is not to be considered as an additional corrosion margin.

1 General

1.1 Application

1.1.1 Net thickness approach

The scantling of a structural element determined for its strength in compliance with the design basis is expressed in terms of net thickness t, i.e. it does not include the corrosion addition.

The corrosion addition, t_c, for a structural element is derived independently from the net scantling requirements as shown in Fig 1.

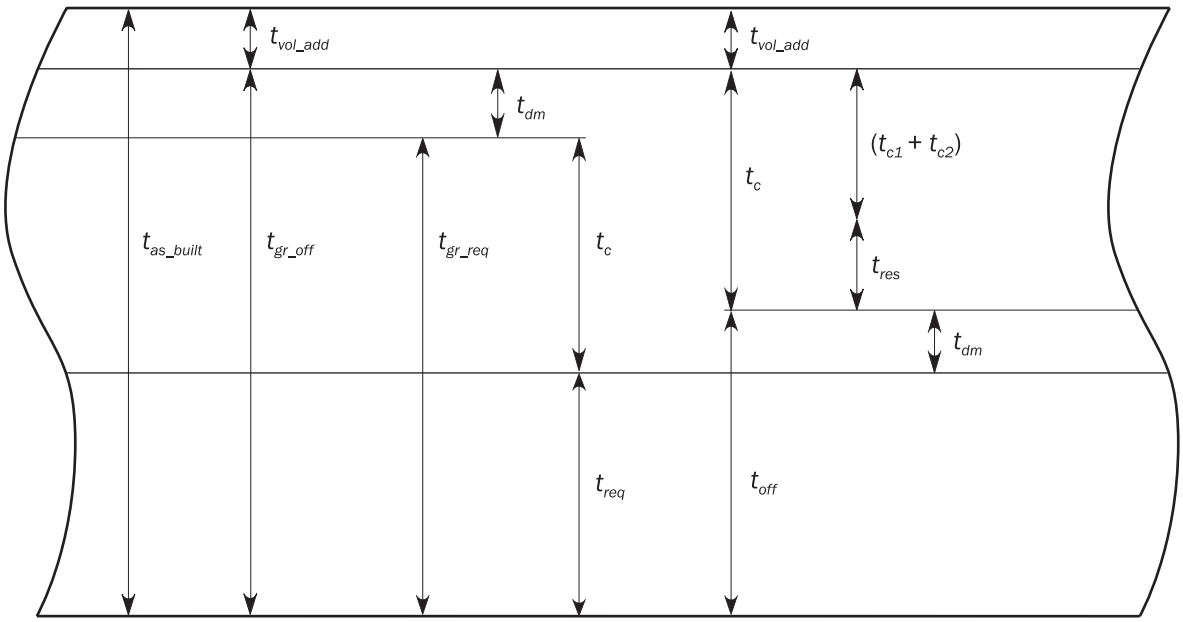
This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the ship-in-operation phase.

1.1.2 Exceptions in gross scantling

Items that are directly determined in terms of gross scantlings do not follow the net scantling approach, i.e. they already include additions for corrosion but without any Owner's extra margin. Gross scantling requirements are identified with the suffix "gr" and examples are:

- scantlings of superstructures and deckhouses as given in Ch 11, Sec 5
- scantlings of bow doors and inner doors as given in Ch 11, Sec 6
- scantlings of side doors and stern doors as given in Ch 11, Sec 7
- scantlings of rudder structures and hull appendages in Part B, Chapter 12
- scantlings of massive pieces made of steel forgings and steel castings.

Figure 1 : Net scantling approach scheme



1.2 Gross and net scantling definitions

1.2.1 Gross required thickness

The gross required thickness, t_{gr_req}, is the thickness obtained by adding the corrosion addition as defined in Ch 4, Sec 3 to the net required thickness, as follows:

$t_{gr_req} = t_{req} + t_c$

1.2.2 Gross offered thickness

The gross offered thickness, t_{gr_off}, is the gross thickness provided at the newbuilding stage, which is obtained by deducting any thickness for voluntary addition from the as-built thickness, as follows:

$t_{gr_off} = t_{as_built} - t_{vol_add}$

1.2.3 Net offered thickness

The net offered thickness, t_{off}, is obtained by subtracting the corrosion addition from the gross offered thickness, as follows:

$t_{off} = t_{gr_off} - t_c = t_{as_built} - t_{vol_add} - t_c$

1.3 Rounding off of scantlings

1.3.1 Thicknesses

The rounding off of thicknesses is to be performed as follows:

a) the gross required thickness t_{gr_req} as defined in [1.2.1] is rounded off to the nearest half-millimetre.

b) the rounded net thickness is taken equal to the rounded gross thickness, obtained in a), minus the corrosion addition t_C.

Note 1: Examples of thickness values rounded off to the nearest half-millimetre are given below for reference:

- for $10{,}75 \leq t_{gr_req} < 11{,}25$ mm:

  The rounded value of t is 11 mm

- for $11{,}25 \leq t_{gr_req} < 11{,}75$ mm:

  The rounded value of t is 11,5 mm

1.3.2 Stiffener section moduli

Stiffener section moduli as calculated in accordance with the Rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3%.

1.4 Scantling compliance

1.4.1 Scantling compliance in relation to the Rules is as follows:

- The net offered thickness of plating is to be equal to or greater than the net required thickness of plating.
- The net offered section modulus, moment of inertia and shear area of local supporting members are to be equal to or greater than the net required properties calculated using the net thickness of the attached plate, web and flange. The net sectional dimensions of local supporting members are defined in Fig 2 and Fig 3. The required section modulus and web net thickness apply to areas clear of the end brackets.
- the offered net sectional properties of primary supporting members and the hull girder are to be equal to or greater than the required net sectional properties which are to be based on the gross offered scantling with a reduction of the applicable corrosion addition, as specified in Tab 1, applied to all component structural members
- the strength assessment methods prescribed are to be assessed by applying the corrosion reduction specified in Tab 1 to the offered gross scantlings. Half of the applied corrosion addition specified in Tab 1 is to be deducted from both sides of the structural members being considered
- corrosion additions are not to be taken less than those given in Ch 4, Sec 3, [1.2].

Any additional thickness specified by the Owner or the builder is not to be included when considering the compliance with the Rules.

The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position are to be determined applying a corrosion magnitude of 0,5 t_c deducted from the surface of the profile cross-section.

Figure 2 : Net sectional properties of local supporting members

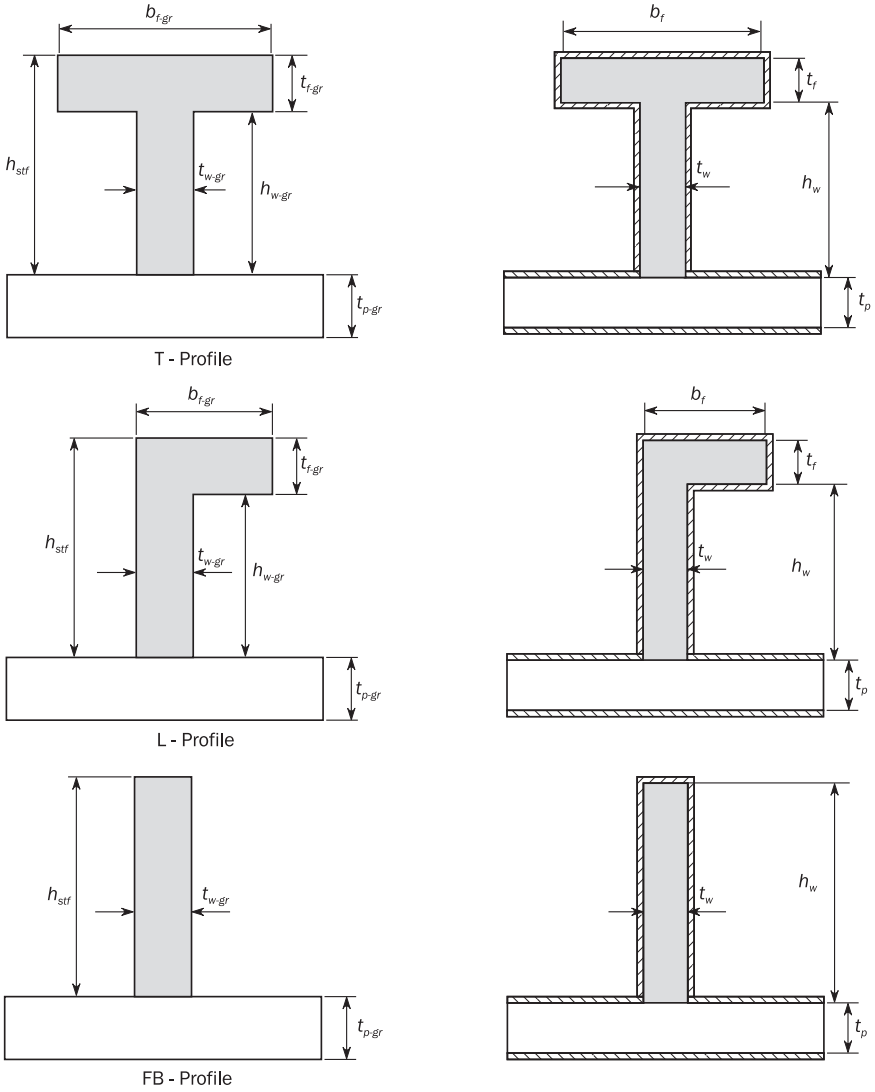


Figure 3 : Net sectional properties of local supporting members (continued)

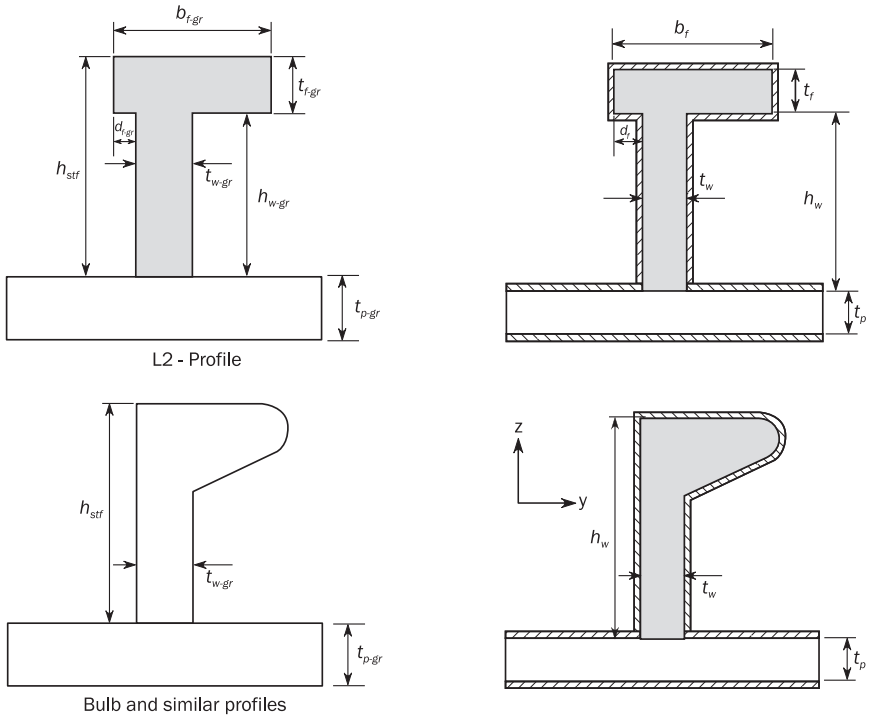


Table 1 : Assessment for corrosion applied to the gross scantlings

Structural requirement	Property/analysis type	Applied corrosion addition
Minimum thickness (all members including PSM)	Thickness	t_c
Local strength (plates, stiffeners)	Thickness / Sectional properties	t_c
	Stiffness / Proportions / Buckling capacity	t_c
Primary supporting members (prescriptive)	Sectional properties **(1)**	0,5 t_c
	Stiffness / Proportions of web and flange / Buckling capacity	t_c
Strength assessment by direct strength analysis	Cargo hold / Complete ship model / Beam grillage	0,5 t_c
	Buckling capacity	t_c
	Local fine mesh	0,5 t_c
Hull girder strength	Sectional properties	0,5 t_c
	Buckling capacity	t_c
Hull girder ultimate strength	Sectional properties	0,5 t_c
	Buckling / collapse capacity	0,5 t_c
Fatigue assessment (simplified stress analysis)	Hull girder section properties Local support member	0,5 t_c
Fatigue assessment (FE stress analysis)	Standard mesh FE model Very fine mesh portion	0,5 t_c

Note 1: Different values may be defined for ships granted a specific service notation, in compliance with the applicable chapters of Part D or Part E.

(1) t_c is to be applied to sectional properties of bulkheads corrugations.

Section 3 Corrosion Additions

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

t_{res} : Reserve thickness, taken equal to 0,5 mm.

1 General

1.1 Applicability

1.1.1 The corrosion additions are applicable to carbon-manganese steels, stainless steels, stainless clad steels and aluminium alloys.

1.2 Corrosion addition determination

1.2.1 Corrosion addition for steel other than stainless steel

The total corrosion addition, t_c, in mm, for both sides of the structural member is obtained as follows:

- for structural members with a gross thickness greater than 10 mm:

  $t_c = t_{c1} + t_{c2} + t_{res}$

- for structural members with a gross thickness less than or equal to 10 mm, t_c is the smallest of the following values:

  $t_{c1} + t_{c2} + t_{res}$

  $0,2\ t_{gr_off}$

The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2}, is specified in Tab 1.

However, when $t_{c1} = t_{c2} = 0$, the total corrosion addition is to be taken as $t_c = 0$.

Note 1: For an internal member within a given compartment, the formula $t_{c1} + t_{c2} + t_{res}$ becomes $2\ t_{c1} + t_{res}$, where t_{c1} is the value specified in Tab 1 for one side exposure to that compartment.

1.2.2 Corrosion addition for steel clad with stainless steel

In case of stainless clad steel, the total corrosion addition is to be obtained as described in [1.2.1] with the following adjustments:

- the corrosion addition for the carbon steel side t_{c1} is the value specified in Tab 1 for the corresponding compartment
- the corrosion addition for the stainless steel side is:

  $t_{c2} = 0$

1.2.3 Corrosion addition for aluminium alloys and stainless steel

The total corrosion addition, t_c, in mm, for compartment boundaries and internal members made of stainless steel or aluminium alloy is to be taken as:

$t_c = 0$

1.2.4 Stiffener

The corrosion addition of a stiffener is determined according to the location of its connection to the attached plating.

The total corrosion addition determined as per [1.2.1] based on the thinner thickness part of the stiffener is to be applied to both web and flange.

1.2.5 When a local structural member/plate is affected by more than one value of corrosion addition, the most onerous value is to be applied to the entire strake.

Table 1 : Corrosion addition for one side of a structural member

Compartment type		t_{c1} or t_{c2}
Ballast water tank **(1)**, bilge tank, drain storage tank, chain locker **(2)**		1,00
Exposed to atmosphere		1,00
Exposed to seawater		1,00
Cargo oil tank, fuel and lube oil tank Integral or independent cargo tank of ships with the service notation **chemical tanker (3)** Fuel chemical tanks **(3)** Independent or integral methanol fuel tank of ships with additional service feature **methanolfuel (10)**		0,50
Liquefied gas tank **(5) (11)**		0,00
Dry bulk cargo hold **(4)**	General **(12)**	1,00
	Inner bottom plating Side plating for single hull ship Inner side plating for double hull ship Transverse bulkhead plating Sloping stool plate of hopper tanks and lower stool	1,75
	Frames, ordinary stiffeners and primary supporting members **(6)**	1,00
Fresh water tank		0,50
Moonpool		1,75
Tanks dedicated to water-based or oil-based process muds or brines		1,25
Hopper well of dredging ships		2,00
Compartment located between independent tank and inner side of ships with the additional service feature **asphalt carrier**		1,00
Cofferdam or void space **(7) (8)**		0,50
Dry spaces (inside of machinery spaces, pump room, store rooms, steering gear space, passageways, etc.)		0,50 **(9)**
Container holds	Transverse bulkheads	0,50
	Elsewhere	1,00
Accommodation spaces		0,00
Compartments other than those mentioned above		0,50

(1) Ballast water tank: does not include cargo oil tanks which may carry ballast according to Regulation 18 of MARPOL 73/78.

(2) 1,0 mm is to be added to the plate surface within 3 m above the upper surface of the chain locker bottom

(3) The corrosion addition t_c may be taken equal to 0 for tanks covered with a protective lining or coating (see Chapter 6 of the IBC Code)

(4) Dry bulk cargo hold: includes holds, intended for the carriage of dry bulk cargoes, which may carry oil or water ballast.

(5) The corrosion addition t_C specified for liquefied gas tanks is to be applied when required in:

- Pt D, Ch 9, Sec 4, [2.1.5], or
- NR529, [6.4.1]

(6) 0,50 mm is to be added within 3 m above the bottom of the hold

(7) This includes:

- cofferdams adjacent to membrane tanks of ships with the service notation **liquefied gas carrier**
- spaces located between the independent tank and the hull structure of ships with the service notation **liquefied gas carrier**
- spaces located between the gasfuel tank and the hull structure of ships with additional service feature **LNGfuel**, **CNGfuel**, **LPGfuel** or **ammoniafuel**

In the cases above, the corrosion addition t_C may be taken equal to 0 in case of environmental control such as inerting around the cargo tank (see Pt D, Ch 9, Sec 4, [2.1.5]).

(8) For the determination of the corrosion addition of the outer shell plating, the pipe tunnel is considered as a ballast water tank.

(9) For the direct strength assessment according to Ch 8, Sec 1 of ships assigned the service notation **container ship**, t_{c1} or t_{c2} is to be taken equal to 0,0 mm

(10) The corrosion addition t_C may be taken equal to 0 for tanks covered with a protective lining or coating.

(11) Including tanks of ships with service notation **liquefied gas carrier** and gas fuel tanks of ships with the additional service feature **LNGfuel**, **CNGfuel**, **LPGfuel** or **ammoniafuel**

(12) Including all structural members and areas within cargo holds of ships with the service notation **cement carrier**

Section 4 Protection of Hull Metallic Structures

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the shipbuilder and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.2 Structures to be protected

1.2.1 All salt water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

For ships assigned with the additional service feature or the additional class notation **CPS (WBT)** according to Pt A, Ch 1, Sec 2, [4.16.12] or Pt A, Ch 1, Sec 2, [6.24.4], reference is to be made to NR530 Coating Performance Standard.

1.2.2 Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of cargo oil or fuel oil.

1.2.3 Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

2 Protection against galvanic corrosion in tanks

2.1 General

2.1.1 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

2.1.2 Where stainless steel or aluminium alloys are fitted in the same tank as non-stainless steel, a protective coating is to cover both materials.

3 Protection of bottom by ceiling

3.1 General

3.1.1 In double bottom ships, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with Ch 7, Sec 4, [6.3.1].

3.2 Arrangement

3.2.1 Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

3.2.2 Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

3.2.3 Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

3.2.4 The Shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

3.2.5 In single bottom ships, ceiling is to be fastened to the reversed frames by galvanised steel bolts or any other equivalent detachable connection.

A similar connection is to be adopted for ceiling over the lateral bilges in double bottom ships.

3.3 Scantlings

3.3.1 The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case by case basis.

4 Protection of decks by wood sheathing

4.1 General

4.1.1 Where decks are intended to carry specific loads, such as caterpillar trucks and unusual vehicles, the Society may require such decks wood sheathed.

4.2 Arrangement

4.2.1 Wood sheathing is to be fixed to the plating by welded studs or bolts of at least 12 mm in diameter, every second frame.

4.2.2 Before fitting the wood sheathing, deck plates are to be provided with protective coating declared to be suitable by the Shipyard.

Caulking is Shipyard's responsibility.

4.3 Scantlings

4.3.1 The thickness of wood sheathing of decks is to be not less than:

- 65 mm if made of pine
- 50 mm if made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

5 Protection of cargo sides by battens

5.1 General

5.1.1 The requirements in [5.2] apply to sides in cargo spaces of ships with the service notation **general cargo ship** or **livestock carrier**.

5.2 Arrangement

5.2.1 In the case of transversally framed sides, longitudinal battens formed by spaced planks are to be fitted to the frames by means of clips.

5.2.2 Where sides are longitudinally framed, battens are to be fitted vertically.

5.2.3 Battens are to extend from the bottom of the cargo space to at least the underside of the beam knees.

5.2.4 Cargo battens are to be not less than 50 mm in thickness and 150 mm in width. The space between battens is not to exceed 300 mm.

Section 5 Structural Detail Principles

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

Z : Net required section modulus, of the stiffener, in cm^3. In the case of two stiffeners connected, Z is the smallest net required section modulus of the two connected stiffeners.

1 Application

1.1 General

1.1.1 The requirements of this Section apply to the hull structure.

2 General principles

2.1 Structural continuity

2.1.1 General

Attention is to be paid to the structural continuity, in particular in the following areas:

- in way of changes in the framing system
- at end connections of primary supporting members or ordinary stiffeners
- in way of the transition zones between central part and fore part, aft part and machinery space (See Ch 11, Sec 1; Ch 11, Sec 2 and Ch 11, Sec 3)
- in way of front, side and aft bulkheads of superstructures
- stepped or knuckled decks contributing to longitudinal strength.

At the termination of a structural member, structural continuity is to be maintained by the fitting of suitable supporting structure.

Abrupt changes in transverse section properties of longitudinal members are to be avoided. Smooth transitions are to be provided.

2.1.2 Longitudinal members

Longitudinal members are to be arranged in such a way that continuity of strength is maintained.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously as far as practicable towards the ends of the ship.

Longitudinals of the bottom, bilge, sheerstrake, deck, upper and lower longitudinal bulkhead and inner side strakes, as well as the latter strakes themselves, the lower strake of the centreline bottom girder and the upper strake of the centreline deck girder, where fitted, are to be continuous through the transverse bulkheads of the cargo area and cofferdams. Alternative solutions may be examined by the Society on a case by case basis, provided they are equally effective.

2.1.3 Primary supporting members

Primary supporting members are to be arranged in such a way that continuity of strength is maintained.

Abrupt changes of web height or cross-section are to be avoided.

2.1.4 Stiffeners

Stiffeners are to be arranged in such a way that continuity of strength is maintained.

Stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members within 0,4 L amidships and as far as practicable outside 0,4 L amidships.

For ships with L less than 90m, alternative arrangements to ensure structural continuity such as brackets may be considered on a case-by-case basis.

Where stiffeners are terminated in way of large openings, foundations and partial girders, compensation is to be arranged to provide structural continuity in way of the end connection.

2.1.5 Plating

Where plates with different thicknesses are joined, the change in the as-built plate thickness is not to exceed 50% of the larger plate thickness in the load carrying direction.

If the difference in thickness is greater than 50% of the larger plate thickness, an intermediate plate is to be inserted. Welding of the plates is to be as per Ch 13, Sec 3, [2.1.2].

This also applies to local insert plates thicker than the plate they are welded to, unless the taper length is increased to at least 4 times the difference in as-built thickness, or the fatigue strength of the weld joint is justified by means of very fine mesh analysis.

2.1.6 Weld joints

Weld joints are to be avoided in areas with high stress concentration.

2.2 Local reinforcements

2.2.1 General

Where stress concentration may occur in way of structural discontinuities, adequate compensation and reinforcement are to be provided.

2.2.2 Reinforcements at knuckles

a) Knuckles are in general to be stiffened to achieve out-of-plane stiffness by fitting ordinary stiffeners or equivalent means in line with the knuckle. Arrangements without stiffener may be accepted on a case-by-case basis depending on the knuckle angle and stress level.

b) Whenever a knuckle in a main member (shell, longitudinal bulkhead, etc) is arranged, stiffening in the form of webs, brackets or profiles is to be connected to the members to which they are to transfer the load (in shear).

c) For longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

d) Generally, the distance between the knuckle and the support stiffening in line with the knuckle is not to be greater than 50 mm. Otherwise, fatigue analysis according to Part B, Chapter 10 is to be submitted by the designer.

2.2.3 Reinforcement in way of attachments for permanent means of access

Local reinforcement, considering location and strength, is to be provided in way of attachments to the hull structure for permanent means of access to and within spaces in the cargo area on ships with service notation **oil tanker** or **bulk carriers**, **bulk carriers ESP**, **self-unloading bulk carriers ESP**, **ore carrier ESP** and **combination carrier ESP**.

2.2.4 Reinforcement of deck structure in way of concentrated loads

The deck structure is to be reinforced in way of concentrated loads, such as anchor windlass, deck machinery, cranes, masts and derrick posts.

Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case-by-case basis.

Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

2.2.5 Reinforcement by insert plates

A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by the Society on a case by case basis.

In any case, doublers and insert plates are to be made of materials with, at least, the same specified minimum yield stress and the same grade as the plates to which they are welded. See also [2.1.5].

2.2.6 Doublers

In general, doublers having width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm

are to be fitted with slot welds, to be effected according to Ch 13, Sec 3, [4.2].

When doublers fitted on the outer shell and strength deck within 0,6L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the above requirements. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by the Society on a case by case basis.

2.3 Connection between steel and aluminium

2.3.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

Any heterogeneous jointing system is considered by the Society on a case-by-case basis.

The use of transition joints made of aluminium/steel-clad plates or profiles is considered by the Society on a case-by-case basis (see NR216 Materials and Welding, Ch 9, Sec 4).

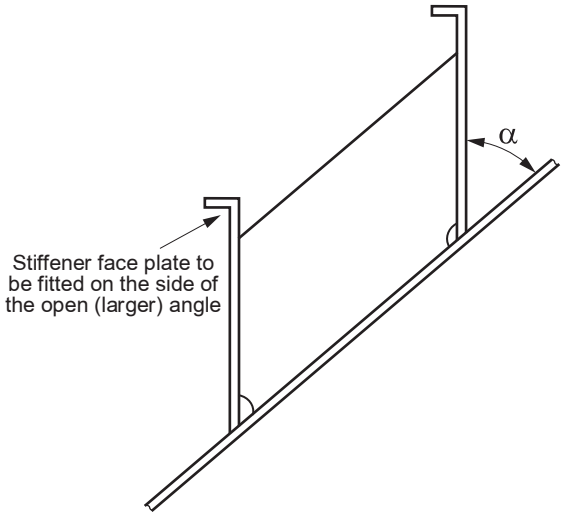
3 Stiffeners

3.1 General

3.1.1 All types of stiffeners (excluding web stiffeners) are to be connected at their ends. However, in special cases such as isolated areas of the ship where end connections cannot be applied, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in [3.2] to [3.4].

3.1.2 Where the angle α between the web plate of the stiffener and the attached plating is less than 50 deg, as shown on Fig 1, a tripping bracket is to be fitted. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 deg, the face plate of the stiffener is to be fitted on the side of the open angle.

Figure 1 : Stiffener on attached plating with an angle less than 50 deg



3.2 Bracketed end connections of non-continuous stiffeners

3.2.1 Where continuity of strength of longitudinal members is provided by brackets, the alignment of the brackets on each side of the primary supporting member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

3.2.2 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member.

3.2.3 The arrangement of the connection between the stiffener and the bracket is to be such that, at no point in the connection, the section modulus is less than that required for the stiffener.

3.2.4 Net web thickness

The net bracket web thickness t_b, in mm, is to comply with the following condition:

$$t_b \geq (2 + f_{bkt}\sqrt{Z})\sqrt{\frac{R_{eH-stf}}{R_{eH-bkt}}}$$

and need not be greater than 13,5 mm,

with:

f_{bkt} : Coefficient taken equal to:

- for brackets with flange or edge stiffener:

  $f_{bkt} = 0,2$

- for brackets without flange or edge stiffener:

  $f_{bkt} = 0,3$

R_{eH-stf} : Specified minimum yield stress of the stiffener material, in N/mm^2

R_{eH-bkt} : Specified minimum yield stress of the bracket material, in N/mm^2.

3.2.5 Brackets at the ends of non-continuous stiffeners

Brackets are to be fitted, at the ends of non-continuous stiffeners, with arm lengths ℓ_1 and ℓ_2 (see Fig 2), in mm, at least equal to ℓ_{bkt}, as defined below:

$$\ell_{bkt} = c_{bkt}\sqrt{\frac{Z}{t_b}}$$

with:

c_{bkt} : Coefficient taken equal to:

- for brackets with flange or edge stiffener:

  $c_{bkt} = 65$

- for brackets without flange or edge stiffener:

  $c_{bkt} = 70$

t_b : Minimum net bracket web thickness, in mm, as defined in [3.2.4]

ℓ_{bkt} is not to be taken less than:

- for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see case (c) in Fig 2:

  $\ell_{bkt} = 1{,}8\ h_{stf}$

- for other cases, see (a), (b) and (d) in Fig 2:

  $\ell_{bkt} = 2{,}0\ h_{stf}$

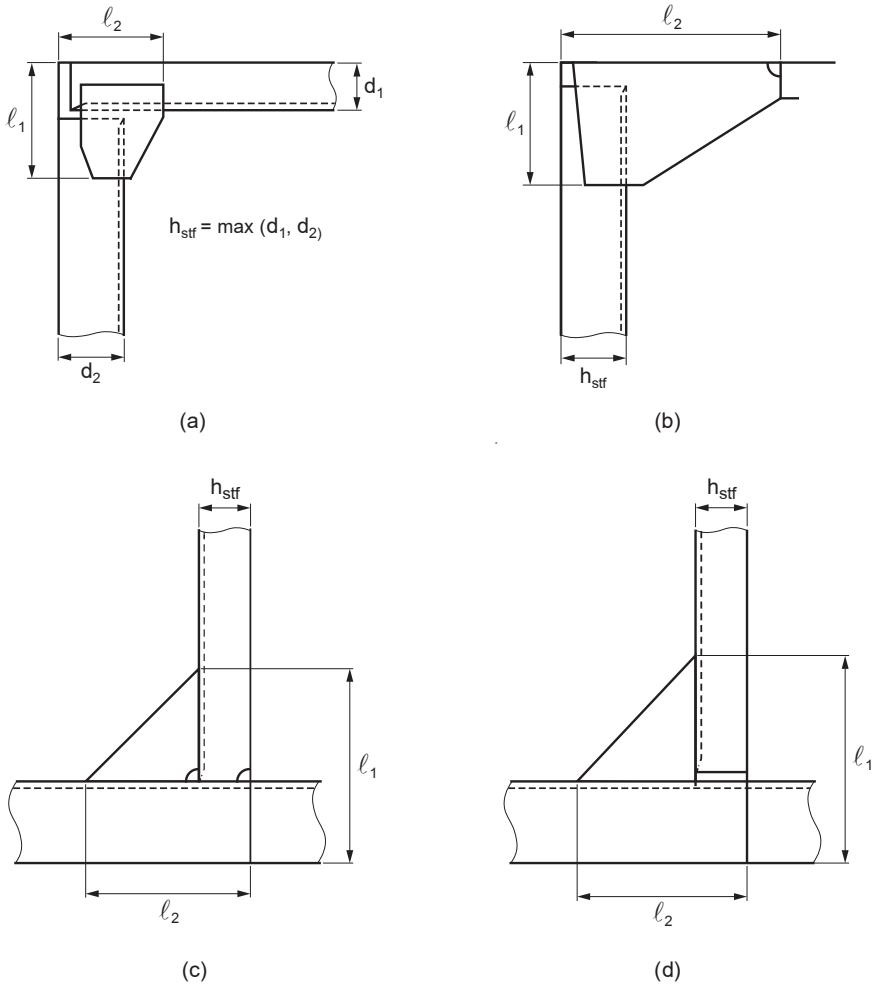
- for connections similar to item (b) in Fig 2 but not lapped:

  $\ell_{bkt} = 2{,}0\ h_{stf}$

- for connections similar to cases (c) and (d) in Fig 2 where the smaller stiffener is connected to a primary supporting member or bulkhead:

  $\ell_{bkt} = 2{,}0\ h_{stf}$

Figure 2 : Bracket arm lengths of non-continuous stiffeners



3.2.6 Brackets with different arm lengths

The arms lengths ℓ_1 and ℓ_2 as shown on Fig 2, measured from the plating to the toe of the bracket, are to be such that:

$\ell_1 + \ell_2 > 2\ \ell_{bkt}$

$\ell_1 \geq 0,8\ \ell_{bkt}$

$\ell_2 \geq 0,8\ \ell_{bkt}$

where ℓ_{bkt} is as defined in [3.2.5].

3.2.7 Edge stiffening of bracket

Where an edge stiffener is required, the web height of the edge stiffener h_w, in mm, is not to be less than:

$$h_w = 45\left(1 + \frac{Z}{2000}\right)$$

without being less than 50 mm.

3.3 Bracketless connections

3.3.1 The design of bracketless connections is to be such as to provide adequate resistance to rotation and displacement of the connection.

3.4 Sniped ends

3.4.1 Sniped ends may be used where dynamic loads are small, provided the net thickness t_p of plating supported by the stiffener, in mm, is not less than:

$$t_p = c_1\sqrt{\left(1000\ell - \frac{s}{2}\right)\frac{sPk}{10^6}}$$

where:

P : Design pressure for the stiffener for the design load set being considered, in kN/m^2

c_1 : Coefficient for the design load set being considered, to be taken as:

- for acceptance criteria set AC-1:
  $c_1 = 1,2$
- for acceptance criteria set AC-2:
  $c_1 = 1,1$
- for acceptance criteria set AC-3:
  $c_1 = 1,0$

k : Material factor, as defined in Ch 4, Sec 1, for the plating.

Sniped stiffeners are not to be used on structures in the vicinity of engines or generators or propeller impulse zone nor on the shell envelope.

3.4.2 Bracket toes and sniped stiffeners ends are to be terminated close to the adjacent member. The distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Tapering of the sniped end is not to be more than 30 deg. The depth of toe or sniped end is not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

4 Primary supporting members (PSM)

4.1 General

4.1.1 Primary supporting members web stiffeners, tripping brackets and end brackets and connections are to comply with [4.2] to [4.5]. Where the structural arrangement is such that these requirements cannot be complied with, adequate alternative arrangement has to be demonstrated to the Society by the designer.

4.2 Web stiffening arrangement

4.2.1 Webs of primary supporting members are generally to be stiffened where the height, in mm, is greater than 100t, where t is the web net thickness, in mm, of the primary supporting member. Alternatively, this requirement may be waived based on a satisfactory buckling analysis as per Ch 9, Sec 1.

In general, the web stiffeners of primary supporting members are to be spaced not more than 110t.

4.3 Tripping bracket arrangement

4.3.1 Tripping brackets are generally to be fitted:

- in way of end brackets toes (see Fig 3, (b))
- at ends of continuous curved face plates (see Fig 3, (c))
- in way of concentrated loads
- near primary supporting members changes of sections.

4.3.2 Tripping brackets are to be fitted at positions along the member span such that they satisfy the criteria for tripping bracket spacing and flange slenderness given in Ch 9, Sec 1.

4.3.3 Where the face plate of the primary supporting members exceeds 180 mm on either side of the web, a tripping bracket is to support the face plate.

4.3.4 Where the face plate of the primary supporting members is symmetrical and greater than 400 mm in width, backing brackets are to be fitted in way of the tripping brackets (see Fig 3, (a)).

4.3.5 Arm length

The arm length of tripping brackets is not to be less than the greater of the following values, in m:

$d = 0,38\ b$

$$d = 0,85 b \sqrt{\frac{s_t}{t}}$$

where:

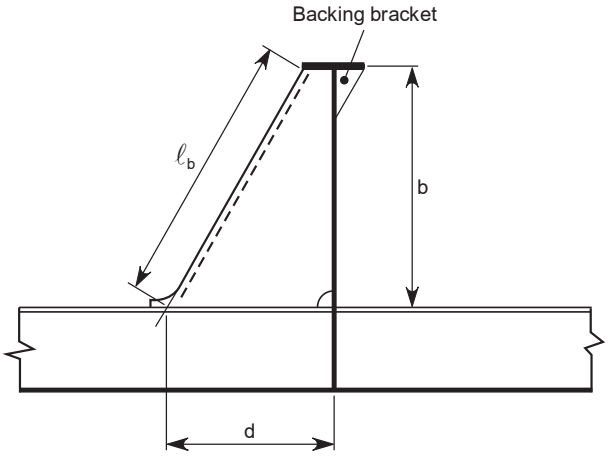
b : Height, in m, of tripping brackets, see Fig 3, (a)

s_t : Spacing, in m, of tripping brackets

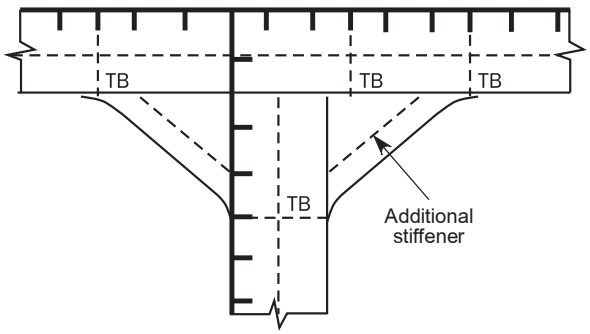
t : Net thickness, in mm, of tripping brackets.

Figure 3 : Primary supporting member - Tripping bracket arrangement

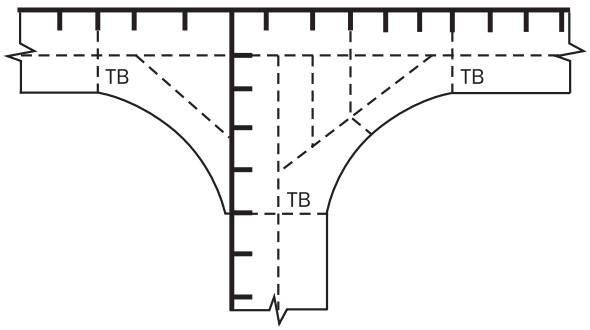
a) Tripping bracket in way of stiffener



b) Tripping brackets at the toe of end brackets



c) Tripping brackets at the ends of continuous curved face plates



4.4 Bracketed end connections

4.4.1 General

Brackets or equivalent structure are to be provided at ends of primary supporting members.

Bracketless connections may be applied according to [4.5], provided there is adequate support of adjoining face plates.

4.4.2 Scantling of end brackets

The scantling of the end brackets is to be such that the section modulus of the primary supporting member with end bracket, excluding face plate where it is sniped, is not less than that of the primary supporting member at mid-span.

The net cross-sectional area A_f, in cm^2, of the bracket face plates is to be such that:

$$A_f \geq \ell_b \, t_b$$

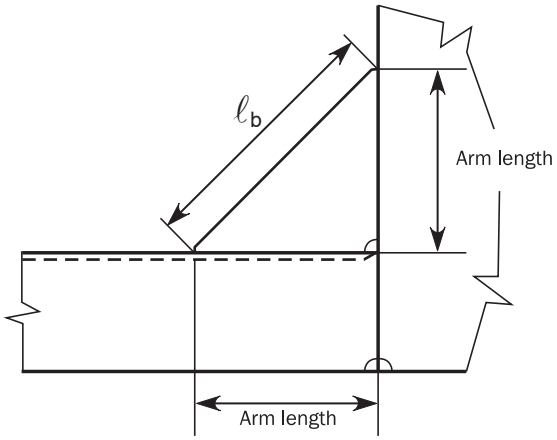
where:

ℓ_b : Length of the bracket edge, in m (see Fig 4). For curved brackets, ℓ_b may be taken as the length of the tangent at midpoint of the edge

t_b : Minimum net bracket web thickness, in mm, as defined in [3.2.4].

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

Figure 4 : Dimension of brackets



4.4.3 Arrangement of end brackets

Where the length ℓ_b of the bracket free edge is greater than 1,5 m, the web of the bracket is to be stiffened as follows:

- the net sectional area, in cm^2, of web stiffeners is to be not less than 16,5 ℓ, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted, and, where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be provided.

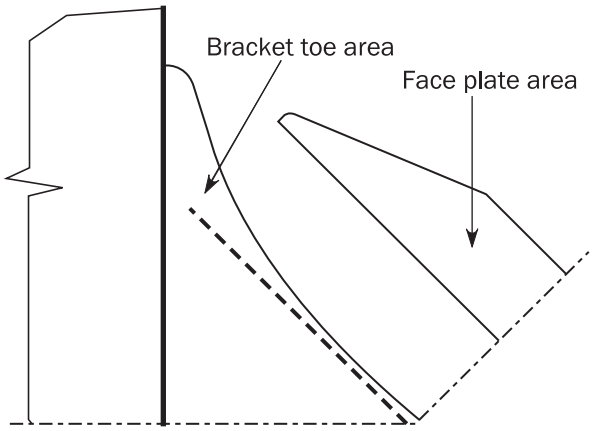
For a ring system, where the end bracket is integral with the web of the two connected members and the face plate runs continuously on the bracket from the web of one member to the other, the full cross section of the larger face plate of the two members is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plate. Butts in face plates are to be kept well clear of the bracket toes.

Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The bracket toes are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. Where primary supporting members are constructed of steel having a strength higher than the strength of the bracket steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto, or welded adjacent to, the edge of the end bracket (see Fig 5), the face plate is to be sniped and tapered at an angle not greater than 30°.

Figure 5 : Bracket face plate adjacent to the edge



4.5 Bracketless end connections

4.5.1 In the case of bracketless crossing between two primary supporting members (see Fig 6), the net thickness of the common part of the webs t_b, in mm, is to be not less than the greatest value obtained from the following formulae:

$$t_b = \frac{Sf_1\sigma_1}{0,5h_2R_y}$$

$$t_b = \frac{Sf_2\sigma_2}{0,5h_1R_{eH}}$$

$t_b = \max(t_1 ; t_2)$

where:

k : Material factor as defined in Ch 4, Sec 1

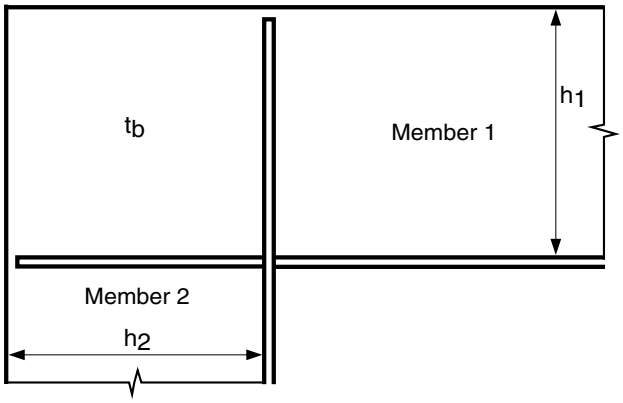
h_1 ,h_2 : Width, in mm, of member 1 and member 2, respectively, see Fig 6

Sf_1 , Sf_2 : Net flange sectional area, in mm^2, of member 1 and member 2, respectively

σ_1 , σ_2 : Normal stresses, in N/mm^2, in member 1 and member 2, respectively

t_1 , t_2 : Net web thicknesses, in mm, of member 1 and member 2, respectively.

Figure 6 : Bracketless end connections between two primary supporting members



4.5.2 In the case of bracketless crossing between three primary supporting members (see Fig 7), when the flange of member 2 and member 3 is continuous, the net thickness, in mm, of the common part of the webs is not to be less than the greater of:

$$t_b = \frac{Sf_1\sigma_1}{0,5h_2R_y}$$

$t_b = \max(t_1 ; t_2)$

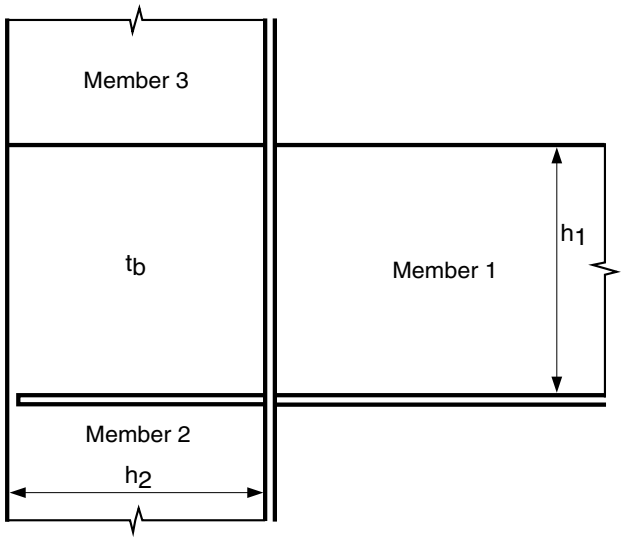
Where Sf_1, σ_1, k, h_2, t_1 and t_2 are as defined in [4.5.1]and Fig 7.

When the flanges of member 2 and member 3 are not continuous, the net thickness of the common part of the webs is to be defined as per [4.5.1].

4.5.3 The common part of the webs is to be generally stiffened where the minimum height of the member 1 and member 2 is greater than 100 t_b . Alternatively, this requirement may be waived based on a satisfactory buckling analysis as per Ch 9, Sec 1.

4.5.4 When lamellar tearing of flanges may occur, the flange in way of the connection may be requested to be of Z quality or a 100% ultrasonic testing of the flange in way of the weld may be required prior to and after welding.

Figure 7 : Bracketless end connections between three primary supporting members



5 Intersection of stiffeners and primary supporting members

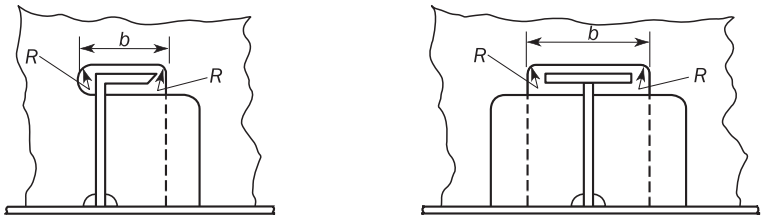
5.1 Cut-outs

5.1.1 Cut-outs for the passage of stiffeners through the web of primary supporting members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

5.1.2 The total depth of cut-outs without collar plate is to be not greater than 50% of the depth of the primary supporting member.

5.1.3 Cut-outs in high stress areas are to be fitted with full collar plates, see Fig 8.

Figure 8 : Full collar plates



5.1.4 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of [5.2], and in areas of high stress concentrations, e.g. in way of primary supporting member toes. See Fig 9 for typical lug arrangements.

5.1.5 On cargo ships with length greater than 150m, a soft heel is to be provided in way of the heel of the primary supporting member web stiffeners at connection to shell envelope longitudinals below the scantling draught T_{sc} and at connection to inner bottom longitudinals, when the calculated direct stress σ_w in the primary supporting member web stiffener according to [5.2] exceeds 80% of the allowable values. The soft heel is to have a keyhole similar to that shown in Fig 10.

A soft heel is not required at the intersection with watertight bulkheads and primary supporting members where a back bracket is fitted or where the primary supporting member web is welded to the stiffener face plate.

When calculating the direct stress, σ_w, the bottom slamming, stern slamming or bow impact loads using the design pressures defined in Ch 5, Sec 5, [4.2] and Ch 5, Sec 5, [4.3] need not be applied.

5.1.6 Cut-outs are to have rounded corners and the corner radii R are to be as large as practicable, with a minimum of 20% of the breadth b of the cut-out or 25 mm, whichever is greater. See Fig 8. The corner radii R do not need be greater than 50 mm.

Consideration is to be given to other shapes, on the basis of maintaining equivalent strength and minimising stress concentration.

Figure 9 : Symmetric and asymmetric cut-outs

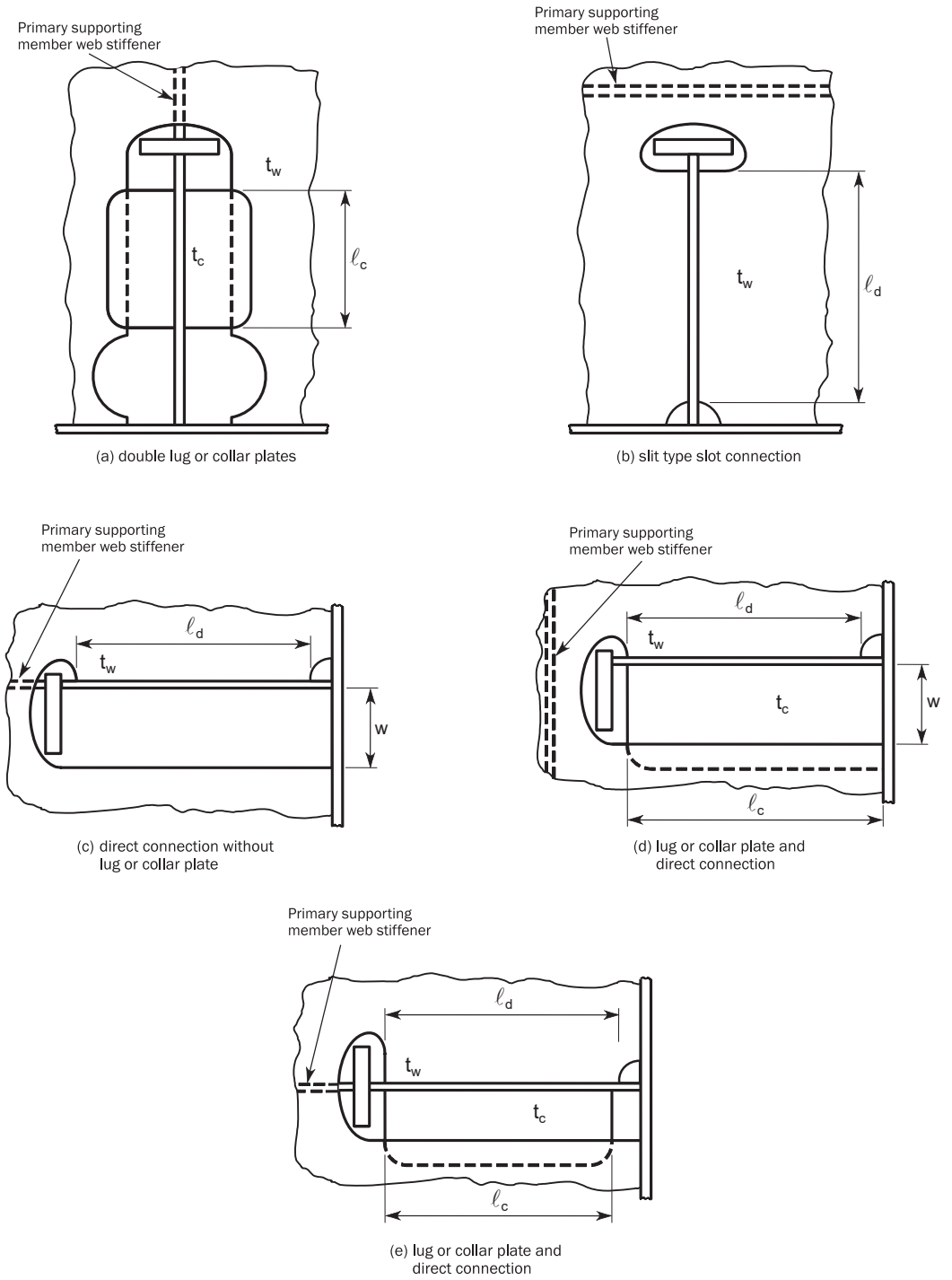
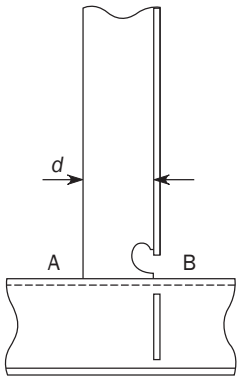


Figure 10 : Typical keyhole for soft heel at the heel of primary supporting member web stiffeners



5.2 Connection of stiffeners to PSM

5.2.1 General

For connection of stiffeners to PSM subjected to lateral pressure, the requirements of [5.2.2] and [5.2.3] are to be complied with.

The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate allowable stress.

For application of [5.2.2] and [5.2.3], the total load W, in kN, transmitted through the stiffener connection to the PSM is to be determined as follows:

a) In general

$$W = \frac{P_1 s_1\left(S_1 - \frac{s_1}{2000}\right) + P_2 s_2\left(S_2 - \frac{s_2}{2000}\right)}{2 \sin\varphi_{w1} \sin\varphi_{w2}} 10^{-3}$$

b) For bottom slamming, stern slamming or bow impact loads

$$W = \frac{P_I \ell_I (s_1 f_{shr1} + s_2 f_{shr2})}{2} 10^{-3}$$

where:

P_1, P_2 : Design pressures applied on the stiffener for the design load set being considered, in kN/m^2, on each side of the considered connection.

s_1, s_2 : Spacings, in mm, between the considered and the adjacent stiffener on each side of the considered connection

S_1, S_2 : Spacings, in m, between the considered and the adjacent PSM, on each side of the considered connection

φ_{w1} : Angle between primary supporting member and attached plating, in deg, as defined in Ch 4, Sec 6.

φ_{w2} : Angle between stiffener and attached plating, in deg, as defined in Ch 4, Sec 6.

P_I : Design impact pressure applied on the stiffener, in kN/m^2, as defined in Ch 5, Sec 5, [4.2] and Ch 5, Sec 5, [4.3].

ℓ_I : Extent of impact load area, in m, along the span:

$$\ell_I = \sqrt{A_I}$$

not to be taken greater than $(S_1 + S_2)$

$A_I = 1{,}1\ L\ B\ C_B\ 10^{-3}$

f_{shr1}, f_{shr2} : Correction factors for portion of load transmitted taken as follows:

$$0,5 \le f_{shr1} = \frac{2\ell_{shr1} - 0,5\ell_I}{2\ell_{shr1}} \le 0,75$$

$$0,5 \le f_{shr2} = \frac{2\ell_{shr2} - 0,5\ell_I}{2\ell_{shr2}} \le 0,75$$

ℓ_{shr1}, ℓ_{shr2}: Effective shear spans of the stiffener, in m, on each side of the considered connection

5.2.2 The load W_1, in kN, transmitted through the shear connection is to be taken as follows:

- for web stiffener connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_1}{4 f_c A_w + A_1}\right)$$

- for web stiffener not connected to the intersecting stiffener:
  $W_1 = W$

where:

W : Total load, in kN, transmitted through the stiffener connection to the PSM, as defined in [5.2.1]

α_a : Panel aspect ratio, equal to:

$$\alpha_a = \frac{s}{1000 S}$$

without being taken greater than 0,25 with:

$$s = \frac{s_1 + s_2}{2}$$

$$S = \frac{S_1 + S_2}{2}$$

A_1 : Effective net shear area, in cm^2, of the connection, to be taken equal to:

- in general:
  $A_1 = A_{1d} + A_{1c}$

- in case of a slit type slot connections area:

  $A_1 = 2\ A_{1d}$

- in case of a typical double lug or collar plate connection area:

  $A_1 = 2\ A_{1c}$

A_{1d} : Net shear connection area, in cm^2, excluding lug or collar plate, given by:

$A_{1d} = \ell_d\ t_w\ 10^{-2}$

ℓ_d : Length of direct connection between stiffener and PSM web, in mm

t_w : Net web thickness of the primary supporting member, in mm

A_{1c} : Net shear connection area, in cm^2, with lug or collar plate, given by:

$A_{1c} = f_1\ \ell_c\ t_c\ 10^{-2}$

f_1 : Shear stiffness coefficient, taken equal to:

- for stiffeners of symmetrical cross-section:

  $f_1 = 1,0$

- for stiffeners of asymmetrical cross-section:

  $f_1 = 140/w$ without being taken greater than 1,0

w : Width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Fig 10.

ℓ_c : Length of direct connection between stiffener and PSM web, in mm

t_c : Net thickness of lug or collar plate, in mm, not to be taken greater than the net thickness of the adjacent PSM web

f_c : Collar load factor taken equal to:

- for intersecting stiffeners of symmetrical cross-section:
  - for $A_w \leq 14$:

    $f_c = 1,85$

  - for $14 < A_w \leq 31$:

    $f_c = 1,85 - 0,0441\ (A_w - 14)$

  - for $31 < A_w \leq 58$:

    $f_c = 1,10 - 0,0130\ (A_w - 31)$

  - for $A_w > 58$:

    $f_c = 0,75$

- for intersecting stiffeners of asymmetrical cross-section:

$$f_c = 0,68 + 0,0172 \frac{\ell_s}{A_w}$$

A_w : Effective net cross-sectional area, in cm^2, of the PSM web stiffener in way of the connection, including backing bracket where fitted, as shown in Fig 11. If the PSM web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_w is to be measured at the throat of the connection, as shown in Fig 11

ℓ_s : Connection length, in mm, equal to:

- for a single lug or collar plate connection to the PSM:

  $\ell_s = \ell_c$

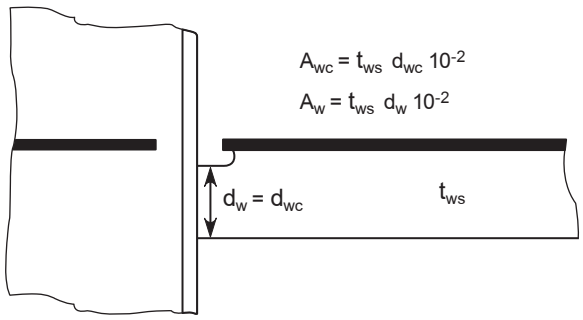
- for a single sided direct connection to the PSM:

  $\ell_s = \ell_d$

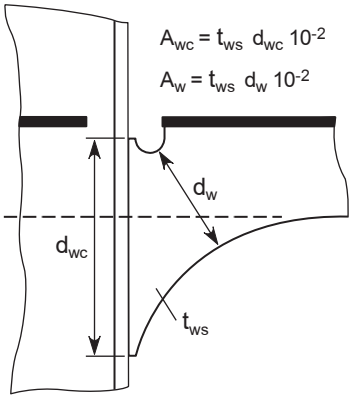
- in case of a lug or collar plus a direct connection:

  $\ell_s = 0,5\ (\ell_c + \ell_d)$.

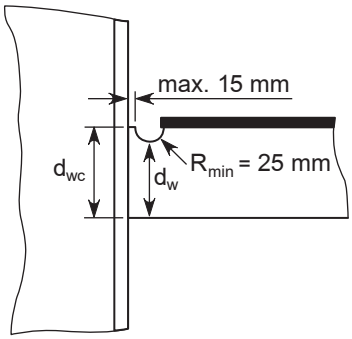
Figure 11 : Primary supporting member web stiffener details



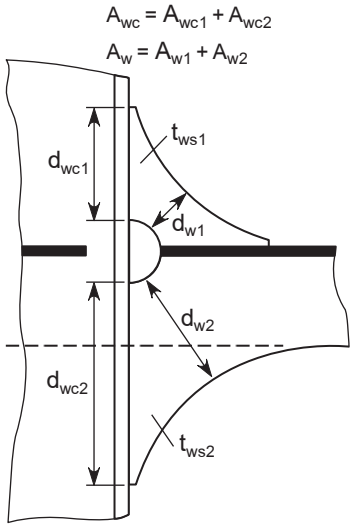
(a) Straight heel no bracket



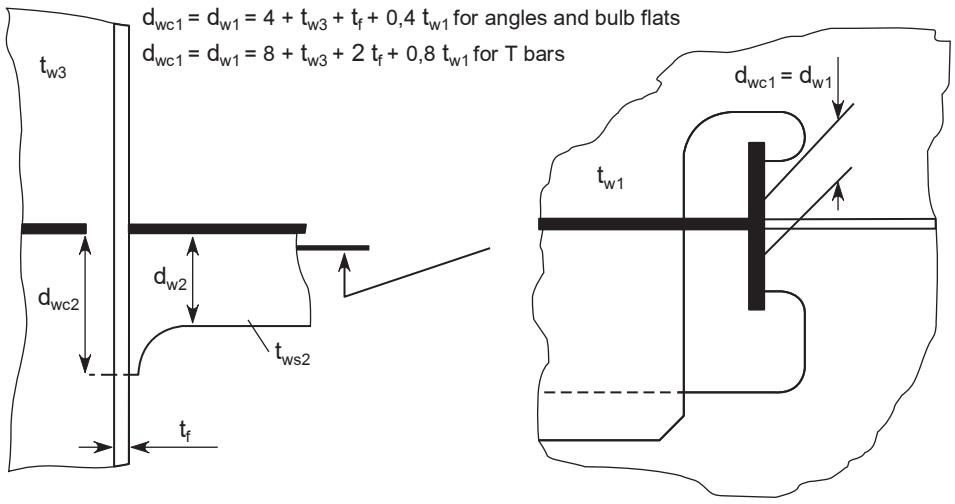
(b) Soft toe and soft heel



(c) Keyhole in way of soft heel



(d) Symmetrical soft toe brackets



(e) Primary supporting member web welded directly to stiffener flange

t_{ws} , t_{ws1} , t_{ws2} : Net thickness of the primary supporting member web stiffener/backing bracket, in mm

d_w , d_{w1} , d_{w2} : Minimum depth of the primary supporting member web stiffener/backing bracket, in mm

d_{wc} , d_{wc1} , d_{wc2} : Length of connection between the primary supporting member web stiffener/backing bracket and the stiffener, in mm

t_f : Net thickness of the flange, in mm. For bulb profile, t_f is to be taken as defined in Ch 4, Sec 6, [1.4.1].

5.2.3 The load W_2, in kN, transmitted through the PSM web stiffener is to be taken as:

- for web stiffener connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_1}{4\, f_c\, A_w + A_1}\right)$$

- for web stiffener not connected to the intersecting stiffener:

$W_2 = 0$

where:

W, α_a, A_1, f_c, A_w: As defined in [5.2.2].

The values of A_w, A_{wc} and A_1 are to be such that the calculated stresses satisfy the following criteria:

- for a connection to the PSM web stiffener not in way of the weld:

$\sigma_w \leq \sigma_{perm}$

- for a connection to the PSM web stiffener in way of the weld:

$\sigma_{wc} \leq \sigma_{perm}$

- for a shear connection to the PSM web:

$\tau_w \leq \tau_{perm}$

where:

σ_w : Direct stress, in N/mm^2, in the PSM web stiffener at the minimum bracket area away from the weld connection:

$$\sigma_w = \frac{10 W_2}{A_w}$$

σ_{wc} : Direct stress, in N/mm^2, in the PSM web stiffener in way of the weld connection:

$$\sigma_{wc} = \frac{10\ W_2}{A_{wc}}$$

with:

A_{wc} : Effective net area, in cm^2, of the PSM web stiffener in way of the weld, as shown in Fig 11

τ_w : Shear stress, in N/mm^2, in the shear connection to the PSM web:

$$\tau_w = \frac{10\ W_1}{A_1}$$

σ_{perm} : Permissible direct stress, in N/mm^2, given in Tab 1 for AC-1, AC-2, AC-3 and AC-4

τ_{perm} : Permissible shear stress, in N/mm^2, given in Tab 1 for AC-1, AC-2, AC-3 and AC-4.

5.2.4 Where a backing bracket is fitted in addition to the PSM web stiffener, it is to be aligned with the web stiffener. The arm length of the backing bracket is not to be less than the depth of the web stiffener. The net cross-sectional area through the throat of the bracket is to be included in the calculation of A_w as shown in Fig 11.

5.2.5 Lapped connections of PSM web stiffeners or tripping brackets to stiffeners are to be avoided as far as possible in the central part.

Table 1 : Permissible stresses for connection between stiffeners and PSMs

Item	Direct stress σ_{perm}, in N/mm^2			Shear stress τ_{perm}, in N/mm^2		
	Acceptance criteria set			Acceptance criteria set		
	AC-1	AC-2	AC-3 AC-4	AC-1	AC-2	AC-3 AC-4
PSM web stiffener	0,83 R_{eH} **(2)**	R_{eH}	R_{eH}	–	–	–
PSM web stiffener to intersecting stiffener in way of weld connection:						
• double continuous fillet	0,58 R_{eH} **(2)**	0,70 R_{eH} **(2)**	R_{eH}	–	–	–
• partial penetration weld	0,83 R_{eH} **(1) (2)**	R_{eH} **(1)**	R_{eH}	–	–	–
PSM web stiffener to intersecting stiffener in way of lapped welding	0,50 R_{eH}	0,60 R_{eH}	R_{eH}	–	–	–
Shear connection including lugs or collar plates:						
• single-sided connection	–	–	–	0,71 τ_{eH}	0,85 τ_{eH}	τ_{eH}
• double-sided connection	–	–	–	0,83 τ_{eH}	τ_{eH}	τ_{eH}

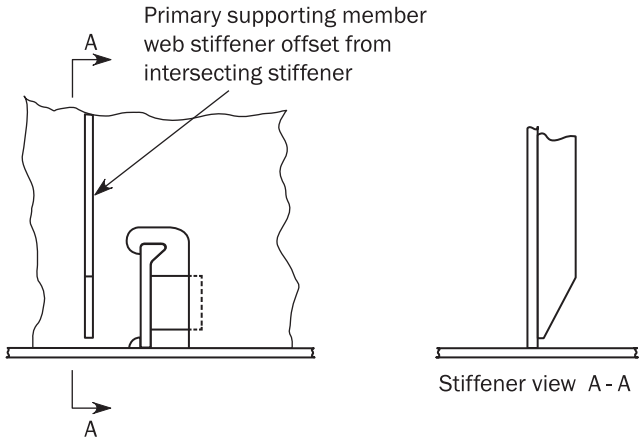
(1) The root face is not to be greater than one third of the gross thickness of the PSM web stiffener.

(2) The permissible stresses may be increased by 5% where a soft heel is provided in way of the heel of the PSM web stiffener.

5.2.6 Where built-up stiffeners have their face plate welded to the side of the web, a symmetrical arrangement of connection to the PSM is to be fitted. This may be achieved by fitting backing brackets on the opposite side of the PSM or bulkhead. The PSM web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

5.2.7 Where the web stiffener of the PSM is parallel to the web of the intersecting stiffener but not connected to it, the offset PSM web stiffener is to be located in close proximity to the slot edge as shown in Fig 12. The ends of the offset web stiffeners are to be suitably tapered and softened.

Figure 12 : Offset PSM web stiffeners



5.2.8 The size of the fillet welds ℓ_{leg}, in mm, is to be taken not less than the greater of:

- for shear connection:

  ℓ_{leg} as calculated in Ch 13, Sec 3, [3.2.6] considering a welding factor W_F equal to 0,25

$$\ell_{leg} = \min\left[\left(\sqrt{2}f_{yd}\frac{1000W_1}{2(\ell_d+\ell_c)\tau_{perm}}+t_{gap}\right);\left(\frac{\sqrt{2}}{2}f_{yd}t_w+t_{gap}\right)\right]$$

- for connection to PSM web stiffener:

  ℓ_{leg} as calculated in Ch 13, Sec 3, [3.2.6] considering a welding factor W_F equal to 0,25

$$\ell_{leg} = \min\left[\left(\sqrt{2}f_{yd}\frac{1000W_2}{2d_{wc}\sigma_{perm}}+t_{gap}\right);\left(\frac{\sqrt{2}}{2}f_{yd}t_{ws}+t_{gap}\right)\right]$$

where:

ℓ_d, ℓ_c, t_w : As defined in [5.2.2]

d_{wc}, t_{ws} : As defined in Fig 11

τ_{perm} : Permissible shear stress, in N/mm^2, defined in [5.2.3].

f_{yd}, t_{gap} : As defined in Ch 13, Sec 3

σ_{perm} : Permissible direct stress, in N/mm^2, defined in [5.2.3].

6 Openings

6.1 General

6.1.1 Minimum radius

Generally, the radius of openings corners is to be not less than 50 mm.

In way of highly stressed areas, the radius is to be taken as the greater of 50 mm and 8% of the opening width, unless duly justified by means of finite element calculations.

6.2 Openings and scallops in stiffeners

6.2.1 Fig 13 shows examples of air holes, drain holes and scallops. In general, the ratio a/b, as defined in Fig 13, is to be between 0,5 and 1,0. In fatigue sensitive areas, further consideration may be required with respect to the details and arrangements of openings and scallops.

In general, scallops and drain holes are to be kept as small as practicable.

6.2.2 Openings and scallops are to be kept (see Fig 14):

- at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration, measured along the length of the stiffener toward the mid-span, and
- at least 50 mm measured along the length in the opposite direction.

In areas where the shear stress is less than 60% of the permissible stress, alternative arrangements may be accepted.

6.2.3 Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width b as shown in Fig 13, are not permitted in stiffeners contributing to the longitudinal strength.

For the other stiffeners, closely spaced scallops/drain holes are not permitted within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted, provided they are of elliptical shape or equivalent to minimise stress concentration and they are cut clear of the welds.

Figure 13 : Examples of air holes, drain holes and scallops

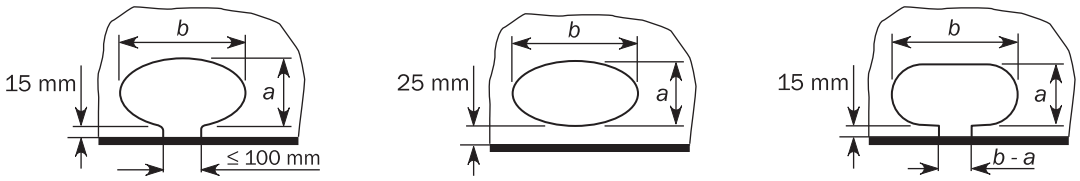
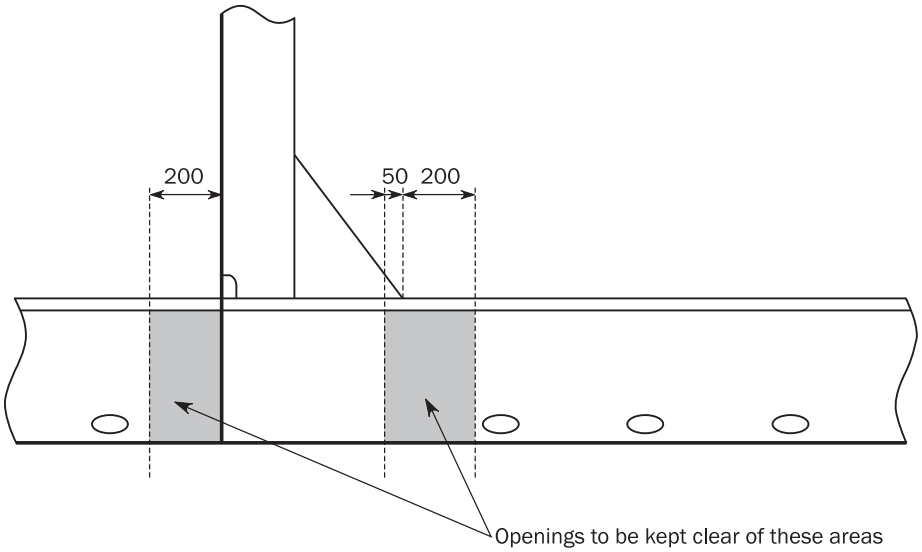


Figure 14 : Location of air and drain holes



6.3 Openings in primary supporting members

6.3.1 General

Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

Examples of high stress areas include:

- floors or double bottom girders close to their span ends or in way of cargo hold bulkheads
- primary supporting member webs in way of end bracket toes
- above the heads and below the heels of pillars.

Where openings are arranged, their shape is to be such that the stress concentration remains within the acceptable limits.

Openings are to be well rounded, with smooth edges.

6.3.2 Manholes and lightening holes

The web openings do not require reinforcement:

- in single skin sections: when the openings have depth not exceeding 25% of the web depth and are so located that the edges are not at less than 40% of the web depth from the face plate
- in double skin sections: when the openings have depth not exceeding 50% of the web depth and are so located that the edges are well clear of cut-outs for the passage of stiffeners.

The opening length is not to be greater than:

- at mid-span of primary supporting members: the distance between the adjacent openings
- at ends of the span: 25% of the distance between the adjacent openings
- for openings cut in single skin sections: the web depth or 60% of the stiffener spacing, whichever is greater.

The ends of the openings are to be equidistant from the cut-outs for the passage of stiffeners.

Where lightening holes are cut in the brackets, the distance from the hole circumference to the bracket free flange is not to be less than the diameter of the lightening hole.

Openings not complying with the above requirement are to be reinforced according to [6.3.3].

6.3.3 Reinforcements around openings

Manholes and lightening holes are to be stiffened according to this requirement, except where alternative arrangements are demonstrated as satisfactory, in accordance with the analysis methods described in Part B, Chapter 8.

On members contributing to longitudinal strength, stiffeners are to be fitted alongside the opening free edges and parallel to the vertical and horizontal axes of the opening. See Fig 15. Edge reinforcement may be used as an alternative to the stiffeners.

Stiffeners may be omitted:

- in one direction if the shortest dimension of the opening is less than 400 mm, and
- in both directions if the sum of the dimensions (length plus width) of the opening is less than 300 mm.

In the case of large openings in the web of PSMs (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in PSMs are to be considered for the reinforcement of these openings.

Where no FE analysis is performed, this may be carried out by assigning an equivalent net shear sectional area to the PSM obtained, in cm^2, according to the following formula:

$$A_{s-n50} = \frac{A_{1\text{-}n50}}{1 + \frac{32\,\ell_{shr}^2\,A_{1\text{-}n50}}{I_{1\text{-}n50}}} + \frac{A_{2\text{-}n50}}{1 + \frac{32\,\ell_{shr}^2\,A_{2\text{-}n50}}{I_{2\text{-}n50}}}$$

where:

$I_{1\text{-}n50}$, $I_{2\text{-}n50}$: Net moments of inertia, in cm^4, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

$A_{1\text{-}n50}$,$A_{2\text{-}n50}$: Net shear sectional areas, in cm^2, of deep webs (1) and (2), respectively, taking account of the web height reduction by the depth of the cut-outs for the passage of the ordinary stiffeners, if any

ℓ_{shr} : Shear span, in m, of deep webs (1) and (2) as defined in Ch 4, Sec 6, [1.1.7].

Deep web (1) and (2) are defined in Fig 16.

Figure 15 : Web plate with openings

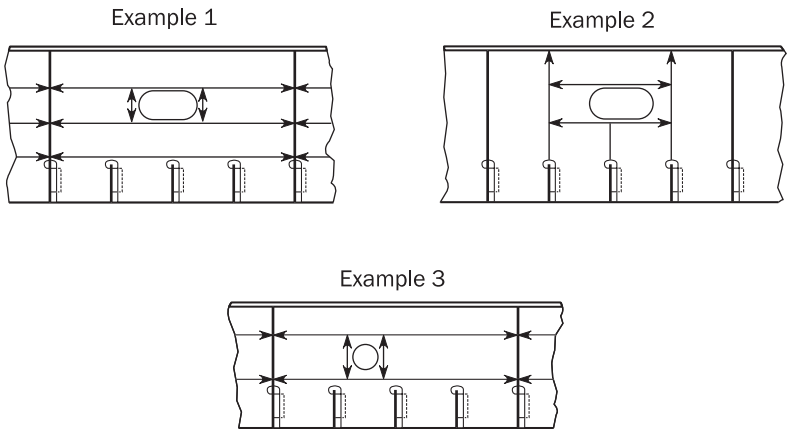
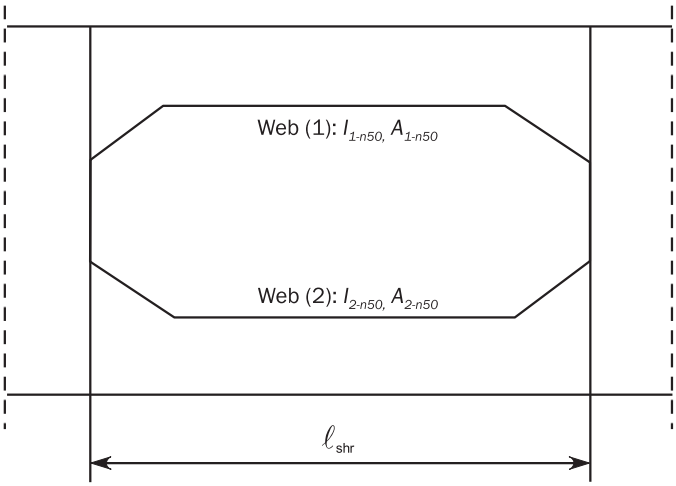


Figure 16 : Large openings in the web of primary supporting members



6.3.4 In the case of large openings as shown in Fig 17, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

The secondary stresses may be calculated in accordance with the following procedure.

Members (1) and (2) are subjected to the following forces, moments and stresses:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

$$\sigma_{F1} = 10\frac{F}{S_1}$$

$$\sigma_{F2} = 10\frac{F}{S_2}$$

$$\sigma_{m1} = \frac{m_1}{w_1}10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2}10^3$$

$$\tau_1 = 10\frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10\frac{K_2 Q_T}{S_{w2}}$$

where:

M_A, M_B : Bending moments, in kN.m, in sections A and B of the primary supporting member

m_1, m_2 : Bending moments, in kN.m, in (1) and (2)

d : Distance, in m, between the neutral axes of (1) and (2)

σ_{F1}, σ_{F2} : Axial stresses, in N/mm^2, in (1) and (2)

σ_{m1}, σ_{m2} : Bending stresses, in N/mm^2, in (1) and (2)

Q_T : Shear force, in kN, equal to Q_A or Q_B, whichever is greater

τ_1, τ_2 : Shear stresses, in N/mm^2, in (1) and (2)

w_1, w_2 : Net section moduli, in cm^3, of (1) and (2)

S_1, S_2 : Net sectional areas, in cm^2, of (1) and (2)

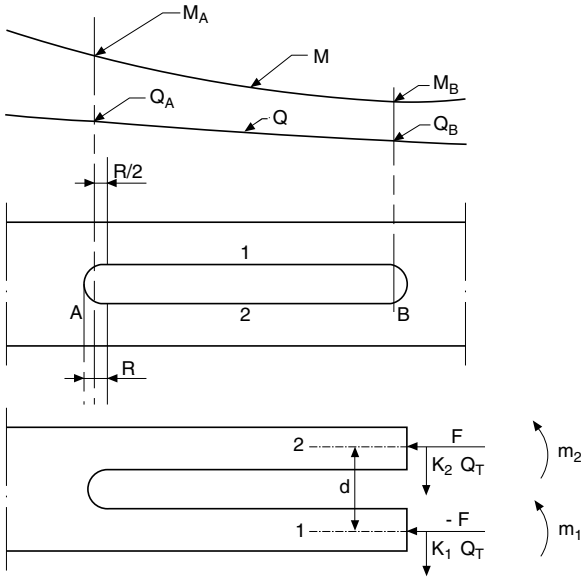
S_{w1}, S_{w2} : Net sectional areas, in cm^2, of webs in (1) and (2)

I_1, I_2 : Net moments of inertia, in cm^4, of (1) and (2) with attached plating

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

Figure 17 : Large openings in primary supporting members - Secondary stresses



The combined stress σ_C calculated at the ends of members (1) and (2) is to be obtained from the following formula:

$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

The combined stress σ_C is to comply with the checking criteria in Ch 7, Sec 6 or Ch 8, App 1, [5.2.3], as applicable. Where these checking criteria are not complied with, the cut-out is to be reinforced according to one of the solutions shown in Fig 18 to Fig 20:

- continuous face plate (solution 1): see Fig 18
- straight face plate (solution 2): see Fig 19
- compensation of the opening (solution 3): see Fig 20
- combination of the above solutions.

Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Figure 18 : Stiffening of large openings in primary supporting members - Solution 1

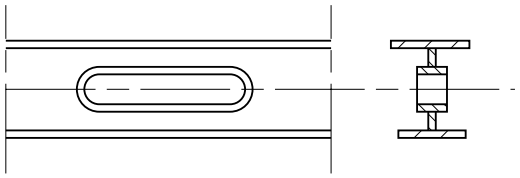


Figure 19 : Stiffening of large openings in primary supporting members - Solution 2

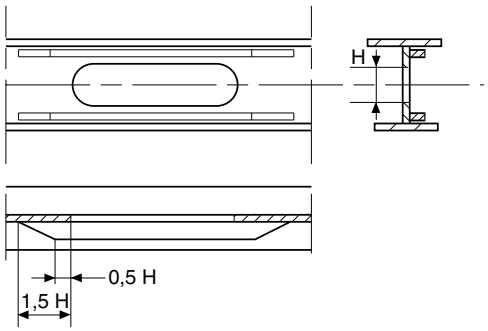
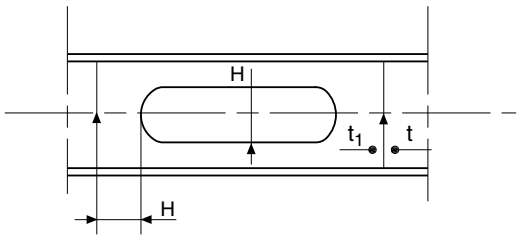


Figure 20 : Stiffening of large openings in primary supporting members - Solution 3

Inserted plate



6.4 Openings in strength deck

6.4.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the ends of superstructures. Openings are to be located as far as practicable from high stress regions such as side shell platings, hatchway corners, or hatch side coamings.

6.4.2 Small opening location

Small openings are generally to be located outside the shaded areas shown in Fig 21 and defined by:

- the bent area of a rounded sheer strake, if any, or the side shell
- the transverse distance e, from the longitudinal edge of the hatchway, equal to:
  $e = 0,25\ (B - b)$
- the longitudinal distance c, from the transverse edge of the hatchway, equal to:
  $c = 0,07\ \ell + 0,1\ b$
  or
  $c = 0,25\ b$
  whichever is greater
- the transverse distance g_i, measured from the limit of the shaded areas at the connection between deck and side, equal to:
  - for a circular opening:
    $g_i = 2\ a_i$
  - for an elliptical opening:
    $g_i = a_i$

where (see Fig 21):

a_i : Transverse dimension, in m, of the small opening i considered

b : Width, in m, of the hatchway considered, measured in the transverse direction

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction.

Distances between small openings are not to be less than:

a) in longitudinal direction (see openings 1 and 3 in Fig 22):
   - $(a_1 + a_3)$ for circular openings
   - $0,75\ (a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one

b) in transverse direction (see openings 1 and 2 in Fig 22):
   - $2,0\ (a_1 + a_2)$ for circular openings
   - $1,5\ (a_1 + a_2)$ for elliptical openings and for an elliptical opening in line with a circular one

If the opening arrangements do not comply with these requirements, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas, see Ch 6, Sec 1, [1.2].

Figure 21 : Position of small openings with respect to sides and hatchways in the strength deck

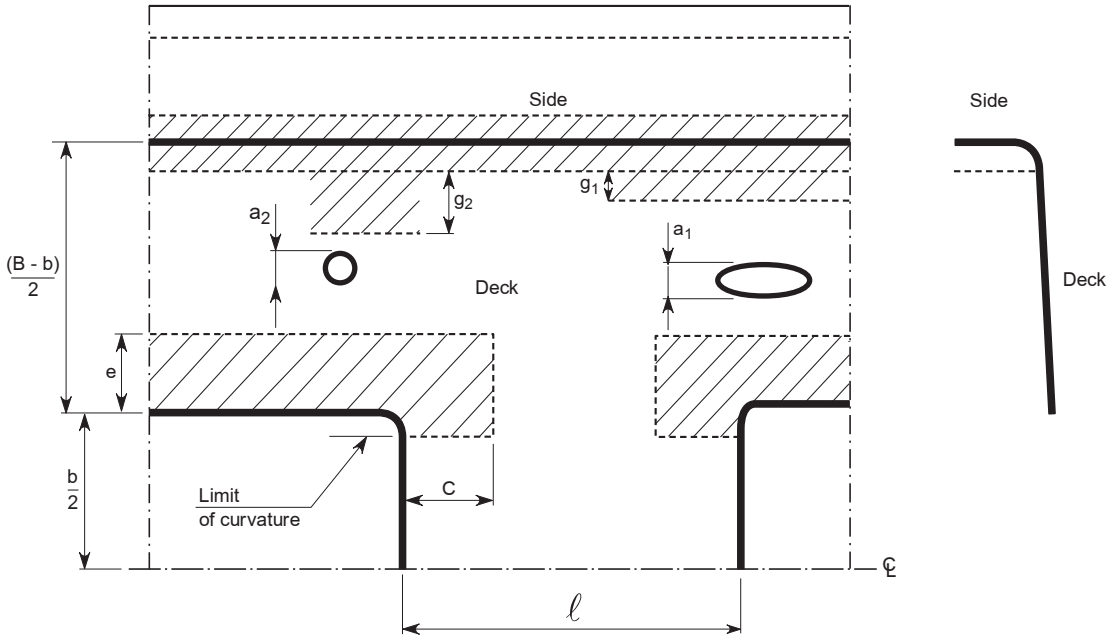
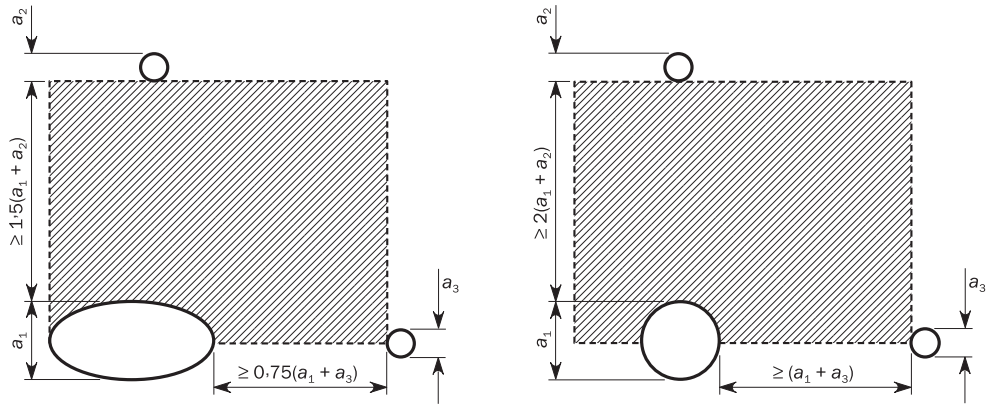


Figure 22 : Distances between small openings in the strength deck



6.5 Corners of hatchways

6.5.1 For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to [6.5.3], are generally to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is to be not less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radiusing, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.

6.5.2 For hatchways located in the positions specified in [6.5.1], insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

6.5.3 Where insert plates are required, their thickness is obtained, in mm, from the following formula:

$$t_{INS} = \left(0,8 + 0,4\frac{\ell}{b}\right)t$$

without being taken less than t or greater than 1,6t

where:

ℓ : as defined in [6.4.2].

b : as defined in [6.4.2].

t : Actual thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

6.5.4 Where insert plates are required, the arrangement shown in Ch 13, App 2, Tab 66 is to be complied with.

6.5.5 For hatchways located in positions other than those in [6.5.1], a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case by case basis.

6.6 Openings in shell plating

6.6.1 Position of openings

Openings in the shell plating are to be located at a vertical distance from the deck at side, taken under the bent area of the rounded sheer strake if any, not less than:

- two times the opening diameter, in case of circular openings
- the transverse dimension of the opening (along the minor axis), in case of elliptical openings.

See also Fig 21.

6.6.2 Local strengthening

Openings in the ship sides, e.g. for pilot doors, are to be well rounded at the corners and located well clear of superstructure ends or of any openings in the deck areas at sides of hatchways.

Openings for sea intakes are to be well rounded at the corners and, within 0,6 L amidships, located outside the bilge strakes. Where arrangements are such that sea intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction. Openings for stabiliser fins are considered by the Society on a case-by-case basis. The gross thickness of the sea chests is to be generally that of the local shell plating, but in no case less than 12 mm.

Above mentioned openings, when deemed necessary by the Society, other openings may be adequately compensated by means of insert plates of increased thickness or doublers sufficiently extended in length. Such compensation is to be partial or total, depending on the stresses occurring in the area of the openings.

Circular openings on the sheer strake need not be compensated where their diameter does not exceed 20% of the sheer strake minimum width as defined in [8.1.4], or 380 mm, whichever is the lesser, and where they are located away from openings on deck at side of hatchways and away from superstructure ends.

7 Bottom structure

7.1 General

7.1.1 Framing system

For ships greater than 120 m in length, the bottom shell and the inner bottom are to be longitudinally stiffened within the central part. Where it is not practicable to apply a longitudinal framing system to fore and aft parts of the central part due to the hull form, transverse framing may be accepted on a case-by-case basis, subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of the changes to the framing system.

7.1.2 Variation in height of double bottom

Any variation in the double bottom height is to be made gradually and over an acceptable length; the knuckles of inner bottom plating are to be located in way of double bottom floors. Where such arrangement is not possible, longitudinal structures, such as partial girders, longitudinal brackets, fitted across the knuckle, are to be arranged.

7.1.3 Drainage of tank top

Effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend over more than one-half height of double bottom.

7.1.4 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the plating.

7.1.5 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders spaced not more than 3 m apart. Otherwise, for a spacing wider than 3 m, the two girders are to be provided with support of the adjacent structure and subject to the Society's approval.

The structures in way of the floors are to provide sufficient continuity of the latter.

7.2 Keel plate

7.2.1 Keel plating is to extend over the flat part of the bottom for the full length of the ship.

The width of the keel, in m, is not to be less than:

0,8 + L/200, without being taken greater than 2,3 m.

7.3 Girders

7.3.1 Centre girder

When fitted, the centre girder is to extend within the central part and is to extend forward and aft as far as practicable. Structural continuity of the centre girder is to be maintained within the full length of the ship.

7.3.2 Side girders

The side girders are to extend within the parallel part of the central part and are to extend forward and aft of the central part as far as practicable.

7.4 Floors

7.4.1 Web stiffeners

Where the web stiffeners are not welded to the longitudinal stiffeners, fatigue strength assessment for the cut-out and connection of longitudinal stiffeners may be required.

7.4.2 Floor spacing

Floors are also to be fitted in way of the watertight bulkheads.

For transversally framed bottom, floors are to be fitted at every frame.

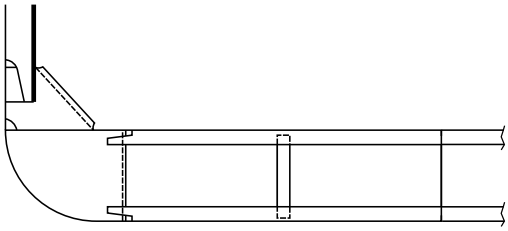
7.5 Open floors

7.5.1 Open floors may be fitted in way of intermediate frames, consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating (See Fig 23).

7.5.2 Open floors are to be attached to the centreline girder and to the margin plate by means of flanged brackets having a width of flange not less than 1/10 of the local double bottom height.

7.5.3 Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

Figure 23 : Open floor



7.6 Bilge keel

7.6.1 Material

The material of the bilge keel and that of the ground bar is to be at least of the same yield stress as the material of the bilge plating to which they are attached.

In addition, when the bilge keel extends over a length greater than 0,15 L, the material of the ground bar and that of the bilge keel are to be, at least, of the same grade and of the same material class as the material of the bilge plating to which they are attached.

7.6.2 Design

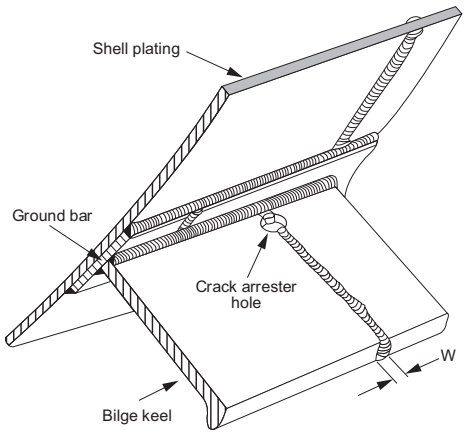
The design of single web bilge keels is to be such that failure to the web occurs before failure of the ground bar. This may be achieved by ensuring that following conditions are both satisfied:

- the web thickness of the bilge keel does not exceed that of the ground bar
- the yield stress of the material of the bilge keel does not exceed that of the ground bar.

In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm (see Fig 24). Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Bilge keels of a design different from that shown in Fig 24 are to be specially considered by the Society.

Figure 24 : Bilge keel construction



7.6.3 Ground bars

Bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Fig 24 to Fig 26. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge plating or 14 mm, whichever is the lesser.

Figure 25 : Bilge keel and design

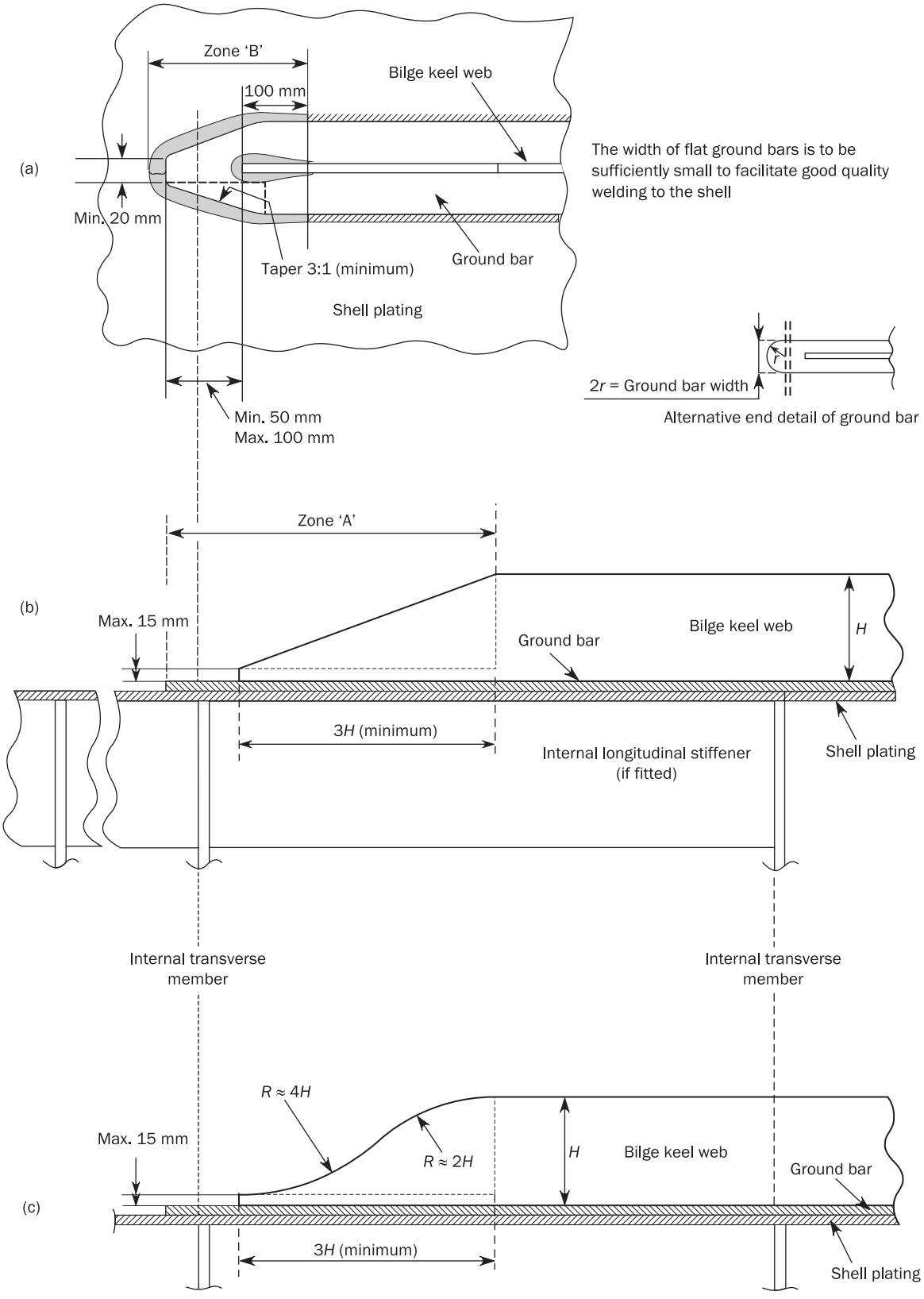
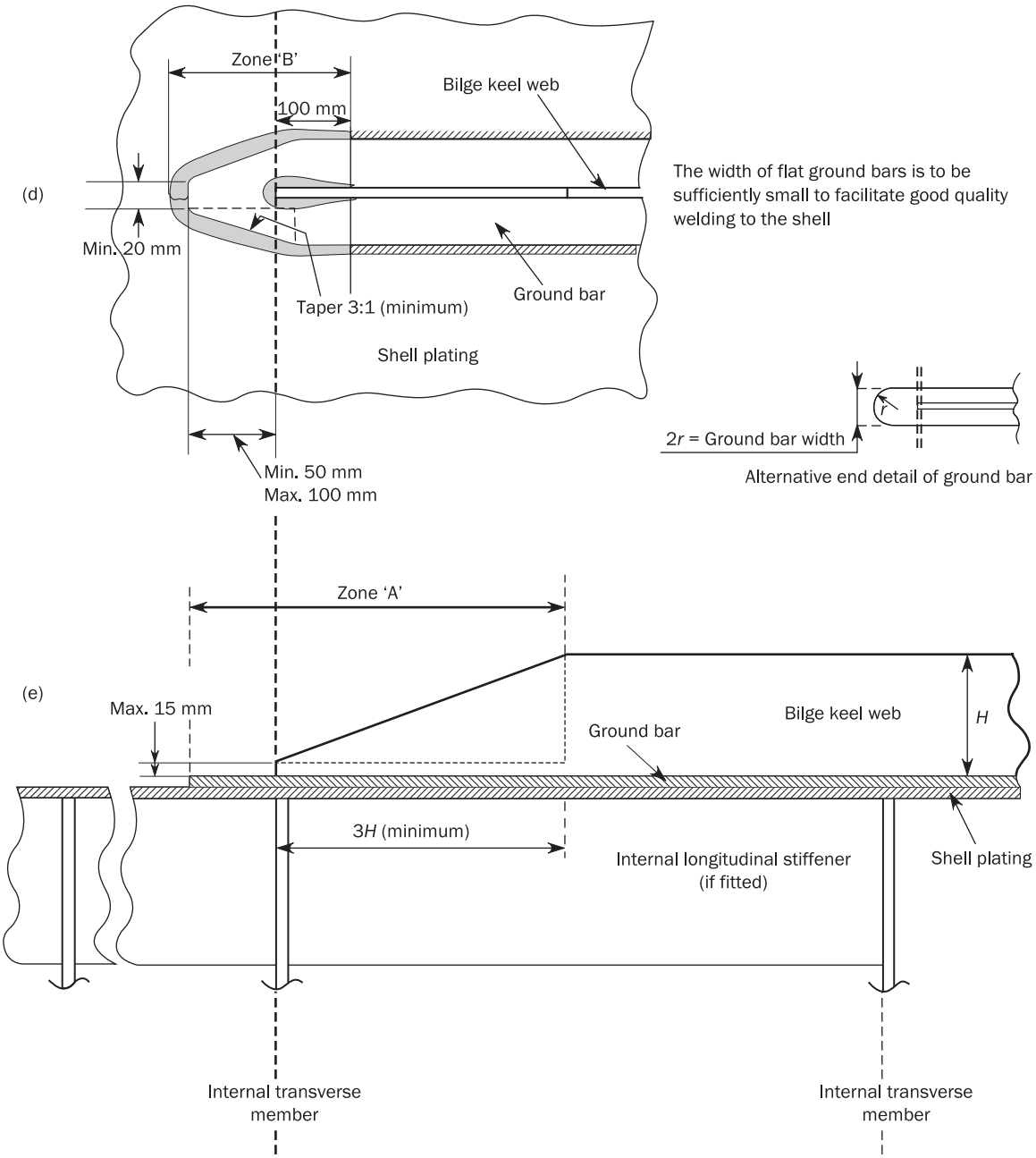


Figure 26 : Bilge keel and design



7.6.4 End details

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see Fig 25 items (a) and (b), and Fig 26 items (d) and (e). Rounded ends are to be as shown in Fig 25, item (c). Cut-outs on the bilge keel web within zone A (see Fig 25 item (b) and Fig 26 item (e)) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground bar, see Fig 25 item (a) and Fig 26 item (d).

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- transverse support member is to be fitted at mid-length between the end of the bilge keel web and the end of the ground bar, see Fig 25 items (a), (b) and (c)
- longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone A (see Fig 25 item (b) and Fig 26 item (e)).

Alternative end arrangements may be considered by the Society on a case by case basis.

7.7 Docking

7.7.1 General

The dry docking arrangement itself is not covered by these Rules.

8 Side structure

8.1 Structural arrangement

8.1.1 Primary supporting members

Side or double side web frames are to be fitted in line with the bottom web frames. Alternative framing arrangements may be considered by the Society on a case by case basis.

For double side arrangement, a vertical framing is to be fitted in way of the structure of the transverse bulkheads.

8.1.2 Longitudinal stiffeners

The longitudinal stiffeners on side shell and inner hull, where fitted, are to be continuous within the length of the parallel part of the central part. They are to be effectively connected to the transverse web frames and bulkheads of the double side structure.

Longitudinal framing of the side shell is to extend outside the central part, as far forward as practicable.

8.1.3 Transverse stiffeners

The transverse stiffeners on side shell and inner hull, where fitted, are to be continuous or fitted with bracket end connections. At their upper and lower ends, the shell and inner hull transverse stiffeners are to be connected by brackets to the supporting stringer plates.

8.1.4 Sheer strake

Sheer strakes are to have breadths, in m, not less than 0,8 + L/200, measured vertically, but need not be greater than 1,8 m.

The sheer strake may be either welded to the stringer plate or rounded.

If the sheer strake is rounded, its radius, in mm, is to be not less than 17 t_s, where:

t_s : Net thickness, in mm, of the sheer strake.

The upper edge of the welded sheer strake is to be rounded, smooth and free of notches. Fixtures, such as bulwarks and eye plates, are not to be directly welded on the upper edge of the sheer strake, except in fore and aft parts. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thickness of the sheer strake.

The welding of deck fittings to rounded sheer strakes is to be avoided within 0,6 L amidships.

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures is to be designed to avoid any discontinuities.

9 Deck structure

9.1 Structural arrangement

9.1.1 Framing system

For ships greater than 120 m in length, deck areas contributing to the longitudinal strength are to be longitudinally framed.

Transverse framing may be accepted on a case-by-case basis subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of changes to the framing system.

9.1.2 Stringer plate

Stringer plates are to have breadths, in m, not less than 0,8 + L/200, measured horizontally, but need not be greater than 1,8 m.

Rounded stringer plates, where adopted, are to comply with the requirements in [8.1.4].

9.1.3 Connection of deckhouses and superstructures

Connection of the deckhouses and superstructures to the strength deck is to be so designed that loads are transmitted to the supporting structure under deck.

10 Bulkhead structure

10.1 Application

10.1.1 The requirements of this Article apply to longitudinal and transverse bulkheads, which may be plane or corrugated.

10.2 Plane bulkheads

10.2.1 General

The bulkheads are to be stiffened in way of the deck girders.

The horizontally framed bulkheads are made of horizontal stiffeners supported by vertical primary supporting members.

The vertically framed bulkheads are made of vertical stiffeners supported by horizontal stringers, if needed.

The crossing of stiffeners through a watertight bulkhead is to be watertight.

Bulkheads that support girders or pillars and longitudinal bulkheads which are fitted in lieu of girders are to be stiffened to provide supports not less effective than required for stanchions or pillars that would be located at the same position.

Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way of the connection are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

10.2.2 End connection of stiffeners

End connections of stiffeners are to be bracketed or welded to the supporting member.

For isolated areas where bracketed or welded end connections cannot be applied due to hull lines, other arrangements including sniped ends are acceptable.

Sniped ends may be used for stiffeners on bulkheads subject to hydrostatic pressure, provided they comply with [3.4].

10.3 Corrugated bulkheads

10.3.1 General

Transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck in the following cases:

- bulkheads normally submitted to liquid pressure, e.g. tank bulkheads and ballast hold bulkheads on ships of 16 m moulded depth and above; and
- any bulkhead on ships of 18 m moulded depth and above.

Otherwise corrugations may extend from inner bottom to deck.

10.3.2 Construction

The main dimensions $b_{f\text{-}cg}$, R, $b_{w\text{-}cg}$, d_{cg}, t_f, t_w, s_{cg} of corrugated bulkheads are defined in Fig 27.

The corrugation angle ϕ is not to be less than 55°.

When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

10.3.3 Corrugated bulkhead depth

The depth of the corrugation, d_{cg}, in mm, is not to be less than:

$$d_{cg} = \frac{1000\,\ell_c}{C}$$

where:

ℓ_c : Mean span of considered corrugation, in m, as defined in [10.3.5].

C : Coefficient to be taken as:

- C = 15 for tank and water ballast cargo hold bulkheads.
- C = 18 for dry cargo hold bulkheads.

10.3.4 Actual section modulus of corrugations

The net section modulus of a corrugation may be obtained, in cm^3, from the following formula:

$$Z = \left[\frac{d_{cg}(3\,b_{f-cg}t_f + b_{w-cg}t_w)}{6}\right] 10^{-3}$$

where:

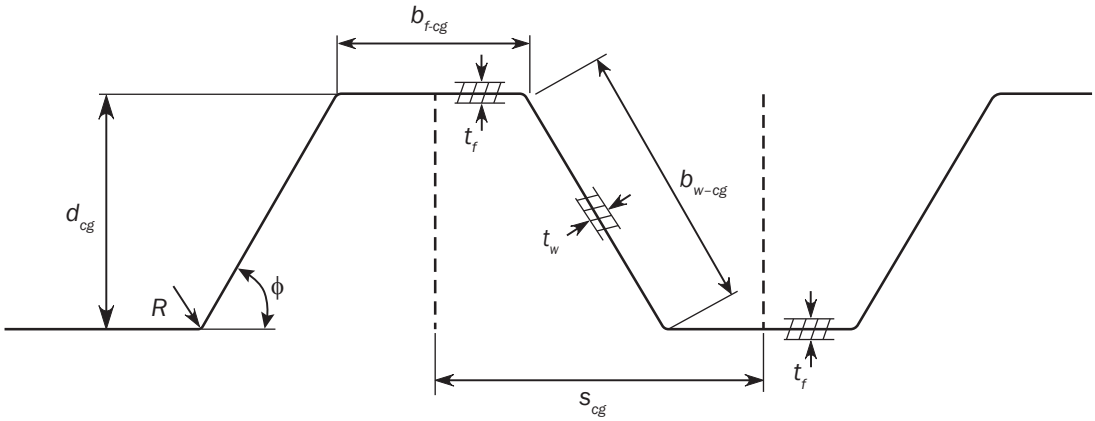
t_f, t_w : Net thickness of the plating of the corrugation, in mm, shown in Fig 27.

d_{cg}, $b_{f\text{-}cg}$, $b_{w\text{-}cg}$:Dimensions of the corrugation, in mm, shown in Fig 27.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$$Z = 0{,}5\; b_{f-cg}t_f d_{cg}\; 10^{-3}$$

Figure 27 : Dimensions of a corrugated bulkhead



10.3.5 Span of corrugations

The span ℓ_c of the corrugations is to be taken as the distance shown in Fig 28.

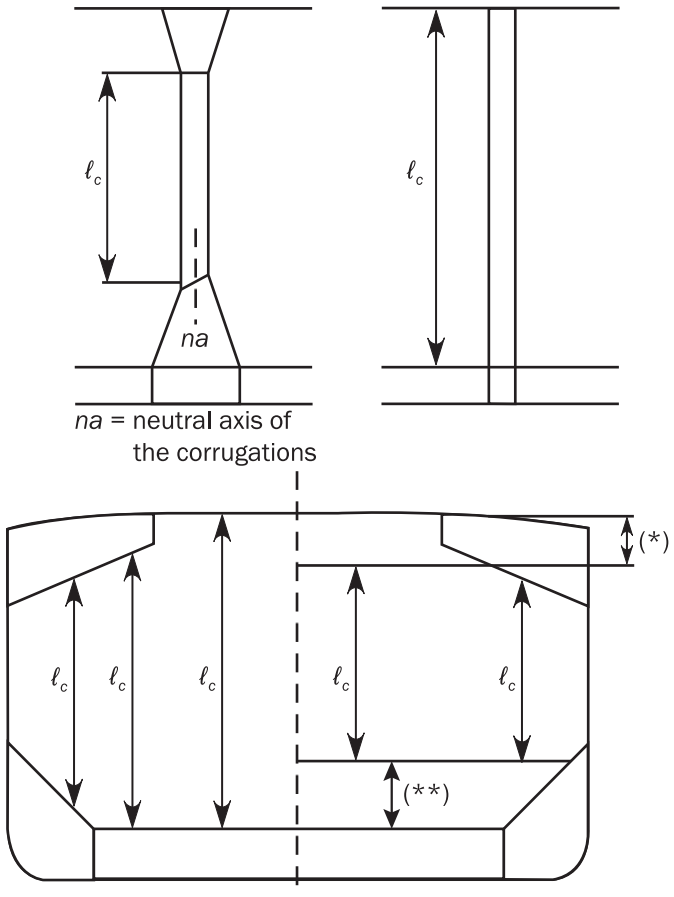
For the definition of ℓ_c, the bottom of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, for non rectangular stool.
- 2 times the depth of corrugation, for rectangular stool.

10.3.6 Structural arrangements

Where corrugated bulkheads are cut in way of primary supporting members, corrugations on each side of the primary member are to be aligned with each other.

Figure 28 : Span of the corrugations



(*) upper stool height
(**) lower stool height

10.3.7 Bulkhead end supports

The strength continuity of corrugated bulkheads is to be maintained at the ends of corrugations.

Where a bulkhead is provided with a lower stool, floors or girders are to be fitted in line with both sides of the lower stool. Where a bulkhead is not provided with a lower stool, floors or girders are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead.

The supporting floors or girders are to be connected to each other by suitably designed shear plates.

At deck, if no upper stool is fitted, transverse or longitudinal stiffeners are to be fitted in line with the corrugation flanges.

When the corrugation flange connected to the adjoining boundary structures (i.e. inner hull, side shell, longitudinal bulkhead, trunk, etc) is smaller than 50% of the width of the typical corrugation flange, an advanced analysis of the connection is required.

10.3.8 Bulkhead stools

Stool side plating is to be aligned with the corrugation flanges.

10.3.9 Lower stool

The lower stool, when fitted, is to have a height not less than:

- 3 corrugation depths for dry cargo hold bulkheads.
- one corrugation depth for tank and water ballast cargo hold bulkheads.

The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures such as longitudinals or similar. Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

The distance d from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with the distance shown on Fig 29.

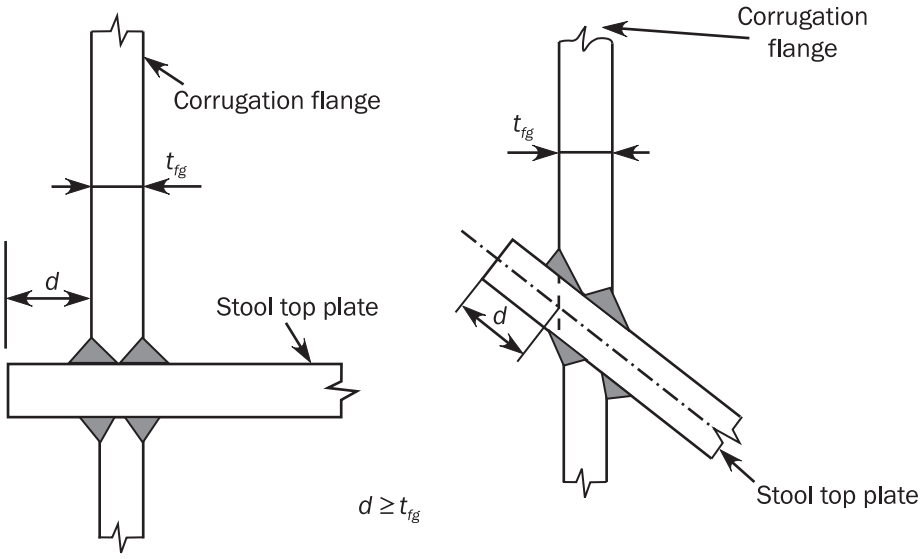
The lower part of the stool side plates is to be in line with double bottom floors or girders as the case may be, and the stool bottom is to have a width not less than:

- 2.5 corrugation depths for dry cargo hold bulkheads.
- one corrugation depth for tank and water ballast cargo hold bulkheads.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or partial penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

Figure 29 : Permitted distance, d, from the edge of the stool top plate to the surface of the corrugation flange



10.3.10 Upper stool

The upper stool, when fitted, is to have a height:

- Not less than two times the corrugation depth for dry cargo hold bulkheads.
- At least one corrugation depth for tank and water ballast cargo hold bulkheads.

Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder or at the inner hull as applicable. Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams.

The upper stool of a transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams. The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools of bulk carriers is to have a width not less than twice the depth of corrugations. The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.4 Wash bulkheads

10.4.1 General

In general, openings in wash bulkheads are to have their aggregate area between 10% and 30% of the bulkhead area.

10.5 Watertight bulkheads of trunks and tunnels

10.5.1 Watertight bulkheads of trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing their openings, are to be to the satisfaction of the Society.

10.6 Bulkheads acting as pillars

10.6.1 Each vertical stiffener, in association with a width of plating equal to:

- 35 times the plating net thickness
- 1/12 of stiffener length, or
- the stiffener spacing, whichever is the smaller,

is to comply with the applicable requirements in Part B, Chapter 7, for the load being supported.

10.6.2 Non-tight corrugated bulkheads

Where non-tight bulkheads are corrugated, each corrugation is to comply with the applicable requirements in Part B, Chapter 7, for the load being supported.

10.7 Watertight doors

10.7.1 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

11 Pillars

11.1 General

11.1.1 Wherever possible, pillars are to be fitted in the same vertical line. If not possible, effective means are to be provided for transmitting the pillar loads to the supports below. Effective arrangements are to be made to distribute the loads at the heads and the heels of all the pillars. Where pillars support eccentric loads, they are to be strengthened to withstand the additional bending moment applied on them.

11.1.2 Pillars connected to the inner bottom are to be fitted at the intersection of girders and floors, or as close thereto as practicable, and the structure above and below the pillars is to be of sufficient strength to provide effective distribution of the load.

Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders, or equivalent structures, are to be fitted as necessary to support the pillars.

11.1.3 In tanks, solid or open section pillars are generally to be fitted. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

11.2 Connections

11.2.1 Heads and heels of the pillars are to be secured by thick doubling plates and brackets, as necessary. Alternative arrangements for doubling plates may be accepted, provided they are considered equivalent, as deemed appropriate by the Society.

Where the pillars are likely to be subjected to tensile loads, heads and heels of the pillars are to be efficiently secured to withstand the tensile loads and the doubling plates are to be replaced by insert plates complying with the through thickness properties requirements in Ch 4, Sec 1, [2.6].

In general, the net thickness of the doubling plates, when fitted, is to be not less than 1,5 times the net thickness of the pillar. Pillars are to be attached at their heads and heels by continuous welding.

11.2.2 Contact pressure

At connexions between pillars and decks, it is to be checked that the contact pressure σ_C, in N/mm^2, is in compliance with the following formula:

$\sigma_C \leq R_{eH}$

where:

$$\sigma_C = 10\frac{F_A}{A_C}$$

with:

F_A : Compression axial load in the pillar, in kN

A_C : Contact area between the pillar and the deck structural members, in cm^2

R_{eH} : Smallest of the assembled elements yield stress, in N/mm^2.

Section 6 Structural Idealisation

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

φ_w : Angle, in deg, between the stiffener or the primary supporting member web and the attached plating, see Fig 14. φ_w is to be taken equal to 90° if the angle is greater or equal than 75° and smaller or equal than 105°.

ℓ_{bdg} : Effective bending span, in m, as defined in:

- [1.1.2] for stiffeners, and
- [1.1.6] for primary supporting members.

ℓ_{shr} : Effective shear span, in m, as defined in:

- [1.1.3] for stiffeners, and
- [1.1.7] for primary supporting members.

LCP : Load Calculation Point.

1 Structural idealisation of stiffeners and primary supporting members

1.1 Effective spans

1.1.1 General

Where arrangements differ from those defined in this Article, the span definition may be specially considered, depending on the actual arrangement at the ends of the stiffeners or primary supporting members.

1.1.2 Effective bending span of stiffeners

The effective bending span ℓ_{bdg} of stiffeners is to be obtained as shown in Fig 1 for single skin structures and in Fig 3 for double skin structures.

If the stiffener on the PSM web is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between PSMs unless a backing bracket is fitted, see Fig 1, items a) and b).

The effective bending span may be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted on the side opposite to that of the stiffener with respect to attached plating are not to be considered as effective in reducing the effective bending span.

In single skin structures, the effective bending span of a stiffener supported by a bracket or by a web stiffener on one side only of the primary supporting member is to be taken as the total span between primary supporting members, as shown in item a) of Fig 1. If brackets are fitted on both sides of the primary supporting member, the effective bending span is to be taken as shown in items b), c) and d) of Fig 1.

Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, see Fig 2.

1.1.3 Effective shear span of stiffeners

The effective shear span ℓ_{shr} of stiffeners is to be obtained as shown in Fig 4 for single skin structures and in Fig 6 for double skin structures.

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted both on the flange or the free edge of the stiffener and to the attached plating on the side opposite to that of the stiffener, the effective shear span may be reduced using the longer effective bracket arm.

Regardless of the support detail, the full length of the stiffener may be reduced by a length, in m, at least equal to s/4000 at each end of the member, hence the effective shear span ℓ_{shr} is not to be taken greater than:

$$\ell_{shr} \leq \ell - \frac{s}{2000}$$

For curved and/or long brackets (high length/height ratio), the effective bracket length is to be taken as the maximum inscribed 1:1,5 right angled triangle as shown in items c) of Fig 4 and Fig 6.

Where the face plate of the stiffener is continuous along the curved edge of the bracket, the bracket length to be considered for determination of the span point location is not to be taken greater than 1,5 times the length of the bracket arm as shown in Fig 5.

Figure 1 : Single skin construction - Effective bending span ℓ_{bdg} of stiffeners supported by web stiffeners

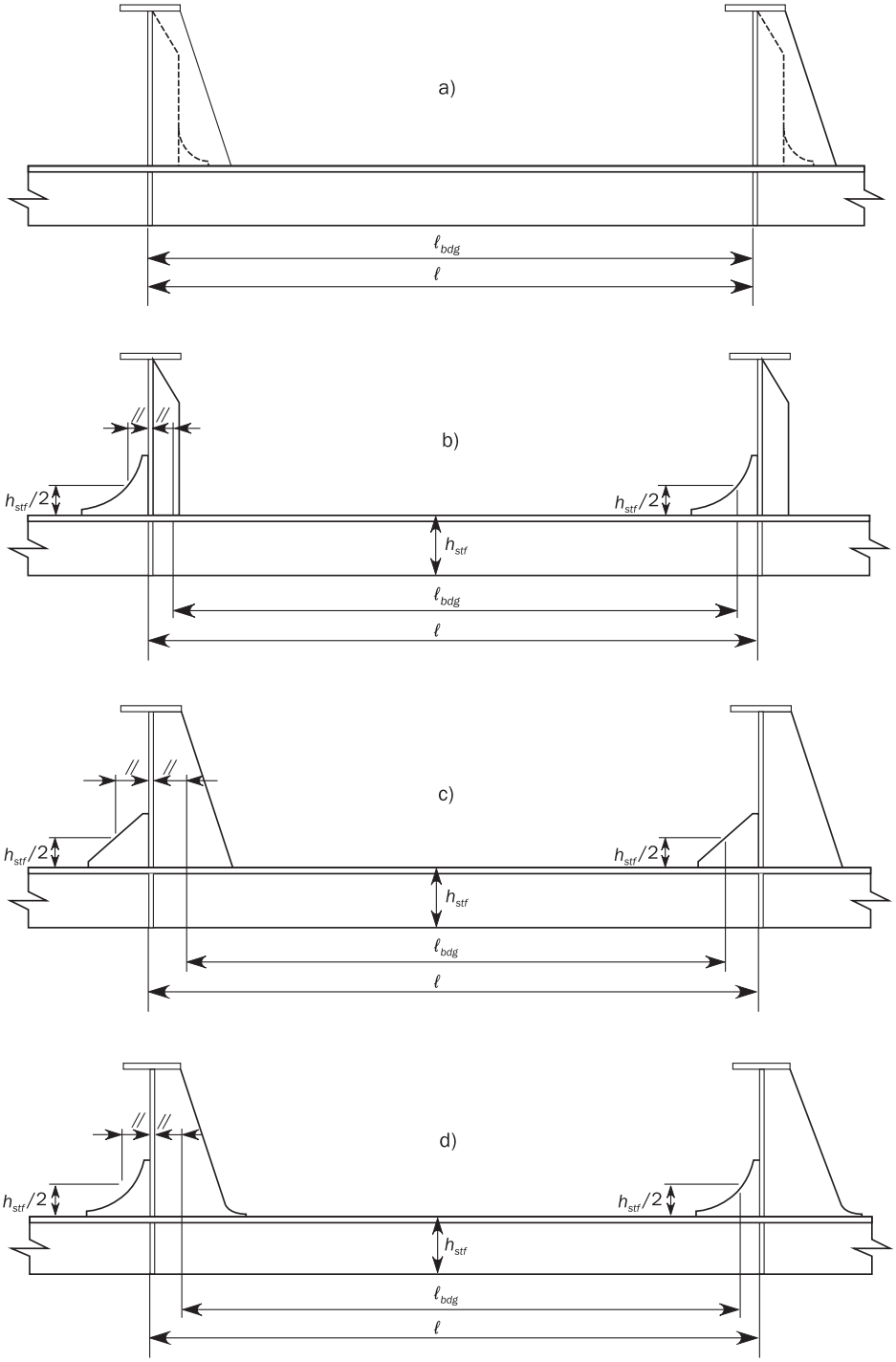


Figure 2 : Effective bending span ℓ_{bdg} for local support members with continuous face plate along bracket edge

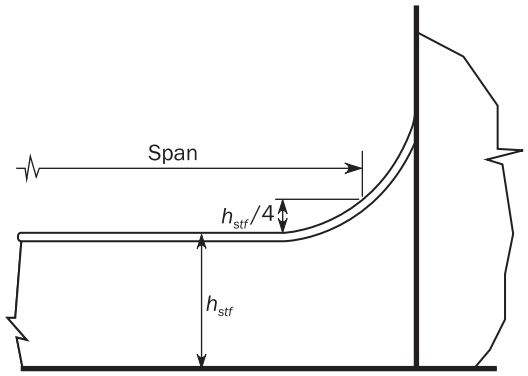


Figure 3 : Double skin construction - Effective bending span ℓ_{bdg} of stiffeners supported by web stiffeners

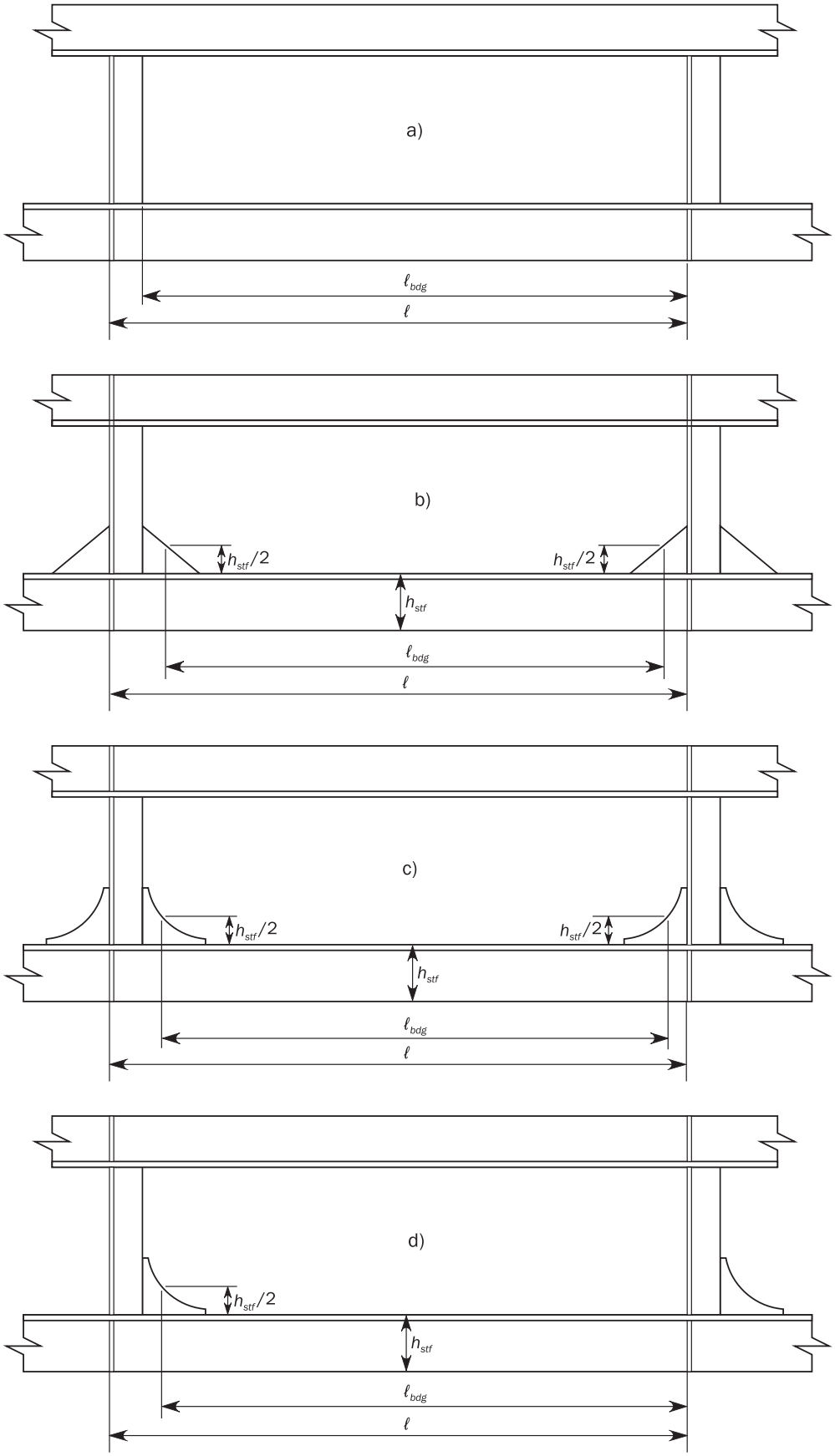


Figure 4 : Single skin construction - Effective shear span ℓ_{shr} of stiffeners supported by web stiffeners

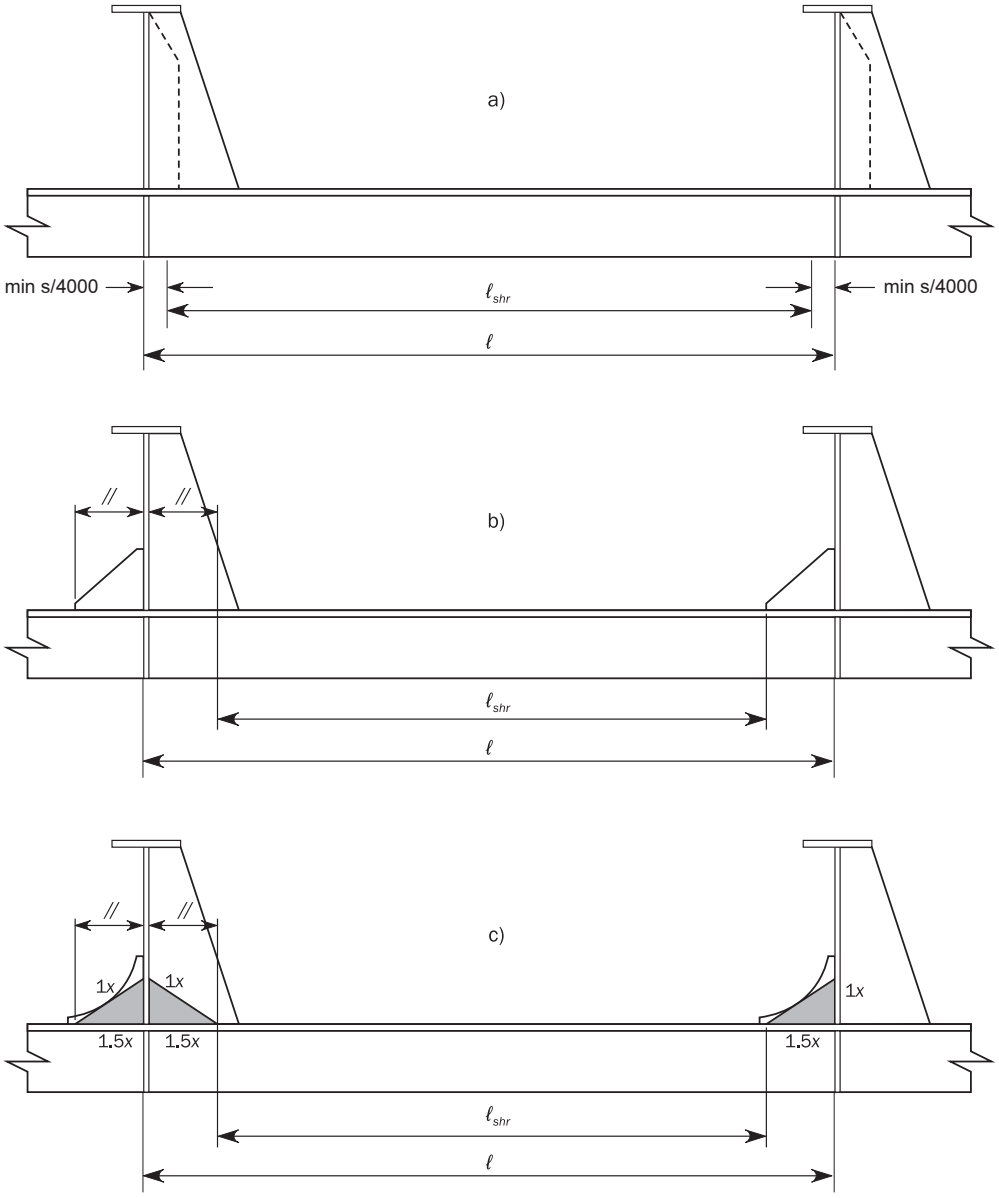


Figure 5 : Effective shear span ℓ_{shr} for local support members with continuous face plate along the bracket edge

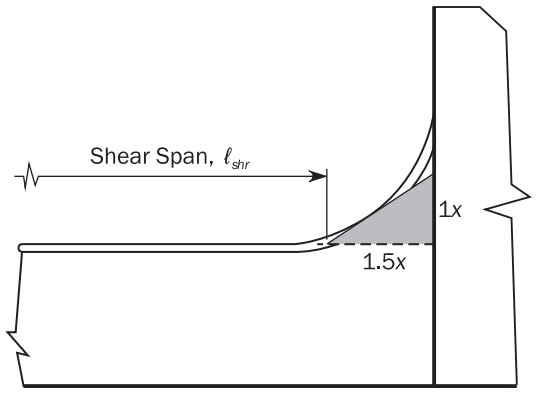
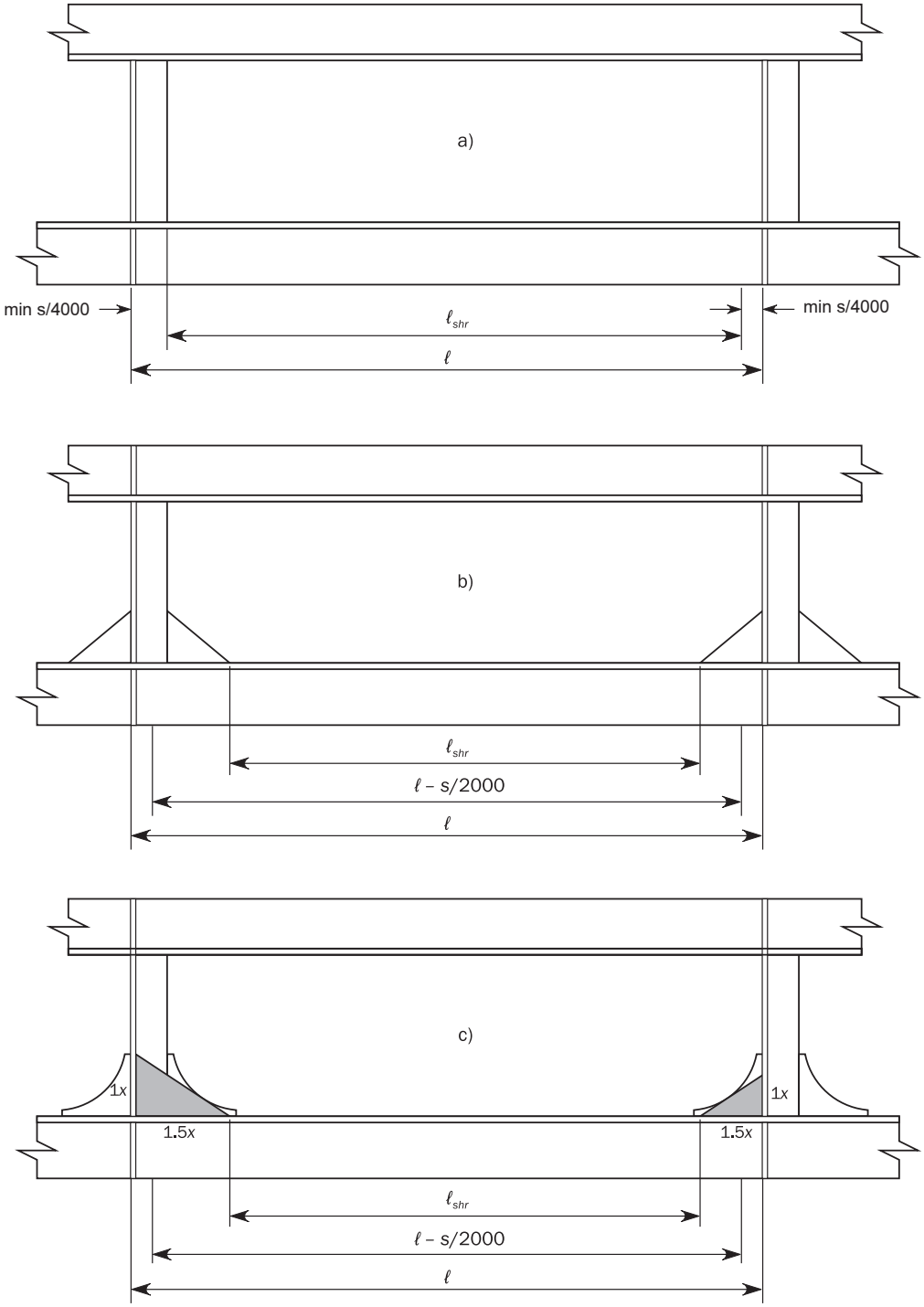


Figure 6 : Double skin construction - Effective shear span ℓ_{shr} of stiffeners supported by web stiffeners



1.1.4 Effect of hull form shape on span of stiffeners

For curved stiffeners, the span is defined as the chord length between span points to be measured at the flange for stiffeners with a flange, and at the free edge for flat bar stiffeners. The calculation of the effective span is to be in accordance with requirements given in [1.1.2] and [1.1.3].

1.1.5 Effective span of stiffeners supported by struts

The arrangement of stiffeners supported by struts is not allowed for ships greater than 120 m in length.

The span ℓ of the stiffeners supported by one strut fitted at mid-distance of the primary supporting members is to be taken as 0,7 ℓ_2.

In case where two struts are fitted at 1/3 and 2/3 of the distance between primary supporting members, the span ℓ of the stiffeners is to be taken as 0,7 ℓ_2.

The spans ℓ_1 and ℓ_2 are defined in Fig 7 and Fig 8.

Figure 7 : Span of stiffeners with one strut

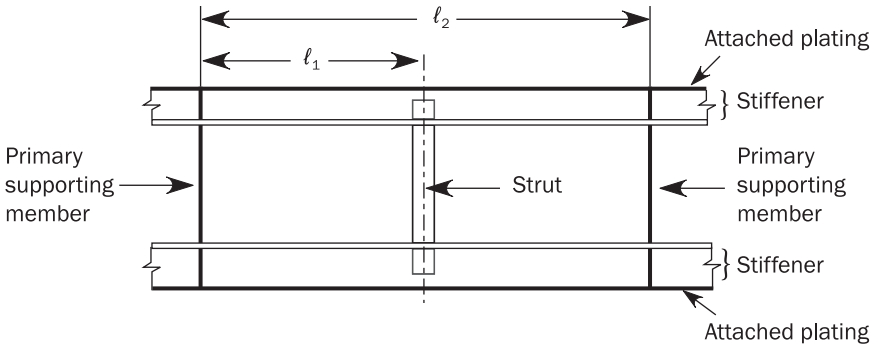
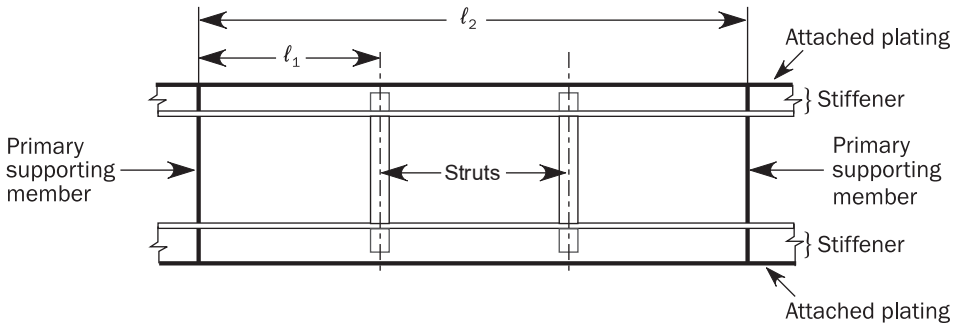


Figure 8 : Span of stiffeners with two struts



1.1.6 Effective bending span of primary supporting members

The effective bending span ℓ_{bdg} of a primary supporting member without end bracket is to be taken as the length of the primary supporting member between supports.

The effective bending span ℓ_{bdg} of a primary supporting member may be taken as less than the full length of the primary supporting member between supports, provided that suitable end brackets are fitted, i.e.:

- in case of separate welded end brackets, ℓ_{bdg} is taken as the length between the points where the depth of the brackets is equal to one-half the web height h_w of the primary supporting member (see item b) of Fig 9)
- in case of end brackets where the face plate of the primary supporting member is continuous along the face of the brackets (see items a), c) and d) of Fig 9), ℓ_{bdg} is taken as the length between the points where the depth of the brackets is equal to one-quarter the web height h_w of the primary supporting member.

The end brackets used to determine the span points are to be either the effective brackets as defined in [1.1.8] or the fitted brackets:

- for straight brackets with a length to height ratio greater than 1,5, the span point is to be taken to the effective bracket: see item c) of Fig 9; otherwise the span point is to be taken to the fitted bracket: see item d) of Fig 9
- for curved brackets, for span positions above the tangent point between fitted bracket and effective bracket, the span point is to be taken to the fitted bracket; otherwise, the span point is to be taken to the effective bracket.

For arrangements where the primary supporting member face plate is carried on to the bracket and backing brackets are fitted, the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary supporting member. Arrangements with small and large backing brackets are shown in items e) and f) of Fig 9.

For arrangements where the height of the primary supporting member is maintained and the face plate width is increased towards the support, the effective bending span ℓ_{bdg} may be taken to a position where the face plate breadth reaches twice the nominal breadth.

1.1.7 Effective shear span of primary supporting members

The effective shear span ℓ_{shr} of a primary supporting member may be reduced and taken between the toes of the effective brackets at ends of the primary supporting member, where these toes are as shown in Fig 10. The effective brackets used to define the toe points are defined in [1.1.8].

For arrangements where the effective backing bracket is larger than the effective bracket in way of the PSM face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in item f) of Fig 10.

1.1.8 Effective bracket

The effective bracket is defined as the maximum size of the right-angled triangular bracket with a length to height ratio of 1,5 that fits inside the fitted bracket. See Fig 9 and Fig 10 for examples.

Figure 9 : Effective bending span ℓ_{bdg} of primary supporting members

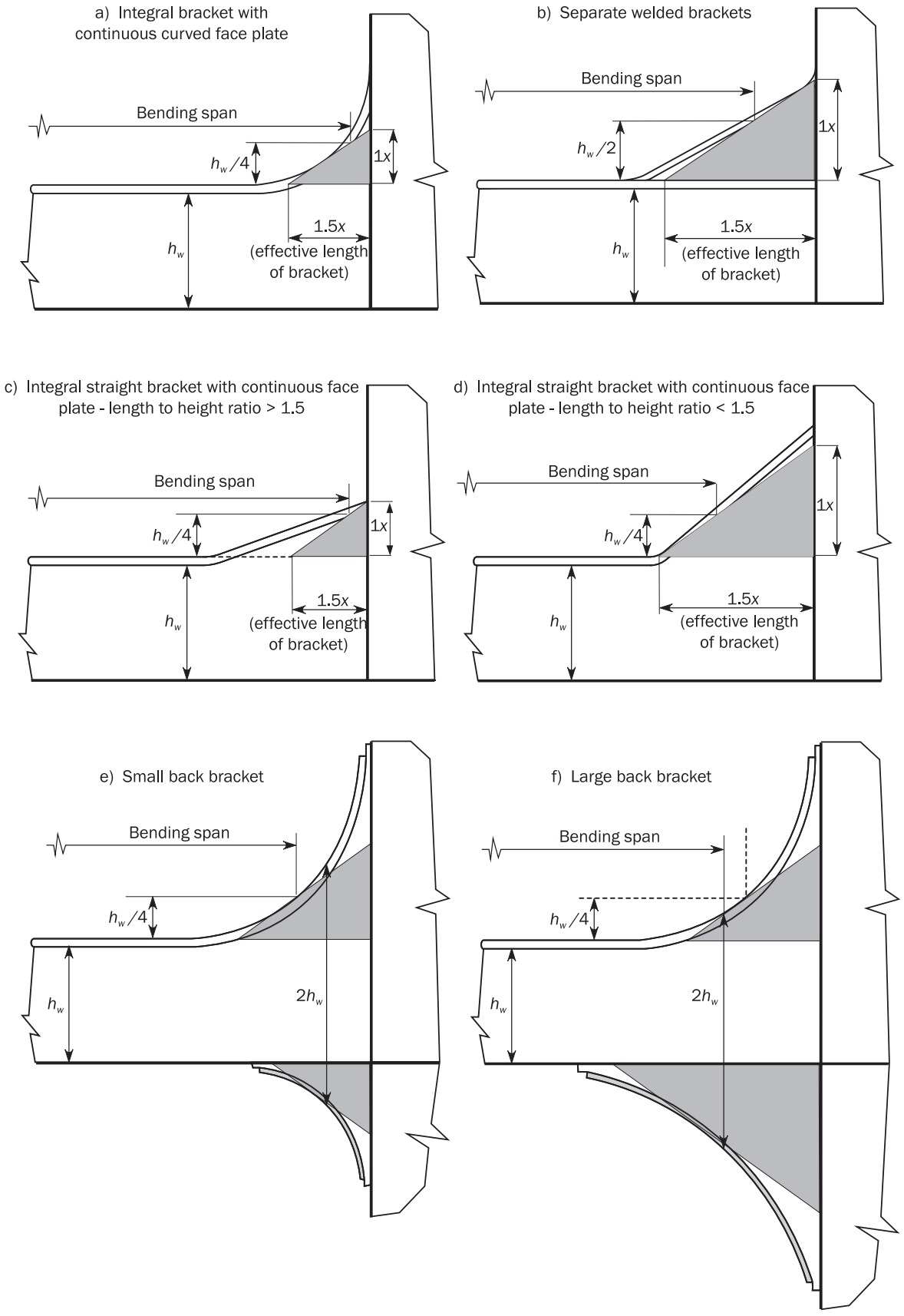
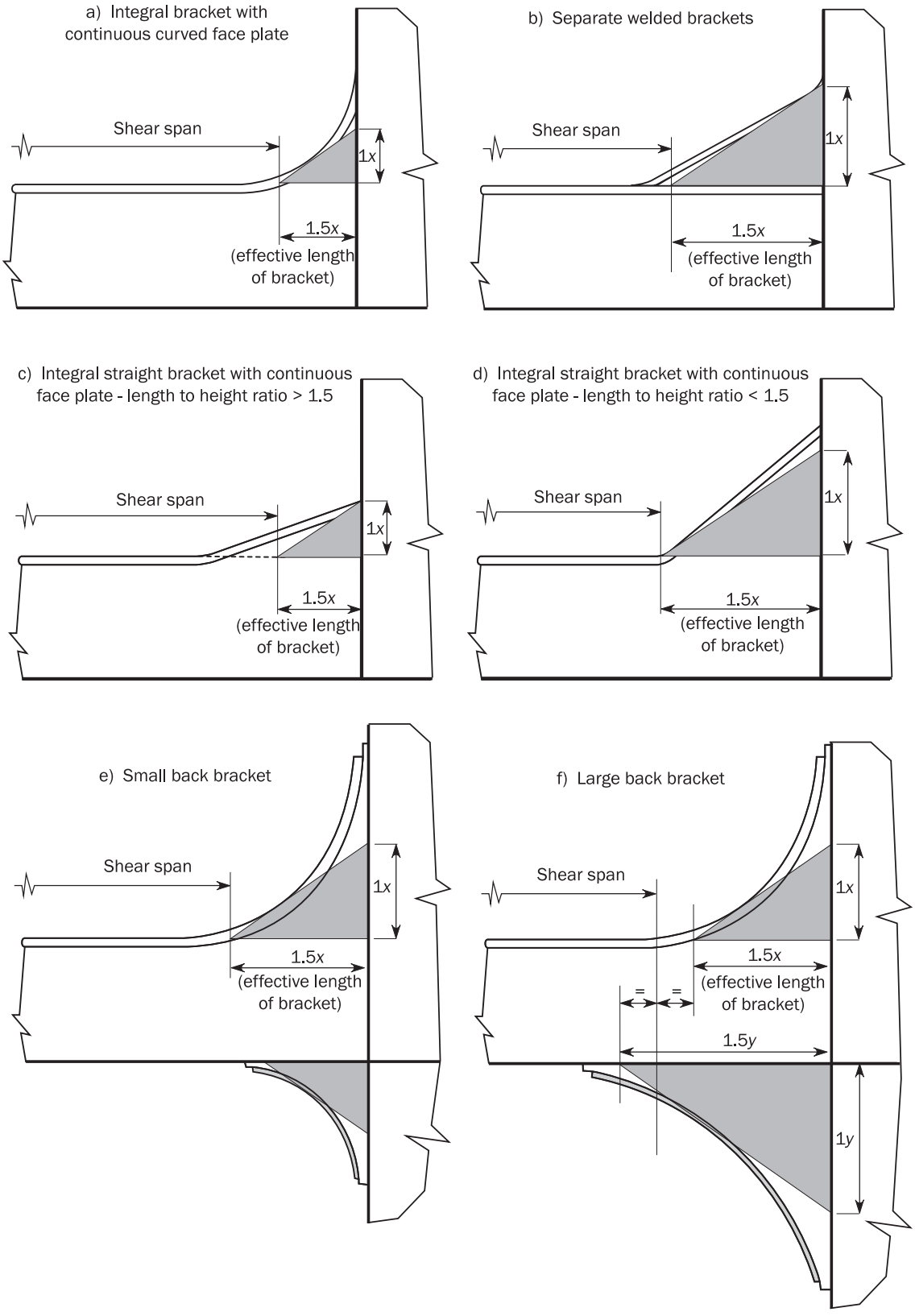


Figure 10 : Effective shear span ℓ_{shr} of primary supporting members



1.2 Spacing and load supporting breadth

1.2.1 Stiffeners

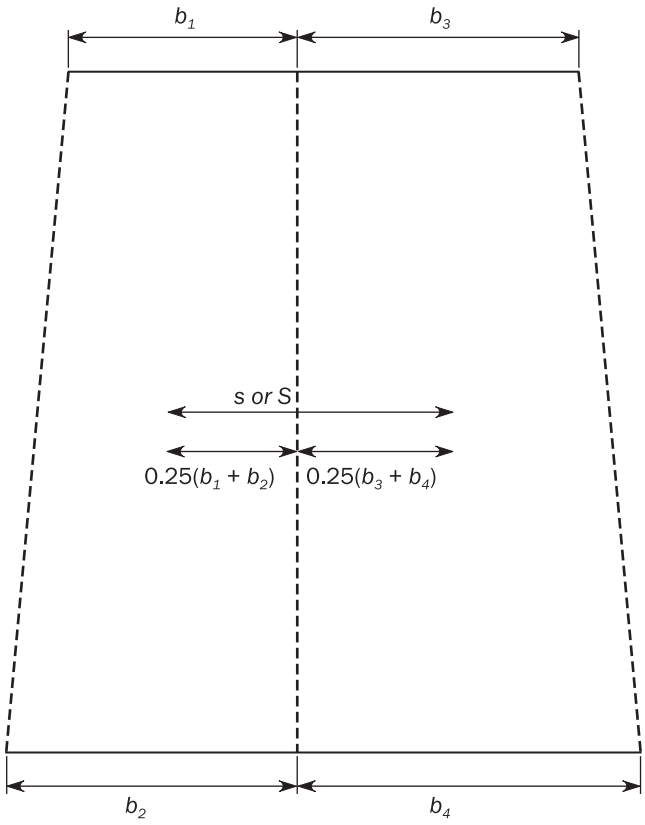
Stiffener spacing s, in mm, for calculation of the effective breadth of the attached plating for stiffeners, is to be taken as the mean spacing between stiffeners at ends (see Fig 11):

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1 , b_2 , b_3 , b_4 : Spacings between stiffeners at ends, in mm.

Figure 11 : Spacing of plating



1.2.2 Primary supporting member

Primary supporting member spacing S, in m, for calculation of the effective breadth of the attached plating for primary supporting members, is to be taken as the mean spacing between adjacent primary supporting members at ends (see Fig 11):

$$S = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1 , b_2 , b_3 , b_4 : Spacings between primary supporting members at ends, in m.

1.2.3 Spacing of curved plating

For curved plating, the stiffener spacing s or the primary supporting member spacing S is to be measured on the mean chord between stiffeners or between primary supporting members, respectively.

1.3 Effective breadth

1.3.1 Stiffeners

a) Yielding check

The effective breadth b_{eff} , in mm, of the attached plating to be considered in the actual net section modulus for the yielding check of a stiffener is to be obtained from the following formulae:

- where the plating extends on both sides of the stiffener:

  b_{eff} = min (200 ℓ ; s)
- where the plating extends on one side of the stiffener (i.e. stiffener bounding an opening):

  b_{eff} = min (100 ℓ ; 0,5 s)

However, where the attached plate net thickness is less than 8 mm, the effective breadth is not to be taken greater than 600 mm.

b) Buckling check

The effective breadth b_{eff} of the attached plating to be considered for the buckling check of stiffeners is given in Ch 9, Sec 1.

1.3.2 Primary supporting members

The effective breadth b_{eff}, in m, of the attached plating for calculation of the section modulus and/or moment of inertia of a primary supporting member is to be taken as:

- for $\frac{\ell_{bdg}}{S\sqrt{3}} \geq 1$: $b_{eff} = S \cdot \min\left[\frac{1,12}{1+\frac{1,75}{\left(\frac{\ell_{bdg}}{S\sqrt{3}}\right)^{1,6}}} ; 1,0\right]$

- for $\frac{\ell_{bdg}}{S\sqrt{3}} < 1$: $b_{eff} = 0,407\frac{\ell_{bdg}}{\sqrt{3}}$

1.3.3 Effective area of curved face plate and curved attached plating of primary supporting members

The effective net area is applicable to primary supporting members for the following calculations:

- actual net section modulus used for comparison with the scantling requirements in Ch 7, Sec 6
- actual effective net area of curved face plates, modeled by beam elements, used in Part B, Chapter 8.

The following effective net area $A_{eff\text{-}n50}$, in mm^2, is only applicable to curved face plates and curved attached plating of primary supporting members and is not applicable for the area of web stiffeners parallel to the face plate.

a) for curved face plates supported by radial brackets or attached plating supported by cylindrical stiffeners:

$$A_{eff\text{-}n50} = \left(\frac{3r_f\ t_{f\text{-}n50} + C_f\ s_r^2}{3r_f\ t_{f\text{-}n50} + s_r^2}\right) t_{f\text{-}n50}\ b_f$$

b) for other curved face plates and curved attached platings: $A_{eff\text{-}n50} = C_f\ t_{f\text{-}n50}\ b_f$

where:

C_f : Flange efficiency coefficient to be obtained from the following formula but not to be greater than 1,0:

- for symmetrical face plate

$$C_f = C_{f1}\frac{1,285}{\beta k_1}$$

- for unsymmetrical face plate

$$C_f = 0,18 + \frac{0,08}{\beta^2}$$

- for attached plating of box girders

$$C_f = C_{f1}\frac{1,285}{\beta}$$

C_{f1} : Coefficient taken equal to:

- for symmetrical face plates:

$$C_{f1} = \frac{(\sinh k_1\beta\ \cosh k_1\beta + \sin k_1\beta\ \cos k_1\beta)}{(\cosh k_1\beta)^2 + (\cos k_1\beta)^2}$$

- for attached plating of box girders with two webs:

$$C_{f1} = \frac{0,78\ (\sinh\beta + \sin\beta)\ (\cosh\beta - \cos\beta)}{(\sinh\beta)^2 + \sin^2\beta}$$

- for attached plating of box girders with multiple webs:

$$C_{f1} = \frac{1,56\ (\cosh\beta - \cos\beta)}{\sinh\beta + \sin\beta}$$

k_1 : Coefficient calculated as:

$$k_1 = 1,4 + 1,25\,(1,4-\beta)^3 \quad \text{for} \quad \beta < 1,4$$

$$k_1 = 1,4 \quad \text{for} \quad \beta \geq 1,4$$

β : Coefficient, in rad, taken equal to:

$$\beta = \frac{1,285\ b_1}{\sqrt{r_f\ t_{f\text{-}n50}}}$$

b_1 : Breadth, in mm, to be taken equal to:

- for symmetrical face plates: $b_1 = 0,5\ (b_f - t_{w\text{-}n50})$
- for unsymmetrical face plates: $b_1 = b_f$
- for attached plating of box girders: $b_1 = s_w - t_{w\text{-}n50}$

s_w : Spacing of supporting webs for box girders, in mm

$t_{f\text{-}n50}$: Net flange thickness, in mm. For calculation of C_f and β of unsymmetrical face plates, $t_{f\text{-}n50}$ is not to be taken greater than $t_{w\text{-}n50}$

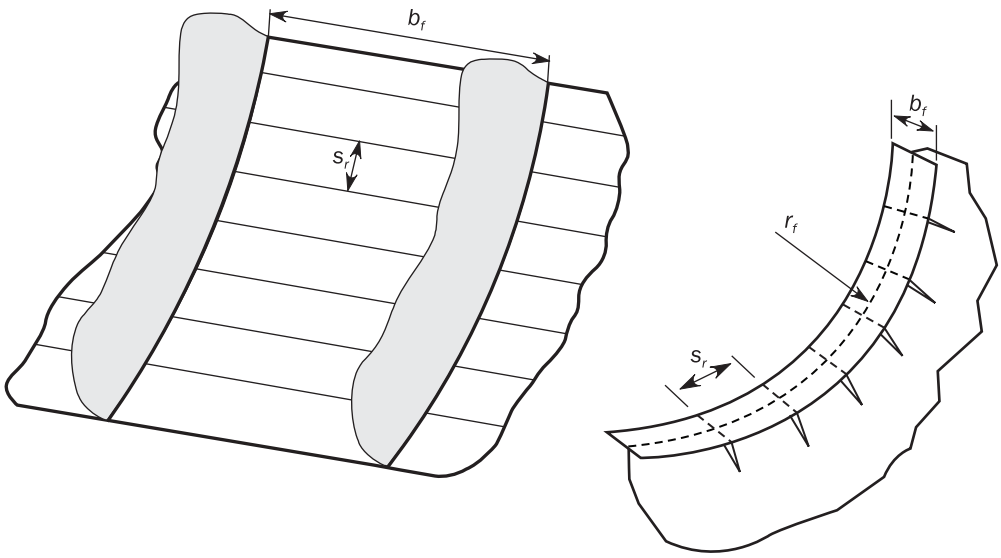
$t_{w\text{-}n50}$: Net web plate thickness, in mm

r_f : Radius, in mm, of face plate or attached plating at mid thickness, see Fig 12

b_f : Breadth, in mm, of face plate or attached plating, see Fig 12

s_r : Spacing, in mm, of tripping brackets or web stiffeners or stiffeners normal to the web plating, see Fig 12.

Figure 12 : Curved shell panel and face plate



1.4 Geometrical properties of stiffeners and primary supporting members

1.4.1 Steel stiffener profile with a bulb section

The properties of bulb sections are to be determined considering the actual stiffener profile.

Where such calculation of properties is not possible, a bulb section equivalent to a built-up section is to be taken for steel stiffeners with a bulb section. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae (see Fig 13):

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6,7} - 2\right)$$

$$t_f = \frac{h'_w}{9,2} - 2$$

$$t_w = t'_w$$

where:

h'_w, t'_w : Net height and thickness of a bulb section, in mm, as shown in Fig 13

α : Coefficient equal to:

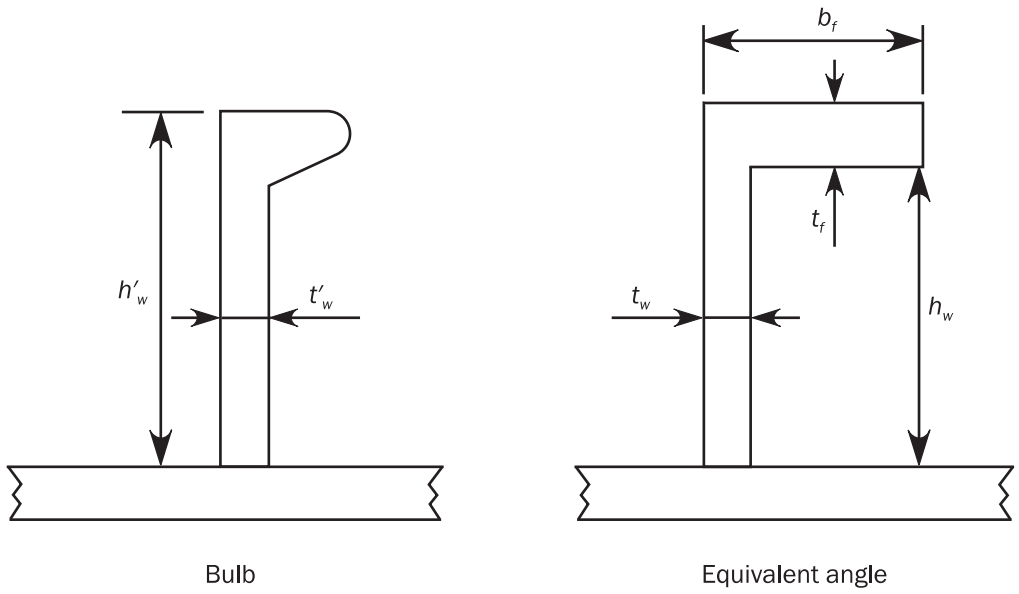
- for $h'_w \leq 120$:

$$\alpha = 1,1 + \frac{(120 - h'_w)^2}{3000}$$

- for $h'_w > 120$:

$\alpha = 1,0$

Figure 13 : Bulb section and its equivalent built-up section



1.4.2 Aluminium stiffener profile with a bulb section

For aluminium stiffeners, the equivalent build-up section as defined in [1.4.1] is not applicable and the properties of bulb sections are to be determined considering the actual stiffener profile.

1.4.3 Net elastic shear area of stiffeners

The net elastic shear area A_{shr}, in cm^2, of stiffeners is to be taken as:

$$A_{shr} = d_{shr}\, t_w\, 10^{-2}$$

where:

d_{shr} : Effective shear depth of stiffener, in mm, as defined in [1.4.4]

t_w : Net web thickness of the stiffener, in mm, as defined in Ch 4, Sec 2, Fig 2.

1.4.4 Effective shear depth of stiffeners

The effective shear depth of stiffeners d_{shr}, in mm, is to be taken as:

$$d_{shr} = (h_{stf} - 0{,}5\, t_{c\text{-}stf} + t_p + 0{,}5\, t_{c\text{-}pl}) \sin \varphi_w$$

where:

h_{stf} : Height of stiffener, in mm, as defined in Ch 4, Sec 2, Fig 2

t_p : Net thickness of the stiffener attached plating, in mm, as defined in Ch 4, Sec 2, Fig 2

$t_{c\text{-}stf}$: Corrosion addition, in mm, of the considered stiffener as given in Ch 4, Sec 3

$t_{c\text{-}pl}$: Corrosion addition, in mm, of the attached plate to the considered stiffener as given in Ch 4, Sec 3.

1.4.5 Elastic net section modulus of stiffeners

The elastic net section modulus Z of stiffeners, in cm^3, is to be taken as:

$$Z = Z_{stf} \sin \varphi_w$$

where:

Z_{stf} : Net section modulus of the stiffener, in cm^3, considered perpendicular to its attached plate, i.e. with $\varphi_w = 90°$

1.4.6 Net moment of inertia of stiffeners

The net moment of inertia I of stiffeners, in cm^4, is to be taken as:

$$I = I_{stf} \sin^2 \varphi_w$$

where:

I_{stf} : Net moment of inertia of the stiffener, in cm^4, considered perpendicular to its attached plate, i.e. with $\varphi_w = 90°$

1.4.7 Effective net plastic shear area of stiffeners

The net plastic shear area $A_{shr\text{-}pl}$ of stiffeners, in cm^2, which is used for assessment against impact loads is to be taken as:

$$A_{shr\text{-}pl} = A_{shr}$$

where:

A_{shr} : Net elastic shear area, in cm^2, as defined in [1.4.3].

1.4.8 Effective net plastic section modulus of stiffeners

The effective net plastic section modulus Z_{pl} of stiffeners, in cm^3, is given by the formula in item a) or item b), depending on:

- the cross-sectional area of the attached plate A_p
- the net cross-sectional area of the ordinary stiffener: $A_w' + A_f$

where:

A_p : Net cross-sectional area of the attached plate, in cm^2, taken equal to:

$$A_p = \frac{s\, t_p}{100}$$

A_f : Net cross-sectional area of the stiffener flange, in cm^2, taken equal to:

$$A_f = \frac{b_f\, t_f}{100}$$

A_w' : Net cross-sectional area of the stiffener web, in cm^2, taken equal to:

$$A_w' = \frac{h_w\, t_w}{100}$$

a) When $A_p \geq A_w' + A_f$, the plastic neutral axis PNA is assumed to be tangent to the edge of the attached plate closest to the stiffener.

$$Z_{pl} = \frac{A_p' x_p + A_w' x_w + A_f x_f}{10}$$

where:

A_p' : Net cross-sectional area of the stiffener, in cm^2, taken equal to:

$A_p' = A_w' + A_f$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = \text{Min}\left(100\frac{A_w' + A_f}{2\, s}\, ;\, \frac{t_p}{2}\right)$$

x_w : Distance, in mm, between the centre of gravity of area A_w' and PNA, taken equal to:

$$x_w = \frac{h_w \sin\varphi_w}{2}$$

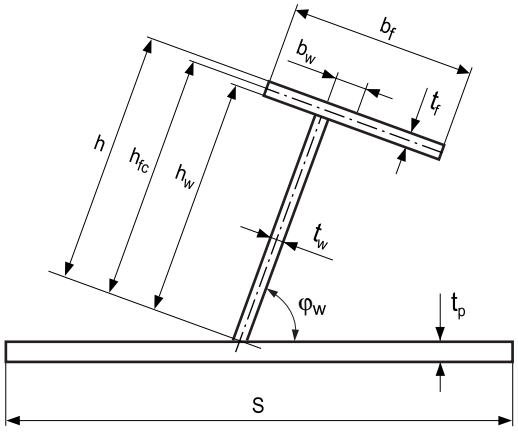
x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$x_f = h_{fc} \sin \varphi_w - b_w \cos \varphi_w$

h_{fc} : Height, in mm, of the stiffener, measured up to the centre of the flange area, see Fig 14

b_w : Distance, in mm, from the mid-thickness plane of the stiffener web to the centre of the flange area, see Fig 14.

Figure 14 : Dimensions of a built section



b) When $A_p < A_w' + A_f$ the plastic neutral axis PNA is located at a distance z_a above the attached plate, in mm, given by:

$$z_a = \frac{(100\, A_f + h_w\, t_w - t_p\, s)\, \sin\varphi_w}{2\, t_w}$$

$$Z_{pl} = \frac{(A_p\, x_p + A_{wa}\, x_{wa} + A_{wb}\, x_{wb} + A_f\, x_f)}{10}$$

where:

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = z_a + \frac{t_p}{2}$$

A_{wa} : Net cross-sectional area, in cm^2, of the part of the stiffener located above PNA, taken equal to:

$$A_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{t_w}{100}$$

x_{wa} : Distance, in mm, between the centre of gravity of area A_{wa} and PNA, taken equal to:

$$x_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{\sin\varphi_w}{2}$$

A_{wb} : Net cross-sectional area, in cm^2, of the part of ordinary stiffener located below the PNA, taken equal to:

$$A_{wb} = \frac{t_w\, z_a}{100\, \sin\varphi_w}$$

x_{wb} : Distance, in mm, between the centre of gravity of area A_{wb} and PNA, taken equal to:

$$x_{wb} = \frac{z_a}{2}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$$x_f = h_{fc} \sin\varphi_w - b_w \cos\varphi_w - z_a$$

1.4.9 Primary supporting member web not perpendicular to attached plating

Where the web of a primary supporting member is not perpendicular to the attached plating, the actual net shear area $A_{sh\text{-}n50}$, in cm^2, and the actual net section modulus Z_{n50}, in cm^3, may be obtained from the following formulae:

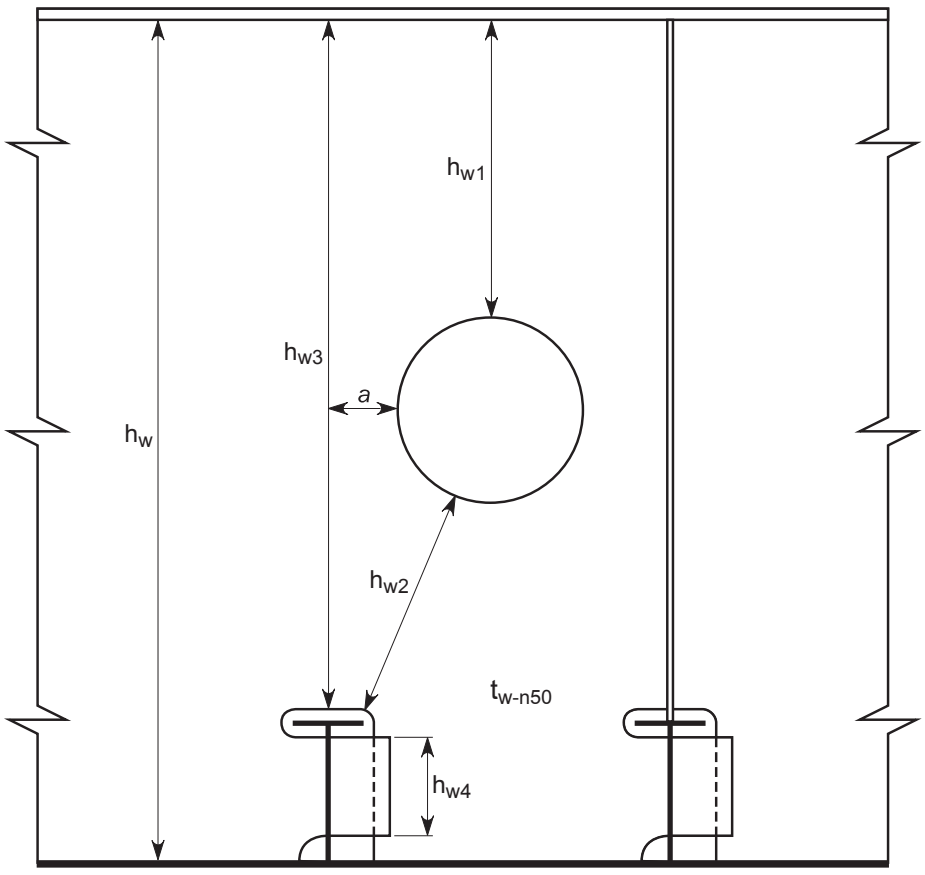
- actual net shear area: $A_{sh\text{-}n50} = A_{sh\text{-}0\text{-}n50} \sin\varphi_w$
- actual net section modulus: $Z_{n50} = Z_{perp\text{-}n50} \sin\varphi_w$

where:

$A_{sh\text{-}0\text{-}n50}$: Actual net shear area, in cm^2, of the primary supporting member assumed to be perpendicular to the attached plating, to be taken equal to: $A_{sh\text{-}0\text{-}n50} = (h_{eff} + t_{f\text{-}n50} + t_{p\text{-}n50})\, t_{w\text{-}n50} \cdot 10^{-2}$

$Z_{perp\text{-}n50}$: Actual section modulus, in cm^3, with attached plating, of the primary supporting member assumed to be perpendicular to the attached plating.

Figure 15 : Dimensions h_{w1}, h_{w2}, h_{w3} and h_{w4} in way of web openings



1.4.10 Shear area of primary supporting members with web openings

The effective web height h_{eff}, in mm, to be considered for the calculation of the effective net shear area $A_{sh\text{-}n50}$ is to be taken as the lesser of:

$h_{eff} = h_w$

$h_{eff} = h_{w3} + h_{w4}$

$h_{eff} = h_{w1} + h_{w2} + h_{w4}$

calculated at a distance 'a' less than $h_w/3$ on each side of the considered cross-section,

where:

h_w : Web height of the primary supporting member, in mm

h_{w1}, h_{w2}, h_{w3}, h_{w4} : Dimensions, in mm, as shown in Fig 15.

1.4.11 Stiffener flange width

In case the stiffener flange thickness requirement in NR615, Sec 2, [4.1.1] item b) is not fulfilled, the effective free flange outstand, used in strength assessment including the calculation of actual net section modulus, is to be taken as $b_{f\text{-}out\text{-}max}$ defined in NR615, Sec 2, [4.1.1].

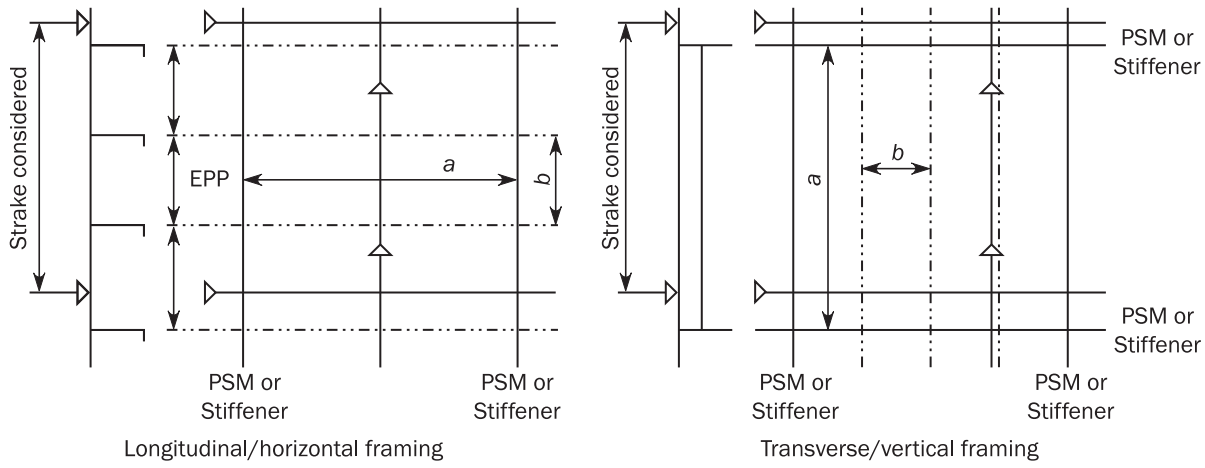
2 Plates

2.1 Idealisation of EPP

2.1.1 EPP

An Elementary Plate Panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, a, and breadth, b, of the EPP are defined respectively as the longer and the shorter plate edges, as shown in Fig 16.

Figure 16 : Elementary Plate Panel (EPP) definition



2.1.2 Strake required thickness

The required thickness of a strake is to be taken as the greatest value required for each EPP within that strake. The requirements given in Tab 1 are to be applied for the selection of strakes to be considered, as shown in Fig 17, where:

a_1 : Distance, in mm, measured inside the considered strake in the direction of the long edge of the EPP, between the strake boundary weld seam and the EPP edge.

The maximum corrosion addition within a strake is to be applied according to Ch 4, Sec 3, [1.2.5].

2.1.3 For direct strength assessment, the EPP is idealised with the mesh arrangement in the finite element model.

2.2 Load Calculation Point

2.2.1 Yielding

For the yielding check, the local pressure and the hull girder stress, used for the calculation of the local scantling requirements, are to be taken at the LCP (Load Calculation Point) having coordinates x, y and z as defined in Tab 2.

2.2.2 Ultimate buckling capacity

The load calculation points of the stiffener attached plating, to be considered for the stiffener ultimate buckling capacity check according to NR615, Sec 5, [2.3.4], are defined in Ch 4, Sec 6, [2].

2.2.3 Buckling

For the prescriptive buckling check of the EPP according to Ch 9, Sec 1, the LCP for the pressure and for the hull girder stresses are defined in Tab 3.

For the finite element buckling check, Ch 9, Sec 1 is applicable.

Figure 17 : Strake considered in a given EPP

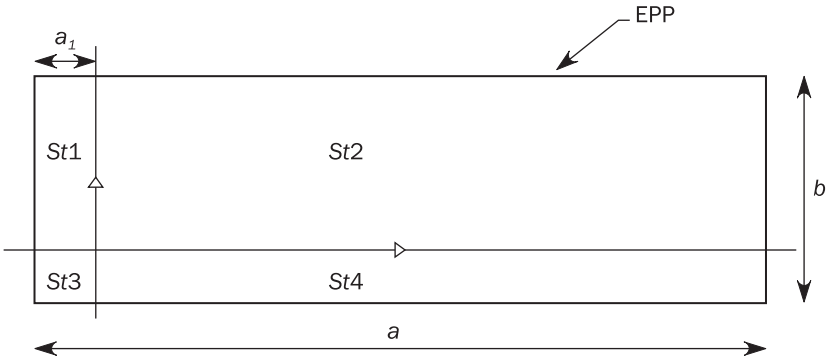


Table 1 : Strake considered in a given EPP

	a/b > 2	a/b ≤ 2
a_1 > b/2	All strakes (St1, St2, St3, St4)	All strakes (St1, St2, St3, St4)
a_1 ≤ b/2	Strakes St2 and St4	All strakes (St1, St2, St3, St4)

Table 2 : LCP coordinates for yielding

LCP coordinates	General **(1)**		Horizontal plating		Vertical transverse structure and transverse stool plating	
	Longitudinal framing (Fig 18)	Transverse framing (Fig 19)	Longitudinal framing	Transverse framing	Horizontal framing (Fig 20)	Vertical framing (Fig 21)
x coordinate	Mid-length of the EPP		Mid-length of the EPP		Corresponding to y and z coordinates	
y coordinate	Corresponding to x and z coordinates		Outboard y coordinate of the EPP		Outboard y coordinate of the EPP, taken at z level **(2)**	
z coordinate	EPP lower edge	The greater of the EPP lower edge or strake lower edge **(3)**	Corresponding to x and y coordinates		EPP lower edge	The greater of the EPP lower edge or strake lower edge **(3)**

(1) All structures other than horizontal platings or vertical transverse structures.

(2) For transom plate, the y coordinate of the load calculation point is to be taken corresponding to the y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

(3) For plating subject to sloshing loads, the LCP z coordinate is to be taken as the one associated to the maximum lateral pressure among the following:

- EPP upper edge
- The point corresponding to the tank filling level (if applicable)
- The greater of the EPP lower edge or strake lower edge.

Table 3 : LCP coordinates for plate buckling

LCP coordinates	LCP for pressure	LCP for hull girder stresses (Fig 22)		
		Bending stresses **(1)**		Shear stresses
		Non horizontal plate	Horizontal plate	
x coordinate	Same coordinates as LCP for yielding. See Tab 2	Mid-length of the EPP		
y coordinate		Corresponding to x and z coordinates	Outboard and inboard ends of the EPP (points A1 and A2)	Mid-point of EPP (point B)
z coordinate		Both upper and lower ends of the EPP (points A1 and A2)	Corresponding to x and y coordinates	

(1) The bending stress for curved plate panel is the mean value of the stresses calculated at points A1 and A2.

Figure 18 : Load calculation point (LCP) for longitudinal framing

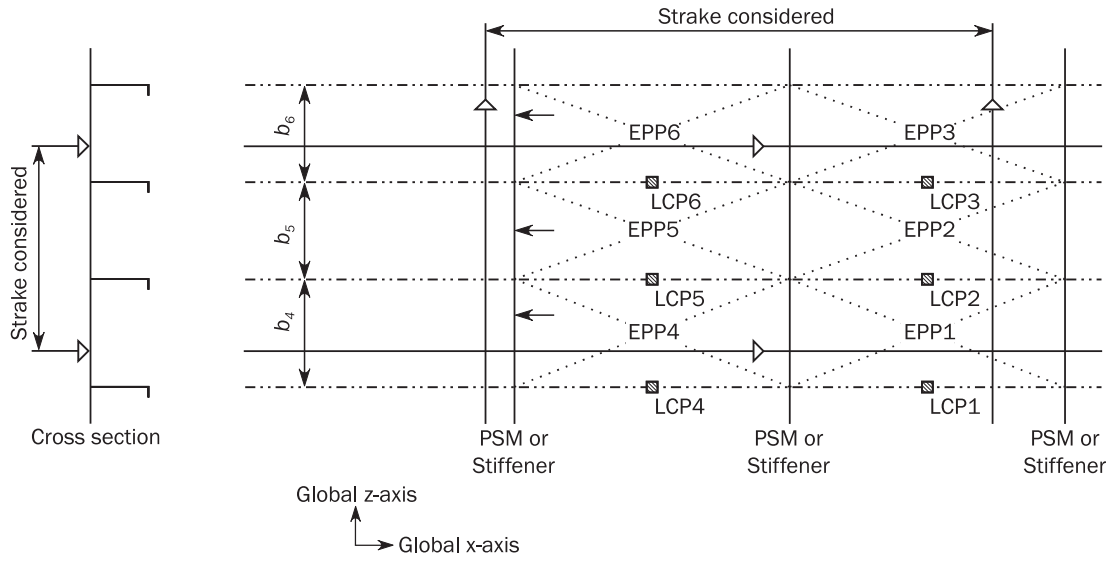


Figure 19 : Load calculation point for transverse framing

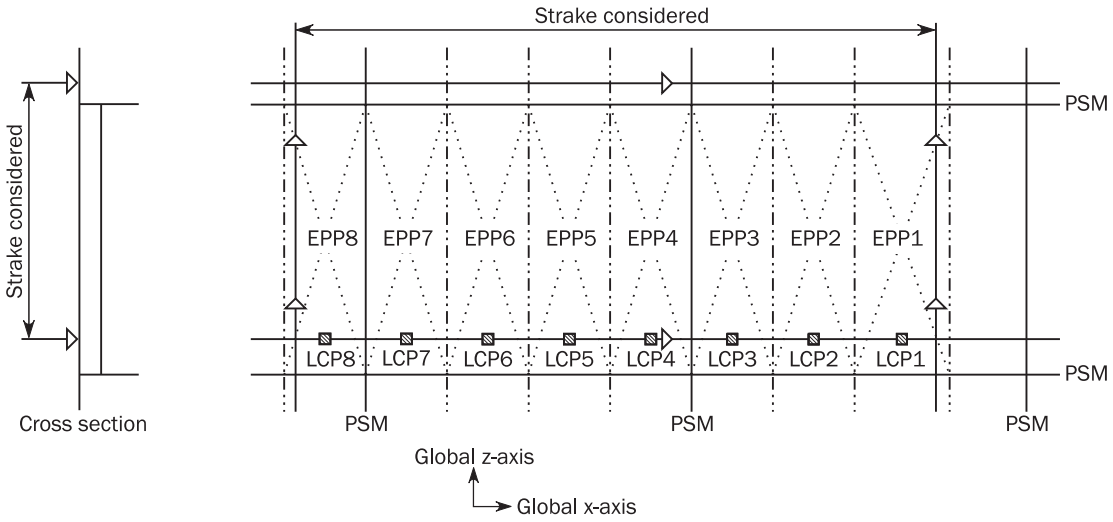


Figure 20 : Load calculation point for horizontal framing on transverse vertical structure

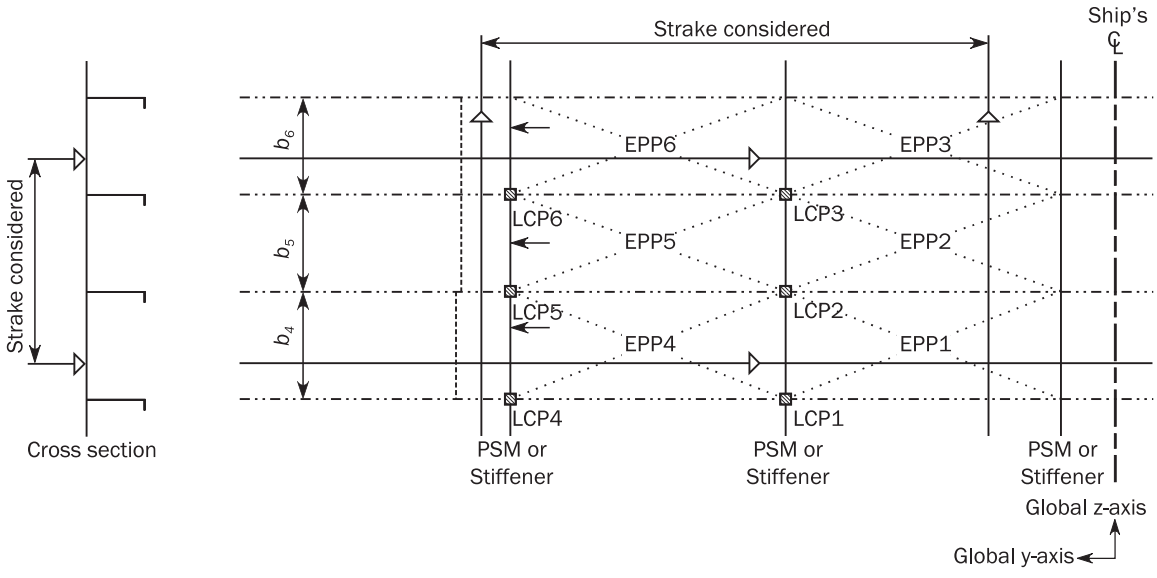


Figure 21 : Load calculation point for vertical framing on transverse vertical structure

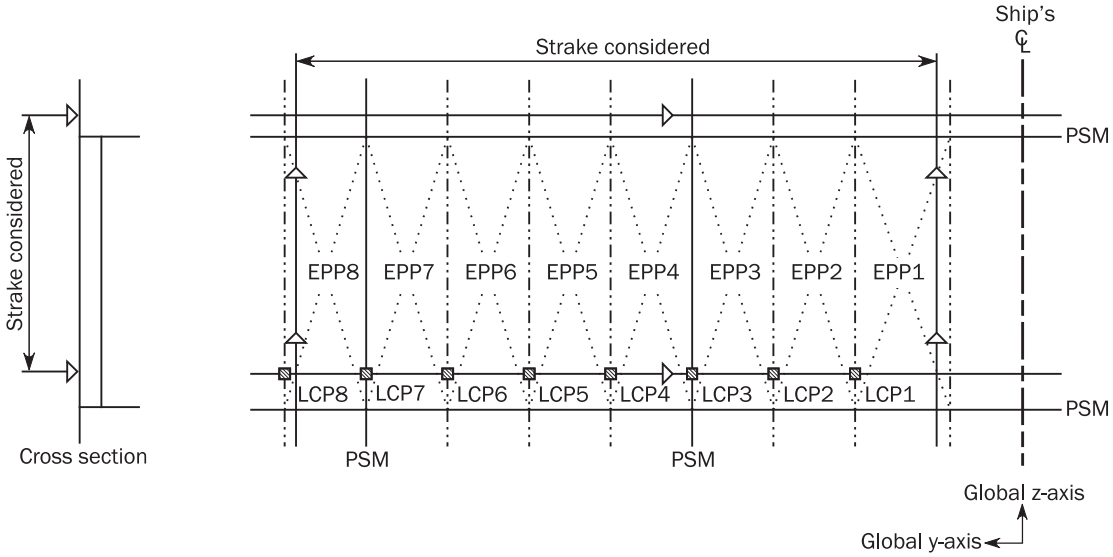
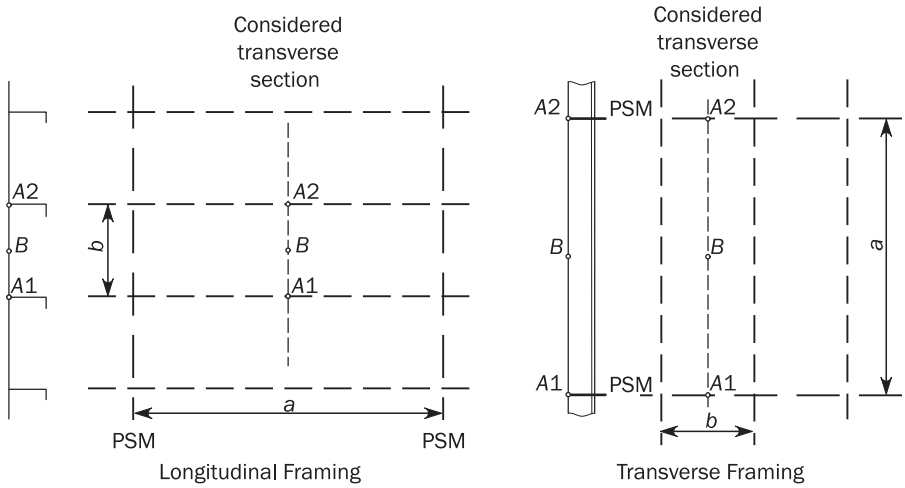


Figure 22 : Load calculation point for plate buckling – Hull girder stresses



3 Stiffeners

3.1 Reference point

3.1.1 The requirements of stiffener section modulus relate to the reference point giving the minimum section modulus. This reference point is located as shown in Fig 23 for typical profiles.

3.2 Load calculation point

3.2.1 LCP for pressure

The load calculation point for the pressure is located at the:

- middle of the full length ℓ of the considered stiffener
- intersection point between the stiffener and its attached plate.

For stiffeners located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to the y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

3.2.2 LCP for hull girder bending stress

The load calculation point for the hull girder bending stress is defined as follows:

- for prescriptive yielding verification according Ch 7, Sec 5 and Ch 11, Sec 4:
  - at the middle of the full length ℓ of the considered stiffener
  - at the reference point given in Fig 23.

- for prescriptive buckling requirements according to Ch 9, Sec 1:
  - at the middle of the full length ℓ of the considered stiffener
  - at the intersection point between the stiffener and its attached plate.

3.2.3 Non-horizontal stiffeners

The lateral pressure P, in kN/m^2, is to be calculated as the maximum between the value obtained at the middle of the full length ℓ and the value obtained from the following formulae:

- when the upper end of the vertical stiffener is below the lowest zero pressure level:

$$P = \frac{P_U + P_L}{2}$$

- when the upper end of the vertical stiffener is at or above the lowest zero pressure level (see Fig 24):

$$P = \frac{\ell_1}{\ell} \frac{P_L}{2}$$

where:

ℓ_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level

P_U, P_L : Lateral pressures, in kN/m^2, at the upper and lower ends of the vertical stiffener span ℓ, respectively.

Figure 23 : Reference point for calculation of section modulus and hull girder stress for local scantling assessment

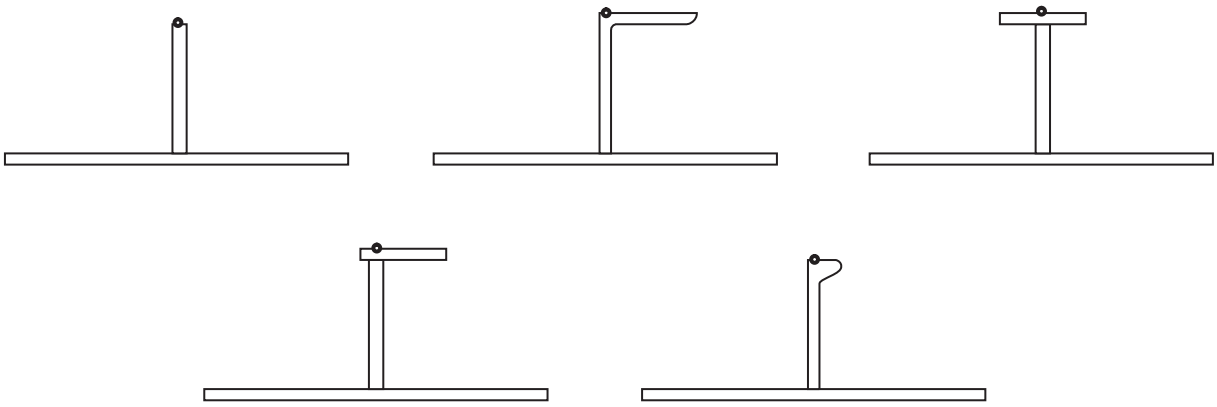
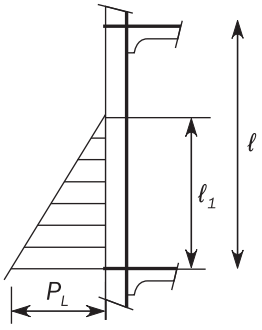


Figure 24 : Definition of pressure for non-horizontal stiffeners



4 Primary supporting members

4.1 Load calculation point

4.1.1 The load calculation point is located at the middle of the full length ℓ, at the attachment point of the primary supporting member with its attached plate.

For primary supporting members located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of load calculation point for the external dynamic pressure calculation.

CHAPTER 5
DESIGN LOADS

Section 1 Introduction
Section 2 Dynamic Load Cases
Section 3 Ship Motions and Accelerations
Section 4 Hull Girder Loads
Section 5 Environmental Loads
Section 6 Internal Loads and cargo loads
Section 7 Design Load Scenarios
Section 8 Loading Conditions

Section 1 Introduction

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

1 General

1.1 Definition

1.1.1 Scope

This Chapter provides the design loads for strength and fatigue assessments.

The load combinations are to be derived for the design load scenarios specified in Ch 5, Sec 7. This Section uses the concept of design load scenarios to specify consistent design load sets which cover relevant operating modes.

1.1.2 Equivalent Design Wave (EDW)

The dynamic loads associated to each dynamic load case are based on the Equivalent Design Wave (EDW) concept. The EDW concept applies a consistent set of dynamic loads to the ship such that a specified dominant load response is equivalent to the required long term response value.

1.1.3 Probability levels for strength and fatigue assessments

In this Chapter, the assessments are to be understood as follows:

- Strength assessment means the assessment for strength criteria, excluding fatigue, for seagoing conditions, ballast water exchange conditions, harbour conditions and flooded conditions, based on loads corresponding to a return period of 25 years (probability level approximately of 10^{-8})
- Fatigue assessment means the assessment for fatigue criteria based on loads corresponding to the probability level of 10^{-2}.

1.1.4 Loads for strength assessment

The strength assessment is to be undertaken for all design load scenarios. The final assessment is to be made on the most demanding strength requirement.

Each design load scenario for strength assessment is composed of a static load case or a static + dynamic load case, where the static and dynamic loads depend on the loading condition being considered.

The static loads are defined in the following Sections:

- still water hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

The EDWs for the strength assessment and the dynamic load combination factors for global loads are listed in Ch 5, Sec 2, [2].

The dynamic loads are defined in the following Sections:

- dynamic hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

1.1.5 Loads for fatigue assessment

Each design load scenario for fatigue assessment is composed of a static + dynamic load case, where the static and dynamic loads depend on the loading condition being considered.

The static loads are defined in the following Sections:

- still water hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

The EDWs for the fatigue assessment and the dynamic load combination factors for global loads are listed in Ch 5, Sec 2, [3].

The dynamic loads are defined in the following Sections:

- dynamic hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

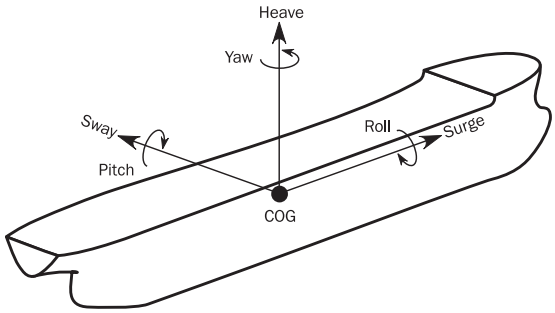
1.2 Sign convention

1.2.1 Sign convention for ship motions

The ship motions are defined with respect to the ship's centre of gravity (COG) as shown in Fig 1, where:

- positive surge is translation in the X-axis direction (positive forward)
- positive sway is translation in the Y-axis direction (positive towards portside of ship)
- positive heave is translation in the Z-axis direction (positive upwards)
- positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and portside up)
- positive pitch motion is positive rotation about a transverse axis through the COG (bow down and stern up)
- positive yaw motion is positive rotation about a vertical axis through the COG (bow moving to portside and stern to starboard).

Figure 1 : Definition of positive motions

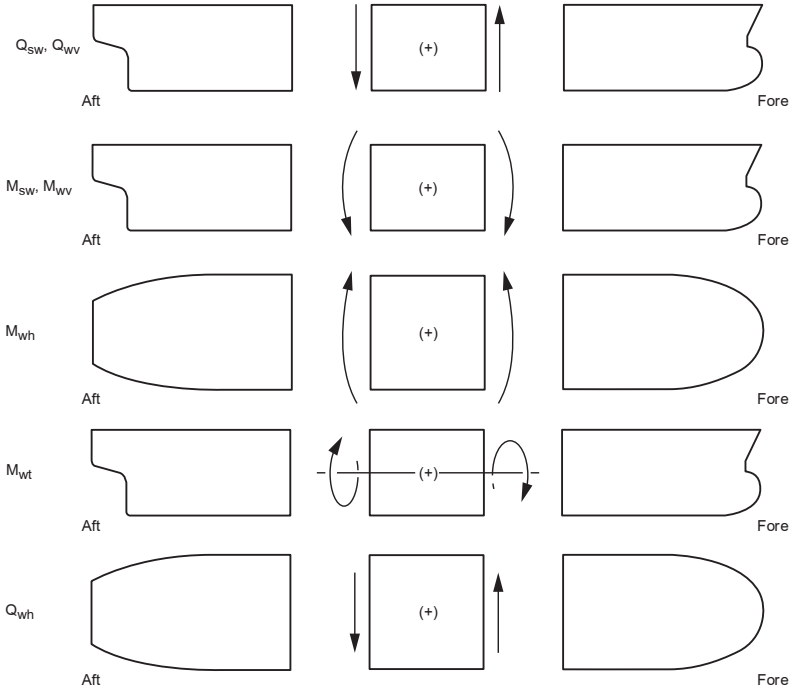


1.2.2 Sign conventions for hull girder loads

The sign conventions of vertical and horizontal bending moments, and vertical and horizontal shear forces, at any ship transverse section, are as shown in Fig 2, namely the:

- vertical shear forces Q_{sw} and Q_{wv} are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration
- vertical bending moments M_{sw} and M_{wv} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment)
- horizontal bending moment M_{wh} is positive when it induces tensile stresses in the starboard side and negative when it induces tensile stresses in the portside
- torsional moment M_{wt} is positive in the case of resulting moment acting aft of the transverse section following negative rotation around the X-axis, and of resulting moment acting forward of the transverse section following positive rotation around the X-axis
- horizontal shear force Q_{wh} is positive in the case of resulting forces acting toward starboard side aft of the transverse section and resulting force acting toward portside forward of the transverse section under consideration.

Figure 2 : Sign conventions for shear forces Q_{sw} , Q_{wv} and Q_{wh} and bending moments M_{sw} , M_{wv} , M_{wh} and M_{wt}



Section 2 Dynamic Load Cases

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

a_{surge} , a_{sway} , a_{heave} , a_{roll} , a_{pitch} , a_{yaw} : Acceleration components, as defined in Ch 5, Sec 3

a_{roll-y} , a_{roll-z} , $a_{pitch-x}$, $a_{pitch-z}$, a_{yaw-x} , a_{yaw-y} : Acceleration components, as defined in Ch 5, Sec 3

f_{TL} : Ratio between draught at the considered loading condition and rule length, to be taken as:

$f_{TL} = T_{LC} / L$

f_{lp} : Factor depending on the longitudinal position along the ship, to be taken as follows:

- $f_{lp} = 1,0$ for $x \leq 0,4\ L$
- $f_{lp} = -1,0$ for $x \geq 0,6\ L$

Intermediate values of f_{lp} are to be obtained by linear interpolation

Load combination factors, to be applied to the:

C_{WV} : Vertical wave bending moment

C_{QV} : Vertical wave shear force

C_{WT} : Wave torsional moment

C_{WH} : Horizontal wave bending moment

C_{QH} : Horizontal wave shear force

C_{XS} : Surge acceleration

C_{XP} : Longitudinal acceleration due to pitch

C_{XY} : Longitudinal acceleration due to yaw

C_{XG} : Gravitational acceleration due to pitch

C_{YS} : Sway acceleration

C_{YR} : Transverse acceleration due to roll

C_{YY} : Transverse acceleration due to yaw

C_{YG} : Gravitational acceleration due to roll

C_{ZH} : Heave acceleration

C_{ZR} : Vertical acceleration due to roll

C_{ZP} : Vertical acceleration due to pitch

$C_{B\text{-}LC}$: Block coefficient at considered loading condition draught T_{LC}, as defined in Ch 1, Sec 3, [2.1.9]. For flooded loading conditions, the value of $C_{B\text{-}LC}$ is to be taken as for the full load condition unless provided in the loading manual

$C_{W\text{-}LC}$: Waterplane coefficient at considered loading condition draught T_{LC}, as defined in Ch 1, Sec 3, [2.1.10]. For flooded loading conditions, the value of $C_{W\text{-}LC}$ is to be taken as for the full load condition unless provided in the loading manual

T_R : Dimensionless roll period, to be taken as:

$T_R = T_\theta\ (g / L)^{0,5}$

without being taken greater than $75/L^{0,5}$

ω_R : Roll angular frequency, in rad/s, to be taken as:

$\omega_R = 2\pi / T_\theta$

1 General

1.1 Definition of EDW and dynamic load cases

1.1.1 The Equivalent Design Waves (EDW) and the dynamic load cases to be used for structural assessment are defined in Tab 1.

1.2 Application

1.2.1 General load cases

The dynamic load cases described in [1.3] are to be applied for the structural assessments that do not require complete ship modeling i.e.:

a) strength assessment:

- for plating, ordinary stiffeners and primary supporting members by prescriptive methods
- for the direct strength method (FE analysis) assessment of structural members, based on partial ship models

b) fatigue assessment:

- for structural details covered by simplified stress analysis
- for structural details covered by FE stress analysis bases on partial ship models.

These dynamic load cases are to be used for design load scenarios described in Ch 5, Sec 7.

1.2.2 Load cases for structural analyses based on complete ship models

When primary supporting members are to be analysed through complete ship models, according to Ch 7, Sec 6, [1.1.2], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 8, App 3, [3] and Ch 8, App 3, [4].

1.3 Description of dynamic load cases

1.3.1 Tab 2 to Tab 7 describe the ship motion responses and the global loads corresponding to each dynamic load case to be considered for the strength and fatigue assessments.

Table 1 : Definition of Equivalent Design Waves (EDW) and dynamic load cases

EDW	Load case	Definition
HVM	HVM1	Head sea with maximum negative vertical bending moment (sagging) amidships **(3)**
	HVM2	Head sea with maximum positive vertical bending moment (hogging) amidships **(3)**
HVMf **(1)**	HVMf1	Head sea with maximum negative vertical bending moment (sagging) at 0,25 L from AE **(3)**
	HVMf2	Head sea with maximum positive vertical bending moment (hogging) at 0,25 L from AE **(3)**
FVM **(2)**	FVM1	Following sea with maximum negative vertical bending moment (sagging) at 0,25 L from AE **(3)**
	FVM2	Following sea with maximum positive vertical bending moment (hogging) at 0,25 L from AE **(3)**
BR	BR1-P	Beam sea with maximum negative roll motion
	BR2-P	Beam sea with maximum positive roll motion
	BR1-S	Beam sea with maximum positive roll motion
	BR2-S	Beam sea with maximum negative roll motion
BP	BP1-P	Beam sea with maximum negative hydrodynamic pressure at the waterline amidships
	BP2-P	Beam sea with maximum positive hydrodynamic pressure at the waterline amidships
	BP1-S	Beam sea with maximum negative hydrodynamic pressure at the waterline amidships
	BP2-S	Beam sea with maximum positive hydrodynamic pressure at the waterline amidships
OHM	OHM1-P	Oblique sea with maximum negative horizontal bending moment amidships
	OHM2-P	Oblique sea with maximum positive horizontal bending moment amidships
	OHM1-S	Oblique sea with maximum positive horizontal bending moment amidships
	OHM2-S	Oblique sea with maximum negative horizontal bending moment amidships
OHS **(2)**	OHS1-P	Oblique sea with maximum negative horizontal shear force and torsion at 0,75 L from AE
	OHS2-P	Oblique sea with maximum positive horizontal shear force and torsion at 0,75 L from AE
	OHS1-S	Oblique sea with maximum positive horizontal shear force and torsion at 0,75 L from AE
	OHS2-S	Oblique sea with maximum negative horizontal shear force and torsion at 0,75 L from AE

(1) Applicable to fatigue assessment only.
(2) Applicable to strength assessment only.
(3) The vertical shear force is also maximised with the dominant load component
Note 1: 1 and 2 denote the maximum positive or negative value of the dominant load component for each load case.
Note 2: P and S denote that the weather side (side of the ship exposed to the incoming waves) is on portside and on starboard side, respectively. The lee side (sheltered side of the ship away from the incoming waves) is on the opposite side.

EDW	Load case	Definition
OVA **(2)**	OVA1-P	Oblique sea with maximum negative vertical acceleration at L from AE
	OVA2-P	Oblique sea with maximum positive vertical acceleration at L from AE
	OVA1-S	Oblique sea with maximum negative vertical acceleration at L from AE
	OVA2-S	Oblique sea with maximum positive vertical acceleration at L from AE

(1) Applicable to fatigue assessment only.
(2) Applicable to strength assessment only.
(3) The vertical shear force is also maximised with the dominant load component
Note 1: 1 and 2 denote the maximum positive or negative value of the dominant load component for each load case.
Note 2: P and S denote that the weather side (side of the ship exposed to the incoming waves) is on portside and on starboard side, respectively. The lee side (sheltered side of the ship away from the incoming waves) is on the opposite side.

Table 2 : Ship responses for HVM, HVMf and FVM load cases

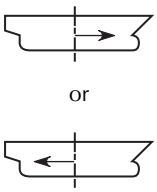
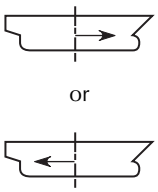
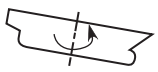
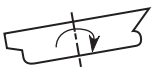
Load case	HVM1 / HVMf1	HVM2 / HVMf2	FVM1	FVM2
EDW	HVM / HVMf		FVM	
Wave heading	Head sea at 180 deg		Following sea at 0 deg	
Effect	Maximum bending moment		Maximum bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	–	–	–	–
HWSF	–	–	–	–
TM	–	–	–	–
Surge	To stern or to bow		To stern or to bow	
a_{surge}				
Sway	–	–	–	–
a_{sway}	–	–	–	–
Heave	Down	Up	Down	Up
a_{heave}				
Roll	–	–	–	–
a_{roll}	–	–	–	–
Pitch	Bow down	Bow up	–	–
a_{pitch}			–	–
Yaw	–	–	–	–
a_{yaw}	–	–	–	–

Table 3 : Ship responses for BR load cases

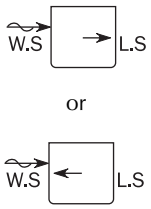
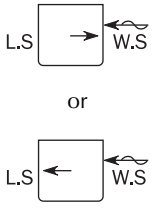
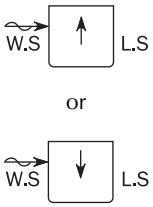
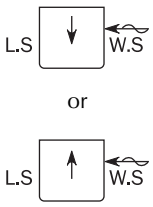
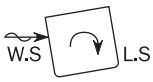
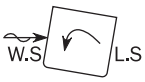
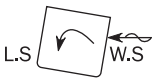
Load case	BR1-P	BR2-P	BR1-S	BR2-S
EDW	BR		BR	
Wave heading	Beam sea at 270 deg	Beam sea at 270 deg	Beam sea at 90 deg	Beam sea at 90 deg
Effect	Maximum roll	Maximum roll	Maximum roll	Maximum roll
VWBM	–	–	–	–
VWSF	–	–	–	–
HWBM	Starboard tensile	Portside tensile	Portside tensile	Starboard tensile
HWSF	–	–	–	–
TM	–	–	–	–
Surge	–	–	–	–
a_{surge}	–	–	–	–
Sway	To portside or to starboard		To portside or to starboard	
a_{sway}				
Heave	Down or up		Up or down	
a_{heave}				
Roll	Portside down	Portside up	Starboard down	Starboard up
a_{roll}				
Pitch	–	–	–	–
a_{pitch}	–	–	–	–
Yaw	–	–	–	–
a_{yaw}	–	–	–	–

Table 4 : Ship responses for BP load cases

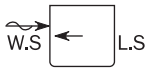
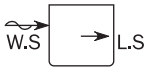
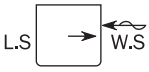
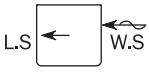
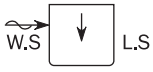
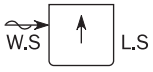
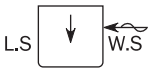
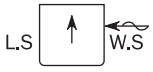
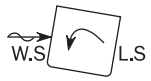
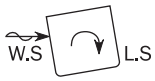
Load case	BP1-P	BP2-P	BP1-S	BP2-S
EDW	BP		BP	
Wave heading	Beam sea at 270 deg		Beam sea at 90 deg	
Effect	Maximum pressure at waterline		Maximum pressure at waterline	
VWBM	Hogging	Sagging	Hogging	Sagging
VWSF	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
HWBM	Portside tensile	Starboard tensile	Starboard tensile	Portside tensile
HWSF	–	–	–	–
TM	–	–	–	–
Surge	–	–	–	–
a_{surge}	–	–	–	–
Sway	To starboard	To portside	To portside	To starboard
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard up or starboard down	
a_{roll}	 or 		 or 	
Pitch	–	–	–	–
a_{pitch}	–	–	–	–
Yaw	To starboard	To portside	To portside	To starboard
a_{yaw}				

Table 5 : Ship responses for OHM load cases

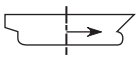
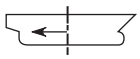
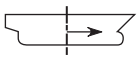
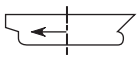
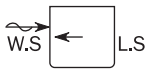
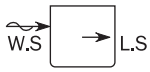
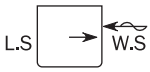
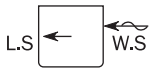
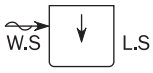
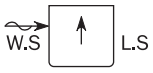
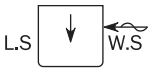
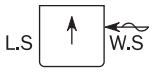
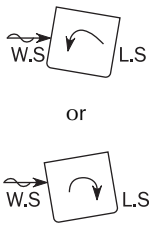
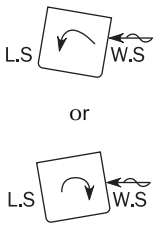
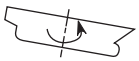
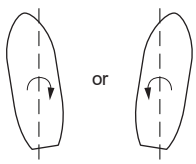
Load case	OHM1-P	OHM2-P	OHM1-S	OHM2-S
EDW	OHM		OHM	
Wave heading	Oblique sea at 240 deg		Oblique sea at 120 deg	
Effect	Maximum horizontal bending moment		Maximum horizontal bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
HWSF	Positive–aft Negative–fore	Negative–aft Positive–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
TM	Negative–aft Positive–fore	Positive–aft Negative–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
Surge	To stern	To bow	To stern	To bow
a_{surge}				
Sway	To starboard	To portside	To portside	To starboard
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard down or starboard up	
a_{roll}				
Pitch	Bow down	Bow up	Bow down	Bow up
a_{pitch}				
Yaw	To portside or to starboard			
a_{yaw}				

Table 6 : Ship responses for OHS load cases

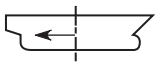
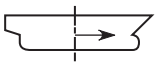
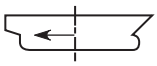
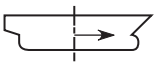
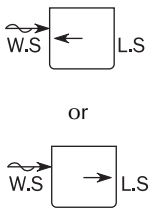
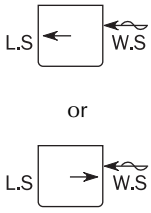
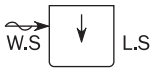
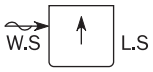
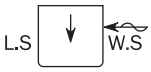
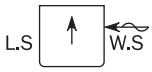
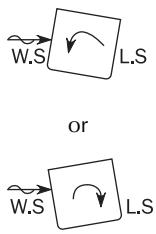
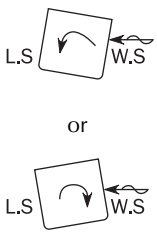
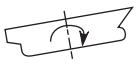
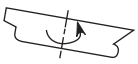
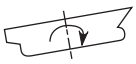
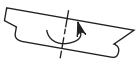
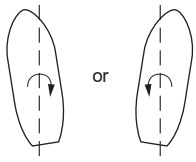
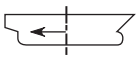
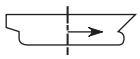
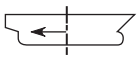
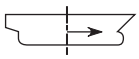
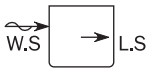
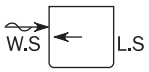
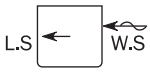
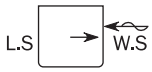
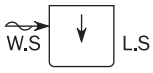
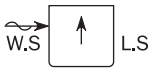
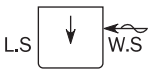
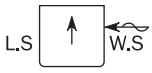
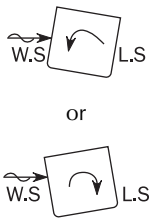
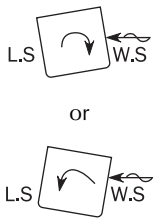
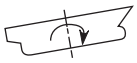
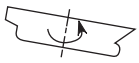
Load case	OHS1-P	OHS2-P	OHS1-S	OHS2-S
EDW	OHS		OHS	
Wave heading	Oblique sea at 300 deg		Oblique sea at 60 deg	
Effect	Maximum horizontal shear force		Maximum horizontal shear force	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
HWSF	Positive–aft Negative–fore	Negative–aft Positive–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
TM	Negative–aft Positive–fore	Positive–aft Negative–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	To starboard or to portside		To starboard or to portside	
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard down or starboard up	
a_{roll}				
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				
Yaw	To portside or to starboard			
a_{yaw}				

Table 7 : Ship responses for OVA load cases

Load case	OVA1-P	OVA2-P	OVA1-S	OVA2-S
EDW	OVA		OVA	
Wave heading	Oblique sea at 240 deg		Oblique sea at 120 deg	
Effect	Maximum vertical acceleration		Maximum vertical acceleration	
VWBM	Hogging	Sagging	Hogging	Sagging
VWSF	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile
HWSF	Negative–aft Positive–fore	Positive–aft Negative–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
TM	Positive–aft Negative–fore	Negative–aft Positive–fore	Negative–aft Positive–fore	Positive–aft Negative–fore
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	To portside	To starboard	To starboard	To portside
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard up or starboard down	
a_{roll}				
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				
Yaw	To starboard	To portside	To portside	To starboard
a_{yaw}				

2 Dynamic load cases for strength assessment

2.1 Selection of EDW

2.1.1 The following Equivalent Design Waves are to be considered for the strength assessment:

- HVM
- FVM
- BR
- BP
- OHM
- OHS
- OVA

2.2 Load combination factors

2.2.1 The load combinations factors LCFs for the determination of each load component to be used for strength assessment are defined in Tab 8 to Tab 13.

Table 8 : Load combination factors LCFs for HVM and FVM load cases - Strength assessment

Load component		LCF	HVM1	HVM2	FVM1	FVM2
Hull girder loads	M_{wv}	C_{WV}	– 1	1	– 1	1
	Q_{wv}	C_{QV}	$-f_{lp}$	f_{lp}	$-f_{lp}$	f_{lp}
	M_{wh}	C_{WH}	0	0	0	0
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0,60 - 10\ f_{TL}$	$10\ f_{TL} - 0,60$	$0,32 - 7,60\ f_{TL}$	$7,60\ f_{TL} - 0,32$
	$a_{pitch-x}$	C_{XP}	– 0,38	0,38	0	0
	a_{yaw-x}	C_{XY}	0	0	0	0
	$g\ \sin\varphi$	C_{XG}	0,36	– 0,36	0	0
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0
	a_{yaw-y}	C_{YY}	0	0	0	0
	$g\ \sin\theta$	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0,10 + 5,70\ f_{TL}$	$-0,10 - 5,70\ f_{TL}$	0,10	– 0,10
	a_{roll-z}	C_{ZR}	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	– 0,38	0,38	0	0

Table 9 : Load combination factors LCFs for BR load cases - Strength assessment

Load component		LCF	BR1-P	BR2-P	BR1-S	BR2-S
Hull girder loads	M_{wv}	C_{WV}	0	0	0	0
	Q_{wv}	C_{QV}	0	0	0	0
	M_{wh}	C_{WH}	$1,20 - 16\ f_{TL}$	$16\ f_{TL} - 1,20$	$16\ f_{TL} - 1,20$	$1,20 - 16\ f_{TL}$
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	a_{yaw-x}	C_{XY}	0	0	0	0
	$g\ \sin\varphi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	$1,71\ \omega_R - 0,73$	$0,73 - 1,71\ \omega_R$	$0,73 - 1,71\ \omega_R$	$1,71\ \omega_R - 0,73$
	a_{roll-y}	C_{YR}	1	– 1	– 1	1
	a_{yaw-y}	C_{YY}	0	0	0	0
	$g\ \sin\theta$	C_{YG}	– 1	1	1	– 1
Vertical accelerations	a_{heave}	C_{ZH}	$0,88 - 0,15\ T_R$	$0,15\ T_R - 0,88$	$0,88 - 0,15\ T_R$	$0,15\ T_R - 0,88$
	a_{roll-z}	C_{ZR}	1	– 1	– 1	1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Table 10 : Load combination factors LCFs for BP load cases - Strength assessment

Load component		LCF	BP1-P	BP2-P	BP1-S	BP2-S
Hull girder loads	M_{wv}	C_{WV}	0,2	– 0,2	0,2	– 0,2
	Q_{wv}	C_{QV}	0,2 f_{lp}	– 0,2 f_{lp}	0,2 f_{lp}	– 0,2 f_{lp}
	M_{wh}	C_{WH}	19 f_{TL} – 1,30	1,30 – 19 f_{TL}	1,30 – 19 f_{TL}	19 f_{TL} – 1,30
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	a_{yaw-x}	C_{XY}	0,10	– 0,10	– 0,10	0,10
	g sinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	1,73 – 2,11 ω_R	2,11 ω_R – 1,73	2,11 ω_R – 1,73	1,73 – 2,11 ω_R
	a_{roll-y}	C_{YR}	0,39 T_R – 1,82	1,82 – 0,39 T_R	1,82 – 0,39 T_R	0,39 T_R – 1,82
	a_{yaw-y}	C_{YY}	0,10	– 0,10	– 0,10	0,10
	g sinθ	C_{YG}	1,35 – 0,27 T_R	0,27 T_R – 1,35	0,27 T_R – 1,35	1,35 – 0,27 T_R
Vertical accelerations	a_{heave}	C_{ZH}	– 1	1	– 1	1
	a_{roll-z}	C_{ZR}	0,39 T_R – 1,82	1,82 – 0,39 T_R	1,82 – 0,39 T_R	0,39 T_R – 1,82
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Table 11 : Load combination factors LCFs for OHM load cases - Strength assessment

Load component		LCF	OHM1-P	OHM2-P	OHM1-S	OHM2-S
Hull girder loads	M_{wv}	C_{WV}	7,70 f_{TL} – 0,85 **(1)**	0,50 – 7,70 f_{TL} **(2)**	7,70 f_{TL} – 0,85 **(1)**	0,50 – 7,70 f_{TL} **(2)**
	Q_{wv}	C_{QV} **(3)**	(7,70 f_{TL} – 0,85) f_{lp}	(0,50 – 7,70 f_{TL}) f_{lp}	(7,70 f_{TL} – 0,85) f_{lp}	(0,50 – 7,70 f_{TL}) f_{lp}
	M_{wh}	C_{WH}	– 1	1	1	– 1
	Q_{wh}	C_{QH}	f_{lp}	– f_{lp}	– f_{lp}	f_{lp}
	M_{wt}	C_{WT}	– f_{lp}	f_{lp}	f_{lp}	– f_{lp}
Longitudinal accelerations	a_{surge}	C_{XS}	0,23	– 0,23	0,23	– 0,23
	$a_{pitch-x}$	C_{XP}	6 f_{TL} – 0,80	0,80 – 6 f_{TL}	6 f_{TL} – 0,80	0,80 – 6 f_{TL}
	a_{yaw-x}	C_{XY}	0,67 – 17,50 f_{TL}	17,50 f_{TL} – 0,67	17,50 f_{TL} – 0,67	0,67 – 17,50 f_{TL}
	g sinφ	C_{XG}	0,37	– 0,37	0,37	– 0,37
Transverse accelerations	a_{sway}	C_{YS}	0,23	– 0,23	– 0,23	0,23
	a_{roll-y}	C_{YR}	13,3 f_{TL} – 0,80	0,80 – 13,3 f_{TL}	0,80 – 13,3 f_{TL}	13,3 f_{TL} – 0,80
	a_{yaw-y}	C_{YY}	0,67 – 17,50 f_{TL}	17,50 f_{TL} – 0,67	17,50 f_{TL} – 0,67	0,67 – 17,50 f_{TL}
	g sinθ	C_{YG}	0,7 – 10,20 f_{TL}	10,20 f_{TL} – 0,7	10,20 f_{TL} – 0,7	0,7 – 10,20 f_{TL}
Vertical accelerations	a_{heave}	C_{ZH}	– 0,17	0,17	– 0,17	0,17
	a_{roll-z}	C_{ZR}	13,3 f_{TL} – 0,80	0,80 – 13,3 f_{TL}	0,80 – 13,3 f_{TL}	13,3 f_{TL} – 0,80
	$a_{pitch-z}$	C_{ZP}	6 f_{TL} – 0,80	0,80 – 6 f_{TL}	6 f_{TL} – 0,80	0,80 – 6 f_{TL}

(1) C_{WV} is to be not greater than 0

(2) C_{WV} is to be not less than 0

(3) When $C_{WV} = 0$, C_{QV} is to be taken equal to 0.

Table 12 : Load combination factors LCFs for OHS load cases - Strength assessment

Load component		LCF	OHS1-P	OHS2-P	OHS1-S	OHS2-S
Hull girder loads	M_{wv}	C_{WV}	$0,41 - C_{W\text{-}LC}$ **(1)**	$C_{W\text{-}LC} - 0,76$ **(2)**	$0,41 - C_{W\text{-}LC}$ **(1)**	$C_{W\text{-}LC} - 0,76$ **(2)**
	Q_{wv}	C_{QV} **(3)**	$(0,41 - C_{W\text{-}LC})\ f_{lp}$	$(C_{W\text{-}LC} - 0,76)\ f_{lp}$	$(0,41 - C_{W\text{-}LC})\ f_{lp}$	$(C_{W\text{-}LC} - 0,76)\ f_{lp}$
	M_{wh}	C_{WH}	-1	1	1	-1
	Q_{wh}	C_{QH}	f_{lp}	$-f_{lp}$	$-f_{lp}$	f_{lp}
	M_{wt}	C_{WT}	$-f_{lp}$	f_{lp}	f_{lp}	$-f_{lp}$
Longitudinal accelerations	a_{surge}	C_{XS}	$0,06 - 0,60\ C_{B\text{-}LC}$	$0,60\ C_{B\text{-}LC} - 0,06$	$0,06 - 0,60\ C_{B\text{-}LC}$	$0,60\ C_{B\text{-}LC} - 0,06$
	$a_{pitch\text{-}x}$	C_{XP}	$1,16\ C_{B\text{-}LC} - 0,32$	$0,32 - 1,16\ C_{B\text{-}LC}$	$1,16\ C_{B\text{-}LC} - 0,32$	$0,32 - 1,16\ C_{B\text{-}LC}$
	$a_{yaw\text{-}x}$	C_{XY}	$7,60\ f_{TL} - 0,43$	$0,43 - 7,60\ f_{TL}$	$0,43 - 7,60\ f_{TL}$	$7,60\ f_{TL} - 0,43$
	$g\ \sin\varphi$	C_{XG}	$0,11 - 0,77\ C_{B\text{-}LC}$	$0,77\ C_{B\text{-}LC} - 0,11$	$0,11 - 0,77\ C_{B\text{-}LC}$	$0,77\ C_{B\text{-}LC} - 0,11$
Transverse accelerations	a_{sway}	C_{YS}	$1,1\ 2C_{W\text{-}LC} - 0,80$	$0,80 - 1,12\ C_{W\text{-}LC}$	$0,80 - 1,12\ C_{W\text{-}LC}$	$1,12\ C_{W\text{-}LC} - 0,80$
	$a_{roll\text{-}y}$	C_{YR}	$11,80\ f_{TL} - 0,65$	$0,65 - 11,80\ f_{TL}$	$0,65 - 11,80\ f_{TL}$	$11,80\ f_{TL} - 0,65$
	$a_{yaw\text{-}y}$	C_{YY}	$7,60\ f_{TL} - 0,43$	$0,43 - 7,60\ f_{TL}$	$0,43 - 7,60\ f_{TL}$	$7,60\ f_{TL} - 0,43$
	$g\ \sin\theta$	C_{YG}	$0,60 - 10,20\ f_{TL}$	$10,20\ f_{TL} - 0,60$	$10,20\ f_{TL} - 0,60$	$0,60 - 10,20\ f_{TL}$
Vertical accelerations	a_{heave}	C_{ZH}	$-0,15$	$0,15$	$-0,15$	$0,15$
	$a_{roll\text{-}z}$	C_{ZR}	$11,80\ f_{TL} - 0,65$	$0,65 - 11,80\ f_{TL}$	$0,65 - 11,80\ f_{TL}$	$11,80\ f_{TL} - 0,65$
	$a_{pitch\text{-}z}$	C_{ZP}	$1,16\ C_{B\text{-}LC} - 0,32$	$0,32 - 1,16\ C_{B\text{-}LC}$	$1,16\ C_{B\text{-}LC} - 0,32$	$0,32 - 1,16\ C_{B\text{-}LC}$

(1) C_{WV} is to be not greater than 0

(2) C_{WV} is to be not less than 0

(3) When $C_{WV} = 0$, C_{QV} is to be taken equal to 0.

Table 13 : Load combination factors LCFs for OVA load cases - Strength assessment

Load component		LCF	OVA1-P	OVA2-P	OVA1-S	OVA2-S
Hull girder loads	M_{wv}	C_{WV}	$0,60 - 3,15\ f_{TL}$ **(2)**	$3,15\ f_{TL} - 0,60$ **(1)**	$0,60 - 3,15\ f_{TL}$ **(2)**	$3,15\ f_{TL} - 0,60$ **(1)**
	Q_{wv}	C_{QV} **(3)**	$(0,60 - 3,15\ f_{TL})\ f_{lp}$	$(3,15\ f_{TL} - 0,60)\ f_{lp}$	$(0,60 - 3,15\ f_{TL})\ f_{lp}$	$(3,15\ f_{TL} - 0,60)\ f_{lp}$
	M_{wh}	C_{WH}	$0,46$	$-0,46$	$-0,46$	$0,46$
	Q_{wh}	C_{QH}	$-0,46\ f_{lp}$	$0,46\ f_{lp}$	$0,46\ f_{lp}$	$-0,46\ f_{lp}$
	M_{wt}	C_{WT}	$0,46\ f_{lp}$	$-0,46\ f_{lp}$	$-0,46\ f_{lp}$	$0,46\ f_{lp}$
Longitudinal accelerations	a_{surge}	C_{XS}	$8,40\ f_{TL} - 0,81$	$0,81 - 8,40\ f_{TL}$	$8,40\ f_{TL} - 0,81$	$0,81 - 8,40\ f_{TL}$
	$a_{pitch\text{-}x}$	C_{XP}	1	-1	1	-1
	$a_{yaw\text{-}x}$	C_{XY}	$0,30 + 13,3\ f_{TL}$	$-0,3 - 13,3\ f_{TL}$	$-0,3 - 13,3\ f_{TL}$	$0,30 + 13,3\ f_{TL}$
	$g\ \sin\varphi$	C_{XG}	$-0,70$	$0,70$	$-0,70$	$0,70$
Transverse accelerations	a_{sway}	C_{YS}	$-0,36$	$0,36$	$0,36$	$-0,36$
	$a_{roll\text{-}y}$	C_{YR}	$0,50 - 1,20\ \omega_R$	$1,20\ \omega_R - 0,50$	$1,20\ \omega_R - 0,50$	$0,50 - 1,20\ \omega_R$
	$a_{yaw\text{-}y}$	C_{YY}	$0,30 + 13,30\ f_{TL}$	$-0,30 - 13,30\ f_{TL}$	$-0,30 - 13,30\ f_{TL}$	$0,30 + 13,30\ f_{TL}$
	$g\ \sin\theta$	C_{YG}	$1,20\ \omega_R - 0,50$	$0,50 - 1,20\ \omega_R$	$0,50 - 1,20\ \omega_R$	$1,20\ \omega_R - 0,50$
Vertical accelerations	a_{heave}	C_{ZH}	$-0,17 - 7,40\ f_{TL}$	$0,17 + 7,40\ f_{TL}$	$-0,17 - 7,40\ f_{TL}$	$0,17 + 7,40\ f_{TL}$
	$a_{roll\text{-}z}$	C_{ZR}	$0,50 - 1,20\ \omega_R$	$1,20\ \omega_R - 0,50$	$1,20\ \omega_R - 0,50$	$0,50 - 1,20\ \omega_R$
	$a_{pitch\text{-}z}$	C_{ZP}	1	-1	1	-1

(1) C_{WV} is to be not greater than 0

(2) C_{WV} is to be not less than 0

(3) When $C_{WV} = 0$, C_{QV} is to be taken equal to 0.

3 Dynamic load cases for fatigue assessment

3.1 Selection of EDW

3.1.1 The following Equivalent Design Waves are to be considered for the fatigue assessment:

- HVM
- HVMf
- BR
- BP
- OHM

3.2 Load combination factors

3.2.1 The load combinations factors LCFs for the determination of each load component to be used for fatigue assessment are defined in Tab 14 to Tab 17.

Table 14 : Load combination factors LCFs for HVM and HVMf load cases - Fatigue assessment

Load component		LCF	HVM1	HVM2	HVMf1	HVMf2
Hull girder loads	M_{wv}	C_{WV}	– 1	1	– 1	1
	Q_{wv}	C_{QV}	$-f_{lp}$	f_{lp}	$-f_{lp}$	f_{lp}
	M_{wh}	C_{WH}	0	0	0	0
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0,80 - 12\ f_{TL}$	$12\ f_{TL} - 0,80$	$1,00 - 16,50\ f_{TL}$	$16,50\ f_{TL} - 1,00$
	$a_{pitch-x}$	C_{XP}	$0,70\ C_{B-LC} - 1,15$	$1,15 - 0,70\ C_{B-LC}$	$11,70\ f_{TL} - 1,07$	$1,07 - 11,70\ f_{TL}$
	a_{yaw-x}	C_{XY}	0	0	0	0
	$g\ \sin\varphi$	C_{XG}	0,57	– 0,57	$0,91 - 9,82\ f_{TL}$	$9,82\ f_{TL} - 0,91$
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0
	a_{yaw-y}	C_{YY}	0	0	0	0
	$g\ \sin\theta$	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0,27 + 3,60\ f_{TL}$	$-0,27 - 3,60\ f_{TL}$	$0,06 + 7,86\ f_{TL}$	$-0,06 - 7,86\ f_{TL}$
	a_{roll-z}	C_{ZR}	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	$0,70\ C_{B-LC} - 1,15$	$1,15 - 0,70\ C_{B-LC}$	$11,70\ f_{TL} - 1,07$	$1,07 - 11,70\ f_{TL}$

Table 15 : Load combination factors LCFs for BR load cases - Fatigue assessment

Load component		LCF	BR1-P	BR2-P	BR1-S	BR2-S
Hull girder loads	M_{wv}	C_{WV}	0	0	0	0
	Q_{wv}	C_{QV}	0	0	0	0
	M_{wh}	C_{WH}	$1,20 - 16\ f_{TL}$	$16\ f_{TL} - 1,20$	$16\ f_{TL} - 1,20$	$1,20 - 16\ f_{TL}$
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	a_{yaw-x}	C_{XY}	0	0	0	0
	$g\ \sin\varphi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	$1,71\ \omega_R - 0,73$	$0,73 - 1,71\ \omega_R$	$0,73 - 1,71\ \omega_R$	$1,71\ \omega_R - 0,73$
	a_{roll-y}	C_{YR}	1	– 1	– 1	1
	a_{yaw-y}	C_{YY}	0	0	0	0
	$g\ \sin\theta$	C_{YG}	– 1	1	1	– 1
Vertical accelerations	a_{heave}	C_{ZH}	$0,88 - 0,15\ T_R$	$0,15\ T_R - 0,88$	$0,88 - 0,15\ T_R$	$0,15\ T_R - 0,88$
	a_{roll-z}	C_{ZR}	1	– 1	– 1	1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Table 16 : Load combination factors LCFs for BP load cases - Fatigue assessment

Load component		LCF	BP1-P	BP2-P	BP1-S	BP2-S
Hull girder loads	M_{wv}	C_{WV}	0,2	– 0,2	0,2	– 0,2
	Q_{wv}	C_{QV}	0,2 f_{lp}	– 0,2 f_{lp}	0,2 f_{lp}	– 0,2 f_{lp}
	M_{wh}	C_{WH}	19 f_{TL} – 1,30	1,30 – 19 f_{TL}	1,30 – 19 f_{TL}	19 f_{TL} – 1,30
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	a_{yaw-x}	C_{XY}	0,10	– 0,10	– 0,10	0,10
	g sinφ	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	1,73 – 2,11 ω_R	2,11 ω_R – 1,73	2,11 ω_R – 1,73	1,73 – 2,11 ω_R
	a_{roll-y}	C_{YR}	0,39 T_R – 1,82	1,82 – 0,39 T_R	1,82 – 0,39 T_R	0,39 T_R – 1,82
	a_{yaw-y}	C_{YY}	0,10	– 0,10	– 0,10	0,10
	g sinθ	C_{YG}	1,35 – 0,27 T_R	0,27 T_R – 1,35	0,27 T_R – 1,35	1,35 – 0,27 T_R
Vertical accelerations	a_{heave}	C_{ZH}	– 1	1	– 1	1
	a_{roll-z}	C_{ZR}	0,39 T_R – 1,82	1,82 – 0,39 T_R	1,82 – 0,39 T_R	0,39 T_R – 1,82
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Table 17 : Load combination factors LCFs for OHM load cases - Fatigue assessment

Load component		LCF	OHM1-P	OHM2-P	OHM1-S	OHM2-S
Hull girder loads	M_{wv}	C_{WV}	7,70 f_{TL} – 0,60 **(1)**	0,60 – 7,70 f_{TL} **(2)**	7,70 f_{TL} – 0,60 **(1)**	0,60 – 7,70 f_{TL} **(2)**
	Q_{wv}	C_{QV} **(3)**	(7,70 f_{TL} – 0,60) f_{lp}	(0,60 – 7,70 f_{TL}) f_{lp}	(7,70 f_{TL} – 0,60) f_{lp}	(0,60 – 7,70 f_{TL}) f_{lp}
	M_{wh}	C_{WH}	– 1	1	1	– 1
	Q_{wh}	C_{QH}	f_{lp}	– f_{lp}	– f_{lp}	f_{lp}
	M_{wt}	C_{WT}	– f_{lp}	f_{lp}	f_{lp}	– f_{lp}
Longitudinal accelerations	a_{surge}	C_{XS}	0,20	– 0,20	0,20	– 0,20
	$a_{pitch-x}$	C_{XP}	– 0,39	0,39	– 0,39	0,39
	a_{yaw-x}	C_{XY}	0,53 – 16 f_{TL}	16 f_{TL} – 0,53	16 f_{TL} – 0,53	0,53 – 16 f_{TL}
	g sinφ	C_{XG}	0,31	– 0,31	0,31	– 0,31
Transverse accelerations	a_{sway}	C_{YS}	0,30	– 0,30	– 0,30	0,30
	a_{roll-y}	C_{YR}	12 f_{TL} – 0,90	0,90 – 12 f_{TL}	0,90 – 12 f_{TL}	12 f_{TL} – 0,90
	a_{yaw-y}	C_{YY}	0,53 – 16 f_{TL}	16 f_{TL} – 0,53	16 f_{TL} – 0,53	0,53 – 16 f_{TL}
	g sinθ	C_{YG}	0,7 – 10,20 f_{TL}	10,20 f_{TL} – 0,7	10,20 f_{TL} – 0,7	0,7 – 10,20 f_{TL}
Vertical accelerations	a_{heave}	C_{ZH}	– 0,26	0,26	– 0,26	0,26
	a_{roll-z}	C_{ZR}	12 f_{TL} – 0,90	0,90 – 12 f_{TL}	0,90 – 12 f_{TL}	12 f_{TL} – 0,90
	$a_{pitch-z}$	C_{ZP}	– 0,39	0,39	– 0,39	0,39

(1) C_{WV} is to be not greater than 0

(2) C_{WV} is to be not less than 0

(3) When $C_{WV} = 0$, C_{QV} is to be taken equal to 0.

Section 3 Ship Motions and Accelerations

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

α : Parameter used for the calculation of L_{ref} and defined throughout Ch 5, Sec 3, Ch 5, Sec 4 and Ch 5, Sec 5 for the motion, acceleration or load under consideration

$a_{pitch-x}$: Longitudinal acceleration due to pitch, in m/s^2, as defined in [3.2.2]

$a_{pitch-z}$: Vertical acceleration due to pitch, in m/s^2, as defined in [3.2.4]

a_{roll-y} : Transverse acceleration due to roll, in m/s^2, as defined in [3.2.3]

a_{roll-z} : Vertical acceleration due to roll, in m/s^2, as defined in [3.2.4]

A_{WP-LC} : Waterplane area at considered loading condition draught T_{LC}, in m^2

a_{yaw-x} : Longitudinal acceleration due to yaw, in m/s^2, as defined in [3.2.2]

a_{yaw-y} : Transverse acceleration due to yaw, in m/s^2, as defined in [3.2.3]

C_α : Parameter defined throughout the Rules for the motion, acceleration or load under consideration

C_{B-LC} : Block coefficient at considered loading condition draught T_{LC}, as defined in Ch 1, Sec 3, [2.1.9].
Specific values may be defined in Tab 4 for typical loading conditions.

C_S : Parameter defined for the considered load

C_{W-LC} : Waterplane coefficient at considered loading condition draught T_{LC}, as defined in Ch 1, Sec 3, [2.1.10].
Specific values may be defined in Tab 4 for typical loading conditions.

C_{XG}, C_{XS}, C_{XP}, C_{XY}, C_{YG}, C_{YS}, C_{YR}, C_{YY}, C_{ZH}, C_{ZR} and C_{ZP}: Load combination factors, as defined in Ch 5, Sec 2

F : Froude's number at 0,75 V, to be taken as:
$F = 0{,}123\ V / L^{0,5}$

$F_{5,0}$: Froude's number at 5 knots, to be taken as:
$F_{5,0} = 0{,}82 / L^{0,5}$

f_α : Speed effect coefficient for the reference length, to be taken as, unless otherwise specified:

- for strength assessment:
  $f_\alpha = 1{,}0$
- for fatigue assessment:
  $f_\alpha = 1{,}0 + C_\alpha (F - F_{5,0})$

f_β : Heading correction factor to be taken as:

- for the extreme sea and the ballast water exchange design load scenario:
  - for BR and BP:
    $f_\beta = 0{,}80$
  - for the other EDWs:
    $f_\beta = 1{,}00$
- for fatigue assessment:
  $f_\beta = 1{,}00$

f_{BL} : Ratio between moulded breadth and rule length, to be taken as:
$f_{BL} = B / L$

f_{nl} : Non-linear factor to be taken as 1,0

f_p : Coefficient to be taken as, unless otherwise specified:

- for strength assessment:
  $f_p = f_{ps}$
- for fatigue assessment:
  - for fatigue due to high-cycle wave loads only:
    $f_p = 1$
  - for fatigue due to loading/unloading, as applicable according to Ch 10, Sec 1, [1.3]:
    $f_p = f_{pLU}$

f_{pLU} : Coefficient for loading/unloading fatigue assessments which depend on the cycle period T_{LU}, in days, and operational limit h_{LU}, in m, to be taken as:

$$f_{pLU} = a_{LU} + b_{LU} \times \ln T_{LU}$$

where:

$$a_{LU} = 1,6 - 0,35e^{-0,2h_{LU}^2}$$

$$b_{LU} = 0,25 + \frac{0,23}{\pi}\operatorname{atan}\left(\frac{h_{LU} - 7}{2}\right)$$

f_{ps} : Coefficient for strength assessments which depend on the applicable design load scenario specified in Ch 5, Sec 7, to be taken as:

- for the extreme sea design load scenario:

  $f_{ps} = 1,0$
- for the ballast water exchange design load scenario:

  $f_{ps} = 0,8$

f_S : Speed effect coefficient, to be taken as:

- for strength assessment:

  $f_S = 1,0$
- for fatigue assessment:

  $f_S = 1,0 + C_S (F - F_{5,0})$

f_{TL} : Ratio between draught at the considered loading condition and rule length, to be taken as:

$f_{TL} = T_{LC} / L$

GM : Metacentric height, in m, for the considered loading condition, as defined in [2.1.1]

H : Wave parameter, in m, as defined in [1.1.1]

h_{LU} : Reference height for loading/unloading fatigue assessment, in m, associated to the navigation notation, as given in Tab 1.

L_c : Length, in m, as defined in Tab 1

L_{ref} : Reference length, in m, to be taken as:

$$L_{ref} = \min\left[\alpha f_\alpha L_c; L\left(\frac{L_c}{40}\right)\right]$$

T_{LU} : Loading/unloading cycle period, in days, to be submitted by the Designer, not to be taken greater than 15 days nor less than 0,5 days

x y z : X, Y and Z coordinates, in m, of the considered point with respect to the coordinate system, as defined in Ch 1, Sec 3, [2.6]

x_G : Longitudinal coordinate, in m, of the ship's centre of gravity, for the considered loading condition, to be taken as:

$x_G = 0,57\ C_{B\text{-}LC}^{0,4}\ L$

z_G : Vertical coordinate, in m, of the ship's centre of gravity, for the considered loading condition, to be taken as:

$$z_G = 1,08\left(\frac{T_{LC}}{2} + \frac{B^2}{12T_{LC}}\right) - GM$$

1 General

1.1 Definitions

1.1.1 Wave parameter

The wave parameter H, in m, is to be taken as:

- for $L \le L_{ref}$:

$$H = f_p A_0\left[1 - A_1\left(1 - \sqrt{\frac{L}{L_{ref}}}\right)^{e_1}\right]$$

- for $L > L_{ref}$:

$$H = f_p A_0\left[1 - A_2\left(\sqrt{\frac{L}{L_{ref}}} - 1\right)^{e_2}\right]$$

where:

A_0 , A_1 , A_2 , e_1 , e_2 : Coefficients defined in Tab 1 for strength and for fatigue assessment

L_{ref} : Reference length calculated with α and f_α values as defined for the considered acceleration, motion or load.

Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the wave parameter H is to be calculated using **unrestricted navigation** parameters unless a specific value for H has been determined by the Society based on the scatter diagram corresponding to the geographical area or the sea condition considered.

1.1.2 Navigation coefficient

For the strength assessment, the navigation coefficient n is to be taken according to Tab 2.

For the fatigue assessment, the navigation coefficient n is to be taken according to Tab 3.

Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the navigation coefficient n is to be taken as n = 1,00 unless a specific value for n has been determined by the Society based on the scatter diagram corresponding to the geographical area or the sea conditions considered.

Table 1 : Wave parameter coefficients for strength and fatigue assessment

Navigation notation	Assessment	A_0	A_1	e_1	A_2	e_2	L_c	h_{lu} **(1)**
unrestricted navigation	Strength	0,90	1,30	1,80	0,90	1,80	552	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
summer zone	Strength	0,78	1,30	1,80	0,90	1,80	500	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
tropical zone	Strength	0,61	1,48	2,01	0,43	1,74	319	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
coastal area	Strength	0,61	1,48	2,01	0,43	1,74	319	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
sheltered area	Strength	0,47	1,55	2,13	0,29	1,69	244	–
	Fatigue	0,14	1,71	1,98	0,37	1,37	236	5,5

(1) Reference height for loading/unloading fatigue assessment, in m, to be considered for the calculation of f_{plu} according to Ch 5, Sec 3

Table 2 : Navigation coefficient for strength assessment

Navigation notation	Navigation coefficient n
unrestricted navigation	1
other navigation notations	$\frac{H}{H_{s,unrestricted}}$

Note 1:
H : Wave parameter as defined in [1.1.1] for the strength assessment and corresponding to the concerned navigation notation
$H_{s,unrestricted}$: Wave parameter as defined in [1.1.1] for the strength assessment and corresponding to the navigation notation **unrestricted navigation**

Table 3 : Navigation coefficient for fatigue assessment

Navigation notation	Navigation coefficient n	
	High-cycle fatigue assessment	Fatigue assessment due to loading /unloading
unrestricted navigation	1	$\frac{H_{f\text{-}LU}}{H_{f\text{-}H,unrestricted}}$
other navigation notations	$\frac{H_{f\text{-}H}}{H_{f\text{-}H,unrestricted}}$	

Note 1:
$H_{f\text{-}H}$: Wave parameter as defined in [1.1.1] for the high cycle fatigue assessment and corresponding to the concerned navigation notation
$H_{f\text{-}LU}$: Wave parameter as defined in [1.1.1] for the loading/unloading fatigue assessment and corresponding to the concerned navigation notation
$H_{f\text{-}H,unrestricted}$: Wave parameter as defined in [1.1.1] for the high cycle fatigue assessment and corresponding to the navigation notation **unrestricted navigation**

2 Ship motions and accelerations

2.1 Ship motions

2.1.1 Roll motion

The roll period T_θ, in s, is to be taken as:

$$T_\theta = \frac{2,3\pi\, k_r}{\sqrt{g\ GM}}$$

The roll angle θ, in deg, is to be taken as:

$$\theta = \frac{9000\,(1,25 - 0,025 T_\theta)}{(B+75)\pi} \cdot f_{fa} \cdot f_{BK}$$

without being taken less than:

$$\frac{1862}{B+75} \cdot f_{fa} \cdot f_{BK}$$

where:

f_{fa} : Coefficient, to be taken as:

- for strength assessment:

  $f_{fa} = f_{ps} \,.\, n$

- for fatigue assessment:

  $f_{fa} = 0,9\,(0,23 - 4 \cdot 10^{-4}\, B\, f_T)\, n$

f_T : Ratio between draught at the considered loading condition and scantling draught, to be taken as:

$f_T = \max\,(T_{LC} / T_{SC}\ ;\ 0,5)$

without being taken greater than 1

f_{BK} : To be taken as:

- for ships without bilge keel:

  $f_{BK} = 1,2$

- for ships with bilge keel:

  $f_{BK} = 1,0$

GM : Metacentric height, in m, for the considered loading condition, as defined in Tab 4, unless a different value is given in the loading manual

k_r : Roll radius of gyration, in m, for the considered loading condition, as defined in Tab 4

n : Navigation coefficient as defined in [1.1.2] for a reference length L_{ref} calculated with:

$$\alpha = \frac{4,6}{T_R^{\,2}}$$

$f_\alpha = 1,0$

2.1.2 Pitch motion

The pitch period T_φ, in s, is to be taken as:

$$T_\varphi = 0,8\sqrt{L}$$

The pitch angle φ, in deg, is to be taken as:

$$\varphi = \frac{1970 \cdot f_S \cdot f_{nl} \cdot H}{L \cdot C_{W\text{-}LC}^{\,0,75}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$\alpha = 0,56$

f_α calculated with $C_\alpha = -0,85$ for fatigue assessment

f_S : Speed effect coefficient calculated with $C_S = 0,9$ for fatigue assessment.

Table 4 : Values of k_r , GM, $C_{B\text{-}LC}$ and $C_{W\text{-}LC}$

Loading condition (1)	service notation	T_{LC}	k_r	GM	$C_{B\text{-}LC}$	$C_{W\text{-}LC}$
Full load condition	**oil tanker**, **cement carrier**, **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	T_{SC}	0,35 B	0,12 B	C_B	C_W
	Other ships			0,07 B		
Full load condition with reduced draught	**oil tanker**, **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	Actual draught	0,35 B	0,12 B	C_B	C_W
	Other ships			0,07 B		
Design fatigue condition	**container ship**	0,85 T_{sc}	0,35 B	0,07 B	C_B	C_W
Partial load condition	**oil tanker**	0,6T_{sc}	0,40 B	0,24 B	$C_{B\text{-}LC}$	$C_{W\text{-}LC}$
	FLS tanker, **asphalt carrier**, **chemical tanker**, **tanker**, **combination carrier**		0,35 B	0,07 B		
Full load / homogeneous heavy cargo condition	**bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	T_{sc}	0,42 B	0,25 B	C_B	C_W
Steel coils condition	**bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**	T_{sc}	0,42 B	0,25 B	C_B	C_W
Alternate heavy cargo condition	**bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	T_{sc}	0,40 B	0,20 B	C_B	C_W
Alternate light cargo condition	**cement carrier**, **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	T_{sc}	0,35 B	0,12 B	C_B	C_W
Heavy ballast condition	**bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	$T_{BAL\text{-}H}$	0,40 B	0,25 B	$C_{B\text{-}LC}$	$C_{W\text{-}LC}$
Normal ballast condition	**oil tanker**, **cement carrier**, **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**	T_{BAL}	0,45 B	0,33 B	$C_{B\text{-}BAL}$	$C_{W\text{-}BAL}$
	Other ships			0,18 B		

(1) For Multi-port (MP) of **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier** (limited to direct strength analysis):

- loading conditions with draught amidships greater than or equal to 0,9 T_{sc}, the values of k_r and GM, unless provided in the loading manual, are to be taken as those from the most appropriate full load condition. $C_{B\text{-}LC}$ and $C_{W\text{-}LC}$ are to be taken equal to respectively C_B and C_W.
- loading conditions with draught amidships between $T_{BAL\text{-}H}$ and 0,9 T_{sc}, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation, based on the draught, between the heavy ballast condition and the most appropriate full load condition. $C_{B\text{-}LC}$ and $C_{W\text{-}LC}$ are to be taken as provided in the loading manual.
- loading conditions with a draught amidships below $T_{BAL\text{-}H}$, the values of k_r and GM for the heavy ballast condition are to be used. $C_{B\text{-}LC}$ and $C_{W\text{-}LC}$ are to be taken as provided in the loading manual.

2.2 Accelerations at the centre of gravity

2.2.1 Surge acceleration

The longitudinal acceleration due to surge, in m/s^2, is to be taken as:

$$a_{surge} = \frac{115 \cdot f_S \cdot f_{nl} \cdot H}{L \cdot f_{TL}^{0,2} \cdot C_{B\text{-}LC}^{0,6}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,37}{C_{W\text{-}LC}^{0,9}}$$

$f_\alpha = 1,0$

f_S : Speed effect coefficient to be taken as:

$f_S = 1,0$.

2.2.2 Sway acceleration

The transverse acceleration due to sway, in m/s^2, is to be taken as:

$$a_{sway} = \frac{115 \cdot f_S \cdot f_{nl} \cdot H}{L \cdot f_{TL}^{0,15} \cdot f_{BL}^{0,5}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,24}{f_{BL}^{0,65}}$$

$f_\alpha = 1,0$

f_S : Speed effect coefficient to be taken as:

$f_S = 1,0$

2.2.3 Heave acceleration

The vertical acceleration due to heave, in m/s^2, is to be taken as:

$$a_{heave} = \frac{350 \cdot f_S \cdot f_{nl} \cdot H}{L \cdot f_{BL}^{0,5}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,35}{f_{TL}^{0,35}}$$

f_α calculated with $C_\alpha = (-16,3\ f_{TL} - 1,10)$ for fatigue assessment

f_S : Speed effect coefficient calculated with $C_S = (19,7\ f_{TL} + 0,55)$ for fatigue assessment.

2.2.4 Roll acceleration

The roll acceleration, a_{roll}, in rad/s^2, is to be taken as:

$$a_{roll} = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_\theta}\right)^2$$

2.2.5 Pitch acceleration

The pitch acceleration, a_{pitch}, in rad/s^2, is to be taken as:

$$a_{pitch} = 6 \cdot 10^4 \cdot \frac{\pi}{180} \cdot \frac{f_S \cdot f_{nl} \cdot H}{L^2 \cdot f_{BL}^{0,5} \cdot C_{W\text{-}LC}^{1,5}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,24}{f_{BL}^{0,8}}$$

f_α calculated with $C_\alpha = (2,83 - 9,13\ C_{B\text{-}LC})$ for fatigue assessment

f_S : Coefficient calculated with $C_S = 2,11$ for fatigue assessment.

2.2.6 Yaw acceleration

The yaw acceleration, a_{yaw}, in rad/s^2, is to be taken as:

$$a_{yaw} = 200,4 \cdot 10^2 \cdot \frac{\pi}{180} \cdot \frac{f_S \cdot f_{nl} \cdot H}{L^2 \cdot f_{BL}^{0,73}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{1,14}{C_{B\text{-}LC}^{0,7}}$$

$f_\alpha = 1,0$

f_S : Coefficient to be taken as $f_S = 1,0$ for fatigue assessment.

3 Accelerations at any position

3.1 General

3.1.1 The accelerations used to derive the inertial loads at any position are defined with respect to the ship fixed coordinate system. Hence the acceleration values defined in [3.2.2] and [3.2.3] include the gravitational acceleration components due to the instantaneous roll and pitch angles.

3.1.2 The accelerations to be applied for the dynamic load cases defined in Ch 5, Sec 2 are given in [3.2].

3.1.3 When required for the assessment of equipments, their foundations and supporting structures, guidance for the determination of the load cases maximizing the various acceleration components is given in [3.3].

3.2 Accelerations for dynamic load cases

3.2.1 General

The accelerations to be applied for the dynamic load cases defined in Ch 5, Sec 2 are given in [3.2.2] to [3.2.4].

3.2.2 Longitudinal acceleration

The longitudinal acceleration a_X at any position for each dynamic load case, in m/s^2, is to be taken as:

$$a_X = -C_{XG}\, g \sin(f_\beta \varphi) + f_\beta (C_{XS}\, a_{surge} + C_{XP}\, a_{pitch\text{-}x} - C_{XY}\, a_{yaw\text{-}x})$$

where:

$a_{pitch\text{-}x}$: Longitudinal acceleration due to pitch, in m/s^2:

$$a_{pitch\text{-}x} = a_{pitch}\,(z - z_G)$$

$a_{yaw\text{-}x}$: Longitudinal acceleration due to yaw, in m/s^2:

$$a_{yaw\text{-}x} = a_{yaw}\, y$$

3.2.3 Transverse acceleration

The transverse acceleration a_Y at any position for each dynamic load case, in m/s^2, is to be taken as:

$$a_Y = C_{YG}\, g \sin\theta + f_\beta (C_{YS}\, a_{sway} + C_{YY}\, a_{yaw\text{-}y}) - C_{YR}\, a_{roll\text{-}y}$$

where:

$a_{roll\text{-}y}$: Transverse acceleration due to roll, in m/s^2:

$$a_{roll\text{-}y} = a_{roll}\,(z - z_G)$$

$a_{yaw\text{-}y}$: Transverse acceleration due to yaw, in m/s^2:

$$a_{yaw\text{-}y} = a_{yaw}\,(x - x_G)$$

3.2.4 Vertical acceleration

The vertical acceleration a_Z at any position for each dynamic load case, in m/s^2, is to be taken as:

$$a_Z = f_\beta (C_{ZH}\, a_{heave} - C_{ZP}\, a_{pitch\text{-}z}) + C_{ZR}\, a_{roll\text{-}z}$$

where:

$a_{roll\text{-}z}$: Vertical acceleration due to roll, in m/s^2:

$$a_{roll\text{-}z} = a_{roll}\, y$$

$a_{pitch\text{-}z}$: Vertical acceleration due to pitch, in m/s^2:

$$a_{pitch\text{-}z} = a_{pitch}\,(x - x_G)$$

3.3 Maximum accelerations for equipment

3.3.1 General

As a guidance for the assessment of equipments, their foundations and supporting structures, the various acceleration components are generally (but not necessarily) maximized by the following load cases:

a_X : OVA for all ship areas

a_Y : BP for fore and midship areas, OVA for the aft area

a_Z : OVA for fore an aft areas, BP for the midship area.

Section 4 Hull Girder Loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

C : Wave coefficient:

$$C = (118 - 0{,}36L)\frac{L}{1000} \quad \text{for } L < 90\text{m} \quad \text{without being taken less than 3,2}$$

$$C = 10{,}75 - \left(\frac{300 - L}{100}\right)^{1{,}5} \quad \text{for } 90\text{m} \le L < 300\text{m}$$

$$C = 10{,}75 \quad \text{for } 300\text{m} \le L \le 350\text{m}$$

$$C = 10{,}75 - \left(\frac{L - 350}{150}\right)^{1{,}5} \quad \text{for } L > 350\text{m}$$

$C_{B\text{-}LC}$: Block coefficient, as defined in Ch 5, Sec 3

F : Froude's number at 0,75 V, as defined in Ch 5, Sec 3

f_{BL} : Ratio between moulded breadth and rule length as defined in Ch 5, Sec 3

f_β : Heading correction factor as defined in Ch 5, Sec 3

H : Wave parameter, as defined in Ch 5, Sec 3

ΔQ_{swf} : Shear force correction at the transverse section considered, in kN, taken as:

- For ships carrying dry bulk cargo, $\Delta Q_{md\text{-}fwd}$ as defined in Ch 8, App 1, [4.3.4].
- For other ships, $\Delta Q_{swf} = 0$

1 Application

1.1 General

1.1.1 The hull girder loads for the static design load scenarios are to be taken as the still water loads defined in Article [2].

1.1.2 The total hull girder loads for the static + dynamic design load scenarios are to be derived for each dynamic load case and are to be taken as the sum of the still water loads defined in Article [2] and the dynamic loads defined in [3.6].

2 Still water loads

2.1 General

2.1.1 Still water load calculation

Still water loads are to be calculated for all the design loading conditions defined in Ch 5, Sec 8 and subdivided into departure and arrival conditions.

The longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions, on the basis of realistic data related to the amount of cargo, ballast, fuel, lubricating oil and fresh water.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and, where approved, included in the loading manual for guidance.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The designer is to supply the data necessary to verify the calculations of still water loads.

2.1.2 Seagoing and harbour/sheltered water conditions

The designer is to provide the permissible still water bending moment and shear force distributions for seagoing and harbour/sheltered water operations.

The permissible still water hull girder loads are to be given, as a minimum:

- at each transverse bulkhead in the cargo hold region
- at the collision bulkhead

- at the engine room forward bulkhead, and
- at the mid-point between the forward and aft engine room bulkheads.

The permissible hull girder bending moments and shear forces at any other position may be obtained by linear interpolation.

Distributions of permissible still water bending moments and shear forces are to be provided in the loading manual.

2.1.3 Still water loads for the fatigue assessment

The still water bending moments, M_{sw}, to be used for the fatigue assessment are to be taken as defined in Tab 1 for each loading condition representative of the intended operation of the ship, given in Ch 10, Sec 1, [2].

Table 1 : Still water bending moment for fatigue assessment

Service notation	Loading condition	M_{sw}
ro-ro cargo ship, **PCTC, PCC** **passenger ship** or **ro-ro passenger ship**	Full load condition	1,00 $M_{sw\text{-}max}$
container ship	Loaded at 0,85 T_{sc}	1,00 $M_{sw\text{-}max}$
bulk carrier, **bulk carrier ESP** **self-unloading bulk carrier ESP** **ore carrier ESP** **combination carrier ESP**	Heavy ballast condition	• 0,75 $M_{sw\text{-}min}$ in way of ballasted hold • 0,45 $M_{sw\text{-}max}$ in way of other cargo holds • linear interpolation between 0,75 $M_{sw\text{-}min}$ and 0,45 $M_{sw\text{-}max}$ for cargo holds adjacent to ballasted hold
all other service notations	Full load condition	1,00 $M_{sw\text{-}min}$
	Normal ballast condition	1,00 $M_{sw\text{-}max}$
$M_{sw\text{-}max}$, $M_{sw\text{-}min}$: permissible vertical still water bending moments in seagoing condition as defined in [2.2.1].		

2.2 Vertical still water bending moments

2.2.1 Permissible vertical still water bending moments in seagoing condition

The permissible vertical still water bending moments in seagoing condition $M_{sw\text{-}max}$ and $M_{sw\text{-}min}$, at any longitudinal position, are to envelop:

- the maximum and minimum still water bending moments calculated, respectively, for all seagoing loading conditions defined in Ch 5, Sec 8. Loading conditions encountered during ballast water exchange need not to be considered for the flooded condition.
- the still water bending moments for all seagoing loading conditions defined in the loading manual.

2.2.2 Permissible vertical still water bending moments in harbour/sheltered water condition

The permissible vertical still water bending moments in harbour/sheltered water condition $M_{sw\text{-}p\text{-}max}$ and $M_{sw\text{-}p\text{-}min}$, at any longitudinal position, are to envelop:

- the maximum and minimum still water bending moments, respectively, for all harbour/sheltered water loading conditions defined in Ch 5, Sec 8
- the still water bending moments for all harbour/sheltered water loading conditions defined in the loading manual
- the permissible still water bending moment in seagoing condition, defined in [2.2.1].

2.2.3 Preliminary still water bending moment

When the permissible still water bending moments are not defined, as a guidance at a preliminary stage, $M_{sw\text{-}max}$ and $M_{sw\text{-}min}$, in kN·m, may be taken as:

$$M_{sw-max} = f_{sw}\left(171\frac{1+n}{2}C \cdot L^2 \cdot B(C_B + 0,7)10^{-3} - M_{wv-h-mid}\right)$$

$$M_{sw-min} = -f_{sw}\left(171\frac{1+n}{2}C \cdot L^2 \cdot B(C_B + 0,7)10^{-3} + M_{wv-s-mid}\right)$$

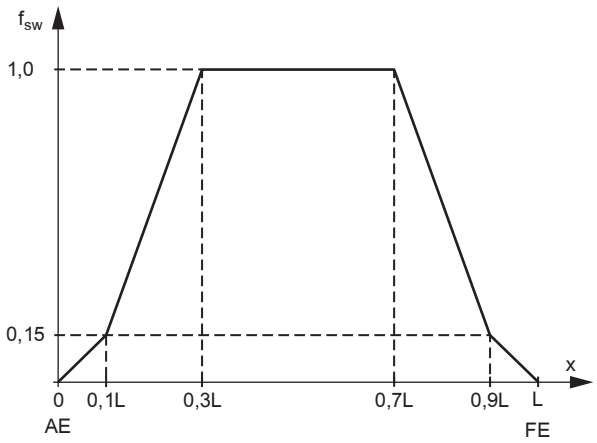
where:

f_{sw} : Distribution factor along the ship length, to be taken as follows (see Fig 1):

- $f_{sw} = 0,0$ for $x \leq 0$
- $f_{sw} = 0,15$ at $x = 0,1\ L$
- $f_{sw} = 1,00$ for $0,3\ L \leq x \leq 0,7\ L$
- $f_{sw} = 0,15$ at $x = 0,9\ L$
- $f_{sw} = 0,0$ for $x \geq L$

Intermediate values of f_{sw} are to be obtained by linear interpolation

Figure 1 : Distribution factor f_{sw}



$M_{wv\text{-}h\text{-}mid}$: Vertical wave bending moment for strength assessment in hogging condition, as defined in:

- ships assigned the service notation **container ship**:
  Pt D, Ch 2, Sec 2, [4.2.1], calculated with $f_{m\text{-}h} = 1,0$ and $f_{ps} = 1,0$
- other ships:
  [3.1.1], calculated with $F_M = 1,0$ and $f_{ps} = 1,0$

$M_{wv\text{-}s\text{-}mid}$: Vertical wave bending moment for strength assessment in sagging condition, as defined in:

- ships assigned the service notation **container ship**:
  Pt D, Ch 2, Sec 2, [4.2.1], calculated with $f_{m\text{-}s} = 1,0$ and $f_{ps} = 1,0$
- other ships:
  [3.1.1], calculated with $F_M = 1,0$ and $f_{ps} = 1,0$

n : Navigation coeficient, as defined in [3.1.1].

Note 1: For ships always in hogging condition such as container ships, $M_{sw\text{-}min}$ may be taken as 0.

2.3 Vertical still water shear forces

2.3.1 Permissible still water shear forces in seagoing condition

The permissible vertical still water shear forces $Q_{sw\text{-}max}$ and $Q_{sw\text{-}min}$ in seagoing condition, at any longitudinal position, are to envelop the corrected still water shear forces for the seagoing loading conditions defined in the loading manual.

The corrected shear force values for each loading condition are to be obtained by deducting the shear force correction ΔQ_{swf} from the values given by the loading manual.

Loading conditions encountered during ballast water exchange need not to be considered for the flooded condition.

2.3.2 Permissible still water shear forces in harbour/ sheltered water and tank testing condition

The permissible vertical still water shear forces $Q_{sw\text{-}p\text{-}max}$ and $Q_{sw\text{-}p\text{-}min}$ in harbour/sheltered water and tank testing conditions, at any longitudinal position, are to envelop:

- the corrected still water shear forces for the harbour/sheltered water loading conditions defined in the loading manual
- the permissible still water shear forces in seagoing condition as defined in [2.3.1].

The corrected shear force values for each loading condition are to be obtained by deducting the shear force correction ΔQ_{swf} from the values given by the loading manual.

3 Wave loads

3.1 Vertical wave bending moments

3.1.1 Vertical wave bending moments for strength assessment

For strength assessment purposes the vertical wave bending moments $M_{wv\text{-}h}$ and $M_{wv\text{-}s}$ at any longitudinal position in kN.m, are to be taken as:

a) For ships assigned the service notation **container ship**: as defined in Pt D, Ch 2, Sec 2, [4.2.1]

b) For other ships:

- hogging conditions:
  $M_{wv\text{-}h} = 190\ F_M\ f_{ps}\ n\ C\ L^2\ B\ C_B\ 10^{-3}$
- sagging conditions:
  $M_{wv\text{-}s} = -110\ F_M\ f_{ps}\ n\ C\ L^2\ B\ (C_B + 0,7)\ 10^{-3}$

where:

F_M : Distribution factor along the ship length, to be taken as follows (see Fig 2):

- $F_M = 0,0$ for $x \leq 0$
- $F_M = 1,0$ for $0,4L \leq x \leq 0,65L$
- $F_M = 0,0$ for $x \geq L$

Intermediate values of F_M are to be obtained by linear interpolation

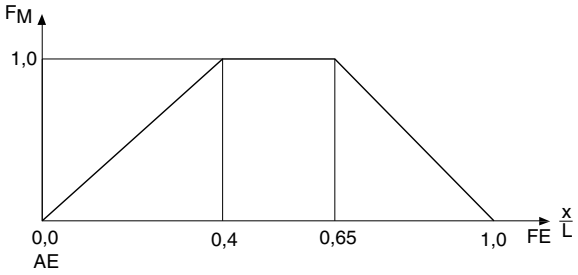
f_{ps} : Coefficient for strength assessments as defined in Ch 5, Sec 3

n : Navigation coefficient as defined in Ch 5, Sec 3, [1.1.2] for a reference length calculated with:

$$\alpha = \frac{315}{486} \cdot \frac{1}{C_W^{1,3}}$$

$f_\alpha = 1,0$

Figure 2 : Distribution factor F_M



3.1.2 Vertical wave bending moments for fatigue assessment

For fatigue assessment purpose, the vertical wave bending moments $M_{wv\text{-}h}$ and $M_{wv\text{-}s}$, in kN·m, at any longitudinal position, are to be taken as:

- in hogging condition:

  $M_{wv\text{-}h} = 1,5\ f_{m\text{-}h}\ H\ L^3\ C_W\ f_{BL}^{0,8}$

- in sagging condition:

  $M_{wv\text{-}s} = -1,5\ f_{m\text{-}s}\ H\ L^3\ C_W\ f_{BL}^{0,8}$

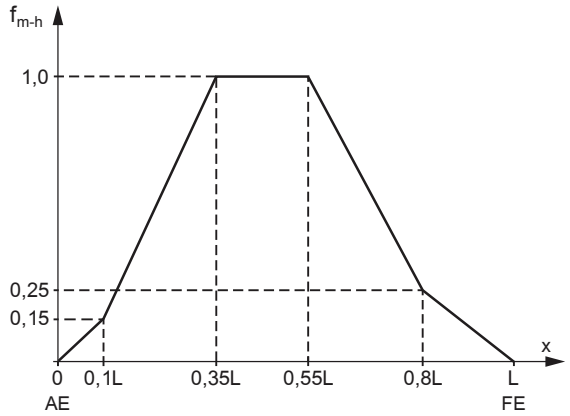
where:

$f_{m\text{-}h}$: Distribution factor for vertical wave bending moment in hogging condition along the ship's length, to be taken as follows (see Fig 3):

- $f_{m\text{-}h} = 0,0$ for $x \leq 0$
- $f_{m\text{-}h} = 0,15$ for $x = 0,1\ L$
- $f_{m\text{-}h} = 1,00$ for $0,35\ L \leq x \leq 0,55\ L$
- $f_{m\text{-}h} = 0,25$ for $x = 0,8\ L$
- $f_{m\text{-}h} = 0,0$ for $x \geq L$

Intermediate values of $f_{m\text{-}h}$ are to be obtained by linear interpolation.

Figure 3 : Distribution factor $f_{m\text{-}h}$

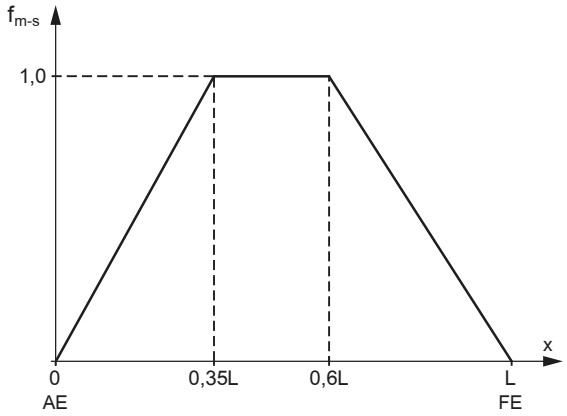


$f_{m\text{-}s}$: Distribution factor for vertical wave bending moment in sagging condition along the ship's length, to be taken as follows (see Fig 4):

- $f_{m\text{-}s} = 0,0$ for $x \leq 0$
- $f_{m\text{-}s} = 1,0$ for $0,35\ L \leq x \leq 0,6\ L$
- $f_{m\text{-}s} = 0,0$ for $x \geq L$

Intermediate values of $f_{m\text{-}s}$ are to be obtained by linear interpolation

Figure 4 : Distribution factor $f_{m\text{-}s}$



H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{315}{486} \cdot \frac{1}{C_W^{1,3}}$$

$f_\alpha = 1,0$

3.2 Vertical wave shear force

3.2.1 Vertical wave shear force for strength assessment

For strength assessment purposes, the vertical wave shear forces $Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$, in kN, at any longitudinal position, are to be taken as:

a) For ships assigned the service notation container ship: as defined in Pt D, Ch 2, Sec 2, [4.2.2]

b) For other ships:

$Q_{wv\text{-}pos} = 30\ F_{Q\text{-}pos}\ f_{ps}\ n\ C\ L\ B\ (C_B + 0,7)\ 10^{-2}$

$Q_{wv\text{-}neg} = 30\ F_{Q\text{-}neg}\ f_{ps}\ n\ C\ L\ B\ (C_B + 0,7)\ 10^{-2}$

where:

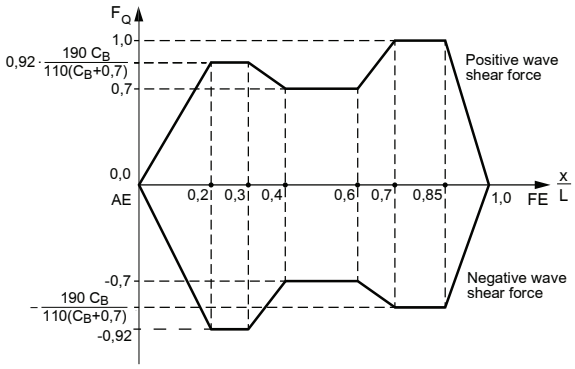
$F_{Q\text{-}pos}$: Distribution factor along the ship length for positive shear force, to be taken as (see Fig 5):

- $F_{Q\text{-}pos} = 0,0$ for $x \leq 0$
- $F_{Q-pos} = 0,92 \cdot \frac{190 C_B}{110(C_B + 0,7)}$ for $0,2L \leq x \leq 0,3L$
- $F_{Q\text{-}pos} = 0,7$ for $0,4L \leq x \leq 0,6L$
- $F_{Q\text{-}pos} = 1,0$ for $0,7L \leq x \leq 0,85L$
- $F_{Q\text{-}pos} = 0,0$ for $x \geq L$

$F_{Q\text{-}neg}$: Distribution factor along the ship length for negative shear force, to be taken as (see Fig 5):

- $F_{Q\text{-}neg} = 0,0$ for $x \leq 0$
- $F_{Q\text{-}neg} = -0,92$ for $0,2L \leq x \leq 0,3L$
- $F_{Q\text{-}neg} = -0,7$ for $0,4L \leq x \leq 0,6L$
- $F_{Q-neg} = -\frac{190 C_B}{110(C_B + 0,7)}$ for $0,7L \leq x \leq 0,85L$
- $F_{Q\text{-}neg} = 0,0$ for $x \geq L$

Figure 5 : Distribution factor $F_{Q\text{-}pos}$ and $F_{Q\text{-}neg}$



n : Navigation coefficient as defined in Ch 5, Sec 3, [1.1.2] for a reference length calculated with:

$$\alpha = \frac{330}{486} \cdot \frac{1}{C_W^{1,3}}$$

$f_\alpha = 1,0$

3.2.2 Vertical wave shear force for fatigue assessment

For fatigue assessment purposes, the vertical wave shear forces $Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$, in kN, at any longitudinal position, are to be taken as:

$Q_{wv\text{-}pos} = f_{q\text{-}pos}\ H\ L^2\ C_W\ f_{BL}^{0,8}$

$Q_{wv\text{-}neg} = -f_{q\text{-}neg}\ H\ L^2\ C_W\ f_{BL}^{0,8}$

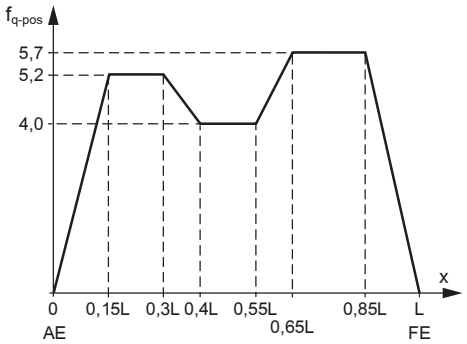
where:

$f_{q\text{-}pos}$: Distribution factor along the ship length for positive wave shear force, to be taken as (see Fig 6):

- $f_{q\text{-}pos} = 0,0$ for $x \le 0$
- $f_{q\text{-}pos} = 5,2$ for $0,15L \le x \le 0,3L$
- $f_{q\text{-}pos} = 4,0$ for $0,4L \le x \le 0,55L$
- $f_{q\text{-}pos} = 5,7$ for $0,65L \le x \le 0,85L$
- $f_{q\text{-}pos} = 0,0$ for $x \ge L$

Intermediate values of $f_{q\text{-}pos}$ are to be obtained by linear interpolation.

Figure 6 : Distribution factor $f_{q\text{-}pos}$



$f_{q\text{-}neg}$: Distribution factor along the ship length for negative wave shear force, to be taken as (see Fig 7):

- $f_{q\text{-}neg} = 1,3$ for $x \le 0$
- $f_{q\text{-}neg} = 5,2$ for $0,15L \le x \le 0,3L$
- $f_{q\text{-}neg} = 4,0$ for $0,4L \le x \le 0,50L$
- $f_{q\text{-}neg} = 5,7$ for $0,6L \le x \le 0,75L$
- $f_{q\text{-}neg} = 0,0$ for $x \ge L$

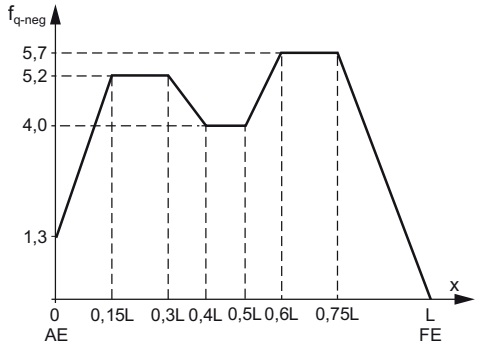
Intermediate values of $f_{q\text{-}neg}$ are to be obtained by linear interpolation

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{330}{486} \cdot \frac{1}{C_W^{1,3}}$$

$f_\alpha = 1,0$

Figure 7 : Distribution factor $f_{q\text{-}neg}$



3.3 Horizontal wave bending moment

3.3.1 The horizontal wave bending moment M_{wh}, in kN·m, at any longitudinal position, is to be taken as:

$$M_{wh} = 2,6 \cdot f_S \cdot f_{nl} \cdot f_m \cdot H \cdot L^3 \cdot C_{B\text{-}LC}{}^{0,3} \cdot \left(\frac{T_{LC}}{L}\right)^{0,8}$$

where:

f_S : Speed effect coefficient as defined in Ch 5, Sec 3 and to be taken as $f_S = 1,0$

f_{nl} : Coefficient considering non-linear effects and to be taken equal to 1,0

f_m : Distribution factor for horizontal wave bending moment along the ship length, to be taken as (see Fig 8):

- $f_m = 0,0$ for $x \leq 0$
- $f_m = 0,25$ for $x = 0,15$ L
- $f_m = 1,00$ for $0,4$ L $\leq x \leq 0,6$ L
- $f_m = 0,20$ for $x = 0,85$ L
- $f_m = 0,0$ for $x \geq$ L

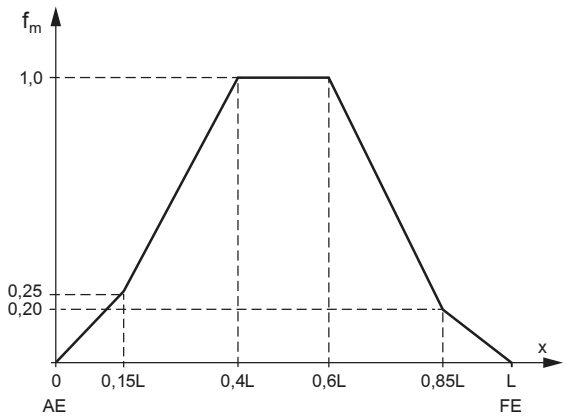
Intermediate values of f_m are to be obtained by linear interpolation

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,65\left(\frac{T_{LC}}{L}\right)^{-0,3}$$

$f_\alpha = 1,0$

Figure 8 : Distribution factor f_m



3.4 Horizontal wave shear force

3.4.1 The horizontal wave shear force Q_{wh}, in kN, at any longitudinal position, is to be taken as:

$Q_{wh} = Q_{wh\text{-}a} + Q_{wh\text{-}f}$

where:

$$Q_{wh\text{-}a} = 10,2 \cdot f_S \cdot f_{q\text{-}a} \cdot f_{nl} \cdot H \cdot L^2 \cdot C_{B\text{-}LC}{}^{0,6} \cdot \left(\frac{T_{LC}}{L}\right)^{0,8}$$

$$Q_{wh\text{-}f} = 19,2 \cdot f_S \cdot f_{q\text{-}f} \cdot f_{nl} \cdot H \cdot L^2 \cdot C_{B\text{-}LC}{}^{0,8} \cdot \frac{T_{LC}}{L}$$

with:

f_S : Speed effect coefficient as defined in Ch 5, Sec 3 and to be taken as $f_S = 1,0$

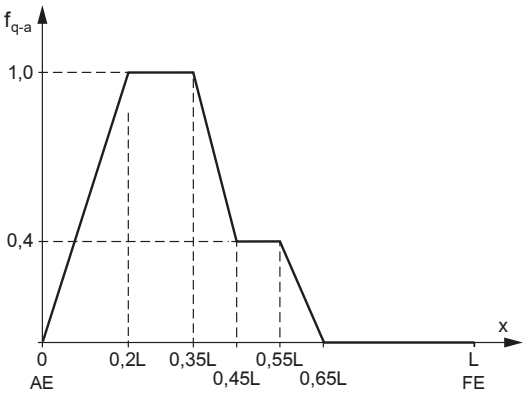
f_{nl} : Coefficient considering non-linear effects and to be taken equal to 1,0

$f_{q\text{-}a}$: Distribution factor for the aft part of the horizontal wave shear force along the ship length, to be taken as (see Fig 9):

- $f_{q\text{-}a} = 0,0$ for $x \leq 0$
- $f_{q\text{-}a} = 1,0$ for $0,20\ L \leq x \leq 0,35\ L$
- $f_{q\text{-}a} = 0,4$ for $0,45\ L \leq x \leq 0,55\ L$
- $f_{q\text{-}a} = 0,0$ for $x \geq 0,65\ L$

Intermediate values of $f_{q\text{-}a}$ are to be obtained by linear interpolation.

Figure 9 : Distribution factor $f_{q\text{-}a}$



$f_{q\text{-}f}$: Distribution factor for the fore part of the horizontal wave shear force along the ship length, to be taken as (see Fig 10):

- $f_{q\text{-}f} = 0,0$ for $x \leq 0,35\ L$
- $f_{q\text{-}f} = 0,4$ for $0,45\ L \leq x \leq 0,55\ L$
- $f_{q\text{-}f} = 1,0$ for $0,65\ L \leq x \leq 0,80\ L$
- $f_{q\text{-}f} = 0,0$ for $x \geq L$

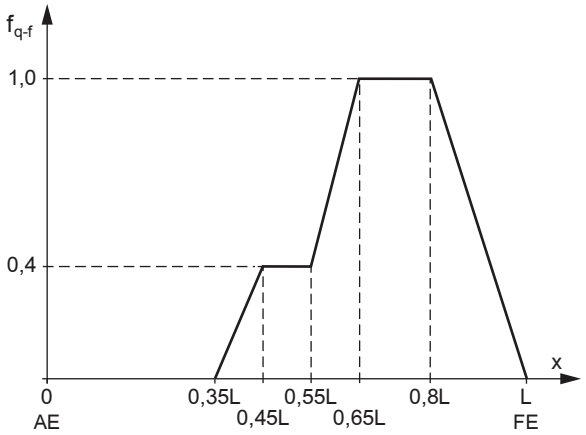
Intermediate values of $f_{q\text{-}f}$ are to be obtained by linear interpolation

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,68\left(\frac{T_{LC}}{L}\right)^{-0,3}$$

$f_\alpha = 1,0$

Figure 10 : Distribution factor $f_{q\text{-}f}$



3.5 Wave torsional moment

3.5.1 The wave torsional moment M_{wt}, in kN·m, at any longitudinal position with respect to the horizontal shear centre, is to be taken as: $M_{wt} = M_{wt\text{-}a} + M_{wt\text{-}f}$

where:

$$M_{wt-a} = Max(M_{wt-a,min}, Q_{wh-a}|z_T - 0,45B|)$$

$$M_{wt-a,min} = 2,50 \cdot f_{q-a} \cdot f_S \cdot H \cdot L^{0,7} \cdot B^{2,3}$$

$$M_{wt-f} = Max(M_{wt-f,min}, Q_{wh-f}|z_T - 0,30B|)$$

$$M_{wt-f,min} = 1,16 \cdot f_{q-f} \cdot f_S \cdot H \cdot L \cdot B^2$$

with:

$Q_{wh\text{-}a}$, $Q_{wh\text{-}f}$: Horizontal wave shear forces as defined in [3.4.1]

z_T : Vertical coordinate from baseline, in m, of the horizontal shear centre at the transverse section under consideration. When z_T is not known, the value is to be taken equal to -0,35 B for ships having large openings in the strength decks as defined in Ch 6, Sec 1, [1.6]

f_S : Coefficient as defined in Ch 5, Sec 3 and to be taken as f_S = 1,0 for fatigue assessment

$f_{q\text{-}a}$, $f_{q\text{-}f}$: Distribution factors in the fore and aft part as defined in [3.4.1]

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,68\left(\frac{T_{LC}}{L}\right)^{-0,3}$$

f_α = 1,0

3.6 Hull girder loads for dynamic load cases

3.6.1 Vertical wave bending moment

The vertical wave bending moment $M_{wv\text{-}LC}$, in kN·m, to be used for each dynamic load case in Ch 5, Sec 2, is defined in Tab 2.

Table 2 : Vertical wave bending moment $M_{wv\text{-}LC}$ for dynamic load cases

$C_{WV} \geq 0$	$M_{wv\text{-}LC} = f_\beta\, C_{WV}\, M_{wv\text{-}h}$
$C_{WV} < 0$	$M_{wv\text{-}LC} = f_\beta\, C_{WV}\, \lvert M_{wv\text{-}s}\rvert$
Note 1: C_{WV} : Load combination factor for vertical wave bending moment, to be taken as specified in Ch 5, Sec 2 $M_{wv\text{-}h}$, $M_{wv\text{-}s}$: Hogging and sagging vertical wave bending moments taking account of the considered design load scenario, as defined in [3.1.1]	

3.6.2 Vertical wave shear force

The vertical wave shear force, $Q_{wv\text{-}LC}$, in kN, to be used for each dynamic load case in Ch 5, Sec 2, is defined in Tab 3.

Table 3 : Vertical wave shear force $Q_{wv\text{-}LC}$ for dynamic load cases

$C_{QV} \geq 0$	$Q_{wv\text{-}LC} = f_\beta\, C_{QV}\, Q_{wv\text{-}pos}$
$C_{QV} < 0$	$Q_{wv\text{-}LC} = f_\beta\, C_{QV}\, \lvert Q_{wv\text{-}neg}\rvert$
Note 1: C_{QV} : Load combination factor for vertical wave shear force, to be taken as specified in Ch 5, Sec 2 $Q_{wv\text{-}pos}$, $Q_{wv\text{-}neg}$: Positive and negative vertical wave shear forces taking account of the considered design load scenario, as defined in [3.2.1]	

3.6.3 Horizontal wave bending moment

The horizontal wave bending moment $M_{wh\text{-}LC}$, in kN·m, to be used for each dynamic load case defined in Ch 5, Sec 2, is to be taken as:

$M_{wh\text{-}LC} = f_\beta\, C_{WH}\, M_{wh}$

where:

C_{WH} : Load combination factor for horizontal wave bending moment, to be taken as specified in Ch 5, Sec 2

M_{wh} : Horizontal wave bending moment taking account of the appropriate design load scenario, as defined in [3.3.1].

3.6.4 Horizontal wave shear force

The horizontal wave shear force $Q_{wh\text{-}LC}$, in kN, to be used for each dynamic load case defined in Ch 5, Sec 2, is to be taken as:

$$Q_{wh\text{-}LC} = f_\beta C_{QH} Q_{wh}$$

where:

C_{QH} : Load combination factor for horizontal wave bending shear force, to be taken as specified in Ch 5, Sec 2

Q_{wh} : Horizontal wave shear force taking account of the appropriate design load scenario, as defined in [3.4.1].

3.6.5 Wave torsional moment

The wave torsional moment $M_{wt\text{-}LC}$, in kN·m, to be used for each dynamic load case defined in Ch 5, Sec 2, is to be taken as:

$$M_{wt\text{-}LC} = f_\beta C_{WT} M_{wt}$$

where:

C_{WT} : Load combination factor for wave torsional moment, to be taken as specified in Ch 5, Sec 2

M_{wt} : Wave torsional moment taking account of the appropriate design load scenario, as defined in [3.5.1].

Section 5 Environmental Loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

B_x : Moulded breadth at the waterline (T_{LC}), in m, at the considered cross-section

$B_{x,max}$: Greatest moulded breadth, in m, measured at the considered cross-section below the weather deck

$C_{B\text{-}LC}$: Block coefficient at the considered loading condition draught, as defined in Ch 1, Sec 3, [2.1.9]

$C_{W\text{-}LC}$: Waterplane coefficient at the considered loading condition draught, as defined in Ch 1, Sec 3, [2.1.10]

f_β : Heading correction factor as defined in Ch 5, Sec 3

f_{BL} , f_{TL} : Ratios as defined in Ch 5, Sec 3

$f_{nl\text{-}g}$: Non-linear coefficient for pressure gradient, to be taken as follows:

- In general:

  $f_{nl-g} = 1$

- For load case BP (strength assessment only):

  $f_{nl-g} = 1,33$

f_{yB} : Ratio between Y-coordinate of the load point and B_x , to be taken as:

$$f_{yB} = \frac{|2y|}{B_x}$$

without being taken greater than 1,0

$f_{yB} = 1,0$ when $B_x = 0$

f_{zT} : Ratio between Z-coordinate of the load point and draught T_{LC} , to be taken as:

$$f_{zT} = \frac{z}{T_{LC}}$$

without being taken less than 0

h_W : Water head equivalent to the pressure at the waterline, in m, to be taken as:

$$h_W = \frac{P_{W,WL}}{\rho g} \cdot f_{nl-g}$$

$P_{W,WL}$: Wave pressure at the waterline (T_{LC}), in kN/m², for the considered load case, to be taken as:

$P_{W,WL} = \text{Max}\ (P_W\ ;\ 0)$

with P_W calculated at $z = T_{LC}$ and:

- when $y \geq 0$:

  $y = B_x / 2$

- when $y < 0$:

  $y = -B_x / 2$

T_R : Dimensionless roll period, as defined in Ch 5, Sec 2.

1 Sea pressure

1.1 Total pressure

1.1.1 The external pressure P_{ex} at any load point of the hull, in kN/m², for the static design load scenarios, is to be taken as:

$P_{ex} = P_S$

The total pressure P_{ex} at any load point of the hull, for the static + dynamic design load scenarios, is to be derived for each load case and is to be taken as:

$P_{ex} = P_S + P_W$

without being taken less, for static + dynamic load scenarios other than fatigue, than:

- 2,5 kN/m² for prescriptive strength assessment
- 0 kN/m² for direct strength analysis

where:

P_S : Hydrostatic pressure, in kN/m², defined in [1.2]

P_W : Hydrodynamic pressure, in kN/m², defined in [1.3] and [1.4].

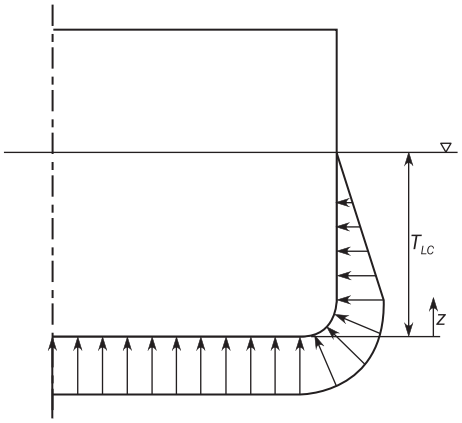
1.2 Hydrostatic pressure

1.2.1 The hydrostatic pressure P_S at any load point, in kN/m², is obtained from Tab 1. See also Fig 1.

Table 1 : Hydrostatic pressure P_S

Location	P_S, in kN/m²
$z < T_{LC}$	$\rho\, g\, (T_{LC} - z)$
$z \geq T_{LC}$	0

Figure 1 : Distribution of hydrostatic pressure P_S



1.3 External dynamic pressure for strength assessment

1.3.1 Hydrodynamic pressure for all load cases

The hydrodynamic pressure P_W at any load point, in kN/m², is to be obtained, for all load cases, from Tab 2.

Table 2 : Hydrodynamic pressure P_W in kN/m² - Strength assessment

Load case as defined in Ch 5, Sec 2, Tab 1	$z \leq T_{LC}$	$T_{LC} < z \leq h_W + T_{LC}$	$z > h_W + T_{LC}$
HVM1, FVM1, BP1-P, BP1-S, OHM2-P, OHM2-S, OHS2-P, OHS2-S, OVA1-P, OVA1-S	$-P_{EDW}$	$P_{W,WL} - \frac{\rho g(z - T_{LC})}{f_{nl-g}}$	0,0
HVM2, FVM2, BP2-P, BP2-S, OHM1-P, OHM1-S, OHS1-P, OHS1-S, OVA2-P, OVA2-S	P_{EDW}		
BR1-P, BR1-S	$-P_{EDW} + P_{SR}$		
BR2-P, BR2-S	$P_{EDW} + P_{SR}$		

Note 1:

P_{EDW} : Hydrodynamic pressure defined in [1.3.2]

P_{SR} : Hydrostatic pressure, in kN/m², due to the roll motion, to be taken as:

$$P_{SR} = -\rho g y \frac{C_{YG}\theta}{180}\pi$$

C_{YG} : Load combination factor for the gravitational acceleration due to roll, as defined in Ch 5, Sec 2

1.3.2 Hydrodynamic pressure at any point

The hydrodynamic pressure P_{EDW} for each EDW as defined in Ch 5, Sec 2, Tab 1, at any load point of the hull, in kN/m², is to be taken as:

- when $f_{yB} \geq f_{zT}$:

$$P_{EDW} = (1 - f_{yB})P_{CL} + (f_{yB} - f_{zT})P_{BL} + f_{zT}P_{WL}$$

- when $f_{yB} < f_{zT}$:

$$P_{EDW} = (1 - f_{zT})P_{CL} + (f_{zT} - f_{yB})P_{M} + f_{yB}P_{WL}$$

where:

P_{CL} : Hydrodynamic pressure at the bottom centreline (see Fig 2) defined in [1.3.3], for the considered EDW

P_{BL} : Hydrodynamic pressure at the bilge line (see Fig 2) defined in [1.3.3], for the considered EDW

P_{WL} : Hydrodynamic pressure at the waterline (see Fig 2) defined in [1.3.3], for the considered EDW

P_M : Intermediate hydrodynamic pressure (see Fig 2), to be taken as:

$P_M = 0,5\ (P_{WL} + P_{WL-O})$

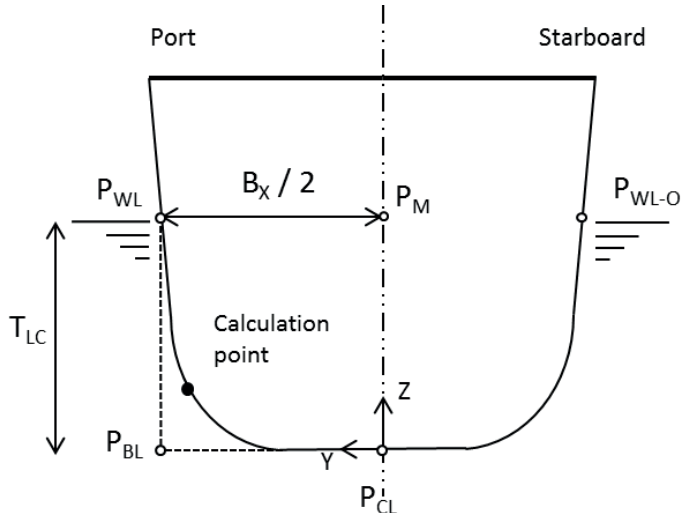
P_{WL-O} : Hydrodynamic pressure at the waterline on the opposite side (see Fig 2), to be taken as:

$P_{WL-O} = P_{WL}$

with P_{WL} as defined in [1.3.3], for the considered EDW, calculated on the side opposite to the load point. When the load point is located on the centreline (y = 0), the lee side is to be considered as the opposite side.

Note 1: Weather side and lee side are detailed in Ch 5, Sec 2, Tab 2 to Ch 5, Sec 2, Tab 7 for each load case.

Figure 2 : Hydrodynamic pressures



1.3.3 Hydrodynamic pressures at the centreline, bilge and waterline

The hydrodynamic pressures at the bottom centreline P_{CL}, at the bilge line P_{BL} and at the waterline P_{WL}, for each EDW, in kN/m², is to be taken as:

$$P_i = \rho\ g\ f_{nl}\ f_\beta\ H\ f_{k,i}$$

where:

$$f_{k,i} = k_i + k_{T,i}\ f_{TL} + k_{CB,i}\ C_{B\text{-}LC} + k_{CW,i}\ C_{W\text{-}LC} + k_{B,i}\ f_{BL} + k_{R,i}\ T_R$$

i : Location where the hydrodynamic pressure is calculated, to be taken as:

- CL at the bottom centreline
- BL at the bilge line
- WL at the waterline

H : Wave parameter defined in Ch 5, Sec 3, for a reference length L_{ref} calculated with α to be taken in Tab 3, for the considered EDW

f_{nl} : Coefficient considering non-linear effects, to be taken in Tab 3, for the considered EDW and design load scenario

k_i , $k_{T,i}$, $k_{CB,i}$, $k_{CW,i}$, $k_{B,i}$, $k_{R,i}$: Coefficients in the longitudinal direction, to be taken in Tab 6 to Tab 17, for the considered EDW. Intermediate values are obtained by linear interpolation.

- When portside is the weather side for the considered load case:
  - for load points located on portside (y>0), the coefficients for the weather side are to be used
  - for load points located on starboard side (y<0), the coefficients for the lee side are to be used

- When starboard side is the weather side for the considered load case:
  - for load points located on starboard side (y<0), the coefficients for the weather side are to be used
  - for load points located on portside (y>0), the coefficients for the lee side are to be used
- When load points are located at centreline (y=0), the coefficients for the weather side are to be used.

1.3.4 Envelope of dynamic pressure

The envelope of dynamic pressure at any point $P_{ex\text{-}max}$ is to be taken as the greatest pressure value obtained from any of the load cases in accordance with [1.3.1].

1.4 External dynamic pressure for fatigue assessment

1.4.1 Hydrodynamic pressure for all load cases

The hydrodynamic pressure P_W for all load cases, at any load point, in kN/m^2, is to be taken as:

$P_w = f_{iw} P_{wf}$

where:

P_{wf} : hydrodynamic pressure, in kN/m^2, as defined in Tab 18

f_{iw} : factor accounting for the non-linearity due to intermittent wetting, to be taken as defined in Tab 19.

Table 3 : Coefficients for hydrodynamic pressure strength assessment

EDW	α	f_{nl} **(1)**
HVM	$0,65\ C_{W\text{-}LC}{}^{-1,3}$	$f_{nl\text{-}1}$
FVM	$0,65\ C_{W\text{-}LC}{}^{-1,3}$	$f_{nl\text{-}2}$
BR	$4,6\ T_R{}^{-2}$	$f_{nl\text{-}3}$
BP	$0,55\ f_{TL}{}^{-0,4}$	$f_{nl\text{-}4}$
OHM	$0,65\ f_{TL}{}^{-0,3}$	$f_{nl\text{-}5}$
OHS	$0,68\ f_{TL}{}^{-0,3}$	$f_{nl\text{-}5}$
OVA	$0,24\ f_{BL}{}^{-0,8}$	$f_{nl\text{-}6}$
(1) $f_{nl\text{-}1}$ to $f_{nl\text{-}6}$ are to be taken from: • Tab 4 for extreme sea design load scenario • Tab 5 for ballast water exchange design load scenario.		

Table 4 : Non-linear coefficients f_{nl} for extreme sea design load scenario

f_{nl}	x/L=0	x/L=0,3	x/L=0,7	x/L=1,0
$f_{nl\text{-}1}$	0,7	0,9	0,9	0,6
$f_{nl\text{-}2}$	0,9	0,9	0,9	0,9
$f_{nl\text{-}3}$	1,0	1,0	1,0	1,0
$f_{nl\text{-}4}$	0,6	0,6	0,6	0,6
$f_{nl\text{-}5}$	0,8	0,8	0,8	0,8
$f_{nl\text{-}6}$	0,5	0,8	0,8	0,6
Note 1: Intermediate values are obtained by linear interpolation.				

Table 5 : Non-linear coefficients f_{nl} for ballast water exchange design load scenario

f_{nl}	x/L=0	x/L=0,3	x/L=0,7	x/L=1,0
$f_{nl\text{-}1}$	0,85	0,95	0,95	0,80
$f_{nl\text{-}2}$	0,95	0,95	0,95	0,95
$f_{nl\text{-}3}$	1,00	1,00	1,00	1,00
$f_{nl\text{-}4}$	0,60	0,80	0,80	0,60
$f_{nl\text{-}5}$	0,90	0,90	0,90	0,90
$f_{nl\text{-}6}$	0,75	0,90	0,90	0,80
Note 1: Intermediate values are obtained by linear interpolation.				

Table 6 : Coefficients for HVM load cases on weather and lee sides Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	17,0	3,27	−3,98	−3,54	0,274	3,18	2,02	−5,09	−18,1	−33,4	−41,3
	$k_{T,CL}$	−31,5	0,777	9,99	−2,12	−27,0	−54,4	−76,9	−93,3	−108	−124	−136
	$k_{CB,CL}$	1,10	−4,01	−8,74	−10,1	−8,00	−3,37	2,93	10,5	18,6	23,3	9,13
	$k_{CW,CL}$	−20,9	−3,07	9,79	13,1	10,0	4,90	1,01	0,778	5,19	13,9	29,0
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	17,4	4,10	−3,88	−3,25	1,94	5,28	1,94	−8,38	−20,9	−32,2	−40,9
	$k_{T,BL}$	−31,4	−2,78	7,71	−12,5	−51,2	−93,1	−128	−149	−152	−143	−120
	$k_{CB,BL}$	1,63	−5,02	−11,5	−13,0	−9,77	−3,30	4,33	11,4	13,9	10,0	6,12
	$k_{CW,BL}$	−21,8	−3,21	12,1	16,4	12,2	5,75	3,10	5,87	12,6	22,7	30,0
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	17,0	2,59	−8,14	−6,20	1,90	6,66	2,22	−8,72	−21,0	−33,0	−37,0
	$k_{T,WL}$	−41,8	−11,6	15,9	14,6	−12,2	−57,9	−113	−163	−192	−205	−273
	$k_{CB,WL}$	1,17	−6,54	−16,8	−19,3	−14,6	−5,76	4,01	11,5	9,98	0,723	−1,97
	$k_{CW,WL}$	−22,0	−1,34	20,4	24,9	17,2	7,98	5,13	8,20	17,9	33,4	36,2
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 7 : Coefficients for FVM load cases on weather and lee sides Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	−21,7	−21,2	−10,8	−2,05	2,51	2,88	0,371	−3,89	−8,95	−12,7	−11,8
	$k_{T,CL}$	20,3	30,0	18,9	1,63	−12,8	−21,6	−24,4	−23,5	−21,4	−16,4	−0,699
	$k_{CB,CL}$	−21,8	−20,0	−13,8	−7,93	−2,24	2,46	5,85	8,43	10,2	9,45	0,391
	$k_{CW,CL}$	33,0	34,7	22,4	10,9	2,78	−1,46	−2,65	−1,95	0,0681	2,53	6,35
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	−21,1	−22,7	−13,2	−1,79	4,03	3,73	−0,209	−5,06	−9,20	−11,7	−11,9
	$k_{T,BL}$	19,8	41,7	28,0	−0,845	−21,6	−32,1	−34,4	−31,2	−24,4	−13,9	−2,86
	$k_{CB,BL}$	−20,4	−23,5	−18,0	−9,18	−1,52	4,19	7,77	9,08	7,69	4,69	0,773
	$k_{CW,BL}$	31,0	38,3	28,2	12,7	1,98	−2,64	−3,03	−1,31	1,75	4,61	6,27
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	−24,5	−27,6	−15,8	−1,32	6,12	5,08	−0,089	−4,85	−9,08	−11,7	−11,1
	$k_{T,WL}$	13,2	63,7	73,4	46,6	18,0	−5,60	−25,7	−39,1	−46,7	−44,0	−8,12
	$k_{CB,WL}$	−24,2	−28,5	−21,8	−9,95	0,259	7,08	10,9	10,5	5,64	2,70	8,46
	$k_{CW,WL}$	36,8	46,5	33,4	13,1	−1,20	−6,00	−5,37	−2,39	3,81	6,89	−1,81
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 8 : Coefficients for BR load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	–3,10	–3,02	–2,38	–1,72	–1,27	–1,04	–1,21	–1,84	–2,54	–2,52	–0,97
	$k_{T,CL}$	–22,7	–23,6	–23,8	–23,3	–23,0	–23,7	–26,4	–30,7	–35,9	–40,9	–44,0
	$k_{CB,CL}$	–1,52	–0,856	–0,49	–0,755	–1,11	–1,32	–1,07	–0,491	0,137	–0,232	–3,03
	$k_{CW,CL}$	2,21	2,22	1,68	1,42	1,37	1,40	1,39	1,49	1,63	2,04	3,20
	$k_{B,CL}$	–2,94	–0,885	0,751	1,58	1,74	1,71	2,03	2,75	2,97	1,43	–2,80
	$k_{R,CL}$	0,714	0,529	0,384	0,293	0,248	0,23	0,25	0,301	0,378	0,451	0,467
BL	k_{BL}	–2,86	–3,43	–1,56	–0,968	–1,19	–0,905	–0,226	–0,744	–2,36	–2,69	–1,08
	$k_{T,BL}$	–17,2	–26,7	–32,9	–31,3	–31,5	–32,4	–35,3	–40,6	–48,8	–51,4	–45,7
	$k_{CB,BL}$	–1,90	–2,17	–1,29	–0,859	–0,644	–1,11	–1,52	–1,93	–1,37	–0,992	–2,94
	$k_{CW,BL}$	2,50	4,24	2,06	0,947	0,98	1,38	1,46	2,59	3,69	3,47	3,30
	$k_{B,BL}$	–1,48	1,16	0,493	–0,433	–0,908	–1,30	–1,38	0,605	2,96	1,85	–2,34
	$k_{R,BL}$	0,454	0,263	0,216	0,241	0,26	0,211	0,144	0,0925	0,173	0,335	0,454
WL	k_{WL}	0,196	–0,151	3,89	2,73	–0,504	–0,508	3,66	4,78	1,39	–1,58	0,197
	$k_{T,WL}$	6,85	–12,5	–31,2	–29,9	–31,8	–33,9	–29,5	–32,2	–44,4	–45,6	–24,0
	$k_{CB,WL}$	–3,80	–3,09	–0,731	–0,0209	0,985	–0,0628	–3,97	–7,46	–6,33	–3,66	–4,14
	$k_{CW,WL}$	3,07	3,75	–3,45	–4,00	–1,81	–0,301	–0,167	2,52	4,79	5,34	4,40
	$k_{B,WL}$	–1,86	0,987	–1,20	–8,49	–10,9	–11,5	–13,5	–11,7	–2,46	3,53	–3,21
	$k_{R,WL}$	–0,155	–0,253	0,133	0,587	0,805	0,713	0,40	0,161	0,143	0,116	0,0294

Table 9 : Coefficients for BR load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}, $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	–2,62	–2,23	–6,08	–7,43	–7,42	–7,28	–6,70	–3,38	1,56	2,90	–0,623
	$k_{T,BL}$	–36,9	–30,7	–15,9	–13,4	–13,1	–13,4	–13,6	–9,44	–3,33	–12,9	–37,9
	$k_{CB,BL}$	1,35	2,23	–0,601	–2,13	–3,02	–3,26	–3,12	–4,27	–6,95	–6,98	–3,61
	$k_{CW,BL}$	–1,27	–4,05	1,72	4,84	5,96	6,18	5,45	3,30	1,34	1,05	3,21
	$k_{B,BL}$	–5,24	–8,45	–13,0	–15,2	–16,0	–16,5	–17,1	–20,1	–23,3	–17,7	–4,38
	$k_{R,BL}$	1,16	1,54	1,70	1,67	1,61	1,58	1,59	1,51	1,24	0,888	0,47
WL	k_{WL}	1,06	0,176	–6,99	–8,37	–7,07	–6,77	–7,29	–3,42	3,58	6,19	1,53
	$k_{T,WL}$	–34,0	–39,4	–29,7	–30,6	–27,3	–26,1	–29,6	–24,9	–11,8	–11,6	–28,9
	$k_{CB,WL}$	3,81	5,74	2,10	–0,121	–1,84	–2,03	–0,622	–0,62	–4,89	–7,41	–5,73
	$k_{CW,WL}$	–5,99	–9,86	0,0271	4,18	5,05	5,13	4,27	0,355	–2,15	–1,28	4,47
	$k_{B,WL}$	–5,11	–7,07	–12,4	–13,9	–15,9	–17,1	–17,3	–20,8	–26,7	–21,6	–6,42
	$k_{R,WL}$	0,995	1,82	2,16	2,08	1,91	1,87	1,96	1,91	1,54	0,972	0,177

Table 10 : Coefficients for BP load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	3,20	5,13	4,24	2,72	1,74	1,55	2,57	5,07	7,07	5,10	1,90
	$k_{T,CL}$	67,9	56,0	54,8	59,1	65,9	74,8	84,9	96,0	107	119	179
	$k_{CB,CL}$	14,2	7,75	3,75	4,93	7,25	8,29	6,98	2,86	−2,53	−1,79	14,7
	$k_{CW,CL}$	−10,9	−8,65	−5,00	−4,77	−5,92	−6,67	−6,50	−5,24	−2,27	−0,484	−10,9
	$k_{B,CL}$	−16,7	−13,0	−14,0	−15,7	−17,0	−19,0	−22,5	−27,7	−32,9	−35,3	−41,8
	$k_{R,CL}$	0,273	0,126	0,0321	−0,0166	−0,0402	−0,0346	0,00217	0,0798	0,263	0,559	0,483
BL	k_{BL}	−18,3	−6,49	15,3	21,1	23,2	23,9	22,3	11,5	−9,27	−22,9	0,263
	$k_{T,BL}$	173	−13,2	−77,0	−84,5	−68,8	−54,0	−47,5	−63,6	−88,7	−49,5	87,1
	$k_{CB,BL}$	−35,6	−12,9	7,91	11,7	12,8	13,7	14,8	17,9	33,3	47,4	24,6
	$k_{CW,BL}$	59,1	40,0	−0,942	−11,0	−14,9	−16,5	−15,5	−6,39	0,678	0,088	−14,4
	$k_{B,BL}$	−1,80	32,1	59,4	68,8	70,1	66,4	60,7	59,8	63,5	44,9	−22,0
	$k_{R,BL}$	−1,64	−2,58	−2,67	−2,73	−2,79	−2,77	−2,63	−2,23	−1,36	−0,693	0,448
WL	k_{WL}	−31,9	−21,5	−0,379	10,7	22,7	24,5	12,8	−2,11	−20,9	−31,6	−3,56
	$k_{T,WL}$	200	2,29	−39,9	−37,0	10,9	42,6	31,2	17,2	18,7	60,7	108
	$k_{CB,WL}$	−46,5	−18,5	8,86	18,1	18,7	21,2	31,6	53,8	75,0	85,6	36,8
	$k_{CW,WL}$	81,3	62,8	21,2	0,709	−15,0	−19,7	−14,9	−18,9	−19,3	−20,6	−24,3
	$k_{B,WL}$	−17,3	9,34	26,3	52,8	59,7	51,1	41,9	42,9	38,0	11,7	−18,2
	$k_{R,WL}$	−1,02	−1,47	−1,21	−1,31	−1,50	−1,39	−1,06	−0,85	−0,451	−0,279	0,395

Table 11 : Coefficients for BP load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}, $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	16,9	6,67	−7,90	−10,8	−10,8	−10,3	−9,59	−4,40	6,67	15,8	2,68
	$k_{T,BL}$	−38,9	100	134	149	165	180	192	210	240	256	255
	$k_{CB,BL}$	48,5	26,6	15,1	14,8	15,8	16,5	17,0	15,3	4,59	−9,26	7,03
	$k_{CW,BL}$	−58,0	−38,4	−12,5	−9,4	−11,0	−12,2	−13,0	−16,3	−17,5	−13,5	−7,91
	$k_{B,BL}$	−29,3	−54,8	−70,8	−73,8	−75,0	−77,8	−81,8	−87,6	−94,0	−89,6	−58,2
	$k_{R,BL}$	2,24	3,16	3,32	3,42	3,47	3,45	3,40	3,20	2,61	1,84	0,547
WL	k_{WL}	9,33	1,25	−11,0	−12,5	−11,6	−10,5	−9,66	−5,50	4,57	13,1	−1,49
	$k_{T,WL}$	−62,0	92,7	150	195	227	250	267	289	314	300	299
	$k_{CB,WL}$	44,8	20,0	14,7	18,0	20,0	21,4	24,2	28,0	20,8	4,92	11,1
	$k_{CW,WL}$	−50,1	−26,7	−7,35	−10,3	−14,9	−17,5	−19,4	−25,9	−29,2	−23,4	−7,84
	$k_{B,WL}$	−20,3	−54,2	−80,9	−87,8	−88,5	−92,7	−99,3	−103	−105	−97,8	−76,2
	$k_{R,WL}$	2,01	2,51	3,03	3,55	3,80	3,74	3,46	2,89	2,00	1,45	0,821

Table 12 : Coefficients for OHM load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	–39,6	–19,1	–6,91	–3,11	–2,37	–2,10	–1,08	1,77	8,16	14,0	9,36
	$k_{T,CL}$	91,4	–17,6	–43,1	–31,2	–10,1	4,72	7,62	2,30	–5,07	–31,3	–140
	$k_{CB,CL}$	–30,9	–13,7	–5,56	–4,04	–4,87	–6,66	–10,0	–16,7	–27,7	–40,4	–30,4
	$k_{CW,CL}$	57,3	30,6	13,1	7,08	5,51	5,89	8,14	12,4	17,0	25,8	33,8
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	–37,8	–26,4	–30,8	–33,6	–36,1	–35,2	–29,9	–20,5	–8,04	1,82	5,81
	$k_{T,BL}$	119	26,8	–0,433	38,7	98,1	136	121	73,7	29,4	–10,1	–133
	$k_{CB,BL}$	–23,4	–11,8	–18,7	–24,8	–30,1	–34,7	–39,1	–42,2	–42,5	–38,3	–31,2
	$k_{CW,BL}$	47,3	32,2	43,7	47,8	49,9	50,7	52,3	52,3	47,0	39,3	38,2
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	–22,68	–13,22	–6,66	–7,51	–13,14	–14,51	–4,92	–2,31	1,10	9,97	13,22
	$k_{T,WL}$	156,87	28,13	–41,81	–50,79	–65,99	–63,84	–38,87	9,31	82,80	136,14	19,03
	$k_{CB,WL}$	11,46	15,03	11,54	6,62	5,06	0,34	-10,51	-8,08	-0,18	-4,08	1,48
	$k_{CW,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{B,WL}$	–15,89	–21,42	–40,94	–49,66	–40,56	–23,26	–16,43	–15,67	–37,41	–59,47	–78,38
	$k_{R,WL}$	1,51	1,04	1,07	1,27	1,47	1,51	1,65	2,17	1,83	1,98	3,27

Table 13 : Coefficients for OHM load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	–38,8	–12,5	9,53	18,7	24,9	30,3	33,2	28,8	20,8	17,0	12,8
	$k_{T,BL}$	56,4	–62,6	–101	–123	–142	–158	–175	–202	–227	–218	–150
	$k_{CB,BL}$	–32,9	–23,6	–13,4	–9,75	–8,62	–7,84	–7,45	–7,90	–8,83	–20,7	–29,3
	$k_{CW,BL}$	59,6	33,2	4,97	–4,97	–10,1	–14,5	–15,9	–8,17	3,33	17,5	29,5
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	–42,7	–10,5	11,2	17,6	25,8	32,5	32,1	25,0	18,7	18,5	4,41
	$k_{T,WL}$	75,6	–56,1	–106	–141	–163	–187	–217	–252	–283	–297	–162
	$k_{CB,WL}$	–38,6	–27,4	–16,9	–16,7	–15,8	–14,9	–11,1	–2,70	0,92	–19,8	–45,0
	$k_{CW,WL}$	69,3	34,8	7,05	4,27	–2,08	–7,47	–7,63	–4,55	0,0669	17,2	54,3
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 14 : Coefficients for OHS load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	12,3	7,12	3,87	2,55	1,38	0,364	0,55	2,51	2,67	−12,4	−44,6
	$k_{T,CL}$	−49,6	−13,6	−13,7	−18,0	−13,1	−4,19	−11,5	−43,8	−85,2	−107	−55,2
	$k_{CB,CL}$	37,1	17,2	7,26	3,34	1,33	−0,0341	−0,421	−0,337	−2,16	−8,38	−21,8
	$k_{CW,CL}$	−33,4	−17,6	−7,93	−4,34	−3,04	−2,62	−2,67	−2,66	1,67	24,0	62,7
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	12,8	−5,20	−25,2	−31,8	−34,6	−35,5	−29,7	−13,2	−1,21	−17,4	−48,1
	$k_{T,BL}$	12,8	60,0	38,0	38,8	65,0	96,1	90,1	12,3	−104	−138	−61,4
	$k_{CB,BL}$	44,7	32,9	17,5	5,85	−2,20	−7,25	−11,3	−13,4	−15,8	−18,4	−22,7
	$k_{CW,BL}$	−43,4	−19,3	14,5	27,9	31,2	29,8	25,3	15,9	16,4	40,5	67,8
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	16,0	−6,82	−27,2	−33,2	−35,5	−31,9	−16,3	0,317	3,40	−21,4	−59,3
	$k_{T,WL}$	−27,9	61,0	61,1	47,1	17,2	−12,3	−34,7	−95,6	−163	−76,9	−131
	$k_{CB,WL}$	49,2	36,7	22,4	5,55	−8,15	−14,0	−23,1	−36,0	−26,0	−27,6	−45,6
	$k_{CW,WL}$	−49,0	−20,3	13,3	30,1	36,3	28,8	17,3	21,7	27,8	57,5	105
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 15 : Coefficients for OHS load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}, $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	10,7	19,6	37,1	41,6	39,5	33,6	26,7	20,1	11,3	−5,84	−40,4
	$k_{T,BL}$	−103	−93,8	−88,2	−108	−114	−90,5	−85,2	−110	−136	−132	−23,3
	$k_{CB,BL}$	27,1	14,2	17,9	17,9	12,5	3	−4,89	−10,9	−17,6	−25	−25,7
	$k_{CW,BL}$	−20,3	−23,7	−47,5	−51,4	−44,7	−33,6	−21,6	−9,23	5,89	28,5	58,8
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	16,2	20,7	38,2	45,3	45,0	37,4	25,6	18,5	11,5	−8,50	−46,9
	$k_{T,WL}$	−195	−157	−140	−133	−121	−86,6	−84,3	−117	−145	−154	−36,7
	$k_{CB,WL}$	33,2	9,44	16,6	24,0	19,7	2,46	−11,0	−21,1	−34,3	−39,6	−41,0
	$k_{CW,WL}$	−28,4	−21,2	−48,0	−59,6	−54,4	−35,4	−13,6	2,81	21,4	45,9	80,2
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 16 : Coefficients for OVA load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	–25,5	–10,5	–1,91	–0,26	–1,39	–2,49	–1,55	3,61	14,7	29,5	35,2
	$k_{T,CL}$	60,0	9,67	10,7	33,8	61,7	84,1	98,9	113	136	167	165
	$k_{CB,CL}$	–4,00	0,827	6,19	7,88	7,13	4,51	–0,323	–8,63	–22,7	–38,4	–19,8
	$k_{CW,CL}$	25,2	9,37	–4,10	–8,70	–8,30	–5,51	–2,06	0,328	1,68	2,66	–8,89
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	–22,1	–5,51	–2,87	–4,19	–6,49	–5,38	1,38	9,28	14,4	20,2	34,5
	$k_{T,BL}$	41,5	–48,7	–27,3	39,6	108	154	163	139	108	110	109
	$k_{CB,BL}$	7,03	19,7	22,8	24,6	23,6	19,0	13,7	9,46	9,70	7,79	–11,6
	$k_{CW,BL}$	12,0	–11,4	–18,8	–23,0	–22,4	–19,1	–17,7	–16,0	–14,9	–15,0	–11,0
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	–23,8	0,807	6,04	1,70	–5,74	–6,46	1,16	7,59	12,3	20,6	19,5
	$k_{T,WL}$	34,8	–103	–103	–31,8	75,2	182	239	225	189	199	252
	$k_{CB,WL}$	2,07	19,5	26,4	32,1	33,0	26,8	20,0	23,2	32,9	24,3	–44,1
	$k_{CW,WL}$	21,8	–13,8	–29,7	–37,3	–35,6	–30,4	–28,0	–28,7	–33,9	–31,5	33,6
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 17 : Coefficients for OVA load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	–25,0	–13,7	–4,56	–0,107	1,76	2,73	3,31	4,80	13,6	29,7	35,5
	$k_{T,BL}$	75,1	96,4	98,1	103	120	141	157	170	200	237	198
	$k_{CB,BL}$	–6,03	–13,3	–12,7	–11,5	–12,4	–14,6	–16,7	–18,9	–23,1	–34,5	–22,6
	$k_{CW,BL}$	25,9	20	10,4	5,17	3,97	4,83	6,43	7,22	1,31	–4,47	–8,97
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	–26,4	–12,4	–0,0823	2,54	2,82	2,83	0,648	0,0939	10,8	31,0	27,9
	$k_{T,WL}$	106	116	98,2	103	134	175	193	193	216	280	327
	$k_{CB,WL}$	–5,46	–13,1	–10,4	–9,67	–12,1	–14,4	–12,6	–4,38	–1,43	–21,8	–37,2
	$k_{CW,WL}$	28,8	19,9	4,87	1,29	2,51	3,64	4,64	–1,50	–16,6	–20,6	8,91
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 18 : Hydrodynamic pressure P_{wf} in kN/m² Fatigue assessment

Load case	$z \leq T_{LC}$	$z > T_{LC}$
HVM1 HVMf1 BP1-P BP1-S OHM2-P OHM2-S	$-P_{EDW}$	$P_{W,WL}$
HVM2 HVMf2 BP2-P BP2-S OHM1-P OHM1-S	P_{EDW}	
BR1-P BR1-S	$-P_{EDW} + P_{SR}$	
BR2-P BR2-S	$P_{EDW} + P_{SR}$	

Note 1:

P_{EDW} : Hydrodynamic pressure as defined in [1.3.2] with P_{CL}, P_{BL}, P_{WL} and P_{WL-O} as defined in [1.3.3], calculated with coefficients to be taken in Tab 20 to Tab 28.

P_{SR} : Hydrostatic pressure due to the roll motion as defined in Tab 2.

Table 19 : Factor f_{iw} for intermittent wetting

P_{wf}	$z \leq T_{LC}$	$z > T_{LC}$
$P_{wf} = 0$	0	0
$P_{wf} > 0$	1	10^a
$P_{wf} < 0$	$1 - 10^b$	0

Note 1:

a, b : Coefficients to be taken as:

$$a = -\frac{2}{3}\left(\frac{z - T_{LC}}{h_W}\right)$$

$$b = -1,2\left[\frac{\rho g(z - T_{LC})}{P_{Wf}}\right]^{1,2}$$

Table 20 : Coefficients for hydrodynamic pressure Fatigue assessment

EDW	α	f_α	f_{nl}
HVM	$0,65\ C_{W\text{-}LC}{}^{-1,3}$	1,0	1,0
HVMf	$0,65\ C_{W\text{-}LC}{}^{-1,3}$		
BR	$4,6\ T_R{}^{-2}$		
BP	$0,55\left(\frac{T_{LC}}{L}\right)^{-0,4}$		
OHM	$0,65\left(\frac{T_{LC}}{L}\right)^{-0,3}$		

Table 21 : Coefficients for HVM load cases on weather and lee sides Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	29,5	9,78	–1,68	–1,73	2,60	5,87	3,98	–5,98	–24,7	–45,3	–50,9
	$k_{T,CL}$	–86,1	–15,2	8,53	–3,38	–33,2	–64,7	–90,0	–110	–130	–139	–104
	$k_{CB,CL}$	5,37	–0,418	–8,14	–11,3	–10,5	–6,22	1,80	14,9	33,5	51,6	34,0
	$k_{CW,CL}$	–32,1	–11,4	6,92	12,0	9,71	4,66	0,107	–1,83	–0,44	0,826	10,9
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	29,6	11,7	1,42	1,73	5,22	5,63	–0,766	–14,0	–29,3	–43,2	–50,1
	$k_{T,BL}$	–86,2	–27,5	–1,08	–20,2	–64,8	–109	–137	–149	–148	–135	–74,6
	$k_{CB,BL}$	4,53	–2,73	–10,9	–11,9	–6,54	1,82	11,5	21,8	28,7	31,0	28,9
	$k_{CW,BL}$	–31,4	–10,8	6,76	10,3	5,99	0,652	–1,62	0,105	5,21	11,7	12,4
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	31,2	8,85	–3,19	1,52	7,44	7,20	0,297	–12,5	–28,3	–45,2	–32,7
	$k_{T,WL}$	–109	–49,9	–2,72	–6,70	–45,7	–101	–144	–184	–220	–241	–272
	$k_{CB,WL}$	7,92	–6,64	–21,3	–20,2	–8,79	5,15	16,6	21,0	18,3	21,1	54,8
	$k_{CW,WL}$	–36,9	–5,19	20,3	18,5	7,29	–1,52	–5,30	0,801	15,2	25,5	–27,4
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 22 : Coefficients for HVMf load cases on weather and lee sides Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	27,1	3,77	–4,09	–1,30	2,70	4,54	2,70	–5,04	–21,0	–41,7	–52,3
	$k_{T,CL}$	–164	–55,5	–24,9	–39,1	–64,4	–85,0	–101	–115	–123	–103	8,38
	$k_{CB,CL}$	–7,65	–10,8	–15,1	–14,4	–10,2	–4,12	3,42	13,1	27,1	45,8	48,4
	$k_{CW,CL}$	–17,1	5,31	17,6	16,7	11,1	4,62	–0,566	–2,08	0,772	1,98	–1,36
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	27,4	4,87	–0,151	5,32	7,17	3,67	–3,11	–13,0	–26,0	–41,4	–51,4
	$k_{T,BL}$	–166	–86,1	–78,2	–109	–135	–146	–149	–151	–135	–85,3	38,7
	$k_{CB,BL}$	–8,73	–18,0	–22,6	–17,7	–8,21	2,28	11,8	19,6	24,1	30,4	43,2
	$k_{CW,BL}$	–16,4	12,0	23,6	17,7	9,64	3,49	–0,233	0,09	5,57	10,4	–0,0756
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	27,2	–5,07	–5,64	5,63	9,32	4,00	–2,29	–11,0	–25,0	–44,3	–42,8
	$k_{T,WL}$	–152	–78,6	–73,1	–113	–133	–149	–171	–201	–205	–170	–157
	$k_{CB,WL}$	–2,10	–27,0	–37,8	–29,0	–11,8	5,32	16,7	17,3	9,89	13,3	52,7
	$k_{CW,WL}$	–24,9	29,1	43,8	30,7	13,8	2,85	–3,75	1,85	19,2	31,4	–13,9
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 23 : Coefficients for BR load cases on weather side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	–3,70	–2,99	–2,21	–1,47	–0,887	–0,481	–0,457	–0,876	–1,37	–0,857	1,44
	$k_{T,CL}$	–31,0	–27,6	–25,6	–23,8	–22,6	–22,7	–24,5	–28,5	–34,2	–41,1	–49,4
	$k_{CB,CL}$	–3,76	–2,21	–1,10	–0,841	–0,847	–0,847	–0,631	0,0509	1,01	1,49	–1,13
	$k_{CW,CL}$	4,26	3,27	2,00	1,22	0,802	0,564	0,501	0,384	0,102	–0,69	–0,327
	$k_{B,CL}$	–3,88	–0,58	1,68	3,03	3,22	3,13	3,23	3,63	3,64	2,13	–0,863
	$k_{R,CL}$	1,12	0,626	0,371	0,218	0,123	0,0561	0,0286	0,0581	0,12	0,172	0,101
BL	k_{BL}	–3,29	–2,50	–0,469	0,261	0,428	1,12	1,75	1,48	0,488	0,848	1,69
	$k_{T,BL}$	–26,5	–30,5	–33,5	–30,8	–28,9	–28,5	–30,1	–34,4	–41,4	–45,8	–49,9
	$k_{CB,BL}$	–4,57	–4,24	–2,47	–0,817	–0,173	–0,372	–0,834	–0,696	–0,28	0,294	–1,15
	$k_{CW,BL}$	5,41	5,60	2,61	0,414	–0,20	–0,117	0,398	1,08	1,73	0,264	–0,362
	$k_{B,BL}$	–1,92	3,43	3,13	1,45	0,907	0,622	0,853	1,93	3,48	3,07	–0,044
	$k_{R,BL}$	0,604	–0,0623	–0,266	–0,289	–0,372	–0,582	–0,804	–0,927	–0,865	–0,612	–0,019
WL	k_{WL}	–0,684	1,76	5,31	3,27	0,924	1,85	5,55	5,96	3,77	2,95	5,36
	$k_{T,WL}$	–1,06	–16,6	–36,8	–39,9	–39,5	–38,1	–32,8	–34,8	–41,7	–39,3	–10,2
	$k_{CB,WL}$	–7,00	–4,23	–0,408	0,403	1,32	0,46	–3,68	–9,59	–9,45	–3,25	–2,11
	$k_{CW,WL}$	7,16	3,14	–4,84	–4,68	–3,04	–2,10	–0,841	5,17	7,53	2,64	–0,598
	$k_{B,WL}$	–0,898	4,44	–0,643	–8,99	–11,1	–11,7	–12,7	–10,9	–3,39	3,45	–0,535
	$k_{R,WL}$	–0,218	–0,652	–0,0948	0,531	0,564	0,187	–0,345	–0,717	–0,913	–1,10	–1,28

Table 24 : Coefficients for BR load cases on lee side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}, $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	–2,97	–3,55	–7,27	–7,88	–7,18	–6,55	–5,60	–2,36	1,92	3,18	1,38
	$k_{T,BL}$	–43,9	–42,6	–32,5	–30,1	–28,8	–28,0	–27,2	–22,5	–17,1	–25,0	–45,8
	$k_{CB,BL}$	0,667	–0,0293	–4,10	–5,32	–5,36	–4,94	–4,64	–4,93	–7,15	–6,92	–1,52
	$k_{CW,BL}$	–1,72	–1,82	4,82	6,99	6,91	6,25	5,13	2,28	0,503	0,465	–0,19
	$k_{B,BL}$	–7,36	–16,1	–23,0	–25,2	–25,6	–25,7	–25,7	–27,4	–27,0	–17,9	–1,67
	$k_{R,BL}$	1,94	2,74	3,19	3,11	2,89	2,73	2,64	2,46	2,03	1,28	0,161
WL	k_{WL}	0,337	–4,17	–11,2	–11,2	–8,87	–8,01	–7,83	–3,81	2,18	4,48	2,74
	$k_{T,WL}$	–39,9	–56,8	–56,8	–58,8	–54,4	–52,1	–52,8	–45,9	–32,3	–29,9	–43,9
	$k_{CB,WL}$	5,64	0,0561	–7,69	–9,75	–9,48	–8,20	–6,08	–4,76	–8,75	–11,6	0,827
	$k_{CW,WL}$	–8,76	–2,23	10,8	13,6	12,1	10,7	8,76	3,52	1,52	3,54	–2,58
	$k_{B,WL}$	–6,92	–19,1	–28,0	–29,7	–31,3	–32,1	–31,5	–32,6	–32,7	–22,2	–0,356
	$k_{R,WL}$	1,90	3,79	4,69	4,54	4,10	3,83	3,72	3,47	2,86	1,70	–0,114

Table 25 : Coefficients for BP load cases on weather side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	3,81	4,50	3,76	2,14	0,883	0,186	0,656	2,58	4,04	1,27	–3,13
	$k_{T,CL}$	72,1	57,2	49,6	47,7	50,2	54,8	61,0	69,3	79,2	92,7	146
	$k_{CB,CL}$	13,9	6,98	2,49	2,88	4,75	5,80	5,14	1,97	–3,32	–4,72	13,1
	$k_{CW,CL}$	–12,4	–8,07	–3,88	–2,66	–3,20	–3,61	–3,72	–3,05	–0,0293	4,18	–6,20
	$k_{B,CL}$	–15,7	–12,9	–12,3	–13,6	–14,1	–14,6	–16,0	–18,6	–21,3	–22,6	–29,8
	$k_{R,CL}$	0,377	0,27	0,114	0,0903	0,107	0,147	0,203	0,279	0,452	0,746	0,83
BL	k_{BL}	–20,7	–7,90	14,0	19,6	20,6	19,9	18,9	10,4	–9,48	–24,9	–4,61
	$k_{T,BL}$	166	14,8	–35,7	–47,7	–42,0	–35,7	–32,0	–44,1	–74,7	–58,0	68,3
	$k_{CB,BL}$	–48,6	–27,1	–8,13	–4,41	–3,22	–2,22	–1,48	–1,40	10,3	34,4	21,0
	$k_{CW,BL}$	72,2	51,0	12,8	3,52	0,735	0,0956	0,196	9,00	19,5	12,7	–7,21
	$k_{B,BL}$	–6,60	18,7	40,9	48,9	51,4	50,9	48,6	49,2	51,6	36,4	–20,6
	$k_{R,BL}$	–1,02	–1,73	–2,23	–2,32	–2,33	–2,24	–2,09	–1,75	–0,981	–0,241	0,779
WL	k_{WL}	–29,9	–24,5	–3,68	10,4	20,1	19,3	11,8	0,714	–20,2	–36,3	–10,2
	$k_{T,WL}$	192	33,9	–0,503	6,99	36,4	56,2	52,2	37,7	13,4	29,1	44,8
	$k_{CB,WL}$	–51,2	–31,3	–10,4	1,62	5,44	8,85	17,9	33,8	50,1	70,4	36,8
	$k_{CW,WL}$	81,4	71,9	37,2	11,7	–4,08	–7,48	–7,83	–10,6	–3,21	–5,32	–18,9
	$k_{B,WL}$	–12,9	4,90	22,5	43,8	48,8	46,0	43,4	43,9	40,2	14,1	–9,51
	$k_{R,WL}$	–0,774	–0,668	–0,978	–1,19	–1,09	–0,925	–0,644	–0,361	0,288	0,734	0,913

Table 26 : Coefficients for BP load cases on lee side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}, $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	21,8	7,83	–7,46	–10,9	–11,7	–12,1	–12,4	–8,40	1,97	10,8	–2,54
	$k_{T,BL}$	–18,9	82,2	100	110	120	128	133	146	173	203	210
	$k_{CB,BL}$	63,2	41,0	29,3	28,4	28,8	29,2	29,8	29,6	18,9	–4,34	6,17
	$k_{CW,BL}$	–77,9	–52,9	–26,9	–23,1	–23,4	–23,6	–23,7	–27,6	–29,0	–16,3	–4,49
	$k_{B,BL}$	–21,3	–36,6	–46,4	–47,6	–48,1	–49,2	–50,3	–53,0	–58,0	–59,1	–37,8
	$k_{R,BL}$	1,76	2,59	2,96	3,14	3,26	3,29	3,26	3,11	2,69	2,05	0,928
WL	k_{WL}	14,6	6,62	–7,47	–10,0	–11,1	–11,0	–11,1	–8,79	0,65	8,90	–5,18
	$k_{T,WL}$	–48,6	74,3	118	161	180	192	201	213	232	237	264
	$k_{CB,WL}$	53,7	39,0	35,3	38,5	39,2	39,5	40,8	43,3	37,0	12,8	–11,5
	$k_{CW,WL}$	–64,3	–49,8	–30,9	–33,0	–34,7	–35,5	–36,0	–39,8	–43,6	–29,7	16,2
	$k_{B,WL}$	–12,7	–30,2	–47,3	–53,9	–54,2	–55,0	–56,8	–58,2	–61,4	–62,2	–52,5
	$k_{R,WL}$	1,44	1,46	2,00	2,70	3,19	3,22	2,98	2,57	1,98	1,59	0,0168

Table 27 : Coefficients for OHM load cases on weather side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	–23,6	–11,9	–6,32	–4,57	–3,99	–3,49	–1,98	2,74	11,1	15,8	6,43
	$k_{T,CL}$	58,2	–21,0	–38,9	–30,1	–15,1	–2,54	4,21	7,85	6,63	–15,7	–125
	$k_{CB,CL}$	–16,5	–4,49	0,939	1,98	1,76	0,85	–2,29	–10,0	–24,1	–35,9	–8,06
	$k_{CW,CL}$	30,1	14,9	6,19	2,91	1,31	0,693	1,66	3,81	8,48	17,5	15,0
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	–17,3	–13,4	–21,9	–25,4	–25,8	–24,0	–18,0	–6,51	5,39	7,32	4,38
	$k_{T,BL}$	70,0	7,05	2,87	35,8	80,4	113	113	83,9	50,3	–0,373	–94,9
	$k_{CB,BL}$	11,0	20,7	13,3	7,72	2,82	–2,62	–8,69	–16,5	–25,5	–27,0	–11,4
	$k_{CW,BL}$	–2,40	–10,7	3,75	8,56	9,14	9,91	10,7	10,5	12,4	19,9	18,2
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	–22,5	–10,4	–17,9	–25,8	–25,6	–20,0	–10,2	0,769	6,05	2,52	–29,2
	$k_{T,WL}$	161	11,5	–54,2	–66,9	–56,1	–36,3	–28,4	–12,1	35,5	77,6	–183
	$k_{CB,WL}$	0,707	23,6	17,7	6,22	–2,12	–10,3	–18,4	–26,5	–37,5	–47,0	–95,9
	$k_{CW,WL}$	10,7	–12,7	–0,534	12,4	13,0	10,7	10,4	13,7	25,9	44,6	141
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 28 : Coefficients for OHM load cases on lee side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	–26,2	–8,79	4,97	12,1	18,2	22,3	24,0	22,1	20,1	15,4	8,47
	$k_{T,BL}$	42,6	–49,8	–88,4	–113	–135	–154	–168	–187	–202	–204	–114
	$k_{CB,BL}$	–35,5	–30,5	–24,8	–23,8	–22,7	–20,3	–18,3	–19,1	–20,8	–26,2	–11,3
	$k_{CW,BL}$	50,6	35,6	20,3	14,9	9,85	5,07	2,68	6,85	11,5	22,0	14,5
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	–25,1	–4,16	5,33	10,8	20,4	25,6	24,2	22,2	21,4	16,3	–9,62
	$k_{T,WL}$	55,0	–42,1	–87,7	–121	–159	–197	–238	–272	–293	–304	–233
	$k_{CB,WL}$	–38,7	–32,0	–31,0	–35,4	–34,1	–29,1	–20,1	–13,2	–22,8	–46,0	–53,3
	$k_{CW,WL}$	52,6	32,2	26,0	28,3	20,5	13,0	8,82	6,37	16,3	42,0	77,7
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

2 Sea chests

2.1 Design pressure

2.1.1 In addition to the sea pressure P_{ex}, in kN/m², as calculated in Article [1] for sides and bottom, the pressure P_{sc} defined by the designer to cover the hazard of an overpressure due to the inlet grating cleaning system is to be considered for the scantling of sea chests without being taken less than 200 kN/m².

3 External pressure on exposed decks

3.1 Application

3.1.1 External pressure on exposed decks is only to be applied for strength assessment.

3.1.2 Green sea pressure defined in [3.2] for exposed decks is to be considered independently of the pressure due to:

- distributed cargo or other equipment loads, and
- any concentrated forces due to cargo or other unit equipment loads,

defined in Ch 5, Sec 6, [6.1] and Ch 5, Sec 6, [6.2] respectively.

3.2 Green sea loads

3.2.1 Pressure on exposed deck

The external dynamic pressure due to green sea P_d at any point of an exposed deck, in kN/m², for the static + dynamic design load scenarios is to be derived for each dynamic load case and is to be taken as defined in [3.2.3] to [3.2.4].

The external dynamic pressure due to green sea P_d at any point of an exposed deck for the static design load scenario is zero.

3.2.2 If a breakwater is fitted on the exposed deck, no reduction of the external dynamic pressure due to green sea is allowed for the area of the exposed deck located aft of the breakwater.

3.2.3 HVM and FVM load cases

The external pressure P_d for HVM and FVM load cases at any load point of an exposed deck, in kN/m², is to be obtained from the following formula:

$P_d = \max(P_{W,d}, \chi P_{W,d\text{-}min})$

where:

$P_{W,d}$: Pressure, in kN/m², obtained at the side of the ship ($y = \pm B_{x,max}/2$) at considered deck height for HVM and FVM load cases as defined in [1.3]

χ : Coefficient defined in Tab 29

$P_{W,d\text{-}min}$: Pressure to be taken as:

- $P_{W,d\text{-}min} = 0$ for direct strength analysis according to Part B, Chapter 8
- The value defined in Tab 30 for the other analyses.

3.2.4 BR, BP, OHM, OHS and OVA load cases

The external pressure P_d for BR, BP, OHM, OHS and OVA load cases, as defined in Ch 5, Sec 2, Tab 1 at any load point of an exposed deck, in kN/m², is to be obtained by linear interpolation between the pressure values at port and starboard side:

$P_{d,stb} = P_{W,d\text{-}stb}$

$P_{d,pt} = P_{W,d\text{-}pt}$

where:

$P_{W,d\text{-}stb}$: Pressure obtained at starboard side of the ship at considered deck height, to be calculated for BR, BP, OHM, OHS or OVA load cases as per [1.3] as appropriate, considering:

- x = longitudinal coordinate of the calculation point
- $y = -B_{x,max}/2$
- z = vertical coordinate of the calculation point

$P_{W,d\text{-}pt}$: Pressure obtained at port side at considered deck height for BR, BP, OHM, OHS, and OVA load cases as defined in [1.3], as appropriate, considering:

- x = longitudinal coordinate of the calculation point
- $y = B_{x,max}/2$
- z = vertical coordinate of the calculation point.

Table 29 : Coefficient χ for pressure on exposed decks

Exposed deck location	χ
Freeboard deck and within the lowest tier	1,00
Within the second tier	0,75
Within the third tier	0,56
Within the fourth tier	0,42
Within the fifth tier	0,32
Within the sixth tier	0,25
Within the seventh tier	0,20
Within the eighth tier	0,15
Top of eighth tier and above	0,10
Note 1: When a deck is located at the limit between two tiers, the coefficient from the tier above is to be considered.	

Table 30 : Minimum pressure on exposed deck $P_{W,d\text{-}min}$

Load line length L_{LL}, in m	Longitudinal position	Minimum pressure on exposed deck $P_{W,d\text{-}min}$, in kN/m²
$L_{LL} < 100$	$0 \le x \le 0,75\ L_{LL}$	$14,9 + 0,195\ L_{LL}$
	$0,75\ L_{LL} < x \le L_{LL}$	$15,8 + \frac{L_{LL}}{3}\left(1 - \frac{5}{3}\frac{(L_{LL} - x)}{L_{LL}}\right) - \left(3,6\frac{(L_{LL} - x)}{L_{LL}}\right)$
$L_{LL} \ge 100$	$0 \le x \le 0,75\ L_{LL}$	34,3
	$0,75\ L_{LL} < x \le L_{LL}$	$34,3 + \frac{p_{WP} - 34,3}{0,25}\left(\frac{x}{L_{LL}} - 0,75\right)$
Note 1: p_{WP} : Pressure, in kN/m², at the forward perpendicular, to be taken equal to: • $49,1 + 0,0726\ (L_{LL} - 100)$ for type B ships • $49,1 + 0,3560\ (L_{LL} - 100)$ for type A, type B-60 or type B-100 ships Type A, type B, type B-60 and type B-100 ships are defined in Ch 1, Sec 3, [2.3] x : Longitudinal coordinate, in m, of the assessed structural member mid-point, measured from the aft end of length L or L_{LL}, as applicable.		

3.2.5 Envelope of dynamic pressure on exposed deck

The envelope of dynamic pressure at any point of an exposed deck $P_{d\text{-}max}$ is to be taken as the greatest pressure value obtained from any of the load cases in accordance with [3.2.3] and [3.2.4].

3.3 Load carried on exposed deck

3.3.1 If loads are carried on an exposed deck, for example containers, cargo or equipment, the static and dynamic pressures due to these loads are to be considered as per Ch 5, Sec 6, [6] and Ch 5, Sec 6, [8].

4 External impact pressure

4.1 Application

4.1.1 Impact pressure is only to be applied for strength assessment.

4.2 Bottom and stern slamming impact pressures

4.2.1 Bottom slamming

The bottom impact pressures P_{SLI} due to slamming are to be obtained, in kN/m², from the following formula, without being taken less than 0:

$$P_{SLI} = 100\frac{h_{SL}^2 - (z - T_F)^2}{T_{RZ}^2 \tan\beta}$$

where:

T_F : Minimum draught at the forward perpendicular, in m, among those foreseen in operation in ballast conditions or conditions of partial loading

h_{SL} : Maximum relative wave elevation, in m, to be taken as follows:

- for x/L < 0,7:

  $h_{SL} = 0$

- for x/L = 0,7:

  $h_{SL} = 4\ H\ C_{B\text{-}LC}^{-0,7}$

- for x/L ≥ 0,9:

  $h_{SL} = f_c\ 19\ H\ C_{B\text{-}LC}^{-0,7}$

For intermediate values of x/L, h_{SL} is to be obtained by linear interpolation

f_c : Correction factor, taken equal to 0,7

H : Wave parameter defined in Ch 5, Sec 3, for a reference length calculated with:

$$\alpha = 0,34\left(\frac{T_{LC}}{L}\right)^{-0,28}$$

$f_\alpha = 1,0$

T_{LC} : Draught amidships, in m, at the loading condition where T_F occurs

T_{RZ} : Mean up crossing period, in s, to be taken as:

$T_{RZ} = 1,2\ L^{0,40}$

β : Longitudinal or transverse deadrise angle at the calculation point, whichever is the greater, but not to be taken less than 10 deg (see Fig 3).

4.2.2 Stern slamming

The stern impact pressures P_{SLI} due to slamming are to be obtained, in kN/m², from the following formula, without being taken less than 0:

$$P_{SLI} = 100\frac{h_{SL}^2 - (z - T_{LC})^2}{T_{RZ}^2 \tan\beta}$$

where:

h_{SL} : Maximum relative wave elevation, in m, to be taken as follows:

- for x/L ≤ 0:

  $h_{SL} = 13,7\ H\ C_{B\text{-}LC}^{2,5}\ C_{W\text{-}LC}^{-4,9}$

- for x/L = 0,2:

  $h_{SL} = 2,7\ H\ C_{B\text{-}LC}^{2,5}\ C_{W\text{-}LC}^{-4,9}$

- for x/L > 0,2:

  $h_{SL} = 0$

For intermediate values of x/L, h_{SL} is to be obtained by linear interpolation.

with:

$C_{B\text{-}LC}$: Block coefficient at considered loading condition draught T_{LC}

$C_{W\text{-}LC}$: Waterplane coefficient at considered loading condition draught T_{LC}

H : Wave parameter defined in Ch 5, Sec 3, for a reference length calculated with:

$\alpha = 0,86$

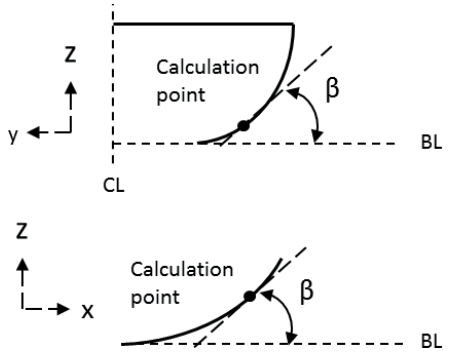
$f_\alpha = 1,0$

T_{RZ} : Mean up crossing period, in s, to be taken as:

$T_{RZ} = 3\ L^{0,26}$

β : Longitudinal or transverse deadrise angle at the calculation point, whichever is the greater, but not to be taken less than 10 deg (see Fig 3).

Figure 3 : Definition of deadrise angle β



4.3 Bow flare impact pressure

4.3.1 The bow flare impact pressure P_{FI} is to be obtained, in kN/m^2, from the following formula:

$$P_{FI} = C_S\, C_Z\, (0{,}22 + 0{,}15 \tan\alpha)(0{,}4V \sin\beta + 0{,}6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the bow flare impact pressure is considered to be acting:

- for plating and ordinary stiffeners:
  $C_S = 1{,}8$
- for primary supporting members:
  $C_S = 1{,}1$

C_Z : Coefficient depending on the distance between the draught for the considered loading condition and the calculation point:

- for $z \geq 21{,}5\ H + T_{LC} - 11$:
  $C_Z = 10{,}75\ H - 0{,}5\ (z - T_{LC})$, not to be taken smaller than 0
- for $z < 21{,}5\ H + T_{LC} - 11$:
  $C_Z = 5{,}5$

H : Wave parameter defined in Ch 5, Sec 3, for a reference length calculated with:

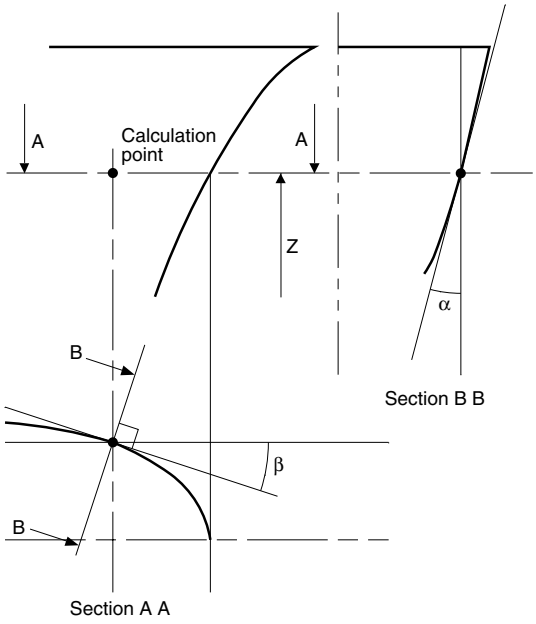
$$\alpha = 0{,}65\ C_{W\text{-}LC}^{-1{,}3}$$

$$f_\alpha = 1{,}0$$

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 4)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 4).

Figure 4 : Definition of angles α and β



4.4 Berthing impact pressure

4.4.1 Application

The impact pressure induced by the contact of the fenders on the side shell during berthing operations, as defined in [4.4.2], is to be applied to ships having a moulded displacement greater than 8000 t.

It applies to the part of the side shell extending from the ballast draught T_{BAL} to 0,25 T_{SC} (minimum 2,2 m) above T_{SC}, in areas where the breadth of the ship is greater than 0,9 B.

4.4.2 The berthing impact pressure $P_{BI,}$ in kN/m², is to be taken as defined in Tab 31.

Table 31 : Berthing impact pressure

Ship moulded displacement Δ at T_{SC}, in t	P_{BI}
$8000 < \Delta \leq 50000$	170
$50000 < \Delta \leq 150000$	180
$150000 < \Delta \leq 250000$	190
$250000 < \Delta \leq 400000$	190
$\Delta > 400000$	210

5 External pressure on front, side and aft bulkheads of superstructures and deckhouses

5.1 Application

5.1.1 External pressure on front, side and aft bulkheads of superstructures and deckhouses is only to be applied for strength assessment.

5.2 Definitions

5.2.1 Superstructures

Superstructures are defined in Ch 1, Sec 3.

5.2.2 Deckhouses

Deckhouses are defined in Ch 1, Sec 3.

5.2.3 Tiers of superstructures and deckhouses

Tiers of superstructures and deckhouses are defined in Ch 1, Sec 3, [2.2.10].

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when (D - T_{SC}) exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 3, Tab 5), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

5.3 Superstructures side bulkheads

5.3.1 Lateral pressure

The lateral pressure is to be obtained as defined in Article [1].

When the side is a tank boundary, the internal lateral pressure, as defined in Ch 5, Sec 6, is also to be considered.

5.4 Deckhouses side and end bulkheads and superstructures end bulkheads

5.4.1 Lateral pressure

The lateral pressure to be used for the determination of scantlings of front, side and aft bulkheads of deckhouses and of front and aft bulkheads of superstructures is to be obtained, in kN/m², from the following formula:

$P_{sd} = 10\, n_D\, a\, c\, [b\, f - (z - T_{sc})]$

to be taken not less than $P_{sd\text{-}min}$

where:

n_D : Navigation coefficient as defined in Tab 32

a : Coefficient defined in Tab 33

c : Coefficient taken equal to:

$$c = 0{,}3 + 0{,}7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1,0

b_1 : Breadth of the superstructure or deckhouse, in m, at the position considered, to be taken not less than 0,25 B_1

B_1 : Actual maximum breadth of the ship at the exposed weather deck level, in m, at the position considered

b : Coefficient defined in Tab 35

f : Coefficient defined in Tab 34

$P_{sd\text{-}min}$: Minimum lateral pressure, in kN/m^2, defined in Tab 36.

Table 32 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
unrestricted navigation	1,00
summer zone	0,90
tropical zone	0.80
coastal area	0,80
sheltered area	0,50
Note 1: Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the value of n_D for **unrestricted navigation** is to be used unless a specific assessment has been performed by the Society based on the scatter diagram corresponding to the geographical area or the sea conditions considered	

Table 33 : Coefficient a - Lateral pressure for superstructures and deckhouses

Type of bulkhead	Location	Coefficient a	Maximum value of a
Unprotected front **(2)**	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Protected front **(2)**	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Side **(1)**	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Aft end	All tiers, when x/L ≤ 0,5	$0,7 + \frac{L}{1000} - 0,8\frac{x}{L}$	$1 - 0,8\frac{x}{L}$
	All tiers, when x/L > 0,5	$0,5 + \frac{L}{1000} - 0,4\frac{x}{L}$	$0,8 - 0,4\frac{x}{L}$

(1) Applicable only to deckhouses side bulkheads

(2) The front bulkhead of a superstructure or deckhouse may be considered as protected when it is located less than B_x behind another superstructure or deckhouse, and the width of the front bulkhead being considered is less than the width of the aft bulkhead of the superstructure or deckhouse forward of it. B_x is the local breadth of the ship at the front bulkhead.

Table 34 : Coefficient f - Lateral pressure for superstructures and deckhouses

Ship length	Coefficient f
L < 150	$\frac{L}{10}e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$
150 ≤ L < 300	$\frac{L}{10}e^{-L/300}$
L ≥ 300	11,03

Table 35 : Coefficient b - Lateral pressure for superstructures and deckhouses

Location of bulkhead **(1)**	Coefficient b
$\frac{x}{L} \le 0,45$	$1 + \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
$\frac{x}{L} > 0,45$	$1 + 1,5\left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x is to be taken as the co-ordinate of the centre of each part considered.	
Note 1:	
C_B : Block coefficient, with $0,6 \le C_B \le 0,8$	

Table 36 : Minimum lateral pressure $P_{sd\text{-}min}$ for superstructures and deckhouses

Location and type of bulkhead	$P_{sd\text{-}min}$, in kN/m²
Lowest tier of unprotected fronts	$30 \le 25,0 + 0,10L \le 50$
Elsewhere:	
• if $z \le T_{SC} + h_{w\text{-}en}$	$15 \le 12,5 + 0,05L \le 25$
• if $T_{SC} + h_{w\text{-}en} < z \le T_{SC} + 2\ h_{w\text{-}en}$	linear interpolation
• if $z > T_{SC} + 2\ h_{w\text{-}en}$	2,5
Note 1:	
$h_{w\text{-}en}$: Envelope of the water heads equivalent to the pressure at the waterline, h_w, calculated for all load cases.	

6 External pressures on hatch covers and coamings

6.1 Application

6.1.1 The external pressures on hatch covers and coamings are to be applied for strength assessment only.

6.2 Green sea loads

6.2.1 Vertical weather design load

The pressure p_W, in kN/m², on the hatch cover panels is to be taken as $P_{W,d\text{-}min}$ defined in [3.2.3] and Tab 30.

6.2.2 Horizontal weather design load

The horizontal weather design load p_A, in kN/m², for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is not to be taken less than the greater of:

- the minimum values p_{Amin} given in Tab 37
- $p_A = 10\ f_n\ f_c\ (f_b\ c_L\ C_w - z)$

where:

f_n : Coefficient defined in Tab 38

f_c : Coefficient taken equal to $0,3 + 0,7\ b'/B_1$ with b'/B_1 to be taken not less than 0,25

b' : Breadth of coaming, in m, at the position considered

B_1 : Actual maximum breadth of ship, in m, on the exposed weather deck at the position considered

f_b : Coefficient taken equal to:

- for $x'/L < 0,45$:

$$f_b = 1,0 + \left(\frac{\frac{x'}{L} - 0,45}{C_B + 0,2}\right)^2$$

- for $x'/L \geq 0,45$:

$$f_b = 1,0 + 1,5\left(\frac{\frac{x'}{L} - 0,45}{C_B + 0,2}\right)^2$$

with $0,6 \leq C_B \leq 0,8$. When determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_B need not be taken less than 0,8

c_L : Coefficient taken equal to:

$$c_L = \sqrt{\frac{L}{90}} \text{ for } L < 90m$$
$$c_L = 1 \quad \text{for } L \geq 90m$$

x' : Distance, in m, between the transverse coaming or the hatch cover skirt plate considered and aft end of the length L. When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x' is to be taken as the distance between aft end of the length L and the centre of each part considered

C_w : Wave parameter, taken equal to:

$$C_w = \frac{L}{25} + 4,1 \quad \text{for } L < 90m$$
$$C_w = 10,75 - \left(\frac{300 - L}{100}\right)^{1,5} \quad \text{for } 90m \leq L < 300m$$
$$C_w = 10,75 \quad \text{for } 300m \leq L \leq 350m$$
$$C_w = 10,75 - \left(\frac{L - 350}{150}\right)^{1,5} \quad \text{for } L > 350m$$

z : Vertical distance, in m, from the summer load line to the midpoint of the stiffener span or to the middle of the plate field.

Note 1: The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilised for the design of substructures of horizontal support according to Ch 11, Sec 9, [8.7].

Table 37 : Minimum design load p_{Amin}

		Ship length L		
		L ≤ 50	50 < L < 250	L ≥ 250
p_{Amin}, in kN/m²	For unprotected fronts	30	25 + L/10	50
	Elsewhere	15	12,5 + L/20	25

Table 38 : Coefficient a Horizontal weather design load for hatch covers and coamings

Location	Coefficient f_n	Maximum value of f_n
Unprotected front coamings and hatch cover skirt plates	$2 + \frac{L}{120}$	4,5
Unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height h_s as defined in Ch 1, Sec 3, [2.2.9]	$1 + \frac{L}{120}$	3,5
Side and protected front coamings and hatch cover skirt plates	$0,5 + \frac{L}{150}$	2,5
Aft ends of coamings and aft hatch cover skirt plates abaft amidships	$0,7 + \frac{L}{1000} - 0,8\frac{x}{L}$	$1 - 0,8\frac{x}{L}$
Aft ends of coamings and aft hatch cover skirt plates forward of amidships	$0,5 + \frac{L}{1000} - 0,4\frac{x}{L}$	$0,8 - 0,4\frac{x}{L}$

7 External pressure on shell doors

7.1 Bow doors

7.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m^2, from the following formula:

$$p_E = 0,5\, n_D\, C_L\, C_Z\, (0,22 + 0,15 \tan\alpha)\, (0,4 V \sin\beta + 0,6 \sqrt{L_1})^2$$

where:

n_D : Navigation coefficient, defined in Tab 39

C_L : Coefficient depending on the ship's length:

$C_L = 0,0125\, L$ for $L < 80$m

$C_L = 1,0$ for $L \geq 80$m

L_1 : Length as defined in Ch 1, Sec 3

V : Maximum ahead service speed, in knots

C_Z : Coefficient defined in [4.3.1], to be taken equal to 5,5

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 5)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 5).

Table 39 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
unrestricted navigation	1,00
coastal area	0,80
sheltered area	0,50
Note 1: Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the value of n_D for **unrestricted navigation** is to be used unless a specific assessment has been performed by the Society based on the scatter diagram corresponding to the geographical area or the sea conditions considered	

7.1.2 Design external forces

The design external forces F_X, F_Y, F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$F_X = p_E\, A_X$

$F_Y = p_E\, A_Y$

$F_Z = p_E\, A_Z$

where:

p_E : External pressure, in kN/m^2, to be calculated according to [7.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig 5

h : Height, in m, to be taken as the lesser of h_1 and h_2

h_1 : Height, in m, of the door between the levels of its bottom and the upper deck

h_2 : Height, in m, of the door between its bottom and top

ℓ : Length, in m, of the door at a height h/2 above the bottom of the door

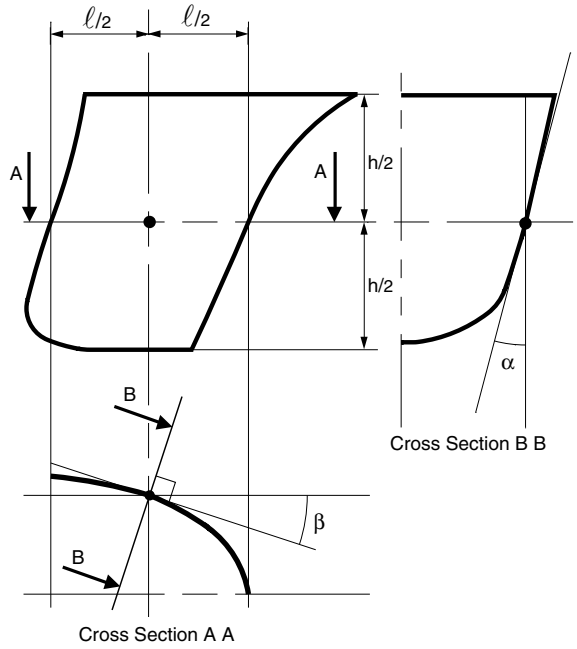
A_X : Area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded

A_Y : Area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser

A_Z : Area, in m^2, of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case by case basis.

Figure 5 : Definition of angles α and β



7.1.3 Closing moment

For visor doors, the closing moment under external loads is to be obtained, in kN.m, from the following formula:

$M_Y = F_X\, a + 10\, W\, c - F_Z\, b$

where:

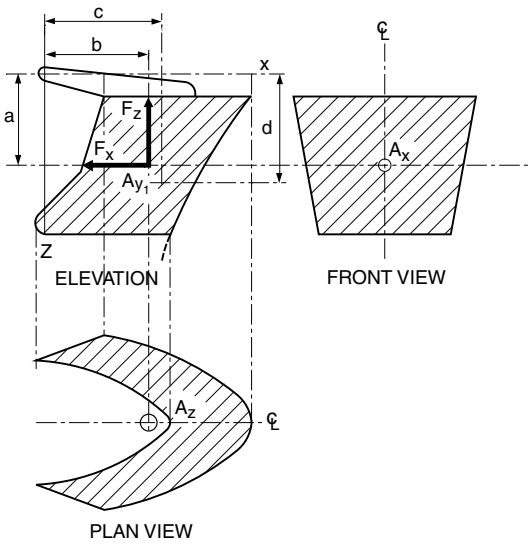
W : Mass of the visor door, in t

a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 6

b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 6

c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 6.

Figure 6 : Bow doors of visor type



7.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken into account.

7.2 Side and stern doors

7.2.1 Design forces in intact ship conditions

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 40.

Table 40 : Design forces for side and stern doors

Structural elements	External force F_E, in kN	Internal force F_I, in kN
Securing and supporting devices of doors opening inwards	$A\ p_E + F_P$	$F_0 + 10\ W$
Securing and supporting devices of doors opening outwards	$A\ p_E$	$F_0 + 10\ W + F_P$
Primary supporting members **(1)**	$A\ p_E$	$F_0 + 10\ W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I.

Note 1:

A : Area, in m^2, of the door opening

W : Mass of the door, in t

F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm

F_0 : The greater of F_C and 5 A, in kN

F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.

p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m^2, from the following formulae:

$p_E = 10\ (T - Z_G) + 25$ for $Z_G < T$

$p_E = 25$ for $Z_G \geq T$

Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m^2, from the following formula:

$$p_E = 0{,}6 n_D C_L (0{,}8 + 0{,}6\sqrt{L_1})^2$$

T : Draught, in m, at the highest subdivision load line

Z_G : Height of the centre of the area of the door, in m, above the baseline

n_D : Navigation coefficient, defined in Tab 39

C_L : Coefficient depending on the ship's length:

$C_L = 0,0125L$ for $L < 80$m

$C_L = 1,0$ for $L \geq 80$m

L_1 : Length as defined in Ch 1, Sec 3

7.2.2 Design pressure in damaged ship conditions

In damaged ship conditions, where doors are located partly or totally below the deepest equilibrium waterline, the following external design pressures, in kN/m^2, are to be considered:

- points at or below the deepest equilibrium waterline:

  $p_E = \rho\ g\ d_F$

- points above the deepest equilibrium waterline:

  $p_E = 0$

where:

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline in the damaged condition at y or from the calculation point to the bulkhead deck at side, whichever is the greater.

The deepest equilibrium waterlines are the most critical waterlines for scantling during intermediate and final equilibrium stages, and are to be provided by the Designer under his own responsibility.

8 External loads on containers

8.1 Wind forces

8.1.1 The forces due to the effect of the wind, applied to one container stowed above deck at tier "i", are to be obtained, in kN, from the following formulae:

- in x direction:

$$F_{X,wind,i} = \frac{1}{2}\rho_a\left[V_W\left(\frac{z_i - T_{LC}}{10}\right)^{\alpha}\right]^2 h_c b_c 10^{-3}$$

- in y direction:

$$F_{Y,wind,i} = \frac{1}{2}\rho_a\left[V_W\left(\frac{z_i - T_{LC}}{10}\right)^{\alpha}\right]^2 h_c \ell_c 10^{-3}$$

where:

ρ_a : Air density, to be taken equal to 1,225 kg/m^3

V_W : Wind speed at 10 m above waterline, to be taken equal to:

- for ships assigned the additional class notation **LASHING** or **LASHING-RSSA( )**: as defined in Pt F, Ch 12, Sec 5, [4.5]
- for other cases: V_W = 35 m/s

α : Coefficient for water surface roughness, to be taken equal to: α = 0,11

z_i : Z coordinate, in m, of the volumetric center of the container at tier " i " with respect to the coordinate system defined in Ch 1, Sec 3, [2.6]

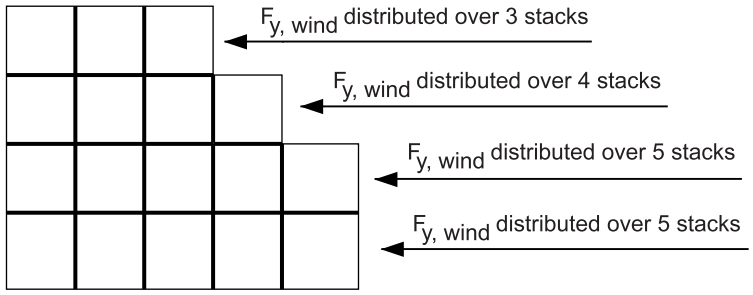
h_C : Height, in m, of a container

ℓ_C, b_C : Dimensions, in m, of the container in the ship longitudinal and transverse directions, respectively.

These forces only act on a stack exposed to wind. In the case of M juxtaposed and connected stacks of the same height, the wind forces are to be distributed over the M stacks.

In the case of juxtaposed and connected stacks of different heights, the wind forces are to be distributed taking into account the number of stacks at the tier considered (see example on Fig 7).

Figure 7 : Distribution of wind forces in the case of connected stacks



Section 6 Internal Loads and Cargo Loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

a_X, a_Y, a_Z : Longitudinal, transverse and vertical accelerations, in m/s^2, calculated at the centre of gravity of the considered compartment, x_C, y_C, z_C, as defined in Ch 5, Sec 3, [3.2]

b_C : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead

B_H : Breadth of the cargo hold, in m, measured at mid-length of the cargo hold and at the mid height between the top of hopper tank and the bottom of topside tank, see Fig 4

B_{IB} : Breadth of inner bottom, in m, measured at mid-length of the cargo hold, see Fig 4

D_1 : Distance, in m, from the base line to the freeboard deck at side amidships

d_F : Filling level of a tank, in m, to be taken as the vertical distance measured with the ship at rest, from the lowest point of the tank to the free surface of the liquid

d_{sc} : Diameter, in m, of a steel coil

f_β : Heading correction factor defined in Ch 5, Sec 3

h_{OF} : Distance, in m, between the top of the tank and the top of the overflow, as defined in Ch 13, Sec 6, [1.3.3].

h_{BC} : Height of bulk cargo, in m, from the inner bottom to the upper surface of bulk cargo, as defined in [3.3.1] or [3.3.2]

h_{DB} : Height, in m, of the double bottom at the centreline, measured at mid-length of the cargo hold, see Fig 4

h_{HPL} : Vertical distance, in m, from the inner bottom at centreline to the upper intersection of hopper tank and side shell or inner side for double side bulk carriers, determined at mid length of the considered cargo hold, as shown in Fig 4

$h_{HPL} = 0$ if there is no hopper tank.

h_{HPU} : Vertical distance, in m, from the inner bottom at centreline to the lower intersection of topside tank and side shell or inner side for double side bulk carriers, determined at mid length of the cargo hold at midship, as shown in Fig 4

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom

H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

K_C : Coefficient taken equal to:

- for $\alpha_p \leq 90°$:

$$K_C = \cos^2\alpha_p + (1 - \sin\Psi)\ \sin^2\alpha_p$$

- for $90° < \alpha_p \leq 120°$:

$$K_C = (1 - \sin\Psi)\ \sin^2\alpha_p$$

- for $\alpha_p > 120°$ and $\alpha_p + \Psi < 180°$:

$$K_C = 0{,}75\ (1 - \sin\Psi)\left[1 - \frac{\alpha_p - 120}{60 - \Psi}\right]$$

- when $\alpha_p + \Psi \geq 180°$:

$$K_C = 0$$

ℓ_C : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead

ℓ_H : Length of the cargo hold, in m, at the centreline between the transverse bulkheads. This is to be measured to the mid-depth of the corrugated bulkhead(s) if fitted

ℓ : Distance, in m, between floors, see Fig 12

ℓ_{lp} : Distance, in m, between outermost dunnage per EPP in the ship X direction, see Fig 13

ℓ_{st} : Length, in m, of a steel coil

M : Mass, in t, of the bulk cargo being considered

M_{Full} : Cargo mass, in t, in a cargo hold corresponding to the volume up to the top of the hatch coaming with a density of the greater of:

M_H/V_{Full} or 1,0 t/m^3.

$M_{Full} = 1{,}0\ V_{Full}$ but not less than M_H

M_H : Cargo mass, in t, in a cargo hold that corresponds to the homogeneously loaded condition at maximum draught with 50% consumables

M_{HD} : Maximum allowable cargo mass, in t, in a cargo hold according to design loading conditions with specified holds empty at maximum draught with 50% consumables and all ballast water tanks in cargo hold region empty

$M_{sc\text{-}ib}$: Equivalent mass of a steel coil, in t, on inner bottom, as defined in [5.3.1]

$M_{sc\text{-}hs}$: Equivalent mass of a steel coil, in t, on hopper side, as defined in [5.3.2]

n_1 : Number of tiers of steel coils

n_2 : Number of load points per EPP of the inner bottom, see [5.1.3]

n_3 : Number of dunnages supporting one row of steel coils

P_{drop} : Overpressure, in kN/m^2, due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow through ballast water exchange

When the total area of tank overflow openings is more than twice the sectional area of the related filling pipe, P_{drop} may be taken equal to 0

Otherwise, P_{drop} is to be defined by the designer, but not to be taken less than 25 kN/m^2

P_{pv} : Design vapour pressure in kN/m^2.

Where a pressure relief valve is fitted, P_{pv} is to be taken equal to:

- 1,1 times the safety valve setting pressure, in general
- 1,0 times the safety valve setting pressure in case of liquefied gas cargo tank or liquefied gas fuel tank.

Where no pressure relief valve is fitted, P_{pv} is to be taken as 0 kN/m^2

perm : Permeability of cargo, to be taken as:

perm = 0,3 for iron ore, coal cargoes and cement

perm = 0 for steel coils and steel packed products

R : Vertical coordinate of the ship rotation centre, to be taken as:

$$R = \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$$

s_{CG} : Spacing of corrugations, in m; see Ch 4, Sec 5, Fig 27

$T\theta$: Roll period, in s, as defined in Ch 5, Sec 3, [2.1.1]

V_{Full} : Volume, in m^3, of cargo hold up to top of the hatch coaming, taken as:

$V_{Full} = V_H + V_{HC}$

V_H : Volume, in m^3, of cargo hold up to level of the intersection of the main deck with the hatch coaming excluding the volume enclosed by hatch coaming, see Fig 4

V_{HC} : Volume, in m^3, of the hatch coaming, from the level of the intersection of the main deck with the hatch side coaming to the top of the hatch coaming, determined for the cargo hold at midship, as shown in Fig 4

V_{TS} : Total volume, in m^3, of the portion of the lower bulkhead stools within the cargo hold length ℓ_H and inboard of the hopper tanks, as shown in Fig 4

W : Mass, in t, of a steel coil

x, y, z : X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1]

x_C, y_C, z_C : X, Y and Z coordinates, in m, of the centre of gravity of the considered compartment, with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1]

x_G, y_G, z_G : X, Y and Z coordinates, in m, of the volumetric centre of gravity of the tank or fully filled cargo hold, i.e. V_{Full}, considered with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1].

In case of partially filled cargo hold, x_G, y_G, z_G to be taken as follows:

x_G, y_G: Volumetric centre of gravity of the cargo hold

$z_G = h_{DB} + h_{BC\text{-}CL} / 2$

$h_{BC\text{-}CL}$ is the height of cargo at the centreline, as defined in [3.3.2]

z_{BC} : Height of the upper surface of the cargo above the baseline in way of the load point, in m, as defined in [3.3.1] and [3.3.2]to be taken as:

$z_{BC} = h_{DB} + h_{BC}$

z_{top} : Z coordinate of the highest point of tank, excluding small hatchways, in m

z_{min} : Z coordinate of the lowest point of tank, in m

α_p : Angle, in deg, between panel considered and the horizontal plane. The angle is to be measured inward and upward from horizontal plane outside cargo hold, between 0 and 180 deg, as shown in Fig 1.

θ : Roll angle, in deg, defined in Ch 5, Sec 3, [2.1.1]

θ_h : Angle, in deg, between inner bottom plate and hopper sloping plate or inner hull, as shown in Fig 4. In general θ_h is such that:

$$\tan\theta_h = \frac{2h_{HPL}}{B_H - B_{IB}}$$

ρ_L : Density of liquid, in t/m^3, typically:

- for ballast water:

  $\rho_L = 1,025$

- for fresh water:

  $\rho_L = 1,0$

- for liquefied natural gas:

  $\rho_L = 0,5$

ρ_c : Density of bulk cargo, in t/m^3, as defined in [3.3.3]

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7,85

φ : Pitch angle, in deg, defined in Ch 5, Sec 3, [2.1.2]

ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); to be taken as:

- in general:

  $\psi = 30°$

- for iron ore:

  $\psi = 35°$

- for cement:

  $\psi = 25°$

1 Pressures due to liquids

1.1 Application

1.1.1 Pressures for the strength and fatigue assessments in intact conditions

The internal pressure P_{in} due to liquid acting on any load point of a tank boundary, in kN/m^2, for the static design load scenarios given in Ch 5, Sec 7, is to be taken as:

$P_{in} = P_{ls}$

The internal pressure P_{in} due to liquid acting on any load point of a tank boundary, in kN/m^2, for the static + dynamic design load scenarios is to be derived for each dynamic load case and is to be taken as:

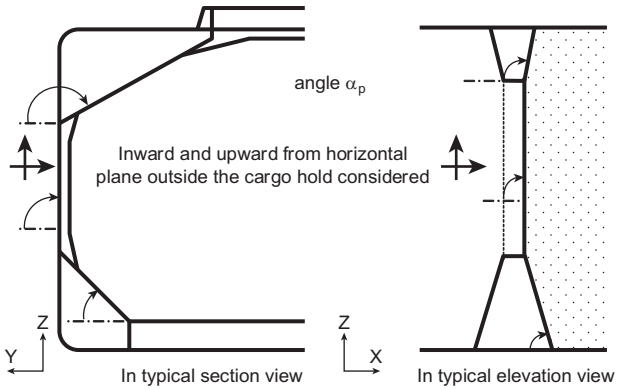
$P_{in} = P_{ls} + P_{ld}$ without being taken less than 0

where:

P_{ls} : Static pressure due to liquid in tank, in kN/m^2, as defined in [1.2]

P_{ld} : Dynamic pressure due to liquid in tank, in kN/m^2, as defined in [1.3].

Figure 1 : Measurement of angle α_p



1.1.2 Pressures for the strength assessment in flooded conditions

The internal pressure P_{in} in flooded condition, in kN/m^2, acting on any load point of the structural watertight boundaries intended to stop vertical and horizontal flooding, for the flooded static design load scenarios given in Ch 5, Sec 7, is to be taken as:

$P_{in} = P_{fs}$

where:

P_{fs} : Static pressure of seawater in flooded condition in the compartment, in kN/m^2, as defined in [1.4].

For corrugations of vertically corrugated transverse bulkheads separating cargo holds of ships intended for the carriage of dry cargoes in bulk, the flooded pressures and forces specified in [4.1] for bulk cargoes in flooded conditions are to be applied.

For double bottom in cargo holds of ships intended for the carriage of dry cargoes in bulk, the flooded pressures and forces specified in [4.2] for bulk cargoes in flooded conditions are to be applied.

1.2 Static liquid pressure in intact conditions

1.2.1 Normal operations at sea and harbour/sheltered water operations

The static pressure P_{ls} due to liquid in tanks during normal operations at sea and harbour/sheltered water operations, in kN/m^2, is to be taken as:

$P_{ls} = \rho_L\, g\, (z_{top} - z) + P_{pv}$

1.2.2 Sequential ballast water exchange

The static pressure P_{ls} due to liquid in ballast tanks associated with ballast water exchange operations by sequential method is to be taken as defined for normal operations at sea in [1.2.1].

1.2.3 Flow through ballast water exchange

The static pressure P_{ls} due to liquid in ballast tanks associated with flow through ballast water exchange operations, in kN/m^2, is to be taken as:

$P_{ls} = \rho_L\, g\, (z_{top} - z + h_{OF}) + P_{drop}$

1.2.4 Ballast water exchange by dilution

The static pressure P_{ls} due to liquid in ballast tanks associated with ballasting operations by means of dilution is to be taken as defined for sequential ballast exchange in [1.2.2].

The ship designer has to inform the Society if the ballast water exchange system implies additional pressure to be considered such as P_{drop}, in addition to the pressure defined in [1.2.2].

1.2.5 Ballasting using ballast water treatment system

The static pressure P_{ls} due to liquid in ballast tanks associated with ballasting operations using a ballast water treatment system is to be taken as defined for sequential ballast exchange in [1.2.2]. The ship designer has to inform the Society if the ballast water treatment system implies additional pressure to be considered such as P_{drop}, in addition to the pressure defined in [1.2.2].

1.2.6 Static liquid pressure for the fatigue assessment

The static pressure P_{ls} due to liquid in tanks to be used for the fatigue assessment, in kN/m^2, is to be taken as follows, depending on their filling level defined in Ch 10, Sec 1, [2.1.1]:

- fully filled tanks:

  $P_{ls} = \rho_L\, g\, (z_{top} - z)$

- consumable tanks filled at 50%:

  $P_{ls} = \rho_L\, g\, (0{,}5\, (z_{min} + z_{top}) - z)$ without being taken less than 0.

1.3 Dynamic liquid pressure in intact conditions

1.3.1 Dynamic pressure on watertight bulkheads

The dynamic pressure P_{ld} due to liquid in tanks, in kN/m^2, is to be taken as:

$P_{ld} = \rho_L\, [a_X\, (x_0 - x) + a_Y\, (y_0 - y) + a_Z\, (z_0 - z)]$

where:

x_0 : X coordinate, in m, of the reference point.

y_0 : Y coordinate, in m, of the reference point.

z_0 : Z coordinate, in m, of the reference point.

The reference point is to be taken as the point with the highest value of V_j, calculated for all the points that define the upper boundary of the tank, as follows:

$V_j = a_X\, (x_j - x_C) + a_Y\, (y_j - y_C) + (a_Z + g)\, (z_j - z_C)$

where:

x_j : X coordinate, in m, of the point j on the upper boundary of the tank

y_j : Y coordinate, in m, of the point j on the upper boundary of the tank

z_j : Z coordinate, in m, of the point j on the upper boundary of the tank.

1.3.2 Dynamic pressure in consumable tanks for the fatigue assessment

The dynamic pressure P_{ld}, in kN/m^2, due to liquid in consumable tanks filled at 50% according to Ch 10, Sec 1, [2.1.1], is to be taken as follows:

- as calculated in [1.3.1] for $z \leq 0,5\ z_{top}$
- equal to 0 for $z > 0,5\ z_{top}$

1.4 Static pressure in flooded conditions

1.4.1 Ships for which damage stability calculations are required

The static pressure P_{fs}, in kN/m^2, acting on structural watertight elements defined as per the Internal Watertight Plan and located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding, is to be taken as:

$P_{fs} = \rho\ g\ d_{FL}$ without being taken less than 0

where:

d_{FL} : Distance, in m, from the calculation point to the deepest equilibrium waterline in the damaged condition at y or from the calculation point to the bulkhead deck at side, whichever is the greater.

The deepest equilibrium waterlines are the most critical waterlines for scantling during intermediate and final equilibrium stages, and are to be provided by the Designer under his own responsibility.

1.4.2 Ships for which damage stability calculations are not required

The static pressure P_{fs}, in kN/m^2, acting on structural watertight elements (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding, is to be obtained from the formula in [1.4.1], where d_F is the vertical distance, in m, from the calculation point to the bulkhead deck at side.

2 Partly filled tanks intended for the carriage of liquid or ballast

2.1 Application

2.1.1 General

Sloshing assessment is to be carried for all liquid cargo, ballast and other liquid tanks with volume exceeding 100m^3, if required by Ch 11, Sec 4, [1.5].

Sloshing assessment is to be carried out for all liquefied gas tanks for which partial filling is contemplated, whatever their volume.

2.1.2 Membrane tanks

Sloshing pressure in membrane tanks of ships having the service notation **liquefied gas carrier** is defined in Pt D, Ch 9, App 1, [2].

Sloshing pressure in membrane tanks of ships assigned the additional service feature **LNGfuel** is defined in Pt D, Ch 9, App 1, [2] as per NR529 C6.4.9.4.1.3.

2.2 Pressure definition

2.2.1 Sloshing pressure

The sloshing pressure P_{sl}, in kN/m^2, due to liquid motion in the longitudinal or transverse direction, acting on bulkheads in tanks intended for the carriage of liquid or ballast, is to be taken as:

$P_{sl} = P_{S\text{-}SL} + P_{W\text{-}SL}$

where:

$P_{S\text{-}SL}$: Static pressure, in kN/m^2, as defined in [2.3.1]

$P_{W\text{-}SL}$: Dynamic sloshing pressure, in kN/m^2, as defined in [2.4.1] or [2.4.2].

The sloshing pressure, P_{sl} is not to be taken less than 12 kN/m^2.

2.2.2 Impact pressure

The impact pressure P_{im}, in kN/m^2, due to liquid motion in the longitudinal or transverse direction, acting on bulkheads in tanks intended for the carriage of liquid or ballast, is to be taken as:

$P_{im} = P_{S\text{-}I} + P_{W\text{-}I}$

where:

$P_{S\text{-}I}$: Static pressure, in kN/m^2, as defined in [2.3.2]

$P_{W\text{-}I}$: Dynamic impact pressure, in kN/m^2, as defined in [2.5.1].

2.3 Static pressure

2.3.1 Static pressure to be used in combination with the dynamic sloshing pressure

The static pressure $P_{S\text{-}SL}$ to be used in combination with the dynamic sloshing pressure defined in [2.4] is to be obtained, in kN/m^2, from the following formulae:

- for $z < d_F + z_{min}$:

  $P_{S\text{-}SL} = \rho_L\, g\, (d_F + z_{min} - z) + P_{pv}$

- for $z \geq d_F + z_{min}$:

  $P_{S\text{-}SL} = P_{pv}$

2.3.2 Static pressure to be used in combination with the dynamic impact pressure

The static pressure $P_{S\text{-}I}$ to be used in combination with the dynamic impact pressure defined in [2.5] is to be obtained, in kN/m^2, from the following formulae:

- for $z < 0,7\,H + z_{min}$:

  $P_{S\text{-}I} = \rho_L\, g\, (0,7\,H + z_{min} - z) + P_{pv}$

- for $z \geq 0,7\,H + z_{min}$:

  $P_{S\text{-}I} = P_{pv}$

2.4 Dynamic sloshing pressure

2.4.1 The sloshing pressure $P_{W\text{-}SL}$ is obtained, in kN/m^2, from the following formulae (see Fig 2):

$$P_{W\text{-}SL} = 0 \qquad \text{for } z \leq 0,8\,d_F + z_{min}$$

$$P_{W\text{-}SL} = \left(5\frac{z - z_{min}}{d_F} - 4\right)\alpha P_0 \qquad \text{for } 0,8\,d_F + z_{min} < z \leq d_F + z_{min}$$

$$P_{W\text{-}SL} = \left(6 - 5\frac{z - z_{min}}{d_F}\right)\alpha P_0 \qquad \text{for } d_F + z_{min} < z < 1,2\,d_F + z_{min}$$

$$P_{W\text{-}SL} = 0 \qquad \text{for } z \geq 1,2\,d_F + z_{min}$$

where:

P_0 : Reference pressure defined in Tab 1 for longitudinal and transverse liquid motion.

α : Coefficient taken equal to (see Fig 3):

$$\alpha = \frac{d_F}{0,6H} \qquad \text{for } d_F < 0,6H$$

$$\alpha = 1 \qquad \text{for } 0,6H \leq d_F \leq 0,7H$$

$$\alpha = \frac{H - d_F}{0,3H} \qquad \text{for } d_F > 0,7H$$

Figure 2 : Sloshing pressure $P_{W\text{-}SL}$

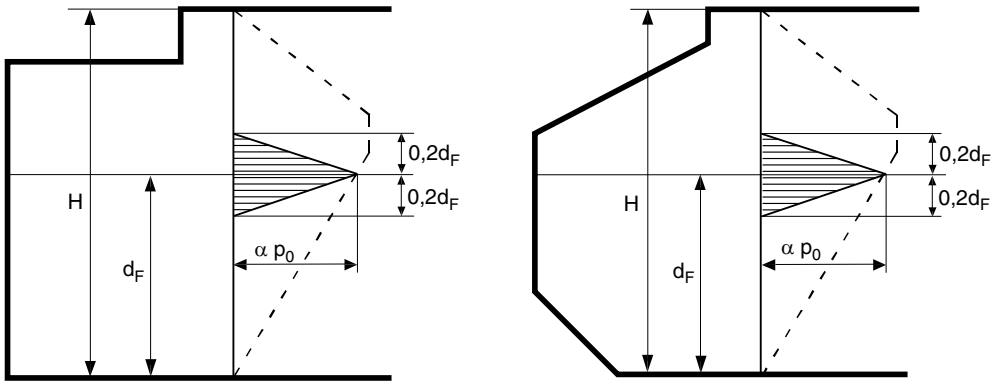


Figure 3 : Coefficient α

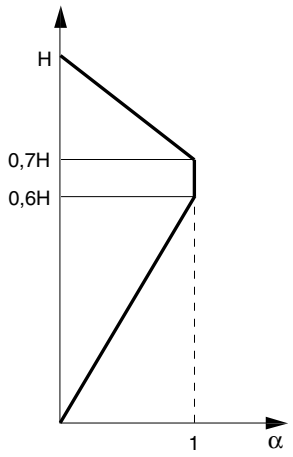


Table 1 : Reference pressure P_0 for calculation of sloshing, and dynamic impact pressure P_{W-I}

Liquid motion direction	Reference pressure P_0, in kN/m²	Dynamic impact pressure P_{W-I}, in kN/m²
Longitudinal	$0,84\varphi_P\rho_L g S \ell_C \varphi \frac{\pi}{180}$	$\varphi_P\rho_L g \ell_C \left(0,9 + \frac{\ell_C}{L}\right)(5 + 0,015L)\varphi\frac{\pi}{180}$
Transverse	$1,93\varphi_R\rho_L g b_C \sqrt{B}\left(1 - 0,3\frac{B}{b_C}\right)\theta\frac{\pi}{180}$	$0,61\varphi_R\rho_L g(0,75B - 8)b_C\theta\frac{\pi}{180}$

Note 1:

φ_P : Coefficient defined as follows:

- $\varphi_P = 1,0$ in the case of smooth tanks or tanks with bottom transverses whose height, in m, measured from the tank bottom, is less than 0,1 H
- $\varphi_P = 0,4$ in the case of tanks with bottom transverses whose height, in m, measured from the tank bottom, is not less than 0,1 H

S : Coefficient defined as follows:

- $S = 1 + 0,02\ L$ if $L \leq 200$ m
- $S = 3 + 0,01\ L$ if $L > 200$ m

φ_R : Coefficient defined as follows:

- if $b_C / B \leq 0,3$: $\varphi_R = 0$
- if $b_C / B > 0,3$:
  - $\varphi_R = 1,0$ in case of smooth tanks or tanks with bottom girders whose height, in m, measured from the tank bottom, is less than 0,1 H
  - $\varphi_R = 0,4$ in case of tanks with bottom girders whose height, in m, measured from the tank bottom, is not less than 0,1 H

2.4.2 Sloshing pressure on tank bottom transverses in the case of longitudinal liquid motion

The sloshing pressure P_{W-SL} to be considered as acting on tank bottom transverses is obtained, in kN/m², from the following formula:

$$P_{W-SL} = 0,84\ \rho_L\ g\ (1,95 - 0,12\ n)\ (z - z_{min})$$

where:

n : Number of bottom transverses in the tank.

2.5 Dynamic impact pressure

2.5.1 The dynamic impact pressure P_{W-I} is obtained, in kN/m², from the formulae defined in Tab 1 for longitudinal and transverse liquid motions.

Where the upper part of a transverse bulkhead or longitudinal bulkhead, inner side or side is sloped, the dynamic impact pressure P_{W-I} may be multiplied by the coefficient ϕ, to be obtained from the following formula:

$$\phi = 1 - \frac{h_T}{0,3H}$$

without being taken less than 0

where:

h_T : Height, in m, of the sloped part of the transverse or longitudinal bulkhead, inner side or side.

2.6 Alternative methods

2.6.1 The Society may accept that the dynamic impact pressure or dynamic sloshing pressure are evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank dimensions and the ship characteristics. The calculations are to be submitted to the Society for verification.

3 Pressures and forces due to dry bulk cargo

3.1 Application

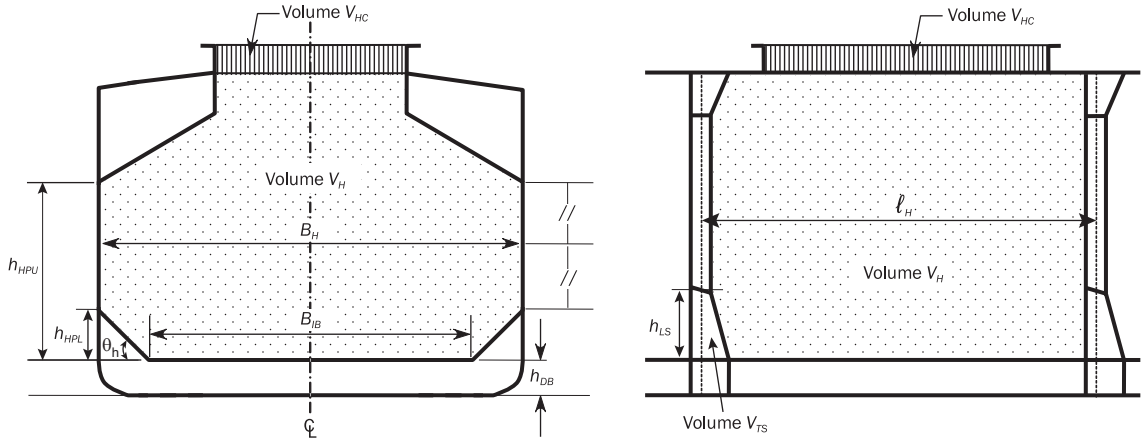
3.1.1 The pressures and forces due to dry cargo in bulk in a cargo hold are to be determined both for fully and partially filled cargo holds according to [3.4] and [3.5].

3.2 Hold definitions

3.2.1 Geometrical characteristics

The main geometrical elements of a dry bulk cargo hold are given in Fig 4.

Figure 4 : Definition of dry bulk cargo hold parameters



3.2.2 Fully and partially filled cargo holds

The definitions of a fully and partially filled dry bulk cargo holds are as follow:

a) Fully filled hold:

The dry bulk cargo density is such that the cargo hold is filled up to the top of the hatch coaming, as shown in Fig 5.

The upper surface of the cargo and its effective height in the hold h_{BC} are to be determined in accordance with [3.3.1].

b) Partially filled hold:

The cargo density is such that the cargo hold is not filled up to the top of the hatch coaming, as shown in Fig 6 or Fig 7.

The upper surface of the cargo and its effective height in the hold h_{BC} are to be determined in accordance with [3.3.2].

3.3 Dry cargo characteristics

3.3.1 Definition of the upper surface of dry bulk cargo for full cargo holds

For a fully filled cargo hold as defined in [3.2.2], including non-prismatic holds, the effective upper surface of the cargo is an equivalent horizontal surface at $h_{BC,}$ in m, above inner bottom at centreline as shown in Fig 5.

The value of h_{BC} is to be calculated at mid length of the cargo hold at the midship, is to be kept constant over the cargo hold region area and is determined as follows:

$$h_{BC} = h_{HPU} + h_0$$

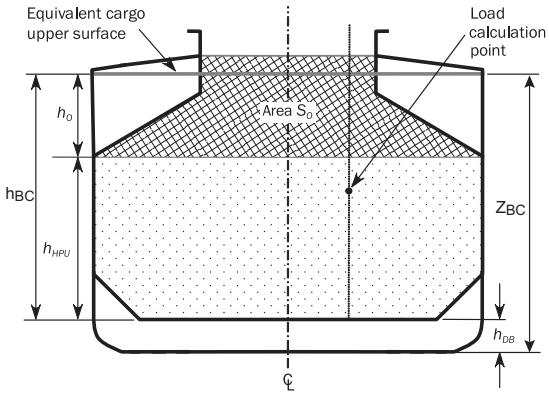
where:

$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{\ell_H}$$

S_0 : Shaded area, in m^2, above the lower intersection of topside tank and side shell or inner side, as the case may be, and up to the level of the intersection of the main deck with the hatch coaming, determined for the cargo hold at the midship as shown in Fig 5.

Figure 5 : Definition of effective upper surface of cargo for a full cargo hold



3.3.2 Definition of upper surface of dry bulk cargo for partially filled cargo holds

For any partially filled cargo hold, as defined in [3.2.2], including non-prismatic holds, the effective upper surface of the cargo is to be made of three parts:

- One central horizontal surface of breadth $B_H/2$, in m, at a height h_{BC-CL}, in m, above the inner bottom
- A sloped surface at each side with an angle $\psi/2$, in degrees, between the central horizontal surface, and the side shell or inner hull, as shown in Fig 6, or the hopper plating, as shown in Fig 7, as the case may be.

The height of cargo surface h_{BC}, in m, is to be calculated at mid length of the considered cargo hold and is to be taken as constant over the length of the hold as follows:

$$\text{For } |y| \le \frac{B_H}{4} \quad ; h_{BC} = h_{BC-CL}$$

$$\text{For } \frac{B_H}{4} < |y| \le \frac{B_2}{2} \quad ; h_{BC} = h_{BC-CL} - \left(|y| - \frac{B_H}{4}\right) \tan\frac{\psi}{2}$$

$$\text{For } |y| > \frac{B_2}{2} \quad ; h_{BC} = 0$$

where:

h_{BC-CL} : Height, in m, of the cargo surface at the centreline, as shown in Fig 6 and Fig 7

B_2 : Maximum breadth of the cargo, in m, as shown in Fig 6 and Fig 7

h_1 : Height, in m, to be taken as:

$$h_1 = \frac{M}{\rho_C \cdot B_H \cdot \ell_H} - \left(\frac{B_H + B_{IB}}{2B_H}\right) h_{HPL} - \frac{3}{16} B_H \tan\frac{\psi}{2} + \frac{V_{TS}}{B_H \cdot \ell_H}$$

- For $h_1 \ge 0$ as shown in Fig 6:

$$h_{BC-CL} = h_{HPL} + h_1 + h_2$$

$$h_2 = \frac{B_H}{4} \tan\frac{\psi}{2}$$

$$B_2 = B_H$$

- For $h_1 < 0$ as shown in Fig 7

$$h_{BC-CL} = h_{11} + h_{22}$$

$$h_{11} = h_{HPL}\left(\frac{B_2 - B_{IB}}{B_H - B_{IB}}\right)$$

$$h_{22} = \left(\frac{B_2}{2} - \frac{B_H}{4}\right) \tan\frac{\psi}{2}$$

$$B_2 = \sqrt{\frac{\frac{1}{\ell_H}\left(\frac{M}{\rho_C} + V_{TS}\right) + \frac{1}{2}\left(\frac{h_{HPL} \cdot B_{IB}^2}{B_H - B_{IB}}\right) + \frac{B_H^2}{16}\tan\frac{\psi}{2}}{\frac{1}{2}\left[\left(\frac{h_{HPL}}{B_H - B_{IB}}\right) + \frac{1}{2}\tan\frac{\psi}{2}\right]}}$$

3.3.3 Mass and density

The dry cargo mass and the density are to be taken as specified in Tab 2.

Figure 6 : Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 \geq 0$

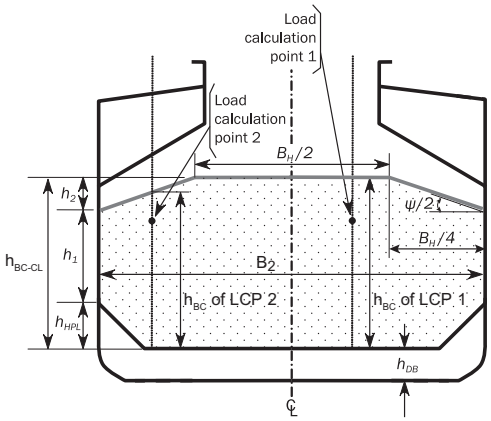


Figure 7 : Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 < 0$

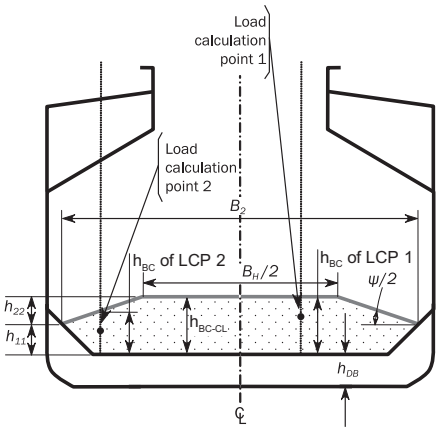


Table 2 : Dry bulk cargo mass (M) and density (ρ_C)

	Homogeneous loading condition		Alternate loading condition **(3)**	
	Fully filled hold	Partially filled hold **(1)**	Fully filled hold	Partially filled hold
Strength assessment	$M = M_{Full}$ • if $\rho_{C\text{-}lm} \leq 1,0$ $\rho_C = \rho_{C\text{-}lm}$ • if $\rho_{C\text{-}lm} > 1,0$ $\rho_C = \max\left(\frac{M_{Full}}{V_{Full}}; 1, 0\right)$	$M = M_H$ $\rho_C = 3,0$ **(2)**	$M = M_{HD} + 0,1\ M_H$ $\rho_C = \frac{M_{HD} + 0,1 \cdot M_H}{V_{Full}}$	$M = M_{HD} + 0,1\ M_H$ $\rho_C = 3,0$ **(2)**
Fatigue assessment	$M = M_H$ • if $\rho_{C\text{-}lm} \leq 1,0$ $\rho_C = \rho_{C\text{-}lm}$ • if $\rho_{C\text{-}lm} > 1,0$ $\rho_C = \frac{M_{Full}}{V_{Full}}$	NA	NA	$M = M_{HD}$ $\rho_C = 3,0$ **(2)**
Strength assessment in flooded conditions	$M = M_H$ • if $\rho_{C\text{-}lm} \leq 1,0$ $\rho_C = \rho_{C\text{-}lm}$ • if $\rho_{C\text{-}lm} > 1,0$ $\rho_C = \frac{M_{Full}}{V_{Full}}$	$M = M_H$ $\rho_C = 3,0$ **(2)**	$M = M_{HD}$ $\rho_C = \frac{M_{HD}}{V_{Full}}$	$M = M_{HD}$ $\rho_C = 3,0$ **(2)**

(1) Applicable only if $\rho_{C\text{-}lm}$ is greater than 1,0

(2) To be taken as 3,0 unless an alternative maximum cargo density is specified in the loading manual.

(3) ρ_C=1,78t/m³ is to be considered for the specific alternate loading condition «hold loaded with $\rho_C \leq 1,78$t/m³»

Note 1:

$\rho_{C\text{-}lm}$: Maximum cargo density specified in the loading manual.

3.3.4 FE application

The following process is to be applied for the bulk cargo pressure loads used in FE analysis:

a) Determine h_{BC} according to [3.3.1] for fully filled cargo hold or [3.3.2] for partially filled cargo hold.

b) Determine the corresponding static pressure as defined in [3.4.2] and static shear pressure as defined in [3.5.2] using ρ_c and apply them in the FE model.

c) Calculate the actual mass of cargo, M_{actual}, in t.

d) Determine the effective cargo density, in t/m³:

$$\rho_{eff} = \frac{M}{M_{actual}} \rho_c$$

e) Calculate the final pressure distribution and shear load using ρ_{eff} instead of ρ_c.

3.4 Dry bulk cargo pressures

3.4.1 Total pressure

The total pressure due to dry bulk cargo acting on any load point of a cargo hold boundary, in kN/m², is to be taken as:

- For strength assessment in intact condition for static design load scenarios given in Ch 5, Sec 7:

  $P_{in} = P_{bs}$

- For strength assessment in intact condition and fatigue assessment for static + dynamic design load scenarios given in Ch 5, Sec 7:

  $P_{in} = P_{bs} + P_{bd}$

but not less than 0.

where:

P_{bs} : Static pressure due to dry bulk cargo, in kN/m², as defined in [3.4.2]

P_{bd} : Dynamic inertial pressure due to dry bulk cargo in cargo holds, in kN/m², as defined in [3.4.3].

Static and dynamic pressures as defined in [3.4.2] and [3.4.3] for FE analysis are to be determined using ρ_{eff} instead of ρ_c.

3.4.2 Static pressure

The dry bulk cargo static pressure P_{bs}, in kN/m², is to be taken as:

$$P_{bs} = \rho_C \, g K_C \, (z_{BC} - z)$$

but not less than 0.

3.4.3 Dynamic pressure

The dry bulk cargo dynamic pressure P_{bd}, in kN/m², for each load case is to be taken as:

- For $z \leq z_{BC}$:

$$P_{bd} = \rho_C \left[\frac{a_X \, (x_G - x) + a_Y \, (y_G - y)}{4} + f_{dc} \, K_C \, a_Z \, (z_{BC} - z) \right]$$

- For $z > z_{BC}$:

  $P_{bd} = 0$

Where:

f_{dc} : Dry cargo factor, taken as 1,0 for strength assessment and 0,5 for fatigue assessment

3.5 Shear load

3.5.1 Application

For FE strength assessment and FE fatigue assessment, the following shear load pressures are to be considered in addition to the dry bulk cargo pressures defined in [3.4] when the load point elevation, z, is lower or equal to z_{BC}

- For static (S) design load scenarios, given in Ch 5, Sec 7: Static shear load, $P_{bs\text{-}s}$, due to gravitational forces acting on hopper tanks and lower stools plating, as defined in [3.5.2].

- For static plus dynamic (S+D) design load scenarios, given in Ch 5, Sec 7: The following dynamic shear load pressures:
  - for the hopper tank and the lower stool plating, as defined in [3.5.3]:

    $P_{bs-s} + P_{bs-d}$
  - for the inner bottom plating in the longitudinal direction, as defined in [3.5.4]:

    P_{bs-dx}
  - for the inner bottom plating in the transverse direction, as defined in [3.5.4]:

    P_{bs-dy}

Shear loads as defined in [3.5.2] to [3.5.4] for FE analysis are to be determined using ρ_{eff} instead of ρ_C.

3.5.2 Static shear load on the hopper tank and lower stool plating

The static shear load pressure, P_{bs-s} (positive downward to the plating) due to dry bulk cargo gravitational forces acting on hopper tank and lower stool plating, in kN/m², is to be taken as:

$$P_{bs-s} = \rho_C \, g \, \frac{(1 - K_C) \, (z_{BC} - z)}{\tan\alpha_p}$$

3.5.3 Dynamic shear load on the hopper tank and lower stool plating

The dynamic shear load pressure, P_{bs-d} (positive downward to the plating) due to dry bulk cargo forces on the hopper tank and lower stool plating, in kN/m², for each dynamic load case is to be taken as:

$$P_{bs-d} = \rho_C \, a_z \, \frac{(1 - K_C) \, (z_{BC} - z)}{\tan\alpha_p}$$

3.5.4 Dynamic shear load along the inner bottom plating for FE analyses

The dynamic shear load pressures, P_{bs-dx} in the longitudinal direction (positive to bow) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m², for each dynamic load case is to be taken respectively as:

$$P_{bs-dx} = -0{,}75 \, \rho_C \, a_X \, h_{BC}$$

The dynamic shear load pressures, P_{bs-dy} in the transverse direction (positive to port) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m², for each dynamic load case is to be taken respectively as

$$P_{bs-dy} = -0{,}75 \, \rho_C \, a_y \, h_{BC}$$

The dynamic shear load pressures P_{bs-dx} and P_{bs-dy} are only used for FE strength assessment.

4 Pressures and forces due to dry cargoes in flooded conditions

4.1 Local loads on vertically corrugated transverse bulkheads in flooded conditions

4.1.1 Application

The pressure defined in this sub-article applies to vertically corrugated transverse watertight bulkheads of the cargo holds of ships intended for the carriage of dry cargoes in bulk for flooded condition assessment.

Each cargo hold is to be considered individually flooded, see Fig 8, Fig 9 and Fig 10.

Figure 8 : Flooded level below upper surface of bulk cargo

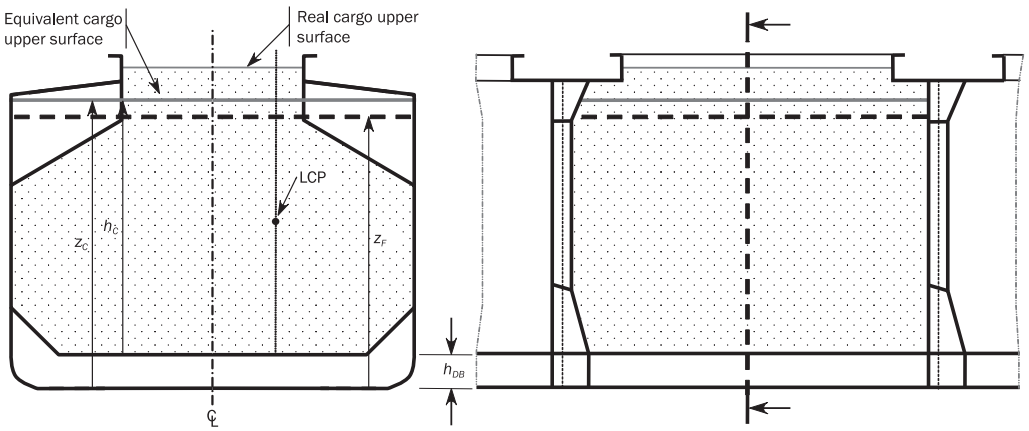


Figure 9 : Flooded level above upper surface of bulk cargo

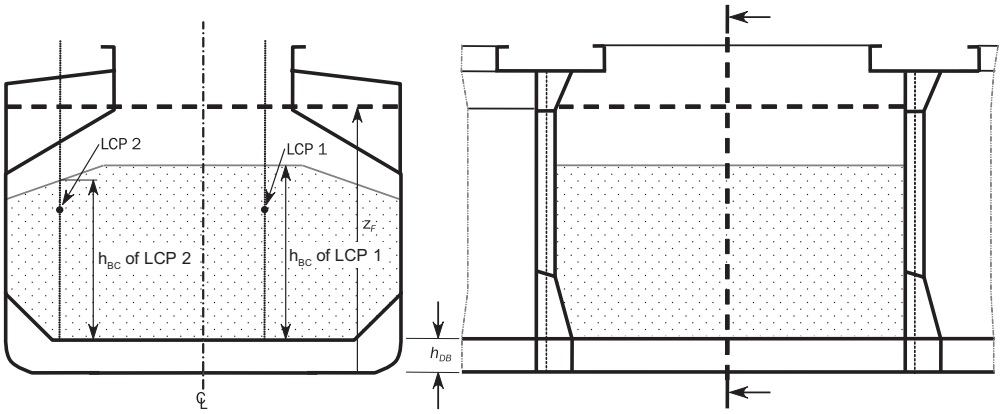
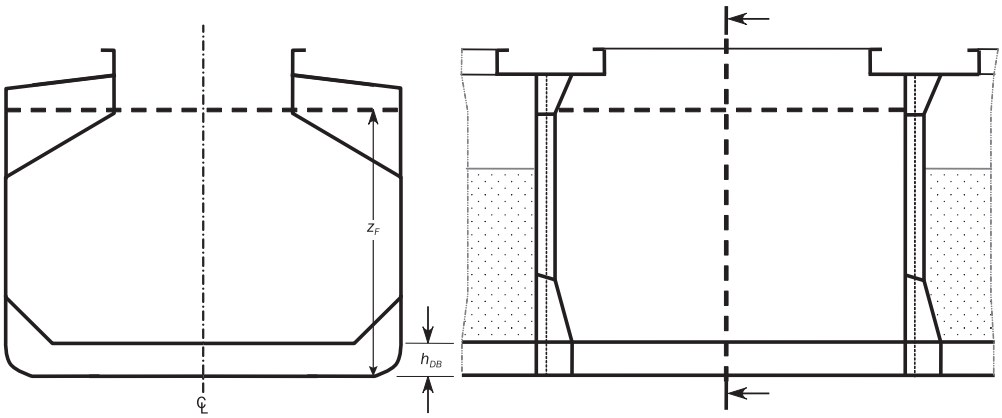


Figure 10 : Flooded cargo hold without cargo



4.1.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of those induced by cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered. This application is to be applied to **self-unloading bulk carrier ESP** where the unloading system maintains the watertightness during seagoing operations. In **self-unloading bulk carrier ESP** with unloading systems that do not maintain watertightness, the combination loads acting on the bulkheads in the flooded conditions are to be considered using the extent to which the flooding may occur.

The most severe combinations of cargo induced loads and flooded loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual considering the individual flooded condition of both loaded and empty holds:

- Homogeneous loading conditions
- Non-homogeneous loading conditions.

For the purpose of this article, the following items are defined as:

- Design load limits:

  The specified design load limits for the cargo holds are to be represented by loading conditions defined by the designer in the loading manual.

- Maximum cargo mass to consider:

  Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1,78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the top of the hatch coaming.

- Homogeneous loading conditions:

  Homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling level, evaluated for each hold, does not exceed 1,20, to be corrected for different cargo densities.

- Packed cargoes:

  Holds carrying packed cargoes (such as steel mill products) are to be considered as empty.

- Unconsidered loading conditions:

  Non-homogeneous partially filled loading conditions associated with Multi-port (MP) loading and unloading operations do not need to be considered for the verification of these requirements.

Table 3 : Flooded level z_F, in m, for vertically corrugated transverse bulkheads

Ship type	Loading condition	Vertically corrugated transverse bulkhead position	
		Foremost	Others
Ships less than 50,000 t deadweight with Type B freeboard	Non-homogeneous loading conditions with cargo density less than 1,78 t/m³	$z_F = 0,9\ D_1$	$z_F = 0,8\ D_1$
	Other cases	$z_F = 0,95\ D_1$	$z_F = 0,85\ D_1$
Other ships	Non-homogeneous loading conditions with cargo density less than 1,78 t/m³	$z_F = 0,95\ D_1$	$z_F = 0,85\ D_1$
	Other cases	$z_F = D_1$	$z_F = 0,9\ D_1$

4.1.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Tab 3.

4.1.4 Flooded patterns

Three different flooded patterns are to be considered:

- the flooded level is below the upper surface of the cargo, (see Fig 8: $z_{BC} > z_F$)
- the flooded level is above the upper surface of the cargo, (see Fig 9: $z_{BC} \leq z_F$)
- the flooded hold is empty, (see Fig 10: $z_{BC} = h_{DB}$).

4.1.5 Pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The static pressure $P_{bf\text{-}s}$, in kN/m², at any point of the vertically corrugated transverse bulkhead located at a level z from the baseline is given in Tab 4 for each flooded pattern defined in [4.1.4].

The force $F_{bf\text{-}s}$, in kN, acting on a corrugation of a transverse bulkhead is given by Tab 5 for each flooded pattern defined in [4.1.4].

where:

$P_{bf\text{-}s\text{-}LE}$: Static pressure calculated according to Tab 4 for $z = h_{LS} + h_{DB}$.

4.1.6 Pressures and forces on vertically corrugated transverse bulkheads of non-flooded cargo holds

The static pressure P_{bs}, in kN/m², at a point of the vertically corrugated transverse bulkhead, located at the level z from the baseline, due to dry bulk cargo of a non-flooded cargo hold acting on the intact side of the transverse bulkhead which is flooded on the other side is to be taken as:

$$P_{bs} = \rho_C\ g\ K_{C-f}\ (z_{BC} - z)$$

but not less than 0.

The resultant force F_{bs}, in kN, acting on a corrugation is to be taken as:

$$F_{bs} = \rho_C\ g s_{cg}\ \frac{(z_{BC} - h_{DB} - h_{LS})^2}{2}\ K_{C-f}$$

Table 4 : Static pressure on vertically corrugated transverse bulkhead of a flooded cargo hold $P_{bf\text{-}s}$

Flooded case	Load point position	Pressure $P_{bf\text{-}s}$, in kN/m²
$z_{BC} > z_F$	$z > z_{BC}$	$P_{bf-s} = 0$
	$z_{BC} \geq z \geq z_F$	$P_{bf-s} = \rho_C\ g\ (z_{BC} - z)\ K_{C-f}$
	$z_F > z \geq h_{DB}$	$P_{bf-s} = \rho g\ (z_F - z) + [\rho_C\ (z_{BC} - z) - \rho\ (1 - perm)\ (z_F - z)]\ g K_{C-f}$
$h_{DB} \leq z_{BC} \leq z_F$	$z > z_F$	$P_{bf-s} = 0$
	$z_F \geq z \geq z_{BC}$	$P_{bf\text{-}s} = \rho g\ (z_F - z)$
	$z_{BC} > z \geq h_{DB}$	$P_{bf-s} = \rho g\ (z_F - z) + [\rho_C - \rho\ (1 - perm)]\ g\ (z_{BC} - z)\ K_{C-f}$

Table 5 : Force acting on a corrugation in the flooded cargo holds $F_{bf\text{-}s}$

Flooded case	Force $F_{bf\text{-}s}$, in kN
$z_{BC} > z_F$	$F_{bf-s} = s_{cg}\left\{\rho_C\ g\ \frac{(z_{BC}-z_F)^2}{2}\ K_{C-f} + \left[\frac{\rho_C\ g\ (z_{BC}-z_F)\ K_{C-f} + P_{bf-s-LE}}{2}\right](z_F - h_{DB} - h_{LS})\right\}$
$z_F \geq z_{BC}$	$F_{bf-s} = s_{cg}\left\{\rho g\ \frac{(z_F-z_{BC})^2}{2} + \left[\frac{\rho g\ (z_F-z_{BC}) + P_{bf-s-LE}}{2}\right](z_{BC} - h_{DB} - h_{LS})\right\}$

4.1.7 Resultant pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The resultant pressure P_R, in kN/m², at each point of the bulkhead, and the resultant force F_R, in kN, acting on a corrugation, given in Tab 6, are to be considered for the assessment in flooded conditions of vertically corrugated transverse bulkhead structures, where:

$P_{bf\text{-}s}$: Pressure in the flooded cargo holds, in kN/m², as defined in [4.1.5]

P_{bs} : Pressure in the non-flooded cargo holds, in kN/m², as defined in [4.1.6]

$F_{bf\text{-}s}$: Force acting on a corrugation in the flooded cargo holds, in kN, as defined in [4.1.5]

F_{bs} : Force acting on a corrugation in the non-flooded cargo holds, in kN, as defined in [4.1.6].

Table 6 : Resultant pressure P_R and resultant force F_R on vertically corrugated transverse bulkhead in flooded condition

Loading condition	Resultant pressure P_R, in kN/m²	Resultant force F_R, in kN
Homogeneous	$P_R = P_{bf\text{-}s} - 0{,}8\ P_{bs}$	$F_R = F_{bf\text{-}s} - 0{,}8\ F_{bs}$
Alternate	$P_R = P_{bf\text{-}s}$	$F_R = F_{bf\text{-}s}$

4.2 Local loads on double bottom in flooded conditions

4.2.1 Application

The pressure defined in this sub-article applies to the double bottom in cargo holds of ships intended for the carriage of dry cargoes in bulk for flooded condition assessment.

Each cargo hold is to be considered individually flooded.

4.2.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold to which the double bottom belongs.

The most severe combinations of cargo induced loads and flooded loads are to be used, depending on the loading conditions included in the loading manual:

- Homogeneous loading conditions;
- Non-homogeneous loading conditions;
- Packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

4.2.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Tab 7.

Table 7 : Flooded level z_F, for double bottom in cargo hold region

Ship type	Cargo hold	
	Foremost	Others
Ships less than 50,000 t deadweight with Type-B freeboard	$z_F = 0{,}95\ D_1$	$z_F = 0{,}85\ D_1$
Other ships	$z_F = D_1$	$z_F = 0{,}9\ D_1$

5 Steel Coil Loads

5.1 General

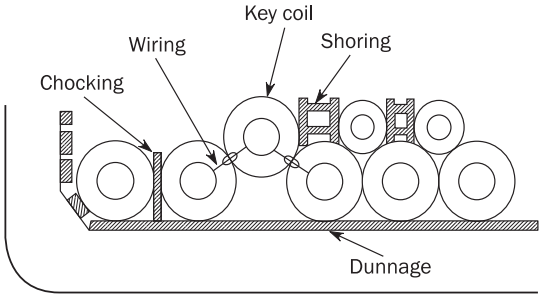
5.1.1 Application

The provision is determined by assuming Fig 11 as the standard means of securing steel coils loaded on wooden dunnage.

It is assumed that all the steel coils have the same characteristics.

In cases where steel coils are lined up in two or more tiers, formulae in [5.1.3] and [5.2] can be applied assuming that only the lowest tier of steel coils is in contact with hopper sloping plate or inner side plate. In other cases, scantling requirements are to be determined on a case-by-case basis.

Figure 11 : Inner bottom loaded by steel coils



5.1.2 Arrangement of steel coils on inner bottom

The two following arrangements of steel coils on the inner bottom are considered:

- The steel coils are positioned without respect to the location of the inner bottom floors, as shown in Fig 12. In this case, n_2 and ℓ_{lp} are given by Tab 8 and Tab 9.
- The steel coils are positioned with respect to the location of the inner bottom floors, as shown in Fig 13.

5.1.3 Arrangement of steel coils independently of the floor locations

For steel coils loaded without respect to the location of floors in the inner bottom, see Fig 12:

- The number n_2 of load point dunnages per elementary plate panels is to be found in comply with Tab 8.
- The distance ℓ_{lp}, in m, between outermost load point dunnages per elementary plate panel is to be found in comply with Tab 9.

Figure 12 : Steel coils loaded independently of inner bottom floors locations

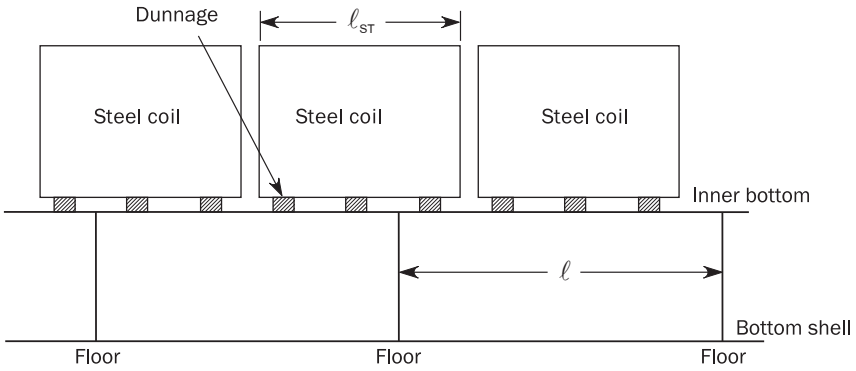
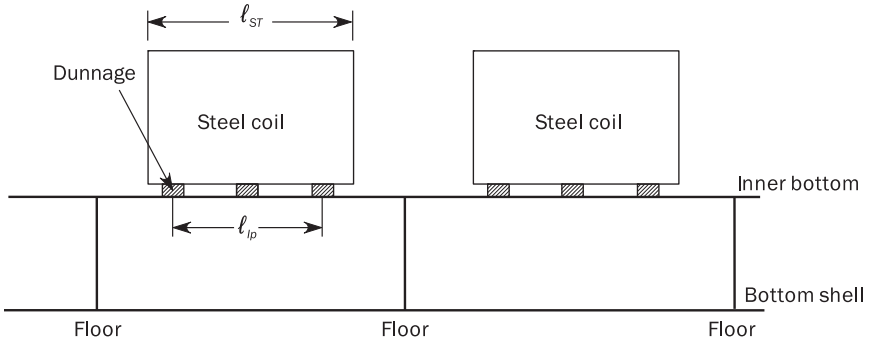


Figure 13 : Steel coils loaded between inner bottom floors



5.1.4 Arrangement of steel coils between floors

For steel coils loaded with respect to the locations of floors in the inner bottom, see Fig 13:

- The number n_2 of load point dunnages per elementary plate panels is to be taken as: $n_2 = n_3$
- The distance ℓ_{lp} between outermost load point dunnages per elementary plate panel is to be taken as the distance between the outermost dunnage supporting one row of steel coils.

Table 8 : Number n_2 of load point dunnages per elementary plate panel

n_2	n_3			
	2	3	4	5
1	$0 < \frac{\ell}{\ell_{st}} \le 0,5$	$0 < \frac{\ell}{\ell_{st}} \le 0,33$	$0 < \frac{\ell}{\ell_{st}} \le 0,25$	$0 < \frac{\ell}{\ell_{st}} \le 0,2$
2	$0,5 < \frac{\ell}{\ell_{st}} \le 1,2$	$0,33 < \frac{\ell}{\ell_{st}} \le 0,67$	$0,25 < \frac{\ell}{\ell_{st}} \le 0,5$	$0,2 < \frac{\ell}{\ell_{st}} \le 0,4$
3	$1,2 < \frac{\ell}{\ell_{st}} \le 1,7$	$0,67 < \frac{\ell}{\ell_{st}} \le 1,2$	$0,5 < \frac{\ell}{\ell_{st}} \le 0,75$	$0,4 < \frac{\ell}{\ell_{st}} \le 0,6$
4	$1,7 < \frac{\ell}{\ell_{st}} \le 2,4$	$1,2 < \frac{\ell}{\ell_{st}} \le 1,53$	$0,75 < \frac{\ell}{\ell_{st}} \le 1,2$	$0,6 < \frac{\ell}{\ell_{st}} \le 0,8$
5	$2,4 < \frac{\ell}{\ell_{st}} \le 2,9$	$1,53 < \frac{\ell}{\ell_{st}} \le 1,87$	$1,2 < \frac{\ell}{\ell_{st}} \le 1,45$	$0,8 < \frac{\ell}{\ell_{st}} \le 1,2$
6	$2,9 < \frac{\ell}{\ell_{st}} \le 3,6$	$1,87 < \frac{\ell}{\ell_{st}} \le 2,4$	$1,45 < \frac{\ell}{\ell_{st}} \le 1,7$	$1,2 < \frac{\ell}{\ell_{st}} \le 1,4$
7	$3,6 < \frac{\ell}{\ell_{st}} \le 4,1$	$2,4 < \frac{\ell}{\ell_{st}} \le 2,73$	$1,7 < \frac{\ell}{\ell_{st}} \le 1,95$	$1,4 < \frac{\ell}{\ell_{st}} \le 1,6$
8	$4,1 < \frac{\ell}{\ell_{st}} \le 4,8$	$2,73 < \frac{\ell}{\ell_{st}} \le 3,07$	$1,95 < \frac{\ell}{\ell_{st}} \le 2,4$	$1,6 < \frac{\ell}{\ell_{st}} \le 1,8$
9	$4,8 < \frac{\ell}{\ell_{st}} \le 5,3$	$3,07 < \frac{\ell}{\ell_{st}} \le 3,6$	$2,4 < \frac{\ell}{\ell_{st}} \le 2,65$	$1,8 < \frac{\ell}{\ell_{st}} \le 2,0$
10	$5,3 < \frac{\ell}{\ell_{st}} \le 6,0$	$3,6 < \frac{\ell}{\ell_{st}} \le 3,93$	$2,65 < \frac{\ell}{\ell_{st}} \le 2,9$	$2,0 < \frac{\ell}{\ell_{st}} \le 2,4$

Table 9 : Distance between outermost load point dunnages per elementary plate panel, ℓ_{lp}, in m

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnages			
2	$0,5\ell_{st}$	$0,33\ell_{st}$	$0,25\ell_{st}$	$0,2\ell_{st}$
3	$1,2\ell_{st}$	$0,67\ell_{st}$	$0,50\ell_{st}$	$0,4\ell_{st}$
4	$1,7\ell_{st}$	$1,20\ell_{st}$	$0,75\ell_{st}$	$0,6\ell_{st}$
5	$2,4\ell_{st}$	$1,53\ell_{st}$	$1,20\ell_{st}$	$0,8\ell_{st}$
6	$2,9\ell_{st}$	$1,87\ell_{st}$	$1,45\ell_{st}$	$1,2\ell_{st}$
7	$3,6\ell_{st}$	$2,40\ell_{st}$	$1,70\ell_{st}$	$1,4\ell_{st}$
8	$4,1\ell_{st}$	$2,73\ell_{st}$	$1,95\ell_{st}$	$1,6\ell_{st}$
9	$4,8\ell_{st}$	$3,07\ell_{st}$	$2,40\ell_{st}$	$1,8\ell_{st}$
10	$5,3\ell_{st}$	$3,60\ell_{st}$	$2,65\ell_{st}$	$2,0\ell_{st}$

5.1.5 Centre of gravity of steel coil cargo

The centre of gravity of the steel coil cargo of the considered cargo hold is to be taken at the following position:

a) Longitudinal position

x_{Gsc} is the X coordinate, in m, of the volumetric centre of gravity of the considered cargo hold with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1].

For better accuracy, in particular in the case of long cargo holds, the length of the holds may be divided into several sub-parts, X_{Gsc} being taken as the centre of gravity of the considered sub-part.

b) Transverse position

$$y_{Gsc} = \varepsilon \frac{B_H}{4}$$

c) Vertical position

$$z_{Gsc} = h_{DB} + \left[1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right]\frac{d_{sc}}{2}$$

where:

ε : Coefficient to be taken as:

- when a port side structural member is assessed:
  $\varepsilon = 1,0$
- when a starboard side structural member is assessed:
  $\varepsilon = -1,0$

5.2 Total loads

5.2.1 Total load on the inner bottom

The total load $F_{sc\text{-}ib}$, in kN, due to steel coil cargoes on the inner bottom is to be taken as:

$$F_{sc-ib} = \cos(f_\beta C_{XG}\,\varphi)\,\cos(C_{YG}\,\theta)\,F_{sc-ib-s} + F_{sc-ib-d}$$

but not less than 0

where:

$F_{sc\text{-}ib\text{-}s}$: Static load, in kN, on the inner bottom, given in [5.3.1]

$F_{sc\text{-}ib\text{-}d}$: Dynamic load, in kN, on the inner bottom, given in [5.4.1]

C_{XG}, C_{YG} : Load combination factors, as defined in Ch 5, Sec 2, [2.2].

5.2.2 Total load on the hopper side and the inner hull

The total load $F_{sc\text{-}hs}$, in kN, due to steel coil cargoes on the hopper side and the inner hull is to be taken as:

$$F_{sc-hs} = \frac{\cos(\theta_h + \varepsilon\, C_{YG}\,\theta)\,\cos(f_\beta C_{XG}\,\varphi)}{\cos\theta_h}\,F_{sc-hs-s} + F_{sc-hs-d}$$

but not less than 0.

where:

$F_{sc\text{-}hs\text{-}s}$: Static load, in kN, on the hopper side and the inner hull given in [5.3.2]

$F_{sc\text{-}hs\text{-}d}$: Dynamic load, in kN, on the hopper side and the inner hull given in [5.4.2]

C_{XG}, C_{YG} : Load combination factors, as defined in Ch 5, Sec 2, [2.2].

5.3 Static loads

5.3.1 Static loads on the inner bottom

The static load $F_{sc\text{-}ib\text{-}s}$, in kN, on the inner bottom due to steel coils is to be taken as:

$$F_{sc-ib-s} = M_{sc-ib}\,g$$

where:

$M_{sc\text{-}ib}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-ib} = K_S\,W\,\frac{n_1\,n_2}{n_3} \quad \text{for } n_2 \le 10 \text{ and } n_3 \le 5$$

$$M_{sc-ib} = K_S\,W n_1\,\frac{\ell}{\ell_{st}} \quad \text{for } n_2 > 10 \text{ or } n_3 > 5$$

K_S : Coefficient to be taken as:

- when steel coils are lined up in one tier with a key coil:
  $K_S = 1,4$
- in other cases:
  $K_S = 1,0$

5.3.2 Static load on the hopper side and the inner hull

The static load $F_{sc\text{-}hs\text{-}s}$, in kN, on the hopper side and the inner hull due to steel coils is to be taken as:

$$F_{sc-hs-s} = \cos\theta_h \cdot M_{sc-hs} \cdot g$$

where:

$M_{sc\text{-}hs}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-hs} = C_k \, W \, \frac{n_2}{n_3} \text{ for } n_2 \leq 10 \text{ and } n_3 \leq 5$$

$$M_{sc-hs} = C_k \, W \, \frac{\ell}{\ell_{st}} \text{ for } n_2 > 10 \text{ or } n_3 > 5$$

C_k : Coefficient to be taken as:

- when steel coils are lined up two or more tiers, or when steel coils are lined up one tier and key coil is located second or 3rd from hopper sloping plate or inner hull plate:
  $C_k = 3,2$
- for other cases:
  $C_k = 2,0$

5.4 Dynamic loads

5.4.1 Dynamic load on the inner bottom

The dynamic load $F_{sc\text{-}ib\text{-}d}$, in kN, on the inner bottom due to steel coils is to be taken as:

$$F_{sc-ib-d} = M_{sc-ib} \, a_z$$

where:

a_z : Vertical acceleration, in m/s^2, as defined in Ch 5, Sec 3, [3.2.4], calculated at the centre of gravity of the steel coil cargo of the considered cargo hold, given in [5.1.5].

5.4.2 Dynamic load on the hopper side and the inner hull

The dynamic load $F_{sc\text{-}hs\text{-}d}$, in kN, on the hopper side and the inner hull due to steel coils is to be taken as:

$$F_{sc-hs-d} = \varepsilon \cdot M_{sc-hs} \, [C_{YR} \, a_{roll} \Omega - f_\beta C_{YS} \, a_{sway} \, \sin\theta_h]$$

where:

Ω : Geometrical coefficient defined as:

$$\Omega = \sqrt{y_{Gsc}^2 + (R - z_{Gsc})^2} \cdot \sin\left(\tan^{-1}\left|\frac{y_{Gsc}}{R - z_{Gsc}}\right| - \theta_h\right)$$

C_{YS}, C_{YR} : Load combination factors, defined in Ch 5, Sec 2, [2.2]

a_{roll} : Roll acceleration, in rad/s^2, defined in Ch 5, Sec 3, [2.2.4]

a_{sway} : Sway acceleration, in m/s^2, as defined in Ch 5, Sec 3, [2.2.2]

ε : Coefficient defined in [5.1.5]

y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [5.1.5]

z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [5.1.5].

6 Loads on decks and platforms

6.1 Pressure due to distributed load

6.1.1 In accommodation and machinery spaces and when a uniform cargo is carried on deck, a distributed load is to be applied. The static and dynamic pressure due to this distributed load is to be considered.

The total pressure P_{dl}, in kN/m^2, due to accommodation or machinery loads or uniform cargo for the static design load scenarios is to be taken as:

$$P_{dl} = P_{dl\text{-}s}$$

The total pressure P_{dl}, in kN/m^2, due to accommodation or machinery loads or uniform cargo for the static + dynamic design load scenario is to be derived for each dynamic load case and is to be taken as:

$P_{dl} = P_{dl\text{-}s} + P_{dl\text{-}d}$

where:

$P_{dl\text{-}s}$: Static pressure, in kN/m², due to accommodation or machinery loads or uniform cargo, to be defined by the Designer without being less than the values given in Tab 10.

For deck loaded with dry uniform cargo, when the $P_{dl\text{-}s}$ value is not specified by the designer, it may be taken equal to 6,9 h_{TD}

$P_{dl\text{-}d}$: Dynamic pressure, in kN/m², due to uniform cargo, to be taken as:

$$P_{dl\text{-}d} = P_{dl\text{-}s}\frac{a_Z}{g}$$

a_Z : Vertical acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

h_{TD} : compartment tweendeck height at side, in m.

6.1.2 Ships with additional service feature heavycargo

For ships with the additional service feature **heavycargo [AREA, X1 kN/m² - AREA, X2 kN/m² - ...]** (see Pt A, Ch 1, Sec 2, [4.2.2]), the values of $p_{dl\text{-}s}$, in kN/m², are to be specified by the Designer for each AREAi, according to [6.1.1], and introducing as Xi values in the above service feature.

Table 10 : Minimum static pressure due to distributed loads

Type of compartment	$P_{dl\text{-}s}$, in kN/m²
Large public spaces, such as restaurants, halls, cinemas, lounges	5,0
Muster stations	5,0
Large rooms, such as: • rooms with fixed furniture • games and hobbies rooms, hospitals	3,0
Cabins	3,0
Other accommodation compartments	2,5
Storage rooms	5,0
Machinery spaces	10,0
Technical spaces, such as AC rooms, elevators machinery space, electrical facilities, pump rooms	5,0
Other decks and platforms	10,0
Dry uniform cargo	10,0

6.2 Concentrated force due to unit cargo

6.2.1 When a unit cargo is carried on a deck, a concentrated load is to be applied. The static and dynamic concentrated forces due to this unit cargo are to be considered, when a direct analysis is applied for stiffeners or for primary supporting members, such as in Ch 7, Sec 5, [1.7] or in Ch 7, Sec 6, [2.2], respectively.

The concentrated force $F_{u\text{-}s}$, in kN, due to this unit cargo for the static design load scenarios is to be taken, in the z direction, as:

$F_{u\text{-}s} = -m_U\, g$

The concentrated force $F_{u\text{-}d}$, in kN, due to this unit cargo for the static + dynamic design load scenarios is to be derived from the dynamic load cases, with components to be taken as defined in Tab 11.

Table 11 : Force $F_{u\text{-}d}$ due to unit cargo

Direction	$F_{u\text{-}d}$, in kN, on exposed deck	$F_{u\text{-}d}$, in kN, on non-exposed deck
x	$-m_U\, a_X$	$-m_U\, a_{X\text{-}env}$
y	$-m_U\, a_Y$	$-m_U\, a_{Y\text{-}env}$
z	$-m_U\, (a_Z + g)$	$-m_U\, (a_{Z\text{-}env} + g)$

Note 1:

m_U : Mass of the unit cargo carried, in t

a_X, a_Y, a_Z : Accelerations, in m/s², at the centre of gravity of the unit cargo carried for the considered load case, to be obtained according to Ch 5, Sec 3, [3.2].

$a_{X\text{-}env}$, $a_{Y\text{-}env}$, $a_{Z\text{-}env}$: Envelope of accelerations, in m/s², at the centre of gravity of the unit cargo carried for the considered load case, to be obtained according to Ch 5, Sec 3, [3.3].

7 Wheeled cargo

7.1 Application

7.1.1 General

Caterpillar trucks and unusual vehicles are considered by the Society on a case by case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case by case basis.

7.1.2 Tyred vehicles

The forces transmitted through the tyres are considered as uniformly distributed pressure on the tyre print area, which dimensions are to be given by the Designer together with the arrangement of wheels on axles, the load per axles and the tyre pressure.

For the assessment of stiffeners and primary supporting members, such forces are considered as concentrated in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

7.1.3 Non-tyred vehicles

The requirements of [7.1.2] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, all the forces transmitted are to be considered as concentrated at the contact area centre.

7.1.4 Fork-lift trucks

Loaded fork-lift trucks are to be considered only for strength assessment in the harbour design load scenario (H: S).

7.2 Forces due to wheeled cargo

7.2.1 Total force induced by a single wheel

The total wheel force P_0, in kN, for the static design load scenarios is to be taken as:

$$P_0 = F_{W\text{-}S}$$

The total wheel force P_0, in kN, for the dynamic design load scenarios is to be taken as:

$$P_0 = F_{W\text{-}S} + F_{W\text{-}D}$$

where:

$F_{W\text{-}S}$: Static wheel force defined in [7.2.2]

$F_{W\text{-}D}$: Dynamic wheel force defined in [7.2.3].

7.2.2 Static force

The static wheel force $F_{W\text{-}S}$, in kN, for the static design load scenarios is to be taken, in the z direction, as:

$$F_{W\text{-}S} = -M\,g$$

Where:

M : Mass supported by a single wheel, in t, taken equal to:

$$M = \frac{Q_A}{n_W}$$

Q_A : Axle load, in t

n_W : Number of individual wheels for the axle considered.

7.2.3 Dynamic force

The dynamic wheel force $F_{W\text{-}D}$, in kN, for the static + dynamic design load scenarios is to be derived from the dynamic load cases, with components to be taken as defined in Tab 12.

Table 12 : Dynamic forces due to wheeled cargo

Direction	F_{W-D}, in kN, General **(1)**	F_{W-D}, in kN, Racking analysis **(2)**
x	–	–
y	–	$-M\ a_Y$
z	$-\alpha\ M\ a_Z$	$-\alpha\ M\ a_Z$

(1) This condition defines the force, applied by one wheel, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, as defined in Part B, Chapter 6.

(2) This condition is to be considered for the racking analysis of ships granted with the service notation **PCTC**, **PCC**, **ro-ro cargo ship** or **ro-ro passenger ship**, as defined in Ch 7, App 1, with M taken equal to the mass, in t, of wheel loads located on the structural member under consideration.

Note 1:

M : Mass of the unit cargo carried, in t

a_Y, a_Z : Accelerations, in m/s^2, at the centre of gravity of the considered vehicle for the considered load case, to be obtained according to Ch 5, Sec 3, [3.2].

α : Coefficient accounting for shock absorbers, taken equal to:

- 0,5 in general
- 1,0 for landing gears of trailers.

8 Loads due to containers

8.1 Forces applied to containers

8.1.1 Centre of gravity of a container

The centre of gravity of each container with its cargo is to be taken at 45% of the container height.

8.1.2 Static and dynamic forces

The static and dynamic forces applied to one container located at tier "i", as defined in Fig 14, are to be obtained, in kN, as specified in Tab 13.

Figure 14 : Container levels in a stack

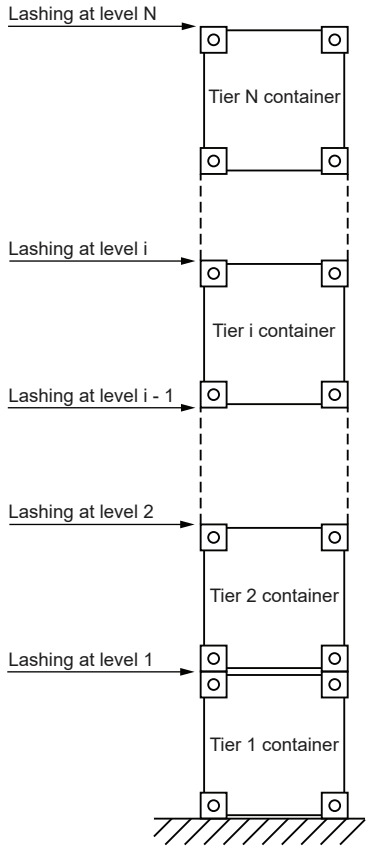


Table 13 : Container at tier "i" - Static and dynamic forces, in kN

Direction	Static force	Dynamic force
x	–	$F_{W,X,i} = -M_i\, a_{X\text{-}env}$
y	–	$F_{W,Y,i} = -M_i\, a_{Y\text{-}env}$
z	$F_{S,i} = -M_i\, g$	$F_{W,Z,i} = -M_i\, a_{Z\text{-}env}$

Note 1:

M_i : Mass, in t, of the container at tier "i"

$a_{X\text{-}env}$, $a_{Y\text{-}env}$, $a_{Z\text{-}env}$: Envelope of accelerations, in m/s², at the centre of gravity of the container, to be obtained according to Ch 5, Sec 3, [3.3].

8.2 Stacks of containers

8.2.1 Static and dynamic forces

The static and dynamic forces and the wind force are to be considered as defined in [8.1.2] and Ch 5, Sec 5, [8.1], respectively, and the forces transmitted at the corners of a stack are to be obtained as specified in Tab 14 (see also Fig 15).

8.2.2 Empty containers

When empty containers are stowed at the top of a stack, static and dynamic forces are to be derived considering the weight of empty containers equal to:

- 2,5 t for twenty feet containers
- 3,5 t for forty feet containers
- 3,5 t for forty-five feet containers.

For other container sizes, the weight of empty containers is to be taken equal to 0,14 times the maximum gross weight of the container.

8.2.3 Effect of cell guides

Where cell guides support the containers stowed in holds, absolute value of $R_{W,MY}$ calculated according to [8.2.1], may be assumed not to be greater than 160 kN, provided that arrangements of cell guides and horizontal transverse cross-ties effectively block the container corners.

Any other arrangement may be accepted, to the Society's satisfaction.

Table 14 : Containers - Static, dynamic and wind forces

	Static force F_S and dynamic and wind force F_W, in kN, acting on each container stack	Vertical static force R_S and dynamic and wind force R_W, in kN, transmitted at the corners of each container stack **(1)**
Static force	$F_S = \sum_{i=1}^{N_C} F_{S,i}$	$R_S = \frac{F_S}{4}$
Dynamic forces	• in x direction: $F_{W,X} = \sum_{i=1}^{N_C} (F_{W,X,i} + F_{X,wind,i})$	$R_{W,1} = \frac{F_{W,Z}}{4} + R_{W,MY} + R_{W,MX}$ $R_{W,2} = \frac{F_{W,Z}}{4} - R_{W,MY} - R_{W,MX}$
	• in y direction: $F_{W,Y} = \sum_{i=1}^{N_C} (F_{W,Y,i} + F_{Y,wind,i})$	$R_{W,3} = \frac{F_{W,Z}}{4} - R_{W,MY} + R_{W,MX}$ $R_{W,4} = \frac{F_{W,Z}}{4} + R_{W,MY} - R_{W,MX}$
	• in z direction: $F_{W,Z} = \sum_{i=1}^{N_C} F_{W,Z,i}$	$R_{W,MY} = \frac{N_C h_C F_{W,X}}{4 \ell_C}$ $R_{W,MX} = \frac{N_C h_C F_{W,Y}}{4 b_C}$

(1) Effect of cell guides may be taken into consideration according to [8.2.3].

Note 1:

$F_{X,wind,i}$: Wind force in the longitudinal direction as defined in Ch 5, Sec 5, [8.1]

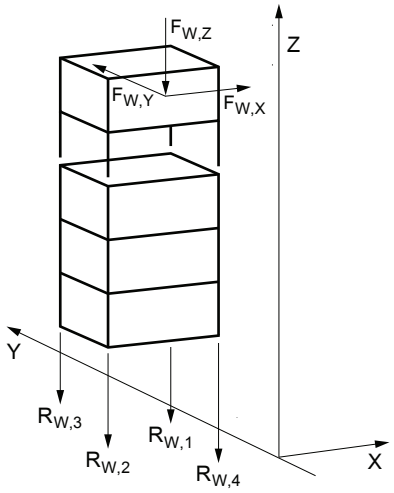
$F_{Y,wind,i}$: Wind force in the transverse direction as defined in Ch 5, Sec 5, [8.1]

N_C : Number of containers per stack

h_C : Height, in m, of a container

ℓ_C, b_C : Dimensions, in m, of the container stack in the ship longitudinal and transverse directions, respectively.

Figure 15 : Stack of containers and forces



9 Loads on hatch covers

9.1 Application

9.1.1 The loads on hatch covers and coamings are to be applied for strength assessment only.

9.2 Cargo loads

9.2.1 Distributed loads

The distributed load on hatch covers p_L, in kN/m^2, due to uniform cargo loads and resulting from heave and pitch (i.e. ship in upright condition), is to be determined according to the following formula:

$p_L = p_C (1 + \alpha_V)$

where:

p_C : Uniform cargo load, in kN/m^2

α_V : Vertical acceleration addition, taken equal to: $\alpha_V = m F$

m : Coefficient taken equal to:

- for $0 \leq x/L \leq 0,2$:

$$m = m_0 - 5(m_0 - 1)\frac{x}{L}$$

- for $0,2 < x/L \leq 0,7$:

$$m = 1$$

- for $0,7 < x/L \leq 1,0$:

$$m = 1 + \left(\frac{m_0 + 1}{0,3}\right)\left(\frac{x}{L} - 0,7\right)$$

m_0 : Coefficient taken equal to: $m_0 = 1,5 + F$

F : Coefficient taken equal to:

$$F = 0,11\frac{V_0}{\sqrt{L}}$$

V_0 : Maximum speed, in knots, at summer load line draught, to be taken not less than $L^{1/2}$.

9.2.2 Concentrated loads

The concentrated load P, in kN, due to unit cargo (except container) and resulting from heave and pitch (i.e. ship in upright condition), is to be determined as follows:

$P = -P_S (1 + \alpha_V)$

where:

P_S : Concentrated force due to unit cargo, in kN

α_V : Vertical acceleration addition, as defined in [9.2.1].

9.2.3 Container loads in upright condition

Where containers are stowed on hatch covers, the load P, in kN, applied at each corner of a container stack and resulting from heave and pitch (i.e. ship in upright condition), is to be determined as follows:

$$P = -9,81\frac{M}{4}(1+\alpha_V)$$

where:

M : Maximum designed mass of the container stack, in t

α_V : Vertical acceleration addition, as defined in [9.2.1].

9.2.4 Container loads in heel condition

Where containers are stowed on hatch covers, the following loads A_Z, B_Z and B_y, in kN, applied at each corner of a container stack and resulting from heave, pitch and rolling motion (i.e. ship in heel condition), are to be determined as follows (see Fig 16):

A_Z, B_Z : Support forces in z-direction at the forward and aft stack corners, taken respectively equal to:

$$A_Z = -9,81\frac{M}{2}(1+\alpha_V)\left(0,45-0,42\frac{h_m}{b}\right)$$

$$B_Z = -9,81\frac{M}{2}(1+\alpha_V)\left(0,45+0,42\frac{h_m}{b}\right)$$

B_y : Support force in y-direction at the forward and aft stack corners, taken equal to:

$$B_y = -2,4\ M$$

where:

M : Maximum designed mass of the container stack, in t, taken as:

$$M = \sum_i W_i$$

α_V : Vertical acceleration addition, as defined in [9.2.1]

h_m : Designed height of the centre of gravity of the stack above hatch cover top, in m, calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container:

$$h_m = \sum_i \frac{z_i W_i}{M}$$

z_i : Distance from hatch cover top to the centre of ith container, in m

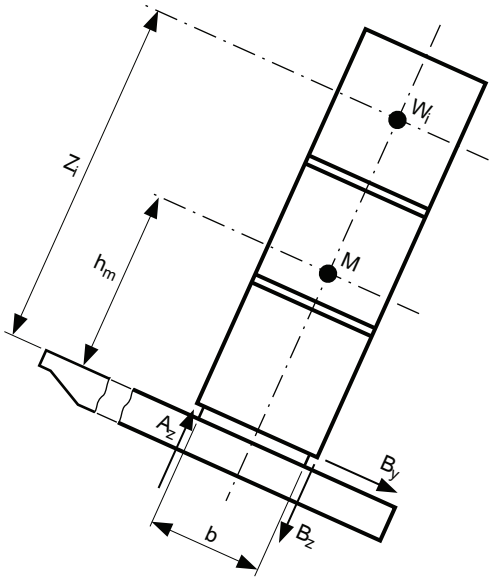
W_i : Weight of ith container, in t

b : Distance between midpoints of foot points, in m.

Values of A_z and B_z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

Note 1: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

Figure 16 : Forces due to container loads



9.2.5 Load cases with partial loading

The loads defined in [9.2.1], [9.2.2] and [9.2.4] are also to be considered for partial non homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Tab 15, are to be considered.

The load case "partial loading of container hatch covers" can be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks are also to be neglected (see Tab 15).

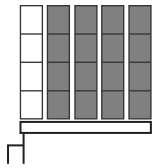
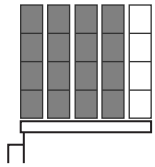
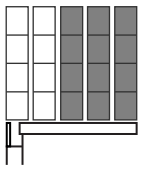
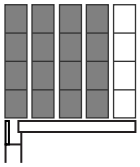
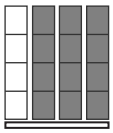
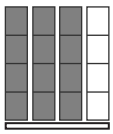
In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. The Society may require that additional partial load cases are to be considered.

9.2.6 Mixed stowage of 20' and 40' container on hatch cover

In the case of mixed stowage (20' and 40' container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40' containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20' containers.

Table 15 : Partial loading of container hatch covers

Heel direction	< (Heel towards coaming)	> (Heel opposite to coaming)
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stacks supported partially by the hatch cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

10 Design pressure for tank testing

10.1 Definition

10.1.1 In order to assess the structure, static design pressures, P_{ST}, in kN/m^2, are to be considered, as obtained from the formulae in Tab 16.

Table 16 : Tank testing design pressures

Compartment	Still water pressure P_{ST}, in kN/m^2
Double bottom tanks Double side tanks	The greater of the following: $P_{ST} = 10\,[(z_{top} - z) + h_{OF}]$ $P_{ST} = 10\,[(z_{top} - z) + 2{,}4]$ $P_{ST} = 10\,(z_{bd} - z)$
Fuel oil tanks	The greater of the following: $P_{ST} = 10\,[(z_{top} - z) + h_{OF}]$ $P_{ST} = 10\,[(z_{top} - z) + 2{,}4]$ $P_{ST} = 10\,[(z_{top} - z) + 0{,}1\,P_{pv}]$ $P_{ST} = 10\,(z_{bd} - z)$
Cargo oil tanks	The greater of the following: $P_{ST} = 10\,[(z_{top} - z) + h_{OF}]$ $P_{ST} = 10\,[(z_{top} - z) + 2{,}4]$ $P_{ST} = 10\,[(z_{top} - z) + 0{,}1\,P_{PV}]$

Compartment	Still water pressure P_{ST}, in kN/m²	
Ballast holds of ships with service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**	The greater of the following:	$P_{ST} = 10\ [(z_{top} - z) + h_{OF}]$ $P_{ST} = 10\ (z_h - z)$
Ballast ducts	The greater of the following:	$P_{ST} = 10\ [(z_{top} - z) + 0,1\ P_{PV}]$ Ballast pump maximum pressure
Deep tanks Peak tanks	The greater of the following:	$P_{ST} = 10\ [(z_{top} - z) + h_{OF}]$ $P_{ST} = 10\ [(z_{top} - z) + 2,4]$
Integral or independent cargo tanks of ships with service notation **chemical tanker**	The greater of the following:	$P_{ST} = 10\ [(z_{top} - z) + 2,4]$ $P_{ST} = 10\ [(z_{top} - z) + 0,1\ P_{PV}]$
Chain locker	$P_{ST} = 10\ (z_{cp} - z)$	
Fuel chemical tanks Independent or integral methanol fuel tank of ships with additional service feature **methanolfuel**	The greater of the following:	$P_{ST} = 10\ [(z_{top} - z) + 2,4]$ $P_{ST} = 10\ [(z_{top} - z) + 0,1\ P_{PV}]$ $P_{ST} = 10\ (z_{bd} - z)$

Note 1:

z_{bd} : Z coordinate, in m, of the bulkhead deck

z_{cp} : Z coordinate, in m, of the top of chain pipe.

z_h : Z co-ordinate, in m, of the top of hatch coaming

Section 7 Design Load Scenarios

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

F_u : Design force due to unit cargo, in kN

F_{W-D} : Dynamic wheel force, in kN, as defined in Ch 5, Sec 6, [7.2.3]

F_{W-S} : Static wheel force, in kN, as defined in Ch 5, Sec 6, [7.2.2]

HBM : Design horizontal bending moment, in kN·m

HSF : Design horizontal shear force, in kN

M_{sw} : Permissible maximum and minimum vertical still water bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [2.2.1]

M_{sw-p} : Permissible maximum and minimum vertical still water bending moment for harbour/sheltered water operation, in kN·m, as defined in Ch 5, Sec 4, [2.2.2]

$M_{sw-t-LC}$: Permissible torsional still water moment for seagoing operation, in kN·m, as defined in Pt D, Ch 2, Sec 2

M_{sw-t-p} : Permissible torsional still water moment for harbour/sheltered water operation, in kN·m, as defined in Pt D, Ch 2, Sec 2

M_{wh-LC} : Horizontal wave bending moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.3]

M_{wt-LC} : Wave torsional moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.5]

M_{wv-LC} : Vertical wave bending moment for the considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.1]

P_0 : Design force due to wheel loads, in kN, as defined in Ch 5, Sec 6, [7.2.1]

P_{bs} : Dry bulk cargo static pressure, in kN/m^2, as defined in Ch 5, Sec 6, [3.4.2]

P_{bd} : Dry bulk cargo dynamic pressure for the considered dynamic load case, in kN/m^2, as defined in Ch 5, Sec 6, [3.4.3]

P_{bf-s} : Static pressure in dry cargo holds under flooded conditions, in kN/m^2, as defined in Ch 5, Sec 6, [4.1.5]

P_{dk} : Design pressure due to uniform cargo, in kN/m^2

P_{dl-s} : Static pressure on decks and platforms, in kN/m^2, as defined in Ch 5, Sec 6, [6.1.1]

P_{dl-d} : Dynamic pressure on decks platforms for a considered dynamic load case, in kN/m^2, as defined in Ch 5, Sec 6, [6.1.1]

P_{im} : Impact pressure due to liquid motion, in kN/m^2, as defined in Ch 5, Sec 6, [2.2.2].

P_{sd} : Lateral pressure on sides of superstructures or deckhouses not contributing to the longitudinal strength, in kN/m^2, as defined in Ch 5, Sec 5, [5.4.1]

Q_{sw} : Permissible hull girder maximum and minimum still water shear force limits for seagoing operation, in kN, as defined in Ch 5, Sec 4, [2.3.1]

Q_{sw-p} : Permissible hull girder maximum and minimum still water shear force limits for harbour/sheltered water operation, in kN, as defined in Ch 5, Sec 4, [2.3.2]

Q_{wh-LC} : Horizontal wave shear force for the considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.4]

Q_{wv-LC} : Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.2]

TM : Design torsional moment, in kN·m

VBM : Design vertical bending moment, in kN·m

VSF : Design vertical shear force, in kN.

1 General

1.1 Application

1.1.1 This Section describes the design load scenarios to be used for:

- strength assessment by prescriptive and direct analysis (Finite Element Analysis or beam models), as given in Article [2]
- fatigue assessment by prescriptive and direct analysis (Finite Element Analysis), as given in [3].

1.1.2 For the strength assessment, the principal design load scenarios are associated either to the qualifier S or S+D.

In addition, specific design load scenarios are to be considered relating to impact loads and sloshing loads in partly filled tanks.

1.1.3 For fatigue assessment, the design load scenarios are S+D (Static + Dynamic) loads, with the prefix 'F' for Fatigue.

2 Design load scenarios for strength assessment

2.1 Principal design load scenarios

2.1.1 The principal design load scenarios for strength assessment are given in Tab 1.

2.2 Design load scenarios for impact and sloshing

2.2.1 The additional design load scenarios relating to impact loads and sloshing loads to be considered are:

- bottom or stern slamming impact
- bow flare impact
- sloshing loads in partly filled tanks
- impact loads in partly filled tanks.

2.2.2 Design load scenarios for bottom or stern slamming impact

For the design load scenarios for bottom or stern slamming impact, only the pressure P_{SLI}, as defined in Ch 5, Sec 5, [4.2], is to be applied to the outer shell.

2.2.3 Design load scenario for bow flare impact

For the design load scenario for bow flare impact, only the pressure P_{FI}, as defined in Ch 5, Sec 5, [4.3], is to be applied to the outer shell.

Table 1 : Principal design load scenarios for strength assessment

Load components			Design load scenario				
			Harbour, sheltered water (H: S) **(1)**	Tank testing (T: S)	Seagoing conditions with extreme sea loads (N: S+D)	Ballast water exchange (BWE: S+D) **(1)**	Flooded conditions (A: S)
Hull girder	VBM		M_{sw-p}	M_{sw-p}	$M_{sw} + M_{wv-LC}$	$M_{sw} + M_{wv-LC}$	M_{sw}
	HBM		–	–	M_{wh-LC}	M_{wh-LC}	–
	VSF		Q_{sw-p}	Q_{sw-p}	$Q_{sw} + Q_{wv-LC}$	$Q_{sw} + Q_{wv-LC}$	–
	HSF		–	–	Q_{wh-LC}	Q_{wh-LC}	–
	TM **(4)**		M_{sw-t-p}	M_{sw-t-p}	$M_{sw-t-LC} + M_{wt-LC}$	$M_{sw-t-LC} + M_{wt-LC}$	–
Local loads	P_{ex}	Exposed decks	–	–	P_d	–	–
		Outer shell	P_S	P_S	$P_S + P_W$	$P_S + P_W$	–
		Sides of superstructures and deckhouses	–	–	$P_S + P_W$ **(2)** P_{sd} **(3)**	–	–
	P_{in}	Ballast tanks	P_{ls}	P_{ST}	$P_{ls} + P_{ld}$	$P_{ls} + P_{ld}$	–
		Liquid cargo tanks				–	–
		Other tanks				–	–
		Watertight boundaries	–	–	–	–	P_{fs}
		Wash bulkheads	–	–	$P_{ls} + P_{ld}$	–	–
		Dry bulk cargo holds	P_{bs}		$P_{bs} + P_{bd}$	–	P_{bf-s}
	P_{dk}	Decks below accommodation and machinery spaces and decks supporting uniform cargo	P_{dl-s}	–	$P_{dl-s} + P_{dl-d}$	–	–
	F_u	Decks supporting unit cargo	F_{u-s}	–	F_{u-d}	–	–
	P_0	Decks submitted to wheeled loads	F_{W-S}	–	$F_{W-S} + F_{W-D}$	–	–

(1) Applicable to prescriptive assessment only.
(2) Contributing to the longitudinal strength.
(3) Not contributing to the longitudinal strength.
(4) Still water torsional moment M_{sw-t} is only applicable to ships assigned with the service notation container ship.

2.2.4 Design load scenario for sloshing in partly filled tanks

For the design load scenario for sloshing, the sloshing pressure P_{sl}, as defined in Ch 5, Sec 6, [2.2.1], is to be applied combined with the still water vertical bending moment for seagoing M_{sw}.

2.2.5 Design load scenario for impact in partly filled tanks

For the design load scenario for impact in partly filled tanks, only the impact pressure P_{im}, as defined in Ch 5, Sec 6, [2.2.2], is to be applied.

3 Design load scenario for fatigue assessment

3.1 Design load scenario

3.1.1 The design load scenario for fatigue assessment is given in Tab 2.

Table 2 : Design load scenario for fatigue assessment

Load components			Fatigue (F: S+D)
Hull girder	VBM		$M_{sw}+ M_{wv-LC}$
	HBM		M_{wh-LC}
	VSF		$Q_{sw} + Q_{wv-LC}$
	HSF		Q_{wh-LC}
	TM **(3)**		$M_{sw-t-LC} + M_{wt-LC}$
Local loads	P_{ex}	Exposed decks	–
		Outer shell	$P_S + P_W$
		Sides of superstructures and deckhouses	–
	P_{in}	Ballast tanks **(1)**	$P_{ls} + P_{ld}$
		Liquid cargo tanks **(1)**	
		Other tanks **(1)**	
		Watertight boundaries	–
		Wash bulkheads	–
		Dry bulk cargo holds	$P_{bs} + P_{bd}$
	P_{dk}	Decks supporting uniform cargo	–
	F_u	Decks supporting unit cargo	–
	P_0	Decks submitted to wheeled loads **(2)**	$F_{W-S}+F_{W-D}$

(1) Applicability and filling levels for each loading condition are defined in Ch 10, Sec 1, [2.1.1]

(2) If needed considering the frequency of loading-unloading operations, the Society may require a specific fatigue assessment of structural elements subjected to wheeled loads in harbour conditions.

(3) Still water torsional moment M_{sw-t} is only applicable to ships assigned with the service notation **container ship**.

Section 8 Loading Conditions

1 Application

1.1 Loading conditions for strength assessment

1.1.1 The typical loading conditions to be considered for strength assessment are given in Article [3].

1.1.2 The loading conditions to be considered for the assessment of longitudinal strength and primary supporting members are to envelop the most critical loading combinations the ship can be subject to when operated in accordance with loading manual.

The loading conditions are to be defined with consideration to:

- all intact loading conditions in loading manual
- operational limitations in loading guidance information
- the ship arrangement and possible combination of local loading and global loading.

1.1.3 Loading conditions from the loading manual which are not covered in this Section are to be considered.

1.2 Loading conditions for fatigue assessment

1.2.1 The loading conditions to be considered for fatigue assessment are given in Article [4].

1.3 Specific loading conditions

1.3.1 Part D and Part E may specify additional loading conditions which are to be considered depending on the ship type.

2 General

2.1 Definitions

2.1.1 In general, the design cargo and ballast loading conditions to be considered for the longitudinal strength assessment are to be assessed for both departure and arrival conditions.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions.

2.1.2 Departure conditions

The departure conditions are to be based on bunker tanks not taken less than 95% full and other consumables (fresh water and stores) taken at 100% capacity.

In case of liquefied gas fuel tank, the filling level is to be based on the definition as per NR529, 6.8.

2.1.3 Arrival conditions

The arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

3 Standard loading conditions for strength assessment

3.1 Seagoing conditions

3.1.1 For all ships, the following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Full load/homogeneous cargo loading conditions including a condition at the scantling draught.

b) Ballast conditions where the ballast tanks may be full or empty. All cargo holds are to be empty. The propeller is to be fully immersed.

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- the allowable stress limits and buckling criteria defined in Ch 6, Sec 1, [3.5] and Ch 6, Sec 1, [3.7] are satisfied for all filling levels between empty and full and
- for ships with the service notation **bulk carrier**, **bulk carrier ESP** or **self-unloading bulk carrier ESP**, the requirements in Pt D, Ch 4, Sec 3, [3.1], as applicable, are complied with all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it is acceptable if, in each condition at departure, arrival and any intermediate condition required in Ch 5, Sec 4, [2.1.1], the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

- trim by stern of 3,0% of the ship's length, or
- trim by bow of 1,5% of the ship's length, or
- any trim that cannot maintain propeller immersion (l/D) not less than 25%, where:

  l : Distance, in m, from propeller centerline to the waterline

  D : Propeller diameter, in m.

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

Note 1: Annex 1 of IACS Unified Requirement UR S11, as amended, contains a guidance for partially filled ballast tanks in ballast loading conditions.

c) Non homogeneous cargo loading conditions.

For cargo loading conditions involving partially filled peak and/or other ballast tanks, the requirements specified in item b apply to the peak tanks only.

d) Special loadings (e.g. light load conditions at less than the maximum draught, deck cargo conditions, etc.), where applicable.

e) When relevant, conditions covering ballast water exchange procedures with the calculations of intermediate conditions just before and just after ballasting and/or deballasting any ballast tank.

For ships with the service notation **general cargo ship** completed by the additional service feature **nonhomload**, the loading conditions to be considered are to include the cases where the selected holds are empty at draught T, according to the indications specified in the ship notation.

3.2 Harbour and sheltered water conditions

3.2.1 The following harbour and sheltered water conditions are to be included in the loading manual:

a) Docking condition afloat.

b) Loading and unloading transitory conditions, where applicable.

For cargo loading conditions involving partially filled peak and/or other ballast tanks, the requirements specified in item b of requirement [3.1.1] apply to the peak tanks only.

c) Short voyage conditions, where applicable.

d) For ships subject to temporary storage of treated sewage and/or grey water in ballast tanks according to IMO BWM.2/Circ.82, and not assigned one of the additional class notations **LI-HG**, loading conditions under which the temporary storage of treated sewage and/or grey water in ballast tanks will be intended to be performed.

4 Standard loading conditions for fatigue assessment

4.1 General

4.1.1 The standard loading conditions to be applied for fatigue assessment are defined in Ch 10, Sec 1, [2].

CHAPTER 6
HULL GIRDER STRENGTH

Section 1 Hull Girder Yield and Buckling Strength

Section 2 Hull Girder Ultimate Strength

Appendix 1 Direct Calculation of Shear Flow

Appendix 2 Hull Girder Ultimate Bending Capacity

Section 1 Hull Girder Yield and Buckling Strength

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

M_{sw} : Permissible maximum and minimum vertical still water bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [2.2.1]

$M_{sw\text{-}p}$: Permissible maximum and minimum vertical still water bending moment for harbour/sheltered water operation, in kN·m, as defined in Ch 5, Sec 4, [2.2.2]

M_{wv} : Vertical wave bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.1.1]

$M_{wv\text{-}LC}$: Vertical wave bending moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.1]

M_{wh} : Horizontal wave bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.3.1]

$M_{wh\text{-}LC}$: Horizontal wave bending moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.3]

M_{wt} : Wave torsional moment in seagoing operation, in kN·m, at any longitudinal position defined in Ch 5, Sec 4, [3.5.1]

n : Navigation coefficient as defined in Ch 5, Sec 3, [1.1.2] for a reference length calculated with the parameters given in Ch 5, Sec 4, [3.1.1]

Q_{sw} : Permissible maximum or minimum still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 5, Sec 4, [2.3.1]

$Q_{sw\text{-}p}$: Permissible maximum or minimum still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 5, Sec 4, [2.3.2]

Q_{wv} : Vertical wave shear force in seagoing condition, in kN, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.2.1]

$Q_{wv\text{-}LC}$: Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.2]

$Q_{wh\text{-}LC}$: Horizontal wave shear force for a considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.4]

z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section with net scantling defined in [1.2], with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

1 Strength characteristics of hull girder transverse sections

1.1 General

1.1.1 This Article specifies the criteria for calculating the hull girder strength characteristics to be used for the hull girder strength assessment in Article [3], in association with the hull girder loads specified in Ch 5, Sec 4.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by all the members contributing to the hull girder longitudinal strength, taking into account the requirements in [1.2.2] to [1.2.13].

1.2.2 Net scantling

The members contributing to the hull girder longitudinal strength are to be considered using net offered scantlings based on gross offered thickness reduced by 0,5 t_c, as defined in Ch 4, Sec 3, when the hull girder strength characteristics are used for the hull girder yielding and buckling check according to Article [3].

1.2.3 Structural members not contributing to hull girder sectional area

The following members are not to be considered in the calculation as they are considered not contributing to the hull girder sectional area:

- superstructures and deckhouses which do not comply with [1.3.2]
- vertically corrugated bulkheads, according to [1.2.7]
- bulwarks and gutter plates
- bilge keels
- sniped or non-continuous longitudinal stiffeners
- non-continuous hatch coamings.

1.2.4 Continuous trunks and longitudinal continuous hatch coamings

Continuous trunks and longitudinal continuous hatch coamings may be included in the hull girder transverse sections, provided that they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.5 Longitudinal stiffeners or girders welded above the strength deck

Longitudinal stiffeners or girders welded above the strength deck, including the deck of any trunk fitted as specified in [1.2.4], are to be included in the hull girder transverse sections.

1.2.6 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area A_{EFF} that can be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$A_{EFF} = A_{LG}\, a$

where:

A_{LG} : Sectional area, in m^2, of longitudinal girders

a : Coefficient:

- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members: a = 1
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \leq 60$:

$$a = 0{,}6\left(\frac{s}{b_1} + 0{,}15\right)^{0{,}5}$$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:

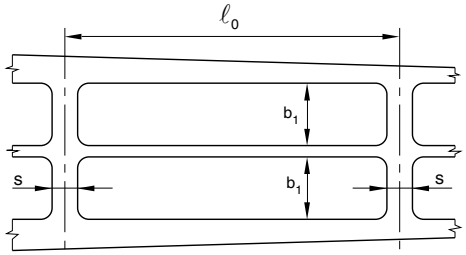
a = 0

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

Figure 1 : Longitudinal girders between hatchways



1.2.7 Longitudinal bulkheads with vertical corrugations

For longitudinal bulkheads with vertical corrugations, the vertical corrugations are not to be included in the hull girder transverse section. Longitudinal bulkheads with vertical corrugations are not effective for hull girder bending, but they are effective for hull girder shear force.

1.2.8 Members in materials other than steel

Where a member contributing to the longitudinal strength is made of material other than steel with a Young's modulus E equal to $2{,}06 \cdot 10^5$ N/mm^2, the steel equivalent net sectional area $A_{SE\text{-}n50}$ that may be included in the hull girder transverse section is obtained, in m^2, from the following formula:

$$A_{SE\text{-}n50} = \frac{E}{2{,}06 \cdot 10^5} A_{M\text{-}n50}$$

where:

$A_{M\text{-}n50}$: Net sectional area, in m^2, of the member under consideration.

1.2.9 Definitions of openings

Openings include:

a) Large openings, i.e. openings which are:
   - elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
   - circular openings exceeding 0,9 m in diameter.

b) Small openings (manholes, lightening holes, single scallops in way of seams, etc.), i.e. openings which are not large openings

c) Isolated openings, i.e. openings spaced not less than 1 m apart in the ship transverse/vertical direction.

1.2.10 Large openings and nearby small openings

Large openings are to be deducted from the sectional area used in the hull girder moment of inertia and section modulus. When small openings are spaced less than 1 m apart, in the ship transverse/vertical direction, from large openings, their total breadth is to be deducted from the sectional area.

Additionally, small openings not complying with the arrangement requirements given in Ch 4, Sec 5, [6.4.2] are to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.11 Isolated small openings

Isolated small openings in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \leq 0{,}06\ (B - \Sigma b)$$

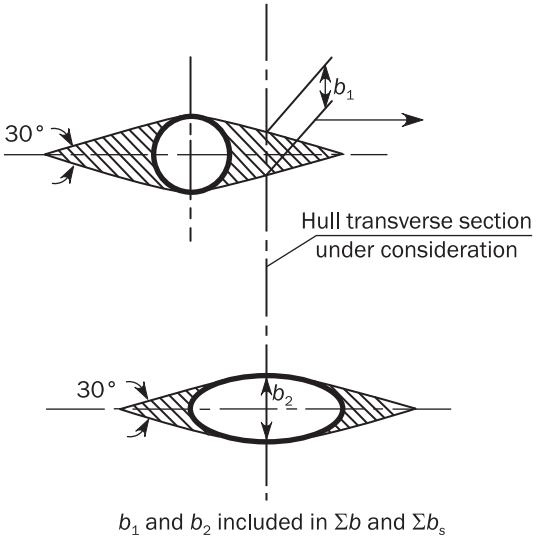
where:

Σb_S : Total breadth of isolated small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2, not deducted from the section area as per [1.2.10]

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2, deducted from the section area as defined in [1.2.10].

Where the total breadth of isolated small openings Σb_s does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

Figure 2 : Calculation of Σb and Σb_s



1.2.12 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than $0{,}25\ h_W$, without being greater than 75 mm for single scallops, where h_W is the web height, in mm, defined in Ch 4, Sec 2.

Otherwise, the excess is to be deducted from the sectional area or compensated.

1.2.13 Non-continuous decks and longitudinal bulkheads

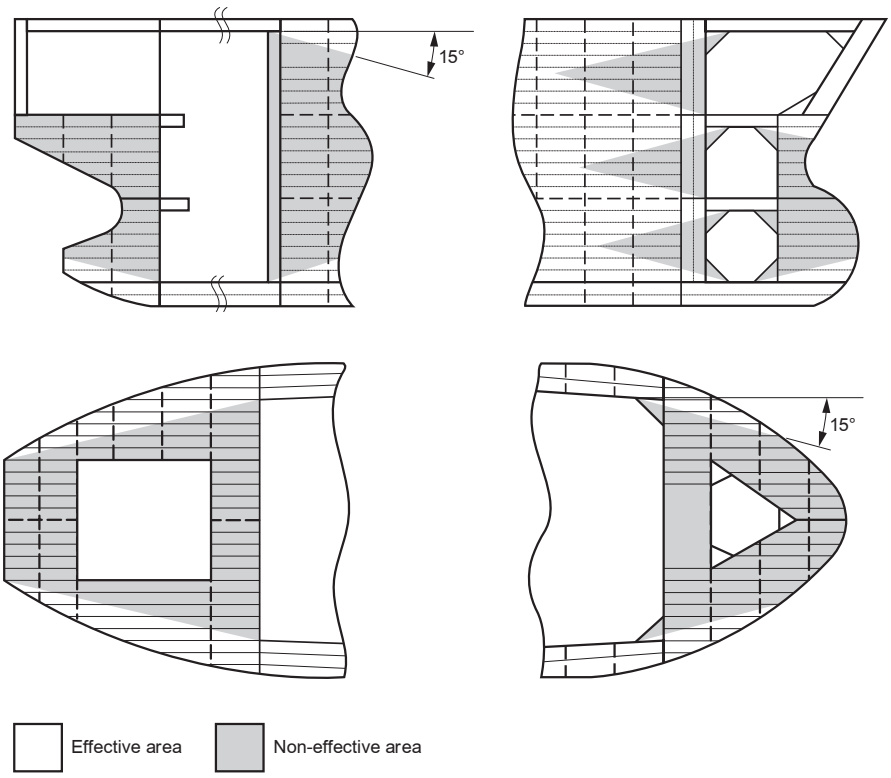
When calculating the effective area in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in Fig 3. The shadow area, which indicates the non-effective area, is obtained by drawing two tangent lines with an angle of 15 deg to the longitudinal axis of the ship.

1.3 Structures contributing to the longitudinal strength

1.3.1 Strength deck

The strength deck is, in general, the uppermost continuous deck. In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

Figure 3 : Effective area in way of non-continuous decks and bulkheads



1.3.2 Other structures

A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength. For the other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case-by-case basis, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal structural members (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model
- by assigning to the plate panel, between the side frames beside each opening, an equivalent thickness, t_{EQ}, in mm, obtained from the following formula:

$$t_{EQ} = 10^3 \left[\ell_P \left(\frac{Gh^2}{12EI_J} + \frac{1}{A_J} \right) \right]^{-1}$$

where (see Fig 4):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of the openings

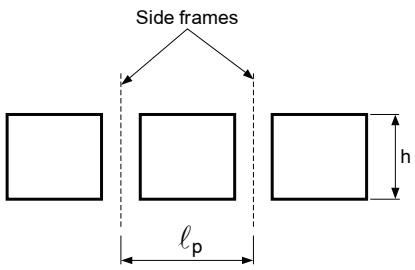
I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m^2, of the frame between two openings in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm^2, of the material used for the frame between two openings, to be taken equal to:

- for steels:
  $G = 8{,}0 \cdot 10^4$ N/mm^2
- for aluminium alloys:
  $G = 2{,}7 \cdot 10^4$ N/mm^2

Figure 4 : Side openings



1.4 Section modulus

1.4.1 The net section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_{y-n50}}{|z - z_n|}$$

1.4.2 The net section moduli at bottom and at the equivalent deck line are obtained, in m3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_{y-n50}}{z_n}$$

- at the equivalent deck line:

$$Z_{AD} = \frac{I_{y-n50}}{V_D}$$

where:

V_D : Vertical distance to the equivalent deck line, in m:

- when no effective longitudinal members specified in [1.2.4]and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_N)/0,9$ from the neutral axis at the centreline:

  $V_D = z_D - z_n$

  where:

  z_D : Z co-ordinate, in m, of strength deck, defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 3, [2.6]

- when effective longitudinal members as specified in [1.2.4]and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - z_N)/0,9$ from the neutral axis at the centreline:

$$V_D = (z_T - z_n)\left(0,9 + 0,2\frac{y_T}{B}\right) \geq z_D - z_n$$

  where:

  y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming or longitudinal ordinary stiffeners or girders welded above the strength deck, with respect to the reference co-ordinate system defined in Ch 1, Sec 3, [2.6].

  y_T and z_T are to be measured for the point which maximises the value of V_D.

1.5 Moments of inertia

1.5.1 The net moments of inertia $I_{y\text{-}n50}$ and $I_{z\text{-}n50}$, in m^4, are those, calculated about the horizontal and vertical neutral axes respectively, of the hull transverse sections defined in [1.2].

1.6 Ships having large openings in the strength deck

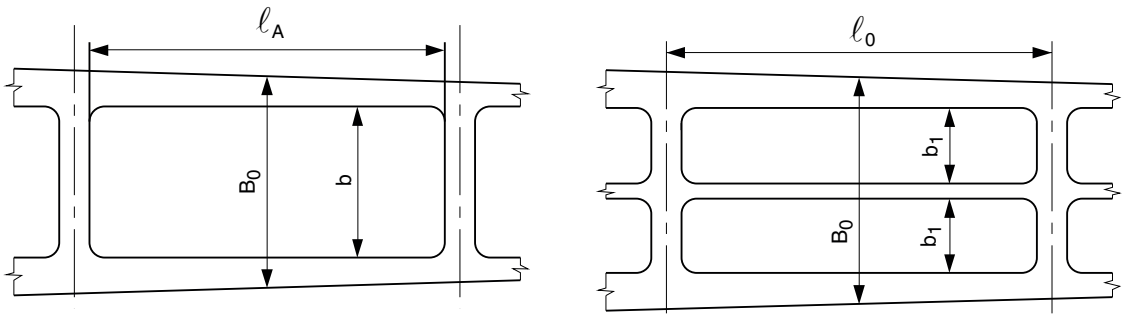
1.6.1 Definition

Ships having large openings in the strength decks are ships for which at least one of the three following conditions occur:

- $b / B_0 > 0,7$
- $\ell_A / \ell_0 > 0,89$
- $b / B_0 > 0,6$ and $\ell_A / \ell_0 > 0,7$

where b, B_0, ℓ_A and ℓ_0 are the dimensions defined in Fig 5. In the case of two or more openings in the same hull transverse section, b is to be taken as the sum of the breadth b_1 of each opening.

Figure 5 : Ships with large openings



2 Hull girder stresses

2.1 Normal stress

2.1.1 Normal stress induced by bending moments

The normal stress σ_L induced, at any point, by bending moments is to be obtained, in N/mm^2, from the following formulae:

- for seagoing operation:

$$\sigma_L = \left(\frac{M_{sw} + M_{wv\text{-}LC}}{I_{y\text{-}n50}}(z - z_n) - \frac{M_{wh\text{-}LC}}{I_{z\text{-}n50}}y\right)10^{-3}$$

- for harbour/sheltered operation:

$$\sigma_L = \frac{M_{sw\text{-}p}}{I_{y\text{-}n50}}(z - z_n)\,10^{-3}$$

2.1.2 Normal stress induced by torque and bending moments

The normal stresses induced by torque and bending moments are to be considered for ships having large openings in the strength decks, as defined in [1.6.1].

The normal stress σ_L induced, at any point, by torque and bending moments is to be obtained, in N/mm^2, from the following formulae:

- for seagoing operation:

$$\sigma_L = \left(\frac{M_{sw} + M_{wv\text{-}LC}}{I_{y\text{-}n50}}(z - z_n) - \frac{M_{wh\text{-}LC}}{I_{z\text{-}n50}}y\right)10^{-3} + \sigma_\Omega$$

- for harbour/sheltered operation:

$$\sigma_L = \frac{M_{sw\text{-}p}}{I_{y\text{-}n50}}(z - z_n)10^{-3} + \sigma_\Omega$$

where:

σ_Ω : Warping stress, in N/mm^2, induced by the wave torsional moment M_{wt} as defined in Ch 5, Sec 4 and obtained through direct calculation analyses based on a structural model in accordance with Article [4].

2.1.3 Material other than steel

In a member made in material other than steel with a Young's modulus E equal to $2{,}06 \cdot 10^5$ N/mm^2 and included in the hull girder transverse sections as specified in [1.2.8], the normal stress σ_L, in N/mm^2, is to be obtained from the following formula:

$$\sigma_L = \frac{E}{2,06 \cdot 10^5}\,\sigma_{LS}$$

where:

σ_{LS} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.1.1] or [2.1.2] considering this member as having the steel equivalent sectional area $A_{SE\text{-}n50}$ defined in [1.2.8].

2.2 Shear stress

2.2.1 Shear stress induced by vertical shear forces

The hull girder shear stress τ_L, in N/mm^2, induced by vertical shear forces is to be determined, at the load calculation point under consideration, from the following formulae:

- for seagoing operation:

$$\tau_L = \frac{Q_{sw} + Q_{wv\text{-}LC}}{t_{n50}/q_{vi}}10^3$$

- for harbour/sheltered operation:

$$\tau_L = \frac{Q_{sw\text{-}p}}{t_{n50}/q_{vi}}10^3$$

where:

q_{vi} : Contribution ratio for hull girder shear force per mm, in mm^{-1}, for the plate i based on net scantlings obtained with half the corrosion addition t_c, which is equal to the unit shear flow per mm, in N/mm, for a unit vertical shear force, from a numerical calculation based on thin-walled beam theory according to Ch 6, App 1.

2.2.2 Shear stress induced by shear forces and torque

For ships having large openings in the strength deck, the hull girder shear stress τ_L, in N/mm^2, induced by shear forces and torque is to be determined, at the load calculation point under consideration, from the following formulae:

- for seagoing operation:

$$\tau_L = \left(\frac{Q_{sw} + Q_{wv\text{-}LC}}{t_{n50} / q_{vi}} + \frac{Q_{wh\text{-}LC}}{t_{n50} / q_{hi}}\right) 10^3 + \tau_\Omega$$

- for harbour/sheltered operation:

$$\tau_L = \frac{Q_{sw-p}}{t_{n50} / q_{vi}} 10^3 + \tau_\Omega$$

where:

q_{vi} : Ratio as defined in [2.2.1]

q_{hi} : Contribution ratio for hull girder shear force per mm, in mm^{-1}, for the plate i based on net scantlings obtained with half the corrosion addition t_c, which is equal to the unit shear flow per mm, in N/mm, for a unit horizontal shear force, from a numerical calculation based on thin-walled beam theory according to Ch 6, App 1

τ_Ω : Shear stress, in N/mm^2, induced by the wave torsional moment M_{wt}, as defined in Ch 5, Sec 4 and obtained through direct calculation analyses based on a structural model in accordance with Article [4].

3 Hull girder strength assessment

3.1 General

3.1.1 The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [3.6] apply.

3.2 Longitudinal extent

3.2.1 The yield strength and buckling strength assessments are to be carried out in way of 0,2L to 0,75L with due consideration given to locations where there are significant changes in hull cross-section, e.g. changes of framing system and the fore and aft ends of the forward superstructure in case of twin island designs.

3.2.2 In addition, yield strength and buckling assessments are to be carried out outside this area. As a minimum, these assessments are to be carried out at forward end of the foremost cargo hold, at aft end of the aftermost cargo hold and at forward end of the engine room.

3.2.3 In addition, for ships with large openings in the strength deck, sections at, or near to, the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

3.2.4 Scantlings of members contributing to the longitudinal strength (see [1.3]) are to be maintained within 0,4 L amidships.

3.3 Hull girder stiffness

3.3.1 Minimum net moment of inertia

The net moment of inertia $I_{y\text{-}n50}$, in m^4, of the hull transverse section at midship is to be not less than $I_{y\text{-}min}$, obtained from the following formula:

$$I_{y-min} = 3,0 \cdot \frac{2n}{n+1} Z'_{R,MIN} L \cdot 10^{-2}$$

where $Z'_{R,MIN}$ is the required net midship section modulus $Z_{R,MIN}$, in m^3, calculated as specified in [3.4.1], but assuming k = 1.

3.4 Hull girder minimum section modulus

3.4.1 The net section moduli, in m^3, Z_{AB} and Z_{AD} at the midship section are to be not less than:

$$Z_{R,MIN} = 0,9 \cdot \frac{1+n}{2} \cdot C \cdot L^2 \cdot B \cdot (C_B + 0,7) \cdot k \cdot 10^{-6}$$

where

C : Coefficient defined in Ch 5, Sec 4

3.4.2 The scantlings of all continuous longitudinal members are to be maintained within 0,4L amidships based on the modulus requirement as specified in [3.4.1].

However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the end of the 0,4L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

3.5 Yield strength assessment

3.5.1 General acceptance criteria

It is to be checked that the equivalent Von Mises stress σ_{eq}, in N/mm², calculated with the load combinations given in [3.5.2] and [3.5.3] for seagoing operations in extreme conditions and for harbour operations, is in compliance with the following formula:

$\sigma_{eq} < \sigma_{perm}$

where:

σ_{eq} : Equivalent Von Mises stress, in N/mm²:

$$\sigma_{eq} = \sqrt{\sigma_L^2 + 3\tau_L^2}$$

σ_{perm} : Permissible hull girder normal stress, in N/mm²:

$$\sigma_{perm} = \frac{R_{eH}}{\gamma_1 \gamma_2}$$

σ_L : Normal stress, in N/mm², calculated for HVM, OHS, OHM and OVA design waves according to:

- [2.1.1] in general
- [2.1.2] for ships having large strength deck openings

τ_L : Shear stress, in N/mm², calculated for HVM, OHS, OHM and OVA design waves according to:

- [2.2.1] in general
- [2.2.2] for ships having large strength deck openings

γ_1 : Partial safety factor for material:

$$\gamma_1 = k\frac{R_{eH}}{235}$$

γ_2 : Partial safety factor for load combinations and permissible stress:

- for normal stresses assessment in seagoing operation:
  - for HVM design waves:
    $\gamma_2 = 1,24$
  - for OHS, OHM, OVA design waves:
    $\gamma_2 = 1,13$
- for normal stresses assessment in harbour/sheltered operation:
  $\gamma_2 = 1,65$
- for shear stresses assessment in seagoing operation:
  $\gamma_2 = 1,13$
- for shear stresses assessment in harbour/sheltered operation:
  $\gamma_2 = 1,29$

3.5.2 Normal stresses assessment

The normal stresses are to be assessed at the following locations of the cross-section:

- at bottom
- at equivalent deck line
- at any point where there is a change of steel yield strength
- at top of continuous hatch coaming for ships assigned the service notation **container ship**.

The assessment is to be performed according to [3.5.1], considering a shear stress τ_L equal to 0.

3.5.3 Shear stresses assessment

The shear stresses are to be assessed for all structural elements contributing to the hull girder shear strength capability.

The assessment is to be performed according to [3.5.1], considering a normal stress σ_L equal to 0.

3.6 Extent of higher strength steel

3.6.1 When a material factor for higher strength steel is used in calculating the required section modulus at bottom or at the equivalent deck line according to [1.4] and when the distribution of vertical normal stresses across the hull girder transverse section can be assumed to be linear, the vertical extent of higher strength steel, $z_{hts,i}$ used in the deck zone or bottom zone and measured respectively from the equivalent deck line or baseline is not to be taken less the value obtained from the following formula:

$$z_{hts,i} = z_1\left(1 - \frac{\sigma_{perm,i}}{\sigma_L}\right)$$

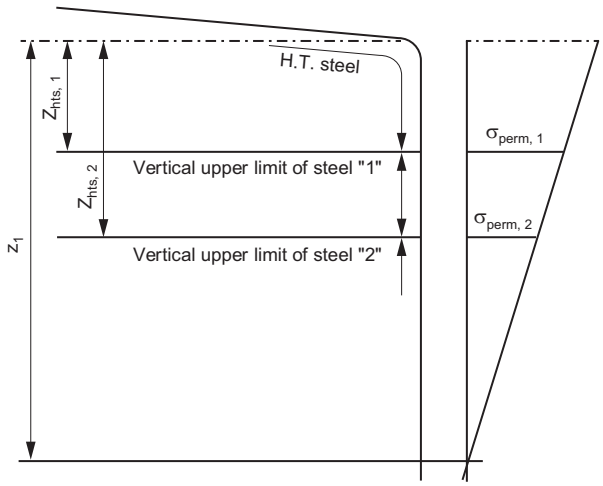
where:

σ_L : Normal stress, in N/mm², at the equivalent deck line or at bottom respectively, calculated according to [2.1]

z_1 : Distance from horizontal neutral axis to the equivalent deck line, defined in [1.4.2]or to the baseline respectively, in m.

$\sigma_{perm,i}$: Allowable normal stress defined in [3.5.1], in N/mm², for the adjacent zone of steel having lower strength (see Fig 6)

Figure 6 : Vertical extent of higher strength steel



3.6.2 The relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see [1]) within the extent defined in [3.6.1].

3.6.3 The higher strength steel is to extend in length at least throughout 0,4 L amidships where it is required for strength purposes according to the provisions of Part B.

3.6.4 Longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified minimum yield stress as the strength deck or bottom structure steel.

3.6.5 The requirement in [3.6.4] is also applicable to non-continuous longitudinal stiffeners welded to the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress in those members is higher than the permissible stress as defined in [3.5.1] for normal strength steel.

3.7 Buckling strength assessment

3.7.1 Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be assessed according to Chapter 8.

4 Structural models for the calculation of normal warping stress and shear stress

4.1 Calculation methods

4.1.1 The calculation of normal warping stress and shear stress induced by torque may be achieved by means of thin-walled beam models.

4.1.2 An alternative methodology such as complete ship FE model (see Ch 8, App 3) for evaluation of warping stress and shear stress induced by torque may be applied, subject to the satisfaction of the Society.

Section 2 Hull Girder Ultimate Strength

1 Application

1.1 General

1.1.1 The requirements of this Section apply to ships with length L equal to or greater than 150 m.

1.1.2 The hull girder ultimate strength is to be assessed between 0,2L and 0,75L.

1.1.3 The hull girder ultimate bending capacity is to be checked to ensure that it satisfies the checking criteria given in Article [2]. Such criteria are applicable to intact ship structures for both hogging and sagging conditions, in seagoing and harbour/ sheltered water conditions.

2 Checking criteria

2.1 General

2.1.1 The vertical hull girder ultimate bending capacity at any hull transverse section is to comply with the following criteria:

$$M \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

where:

M : Vertical bending moment, in kN·m, to be obtained as specified in [2.2.1]

M_U : Hull girder ultimate bending moment capacity, in kN·m, to be obtained as specified in [2.3]

γ_M : Partial safety factor covering material, geometric and strength prediction uncertainties, to be taken equal to 1,05

γ_{DB} : Partial safety factor covering the effect of double bottom bending under lateral loads, to be taken equal to:

- for hogging conditions:
  - 1,25 for empty holds of ships assigned with the service notation:
    general cargo ship,
    bulk carrier,
    bulk carrier ESP or
    combination carrier/OBO ESP
    and which may operate in alternate conditions at scantling draught
  - 1,15 otherwise
- for sagging conditions: 1,0.

For hull transverse sections where the breadth of the inner bottom is less than the one amidships, or where the double bottom structure differs from the one amidships (e.g. engine room sections), the factor γ_{DB} for hogging condition may be reduced, based upon agreement with the Society.

2.2 Hull girder ultimate bending loads

2.2.1 The vertical hull girder bending moment M, in kN·m, in hogging and sagging conditions, to be considered in the ultimate strength check, is to be taken as:

$$M = \gamma_S M_{sw} + \gamma_W M_{wv}$$

where:

M_{sw} : Permissible hogging and sagging vertical still water bending moment, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [2.2.1] and Ch 5, Sec 4, [2.2.2]

M_{wv} : Vertical wave bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.1.1]

γ_S : Partial safety factor for the still water bending moment, to be taken equal to 1,0

γ_W : Partial safety factor for the vertical wave bending moment, to be taken equal to 1,2.

2.3 Hull girder ultimate bending moment capacity

2.3.1 General

The hull girder ultimate bending moment capacity M_U is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses.

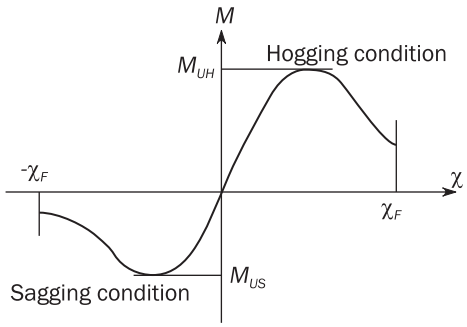
2.3.2 Determination of hull girder ultimate bending moment capacity

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment M versus the curvature χ of the transverse section considered (M_{UH} for hogging condition and M_{US} for sagging condition, see Fig 1). The curvature χ is positive for hogging condition and negative for sagging condition.

The hull girder ultimate bending moment capacity M_U is to be calculated according to Ch 6, App 2.

2.3.3 The effective area to be considered for the hull girder ultimate strength capacity assessment is specified in Ch 6, App 2.

Figure 1 : Bending moment capacity versus curvature χ



Appendix 1 Direct Calculation of Shear Flow

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 3.

1 Calculation formula

1.1 General

1.1.1 This Appendix describes the procedures for direct calculation of shear flow around a ship cross-section due to hull girder vertical shear force. The shear flow q_v, at each location in the cross-section, is calculated considering the cross-section subjected to a unit vertical shear force of 1 N.

The unit shear flow per mm q_v, in N/mm, is to be taken as: $q_v = q_D + q_I$

where:

q_D : Determinate shear flow, as defined in [1.2]

q_I : Indeterminate shear flow which circulates around the closed cells, as defined in [1.3].

In the calculation of the unit shear flow q_v, the longitudinal stiffeners are to be taken into account.

1.2 Determinate shear flow q_D

1.2.1 The determinate shear flow q_D, in N/mm, at each location in the cross-section is to be obtained from the following line integration:

$$q_D(s) = -\frac{1}{10^6\, I_{y\text{-}n50}} \int_0^s (z - z_n)\, t_{n50}\, ds$$

where:

s : Coordinate value of the running coordinate along the cross-section, in m

$I_{y\text{-}n50}$: Net moment of inertia of the cross-section, in m^4

t_{n50} : Net thickness of plating, in mm.

1.2.2 It is assumed that the cross-section is composed of line segments as shown in Fig 1, where each line segment has a constant plate net thickness. The determinate shear flow is obtained by the following equation:

$$q_{Dk} = -\frac{t_{n50} \cdot \ell}{2 \cdot 10^6\, I_{y\text{-}n50}} (z_k + z_i - 2 z_n) + q_{Di}$$

where:

q_{Dk}, q_{Di} : Determinate shear flow, at node k and node i respectively, in N/mm

ℓ : Length of line segments, in m

z_i, z_k : Z coordinates, in m, of the end points i and k of a line segment, as defined in Fig 1.

1.2.3 Where the cross-section includes closed cells as shown in Fig 2, the closed cells are to be cut with virtual slits, as shown in Fig 3 in order to obtain the determinate shear flow.

These virtual slits are not to be located in walls which form part of another closed cell.

Figure 1 : Definition of line segment

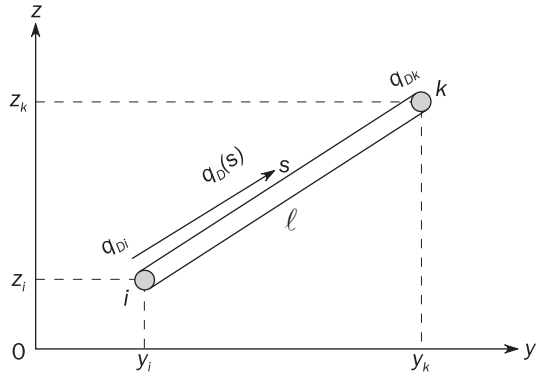


Figure 2 : Closed cells and common wall

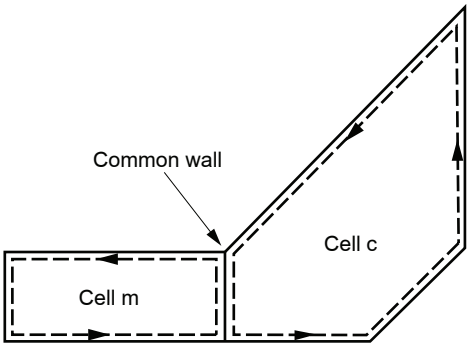
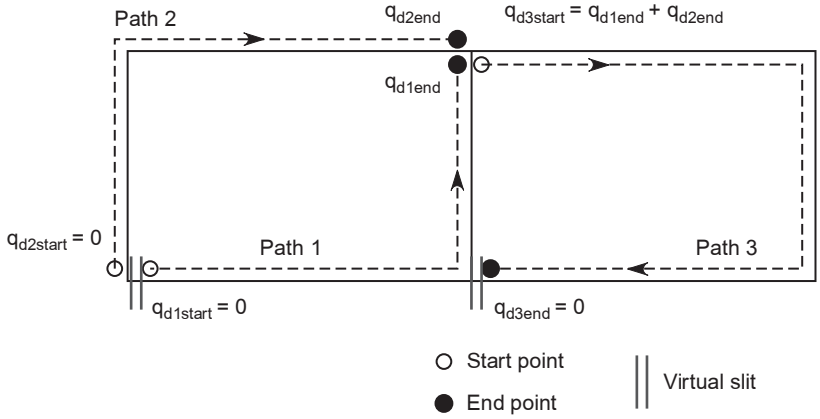


Figure 3 : Placement of virtual slits and calculation of determinate shear flow at bifurcation points



1.2.4 Determinate shear flow at bifurcation points is to be calculated by water flow calculations or similar, as shown in Fig 3.

1.3 Indeterminate shear flow q_I

1.3.1 The indeterminate shear flow q_I around the closed cells of a cross-section is considered as a constant value within the same closed cell. The following system of equations for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all the closed cells are performed.

$$q_{Ic} \oint_c \frac{1}{t_{n50}}\,ds - \sum_{m=1}^{Nw}\left(q_{Im} \oint_{cm} \frac{1}{t_{n50}}\,ds\right) = -\oint_c \frac{q_D}{t_{n50}}\,ds$$

where (see Fig 2:

Nw : Number of common walls shared by cell c and all the other cells

cm : Common wall shared by cells c and m

q_{Ic}, q_{Im} : Indeterminate shear flows around the closed cells c and m respectively, in N/mm.

1.3.2 Under the assumption of the assembly of line segments as shown in Fig 1 and constant plate thickness of each line segment, the equation in [1.3.1] is expressed as follows:

$$q_{Ic} \sum_{j=1}^{Nc}\left(\frac{\ell}{t_{n50}}\right)_j - \sum_{m=1}^{Nw}\left\{q_{Im}\left|\sum_{j=1}^{Nm}\left(\frac{\ell}{t_{n50}}\right)_j\right|_m\right\} = -\sum_{j=1}^{Nc}\phi_j$$

$$\phi_j = \left[-\frac{\ell^2}{6\cdot 10^3 I_{y\text{-}n50}}(z_k + 2z_i - 3z_n) + \frac{\ell}{t_{n50}}q_{Di}\right]_j$$

where (see Fig 2:

Nc : Number of line segments in cell c

Nm : Number of line segments on the common wall shared by cells c and m

q_{Di} : Determinate shear flow, in N/mm, calculated according to [1.2.2].

The difference in the directions of running coordinates specified in [1.2] and the present [1.3] is to be considered.

1.4 Computation of sectional properties

1.4.1 Properties of the cross-section are to be obtained by the following formulae, where the cross-section is assumed to be made of the assembly of line segments:

$$\ell = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a_{n50} = 10^{-3}\, \ell\, t_{n50}$$

$$A_{n50} = \sum a_{n50}$$

$$s_{y\text{-}n50} = \frac{a_{n50}}{2}\,(z_k + z_i)$$

$$S_{y\text{-}n50} = \sum s_{y\text{-}n50}$$

$$i_{y0\text{-}n50} = \frac{a_{n50}}{3}\,(z_k^2 + z_k\, z_i + z_i^2)$$

$$I_{y0\text{-}n50} = \sum i_{y0\text{-}n50}$$

where:

y_i, z_i : Y and Z coordinates of start point i of a line segment, in m, as defined in Fig 1

y_k, z_k : Y and Z coordinates of end point k of a line segment, in m, as defined in Fig 1

a_{n50}, A_{n50} : Areas of the line segment and the cross-section respectively, in m^2

$s_{y\text{-}n50}$, $S_{y\text{-}n50}$: First moments of the line segment and the cross-section about the baseline, in m^3

$i_{y0\text{-}n50}$, $I_{y0\text{-}n50}$: Moments of inertia of the line segment and the cross-section about the baseline, in m^4.

1.4.2 The height of the horizontal neutral axis z_n, in m, is to be obtained as follows:

$$z_n = \frac{S_{y\text{-}n50}}{A_{n50}}$$

1.4.3 The moment of inertia about the horizontal neutral axis, in m^4, is to be obtained as follows:

$$I_{y\text{-}n50} = I_{y0\text{-}n50} - z_n^2\, A_{n50}$$

Appendix 2 Hull Girder Ultimate Bending Capacity

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 3.

$Z_{B\text{-}n50}$: Net section moduli at bottom, in m^3, to be taken as:

$$Z_{B\text{-}n50} = \frac{I_{y\text{-}n50}}{z_n}$$

$Z_{D\text{-}n50}$: Net section moduli at deck, in m^3, to be taken as:

$$Z_{D\text{-}n50} = \frac{I_{y\text{-}n50}}{|z_D - z_n|}$$

z_D : Z coordinate, in m, of the strength deck at side, defined in Ch 6, Sec 1, [1.3]

z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section, defined in Ch 6, Sec 1

R_{eHs} : Minimum yield stress, in N/mm^2, of the material of the considered stiffener

R_{eHp} : Minimum yield stress, in N/mm^2, of the material of the considered plate

$A_{s\text{-}n50}$: Net sectional area, in cm^2, of stiffener, without attached plating

$A_{p\text{-}n50}$: Net sectional area, in cm^2, of attached plating.

1 General

1.1 Application

1.1.1 This Appendix provides the criteria to obtain the ultimate longitudinal bending moment capacity M_U to be used in the hull girder ultimate capacity check according to Ch 6, Sec 2.

1.1.2 M_U is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.2 Methods

1.2.1 Incremental-iterative method

The hull girder ultimate bending moment capacity is to be assessed by the incremental-iterative method defined in Article [2].

1.2.2 Alternative methods

Principles for alternative methods for the calculation of the hull girder ultimate bending moment capacity, e.g. the non-linear finite element analysis, are given in [3].

Application of alternative methods is to be agreed by the Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

1.3 General assumptions

1.3.1 The method for calculating the ultimate hull girder bending capacity is to identify the critical failure modes of all the main longitudinal structural elements.

1.3.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.3 Only vertical bending is considered, except for ships having large openings in the strength decks for which the effects of shear force, torsional loading, horizontal bending moment and lateral pressure are to be considered.

2 Incremental-iterative method

2.1 Assumptions

2.1.1 In applying the procedure described in [2.2], the following assumptions are generally to be made:

- the ultimate strength is calculated at hull transverse sections between two adjacent transverse webs
- the hull girder transverse section remains plane during each curvature increment

- the hull material has an elasto-plastic behaviour
- the hull girder transverse section is divided into a set of elements which are considered to act independently.

These elements are:

- transversely framed plating panels and/or stiffeners with attached plating, whose structural behaviour is described in [2.3.1]
- hard corners, constituted by plating crossing, whose structural behaviour is described in [2.3.2].

According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain ε is to be obtained, for each curvature increment, from the non-linear load-end shortening curves σ-ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress σ is selected as the lowest value among those obtained from each of the considered load-end shortening curves σ-ε.

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging conditions, obtained from the following formula:

$$\chi_F = \pm 0,003 \frac{M_Y}{EI_{y\text{-}n50}}$$

where:

M_Y : The lesser of the following values M_{Y1} and M_{Y2}, in kN·m:

$M_{Y1} = 10^3 R_{eH} Z_{B\text{-}n50}$

$M_{Y2} = 10^3 R_{eH} Z_{D\text{-}n50}$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Procedure

2.2.1 General

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart of Fig 1.

In this procedure, the hull girder ultimate bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross-section as shown in Fig 1.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, due to the non-linear σ-ε relationship. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements on the transverse section.

Once the position of the neutral axis is known and the relevant element stress distribution in the section is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

The main steps of the incremental-iterative approach described above are summarised as follows (see also Fig 1):

- Step 1: Divide the transverse section of hull into stiffened plate elements
- Step 2: Define stress-strain relationships for all the elements, as shown in Tab 1
- Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of the incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck):

$$\chi_1 = \Delta\chi = 0,01 \frac{R_{eH}}{E} \cdot \frac{1}{z_D - z_n}$$

where:

z_D : Z coordinate, in m, of the strength deck at side, with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

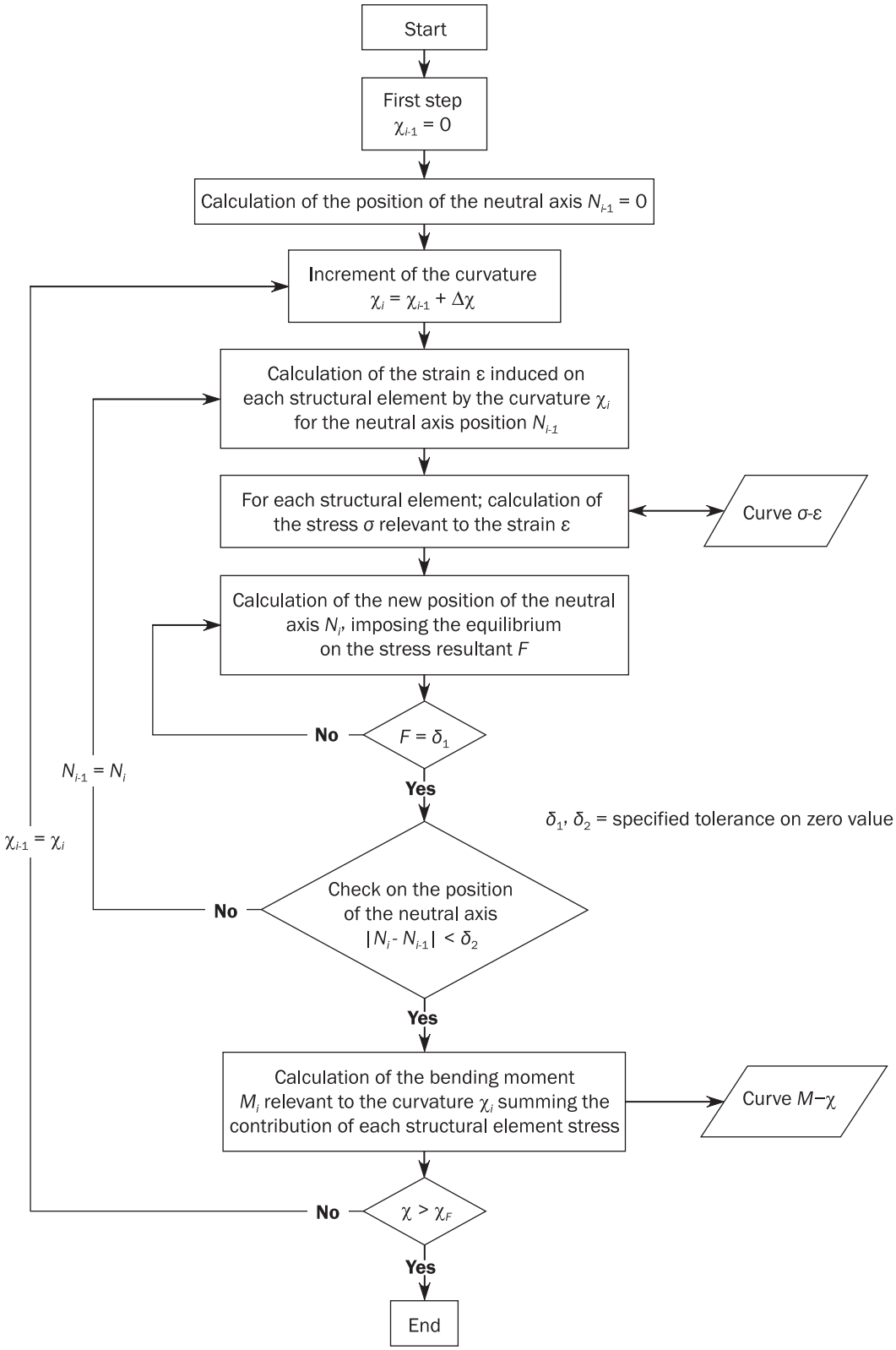
z_n : Z coordinate, in m, of the horizontal neutral axis of the hull transverse section, with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

- Step 4: Calculate, for each element, the corresponding strain $\varepsilon_i = \chi\ (z_i - z_n)$ and the corresponding stress σ_i
- Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section:

  $\Sigma\ (A_{i\text{-}n50}\ \sigma_i) = \Sigma\ (A_{j\text{-}n50}\ \sigma_j)$,

  the i-th element being under compression and the j-th element under tension

Figure 1 : Flow chart of the procedure for the evaluation of the curve M-χ



- Step 6: Calculate the corresponding moment by summing the contributions of all the elements:

$$M_U = \sum \sigma_{Ui} \, A_{i\text{-}n50} \, |(z_i - z_{NA_cur})|$$

- Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value M_U. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

2.2.2 Modeling of the hull girder cross-section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modeled, taking account of the fact that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into either a stiffened plate element, an attached plate of a stiffener element, or a hard corner element.

The plate panel is categorised into the following two kinds:

- longitudinally stiffened panel, the longer side of which is in the ship longitudinal direction, and
- transversely stiffened panel, the longer side of which is in the direction perpendicular to the ship longitudinal direction.

a) Hard corner element

Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

The extent of a hard corner element from the point of intersection of the plates is taken equal to (see Fig 2):

- 20 t_{n50} on a transversely stiffened panel, and
- 0,5 s on a longitudinally stiffened panel,

where:

t_{n50} : Net offered thickness of the plate, in mm

s : Spacing of the adjacent longitudinal stiffener, in mm.

Sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners. Enlarged stiffeners, with or without web stiffening, used for Permanent Means of Access (PMA) are not to be considered as a large girder, so the attached plate/web connection is only considered as a hard corner, see Fig 3.

b) Stiffener element

The stiffener constitutes a stiffener element together with the attached plate.

The attached plate width is, in principle, equal to:

- the mean spacing of the stiffener, when the panels on both sides of the stiffener are longitudinally stiffened, or
- the width of the longitudinally stiffened panel, when the panel on one side of the stiffener is longitudinally stiffened and the other panel is transversely stiffened, see Fig 2.

c) Stiffened plate element

The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Fig 2.

The typical examples of modeling of hull girder section are illustrated in Fig 3. Notwithstanding the foregoing principle, these figures are to be applied to the modeling in the vicinity of upper deck, sheer strake and hatch coaming.

Figure 2 : Extension of the breadth of an attached plating and hard corner element

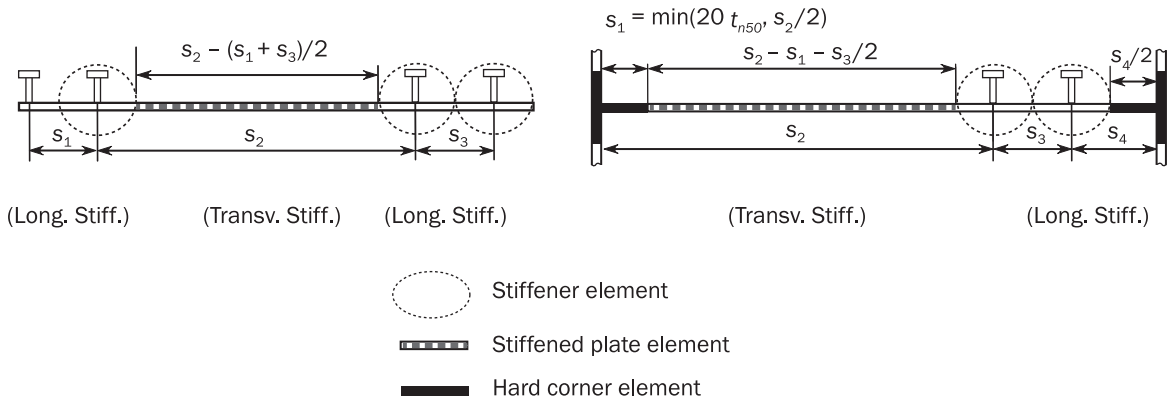
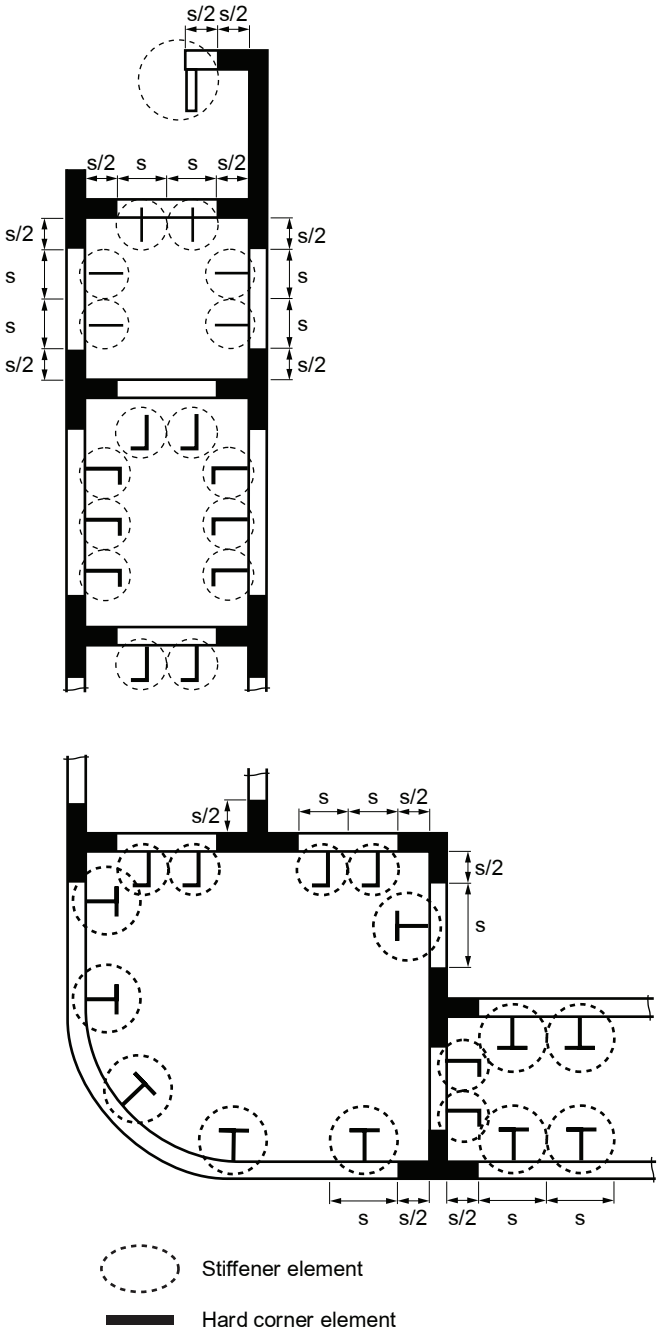


Figure 3 : Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section



- in case of knuckle points as shown in Fig 4, the plating area adjacent to the knuckles in a plating having an angle greater than 30° is defined as a hard corner. The extent, from the knuckle point, of one side of the corner is taken equal to 20 t_{n50} on transversely framed panels and to 0,5 s on longitudinally framed panels
- where plate elements are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels
- where openings are provided in stiffened plate elements, the openings are to be considered in accordance with Ch 6, Sec 1, [1.2.9]
- where an attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress, obtained from the following formulae, are to be used for the calculation:

$$t_{n50} = \frac{t_{1\text{-}n50}\, s_1 + t_{2\text{-}n50} s_2}{s}$$

$$R_{eHp} = \frac{R_{eHp1}\ t_{1\text{-}n50}\ s_1 + R_{eHp2}\ t_{2\text{-}n50}\ s_2}{t_{n50}\, s}$$

where:

R_{eHp1} , R_{eHp2} , $t_{1\text{-}n50}$, $t_{2\text{-}n50}$, s_1 , s_2 , s : As shown in Fig 5.

Figure 4 : Plating with knuckle point

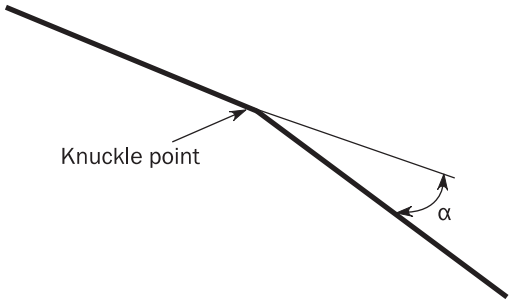
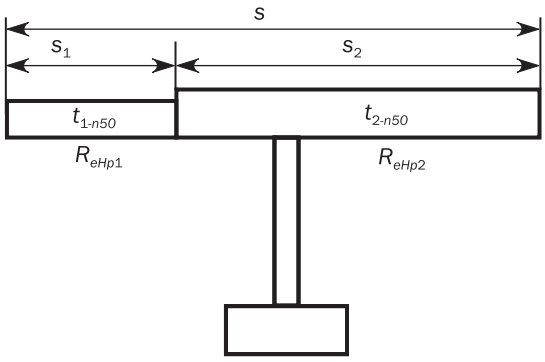


Figure 5 : Element with different thickness and/or different yield strength



2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may collapse, following one of the modes of failure specified in Tab 1.

- where the plate elements are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.3.3] to [2.3.8], taking account of the non-continuous longitudinal stiffener. In the calculation of the total forces for checking the hull girder ultimate strength, the area of the non-continuous longitudinal stiffener is to be assumed as zero.

- where an opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in the calculation of the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 6, Sec 1, [1.2.9] to Ch 6, Sec 1, [1.2.13].
- for the stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as the full plate width, i.e. to the intersection of the other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of the stiffener element, if any. In the calculation of the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Table 1 : Modes of failure of stiffened plate elements and stiffener elements

Elements	Mode of failure	Curve σ-ε defined in
Lengthened stiffened plate elements or lengthened stiffener elements	Elasto-plastic collapse	[2.3.3]
Shortened stiffener elements	Beam column buckling	[2.3.4]
	Torsional buckling	[2.3.5]
	Web local buckling of flanged profiles	[2.3.6]
	Web local buckling of flat bars	[2.3.7]
Shortened stiffened plate elements	Plate buckling	[2.3.8]

2.3.2 Hard corner element

The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.3.3].

2.3.3 Elasto-plastic collapse of structural elements (hard corner element)

The load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 6):

$\sigma = \Phi R_{eHA}$

where:

R_{eHA} : Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eHp} A_{p\text{-}50} + R_{eHs} A_{s\text{-}n50}}{A_{p\text{-}n50} + A_{s\text{-}n50}}$$

Φ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \leq \varepsilon \leq 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain, equal to:

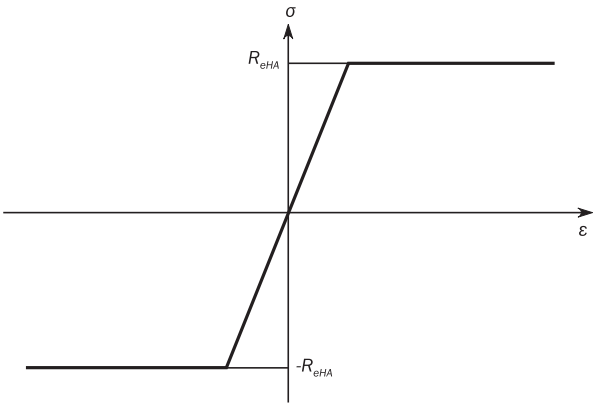
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

Figure 6 : Load-end curve σ-ε for elasto-plastic collapse



2.3.4 Beam column buckling

The load-end shortening curve σ_{CR1}-ε for the beam column buckling of stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s\text{-}n50} + A_{pE\text{-}n50}}{A_{s\text{-}n50} + A_{p\text{-}n50}}$$

where:

Φ : Edge function, as defined in [2.3.3]

σ_{C1} : Critical stress, in N/mm^2, equal to:

- for $\sigma_{E1} \leq \frac{R_{eHB}}{2}\varepsilon$:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon}$$

- for $\sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$:

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\,\varepsilon}{4\sigma_{E1}}\right)$$

R_{eHB} : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eHp}\ A_{pEl\text{-}n50}\ \ell_{pE} + R_{eHs}\ A_{s\text{-}n50}\ \ell_{sE}}{A_{pEl\text{-}n50}\ \ell_{pE} + A_{s\text{-}n50}\ \ell_{sE}}$$

$A_{pEl\text{-}n50}$: Effective area, in cm², equal to: $A_{pEl\text{-}n50} = 10\ b_{E1}\ t_{n50}$

ℓ_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate

ℓ_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{E1} to the top of the stiffener

ε : Relative strain, as defined in [2.3.3]

σ_{E1} : Euler column buckling stress, in N/mm², equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E\text{-}n50}}{A_{E\text{-}n50}\ \ell^2}\ 10^{-4}$$

$I_{E\text{-}n50}$: Net moment of inertia of stiffeners, in cm⁴, with attached plating of width b_{E1}

$A_{E\text{-}n50}$: Net area, in cm², of stiffeners with attached plating of width b_E

b_{E1} : Effective width corrected for relative strain, in m, of the attached plating, equal to:

- for $\beta_E > 1{,}0$:

$$b_{E1} = \frac{s}{\beta_E} 10^{-3}$$

- for $\beta_E \leq 1{,}0$:

$$b_{E1} = 10^{-3}\ s$$

$$\beta_E = \frac{s}{t_{n50}} \sqrt{\frac{\varepsilon\ R_{eHp}}{E}}$$

$A_{pE\text{-}n50}$: Net sectional area, in cm², of attached plating of width b_E, equal to: $A_{pE\text{-}n50} = 10\ b_E\ t_{n50}$

b_E : Effective width, in m, of the attached plating, equal to:

- for $\beta_E > 1{,}25$:

$$b_E = 10^{-3}\left(\frac{2{,}25}{\beta_E} - \frac{1{,}25}{\beta_E^2}\right)s$$

- for $\beta_E \leq 1{,}25$:

$$b_E = 10^{-3}\ s$$

2.3.5 Torsional buckling

The load-end shortening curve σ_{CR2}-ε for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi\ \frac{A_{s\text{-}n50}\ \sigma_{C2} + A_{p\text{-}n50}\ \sigma_{CP}}{A_{s\text{-}n50} + A_{p\text{-}n50}}$$

where:

Φ : Edge function, as defined in [2.3.3]

σ_{C2} : Critical stress, in N/mm², equal to:

- for $\sigma_{E2} \leq \frac{R_{eHs}}{2}\ \varepsilon$:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon}$$

- for $\sigma_{E2} > \frac{R_{eHs}}{2}\ \varepsilon$:

$$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\ \varepsilon}{4\sigma_{E2}}\right)$$

σ_{E2} : Euler column buckling stress, in N/mm², taken equal to σ_{ET}, as defined in Ch 9, Sec 1.

ε : Relative strain, as defined in [2.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm², equal to:

- for $\beta_E > 1{,}25$:

$$\sigma_{CP} = \left(\frac{2{,}25}{\beta_E} - \frac{1{,}25}{\beta_E^2}\right)R_{eHp}$$

- for $\beta_E \leq 1{,}25$: $\sigma_{CP} = R_{eHp}$

β_E : Coefficient, as defined in [2.3.4].

2.3.6 Web local buckling of stiffeners made of flanged profiles

The load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 \; b_E \; t_{n50} \; R_{eHp} + (h_{we} \; t_{w\text{-}n50} + b_f \; t_{f\text{-}n50}) \; R_{eHs}}{s \; t_{n50} + h_w \; t_{w\text{-}n50} + b_f \; t_{f\text{-}n50}}$$

where:

Φ : Edge function, as defined in [2.3.3]

b_E : Effective width, in m, of the attached shell plating, as defined in [2.3.4]

h_{we} : Effective height of the web, in mm, equal to:

- for $\beta_w > 1,25$:

$$h_{we} = \left(\frac{2,25}{\beta_w} - \frac{1,25}{\beta_w^2}\right) h_w$$

- for $\beta_w \leq 1,25$:

$$h_{we} = h_w$$

$$\beta_w = \frac{h_w}{t_{w\text{-}n50}} \sqrt{\frac{\varepsilon \; R_{eHs}}{E}}$$

ε : Relative strain, as defined in [2.3.3].

2.3.7 Web local buckling of stiffeners made of flat bars

The load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi \; \frac{A_{p\text{-}n50} \; \sigma_{CP} + A_{s\text{-}n50} \; \sigma_{C4}}{A_{p\text{-}n50} + A_{s\text{-}n50}}$$

where:

Φ : Edge function, as defined in [2.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm^2, as defined in [2.3.5]

σ_{C4} : Critical stress, in N/mm^2, equal to:

- for $\sigma_{E4} \leq \frac{R_{eHs}}{2} \; \varepsilon$:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon}$$

- for $\sigma_{E4} > \frac{R_{eHs}}{2} \; \varepsilon$:

$$\sigma_{C4} = R_{eHs} \left(1 - \frac{R_{eHs} \; \varepsilon}{4 \sigma_{E4}}\right)$$

σ_{E4} : Local Euler buckling stress, in N/mm^2, equal to:

$$\sigma_{E4} = 160000 \left(\frac{t_{w\text{-}n50}}{h_w}\right)^2$$

ε : Relative strain, as defined in [2.3.3].

2.3.8 Plate buckling

The load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \Phi R_{eHp} \left[\frac{s}{\ell}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)10^{-3} + 0,1\left(1 - \frac{s}{\ell}10^{-3}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right]$$

without being taken greater than $\Phi \; R_{eHp}$,

where:

Φ : Edge function, as defined in [2.3.3]

β_E : Coefficient, as defined in [2.3.4].

s : Plate breadth, in mm, taken as the spacing between the stiffeners

ℓ : Longer side of the plate, in m.

3 Alternative methods

3.1 General

3.1.1 The bending moment-curvature relationship M-χ may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response, with due consideration to:

a) non-linear geometrical behaviour

b) inelastic material behaviour

c) geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners)

d) simultaneously acting loads:
   - bi-axial compression
   - bi-axial tension
   - shear and lateral pressure

e) boundary conditions

f) interactions between buckling modes

g) interactions between structural elements such as plates, stiffeners, girders, etc

h) post-buckling capacity

i) overstressed elements on the compression side of hull girder cross-section possibly leading to local permanent sets/buckle damages in plating, stiffeners etc (double bottom effects or similar).

3.2 Non-linear finite element analysis

3.2.1 Advanced non-linear finite element analysis models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses, with due consideration to the items listed in [3.1.1].

3.2.2 Particular attention is to be given to modeling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

CHAPTER 7
HULL SCANTLINGS

Section 1 General

Section 2 Load Application

Section 3 Minimum Thickness

Section 4 Plating

Section 5 Stiffeners

Section 6 Primary Supporting Members and Pillars

Appendix 1 Analyses of Primary Supporting Members Subject to Wheeled Loads

Section 1 General

1 Application

1.1 Application

1.1.1 This Chapter applies to hull structure over the full length of the ship including fore end, cargo hold region, machinery space, aft end, side shell, engine casing, exposed and internal decks.

1.1.2 This Chapter provides requirements for evaluation of plating, stiffeners and primary supporting members (PSM) subject to lateral pressure, local loads and hull girder loads, as applicable. Requirements are specified in:

- Ch 7, Sec 2 for load application
- Ch 7, Sec 3 for minimum thickness of plates, stiffeners and PSM
- Ch 7, Sec 4 for plating
- Ch 7, Sec 5 for stiffeners
- Ch 7, Sec 6 for PSM and pillars.

1.1.3 Required scantlings

The offered net scantling is to be greater than, or equal to, the required scantlings based on requirements provided in this Chapter.

1.1.4 Additional local strength requirements

Additional local strength requirements are provided as listed below:

- fore part, bow flare impact and bottom forward slamming: Ch 11, Sec 1
- machinery space: Ch 11, Sec 2
- aft part and stern impact: Ch 11, Sec 3
- sloshing: Ch 11, Sec 4.
- superstructures, deckhouses and companionways: Ch 11, Sec 5

1.2 Acceptance criteria

1.2.1 Acceptance criteria sets are to be selected as defined in Ch 7, Sec 2, Tab 1 to Ch 7, Sec 2, Tab 4.

Section 2 Load Application

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

P_{ex} : Design external pressure, in kN/m^2, defined in Ch 5, Sec 5

P_{in} : Design internal pressure, in kN/m^2, defined in Ch 5, Sec 6

P_d : Green sea pressure for a considered dynamic load case, in kN/m^2, as defined in Ch 5, Sec 5

P_{dl} : Design pressure due to uniform cargo, in kN/m^2, defined in Ch 5, Sec 6

P_{sc} : Overpressure due to the inlet grating cleaning system, in kN/m^2, defined in Ch 5, Sec 5

F_{sc} : Load due to steel coil cargoes, in kN, taken equal to $F_{sc\text{-}ib\text{-}s}$, $F_{sc\text{-}ib}$, $F_{sc\text{-}hs\text{-}s}$ or $F_{sc\text{-}hs}$, as defined in Ch 5, Sec 6

F_u : Design force due to unit cargo, in kN, taken equal to $F_{u\text{-}s}$ or $F_{u\text{-}d}$, as defined in Ch 5, Sec 6

R : Vertical force at the corners of container stacks, in kN, taken equal to R_s, R_w, as defined in Ch 5, Sec 6.

1 Load combination

1.1 Hull girder

1.1.1 Normal stress

The hull girder normal stress σ_L, in N/mm^2, is to be calculated according to Ch 6, Sec 1, [2.1] at the considered position for each design load set defined in [2].

1.2 Pressure combination

1.2.1 Elements of the outer shell

The static and dynamic lateral pressures to be considered are the differences between the internal pressures and the external sea pressures at the corresponding loading condition. At least the two following cases are to be considered:

- combination of the maximum external pressure with the minimum internal pressure (generally full load with empty ballast)
- combination of the minimum external pressure with the maximum internal pressure (generally ballast loading condition).

If the compartment adjacent to the outer shell is not intended to carry liquids, the internal pressures and external sea pressures are to be considered independently.

1.2.2 Elements other than those of the outer shell

The static and dynamic lateral pressures on an element separating two adjacent compartments are those obtained considering the two compartments individually loaded.

2 Design load sets

2.1 Application of load components

2.1.1 Application

These requirements apply to:

a) plating and stiffeners along the full length of the ship

b) the primary supporting members assessed by means of prescriptive analysis or beam model according to Pt B, Ch 7, Sec 6 (see Ch 7, Sec 6, Tab 1).

2.1.2 Load components

The static and dynamic load components are to be determined in accordance with Ch 5, Sec 7, Tab 1.

Radius of gyration k_r and metacentric height GM are to be in accordance with Ch 5, Sec 3, Tab 4 for the considered loading conditions specified in the design load sets given in Tab 1.

2.1.3 Design load sets

Design load sets are defined in Tab 1 for:

- plating and stiffeners along the full length of the ship
- primary supporting members located outside the cargo hold region
- primary supporting members along the full length of non-cargo ships.

For primary supporting members located within the cargo hold region of ships carrying containers, dry bulk or liquid cargo, design load sets are defined respectively in Tab 2, Tab 3 and Tab 4.

Only the design load sets corresponding to the loading conditions defined in Ch 5, Sec 8 for the considered ship type are to be applied.

Table 1 : Design load sets

Item	Design load set	Load component	Draught	Acceptance criteria **(7)**	Design load scenario / Loading condition
Outer shell, superstructure walls and exposed deck	SEA-1	P_{ex} , P_d	T_{SC}	AC-2	Sea-going / Full load condition
	SEA-2 **(1)**	P_{ex}	T_{SC}	AC-1	Harbour condition
Water ballast tank	WB-1	$P_{in} – P_{ex}$ **(2)**	T_{BAL}	AC-2	Sea-going / Normal ballast condition
	WB-2	$P_{in} – P_{ex}$ **(2)**	T_{BAL}	AC-2	Water ballast exchange / Normal ballast condition
	WB-3	$P_{in} – P_{ex}$ **(2)**	0,25 T_{SC} **(10)**	AC-1	Harbour condition
	WB-4	$P_{in} – P_{ex}$ **(2)**	0,25 T_{SC} **(10)**	AC-3	Tank testing condition
Water ballast tank and bulk cargo hold assigned as ballast hold	WB-5	$P_{in} – P_{ex}$ **(2)**	T_{BAL-H} **(6)**	AC-2	Sea-going / Heavy ballast condition
	WB-6 **(8)**	$P_{in} – P_{ex}$ **(2)** **(11)**	T_{BAL-H} **(6)**	AC-2	Water ballast exchange / Heavy ballast condition
	WB-7 **(9)**	P_{in}	–	AC-1	Harbour condition
	WB-8 **(9)**	P_{in}	–	AC-3	Tank testing condition
Liquid cargo hold	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Dry bulk cargo hold	FBC-0	P_{in} **(12)**	–	AC-3 **(13)**	Flooded / flooded and opposite holds empty
	BC-1	P_{in}	T_{SC}	AC-2	Sea-going / Homogeneous loading, fully filled
	FBC-1	P_{in} **(12)**	–	AC-3 **(13)**	Flooded / Homogeneous, flooded and opposite holds fully filled
	BC-2	P_{in}	–	AC-1	Harbour / Homogeneous loading, fully filled
	BC-3	P_{in}	T_{SC}	AC-2	Sea-going / Homogeneous heavy cargo, partially filled
	FBC-3 **(14)**	P_{in} **(12)**	–	AC-3 **(13)**	Flooded / Homogeneous heavy cargo, flooded and opposite holds partially filled
	BC-4	P_{in}	–	AC-1	Harbour / Homogeneous heavy cargo, partially filled
	BC-5	P_{in}	T_{SC}	AC-2	Sea-going / Alternate light cargo, fully filled
	FBC-5 **(15)**	P_{in} **(12)**	–	AC-3 **(13)**	Flooded / Alternate light, flooded hold fully filled, opposite hold empty
	BC-6	P_{in}	–	AC-1	Harbour / Alternate light cargo, fully filled
	BC-7	P_{in}	T_{SC}	AC-2	Sea-going / Alternate heavy cargo, partially filled
	FBC-7 **(15)**	P_{in} **(12)**	–	AC-3 **(13)**	Flooded / Alternate heavy, flooded hold partially filled, opposite hold empty
	BC-8	P_{in}	–	AC-1	Harbour / Alternate heavy cargo, partially filled
	BC-9	F_{sc-ib} or F_{sc-hs}	T_{SC}	AC-2	Sea-going / Steel Coils condition
	BC-10	$F_{sc-ib-s}$ or $F_{sc-hs-s}$	T_{SC}	AC-1	Harbour / Steel Coils condition

Item	Design load set	Load component	Draught	Acceptance criteria **(7)**	Design load scenario / Loading condition
Other tanks (fuel oil tank, fresh water tank, bilge tank, drain storage tank)	TK-1	$P_{in} - P_{ex}$ **(2)**	T_{BAL}	AC-2	Sea-going / Normal ballast condition
	TK-2	$P_{in} - P_{ex}$ **(2)**	0,25 T_{SC} **(10)**	AC-1	Harbour condition
	TK-3 **(5)**	$P_{in} - P_{ex}$ **(2)** **(11)**	0,25 T_{SC} **(10)**	AC-3	Tank testing condition
Sea chest	SC-1	P_{sc}	–	AC-1	Harbour / Inlet grating cleaning overpressure
Structural watertight boundaries intended to stop vertical and horizontal flooding	FD-1 **(4)**	P_{in}	T_{SC}	AC-3	Flooded condition
Exposed deck, internal decks or platforms	DL-1 **(3)**	P_{dl} , F_U	T_{SC}	AC-2	Sea-going / Full load condition
	DL-2 **(3)**	P_{dl} , F_U	–	AC-1	Harbour condition

(1) For outer shell only
(2) P_{ex} is to be considered for external shell only
(3) Distributed or concentrated loads only. Need not be combined with simultaneously occurring green sea pressure
(4) Not applicable to external shell and to vertically corrugated transverse bulkheads separating dry bulk cargo holds
(5) Not applicable to gas fuel tanks
(6) Minimum draught among heavy ballast conditions is to be used
(7) See acceptance criteria definition in Ch 1, Sec 2, [3.4]
(8) Not to be applied to bulk cargo hold assigned as ballast hold
(9) Dry bulk cargo hold only
(10) 0,7 T_{SC} is to be used for ships assigned with service notations **ro-ro cargo ship**, **PCTC**, **PCC**, **ro-ro passenger ship** or **passenger ship**
(11) P_{ex} is not to be considered for tanks tested in dry dock conditions
(12) Loads for the flooded hold and opposite hold are defined in Ch 5, Sec 6, [4.1.7]
(13) Applicable only to plane bulkheads. For vertically corrugated bulkheads, specific criteria are given in Ch 7, Sec 4, [2]
(14) Applicable only to homogeneous heavy cargo loading condition
(15) Applicable only to non homogeneous loading conditions.

Table 2 : Design load sets for primary supporting members within container holds

Item	Design load set	Load component	Draught	Acceptance criteria	Design load scenario / Loading condition
Double bottom floors and girders	PC-1	$R - P_{ex}$	0,9 T_{SC}	AC-2	Sea-going / Containers stacks forces and sea pressure
	SEA-2	P_{ex}	T_{SC}	AC-1	Harbour condition / Sea pressure only
Side transverses and stringers	SEA-1	P_{ex}	T_{SC}	AC-2	Sea-going / Full load condition
Note 1: For the other primary supporting members, design load sets listed in Tab 1 are to be considered.					

Table 3 : Design load sets for primary supporting members within dry bulk cargo holds

Item	Design load set	Load component	Draught	Acceptance criteria **(3)**	Design load scenario / Loading condition
Bulk cargo hold assigned as ballast hold	WB-5	$P_{in} - P_{ex}$ **(1)**	T_{BAL-H}	AC-2	Sea-going / Heavy ballast condition
	WB-7	P_{in}	–	AC-1	Harbour condition
	WB-8	P_{in}	–	AC-3	Tank testing condition
Dry bulk cargo hold	BC-11	$P_{in} - P_{ex}$ **(1)**	T_{SC}	AC-2	Cargo loading condition
	BC-12	$P_{in} - P_{ex}$ **(1)**	–	AC-1	Harbour condition
	FBC-0	P_{in} **(4)**	–	AC-3 **(5)**	Flooded / flooded and opposite holds empty
	FBC-1	P_{in} **(4)**	–	AC-3 **(5)**	Flooded / Homogeneous, flooded and opposite holds fully filled
	FBC-3 **(6)**	P_{in} **(4)**	–	AC-3 **(5)**	Flooded / Homogeneous heavy cargo, flooded and opposite holds partially filled
	FBC-5 **(7)**	P_{in} **(4)**	–	AC-3 **(5)**	Flooded / Alternate light, flooded hold fully filled, opposite hold empty
	FBC-7 **(7)**	P_{in} **(4)**	–	AC-3 **(5)**	Flooded / Alternate heavy, flooded hold partially filled, opposite hold empty
Structural watertight boundaries intended to stop vertical and horizontal flooding	FD-1 **(2)**	P_{in}	T_{SC}	AC-3	Flooded condition

(1) P_{ex} is to be considered for external shell only

(2) Not applicable to external shell and vertically corrugated transverse bulkheads separating dry bulk cargo holds

(3) See acceptance criteria definition in Ch 1, Sec 2, [3.4]

(4) Loads for the flooded hold and opposite hold are defined in Ch 5, Sec 6, [4.1.7]

(5) Applicable only to plane bulkheads. For vertically corrugated bulkheads, specific criteria are given in Ch 7, Sec 6, [4.7]

(6) Applicable only to homogeneous heavy cargo loading condition

(7) Applicable only to non-homogeneous loading conditions.

Table 4 : Design load sets for primary supporting members within liquid cargo holds

Item	Design load set **(4)**	Load component	Draught	Acceptance criteria **(5)**	Design load scenario / Loading condition
Double bottom floors and girders **(2)**	SEA-1	P_{ex}	0,9 T_{SC} **(1)**	AC-2	Sea-going / Full load condition
	SEA-2	P_{ex}	T_{SC}	AC-1	Harbour / Full load condition
	LC-2	$P_{in} - P_{ex}$	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-6	$P_{in} - P_{ex}$	**(3)**	AC-1	Harbour / Partial load condition
Side transverses **(2)**	SEA-1	P_{ex}	0,9 T_{SC}	AC-2	Sea-going / Full load condition
	SEA-2	P_{ex}	T_{SC}	AC-1	Harbour / Full load condition
	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Deck transverses	SEA-1	P_{ex} **(6)**	T_{SC}	AC-2	Sea-going / Full load condition
	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition

Item	Design load set **(4)**	Load component	Draught	Acceptance criteria **(5)**	Design load scenario / Loading condition
Vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkheads and corrugations on corrugated bulkheads	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Cross ties in centre tanks **(7)**	LC-1	$\frac{P_{in-p} + P_{in-s}}{2}$	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	$\frac{P_{in-p} + P_{in-s}}{2}$	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Cross ties in wing tanks **(8)**	LC-7	$\frac{P_{in} + P_{ex}}{2}$	T_{SC}	AC-2	Sea-going / Full load condition
	LC-8	$\frac{P_{in} + P_{ex}}{2}$	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-9	$\frac{P_{in} + P_{ex}}{2}$	T_{SC}	AC-1	Harbour condition
	LC-10	$\frac{P_{in} + P_{ex}}{2}$	T_{SC}	AC-3	Tank testing condition
Structural watertight boundaries intended to stop vertical and horizontal flooding	FD-1 **(9)**	P_{in}	T_{SC}	AC-3	Flooded condition

P_{in-p} : Design pressure from port side wing cargo tank, in kN/m².

P_{in-s} : Design pressure from starboard side wing cargo tank, in kN/m².

(1) If the loading condition where the combination of an empty cargo tank and a mean ship's draught greater than 0,9 T_{SC} is included in ship's loading manual, the maximum corresponding draught is to be considered

(2) Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in Chapter 4. Where the optional loading conditions exceed the minimum Rule required loading conditions, the draughts will be subject to special consideration.

(3) For ships with two watertight or oil-tight longitudinal bulkheads, the draught is to be taken as 0,25 T_{SC}. For ships with a centreline bulkhead, the draught is to be taken as 0,33 T_{SC}.

(4) When the ship's configuration cannot be described by the structural members or structural configurations identified above, the applicable Design Load Sets to determine the scantling requirements of primary supporting member are to be selected so as to cover the following cases, as applicable:

- A full tank on one side of the member with the tank or space on the other side empty.
- A full tank on one side of the member with the external pressure minimised.
- External pressure maximised with the adjacent tank or space empty.

The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the AC-1 and AC-2 acceptance criteria are to be selected.

(5) See acceptance criteria definition in Ch 1, Sec 2, [3.4]

(6) Green sea pressure only or other loads on deck

(7) Full wing cargo tanks, centre tank empty

(8) Full centre tank, wing cargo tanks empty

(9) Not applicable to external shell and vertically corrugated transverse bulkheads separating dry bulk cargo holds.

Section 3 Minimum Thickness

1 Minimum thickness

1.1 General requirements

1.1.1 The gross thickness, in mm, of all structural elements including plating, web and face plate, if any, of stiffeners and tripping brackets, web plating and flange of primary supporting members, is to be not less than 5,0 mm.

1.1.2 Web and tripping brackets

In addition to [1.1.1], the net thickness of the web of stiffeners or primary supporting members and of tripping brackets, in mm, is to be:

- not less than 40% of the net required thickness of the attached plating, to be determined according to Ch 7, Sec 4.
- less than twice the net offered thickness of the attached plating.

Section 4 Plating

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

α_p : Correction factor for the panel aspect ratio, to be taken as follows:

$$\alpha_p = 1,2 - \frac{b}{2,1\ a}$$

without being taken greater than 1,0

K_{corr} : Coefficient to take into account the corrosion:

- in general:
  $K_{corr} = 1,0$
- for tank testing at construction stage:
  $K_{corr} = 1,2$

P : Pressure for the considered design load set (see Ch 7, Sec 2, [2]), in kN/m², calculated at the load calculation point defined in Ch 4, Sec 6, [2.2]

σ_L : Hull girder normal stress, in N/mm², as defined in Ch 7, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 4, Sec 6, [2.2]

χ : Coefficient taken equal to:

- in intact condition:
  $\chi = 1,00$
- in accidental condition:
  - for collision bulkheads:
    $\chi = 1,00$
  - for other watertight boundaries of compartments:
    $\chi = 1,15$

1 Plating subject to lateral pressure

1.1 Yielding check

1.1.1 Plating

The net thickness t, in mm, of plate panels subject to lateral pressure is to be not less than the greatest of the values obtained, for all the applicable design load sets defined in Ch 7, Sec 2, [2.1.3], from the following formula:

$$t = 0,0158\ \alpha_p\ b\ K_{R,a}\sqrt{\frac{|P|}{\chi\ C_a\ R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient for plate, taken equal to:

$$C_a = K_{corr}\beta - \alpha\frac{|\sigma_L|}{R_{eH}}$$

without being taken greater than $K_{corr}C_{a\text{-}max}$

β, α : Coefficients as defined in Tab 1

$C_{a\text{-}max}$: Maximum permissible bending stress coefficient, as defined in Tab 1.

$K_{R,a}$: Coefficient to take into account the curvature of the plate panel, taken equal to:

- for curved plate panels:

$$K_{R,a} = 1 - \left(\frac{b}{2R}\cdot 10^{-3}\right)$$

to be taken not less than 0,5

- for flat panels:
  $K_{R,a} = 1$

R : Radius of curvature of the plate panel, in m, measured in a plane perpendicular to the longer plate edge.

Table 1 : Coefficients β, α and $C_{a\text{-}max}$

Acceptance criteria set	Structural member		β	α	$C_{a\text{-}max}$
AC-1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely stiffened plating		1,0	
	Other members		0,8	0	
AC-2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely stiffened plating		1,0	
	Other members		1,0	0	1,0
AC-3	Longitudinal strength members	Longitudinally stiffened plating	1,1	0,5	1,0
		Transversely stiffened plating		1,0	
	Other members		1,0	0	

1.2 Plating of corrugated bulkheads

1.2.1 Cold and hot formed corrugations

The net plate thickness t, in mm, of corrugated bulkheads is not to be taken less than the greatest value calculated for all applicable design load sets, as defined in Ch 7, Sec 2, [2.1.3], given by:

$$t = 0,0158 b_p \sqrt{\frac{|P|}{C_{CB}\, R_{eH}}}$$

where:

b_p : Plate width, in mm, taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, see Ch 4, Sec 5, Fig 27

C_{CB} : Permissible bending stress coefficient for corrugated bulkhead plating taken equal to:

- For acceptance criteria set AC-1 for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads: $C_{CB} = 0,75$
- For acceptance criteria set AC-2 for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads: $C_{CB} = 0,90$
- For acceptance criteria set AC-3 for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads: $C_{CB} = K_{corr}\, 0,95$
- For horizontally corrugated longitudinal bulkheads, without being greater than $C_{CB\text{-}max}$:

$$C_{CB} = K_{corr}\beta_{CB} - \alpha_{CB}\frac{|\sigma_L|}{R_{eH}}$$

β_{CB} : Coefficient as defined in Tab 2

α_{CB} : Coefficient as defined in Tab 2

$C_{CB\text{-}max}$: Maximum permissible bending stress coefficient as defined in Tab 2.

Table 2 : Coefficients β_{CB}, α_{CB} and $C_{CB\text{-}max}$

Acceptance criteria set	Structural member	β_{CB}	α_{CB}	$C_{CB\text{-}max}$
AC-1	Horizontally corrugated longitudinal bulkheads	0,9	0,5	0,75
AC-2		1,05	0,5	0,9
AC-3		1,1	0,5	0,95

1.2.2 Built-up corrugations

In addition to [1.2.1], the net required thickness of the wider plating of built-up corrugations, t_w in mm, is to be taken as the greatest value calculated for all applicable design load sets, as defined in Ch 7, Sec 2, [2.1.3], given by:

$$t_W = \sqrt{\frac{5 b_W^{\,2}\, |P| 10^{-4}}{C_{CB}\, R_{eH}} - t_N^{\,2}}$$

t_N : Net required thickness of the narrower plating, either flange or web, in mm, as obtained in [1.2.1]

b_W : Plate width, in mm, of the wider plating, taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, whichever is greater, see Ch 4, Sec 5, Fig 27

1.3 Buckling check

1.3.1 The buckling check of plate panels is to be performed according to Ch 9, Sec 1.

2 Transverse vertically corrugated bulkheads separating dry bulk cargo holds in flooded condition

2.1 Application

2.1.1 These requirements apply to vertically corrugated transverse watertight bulkheads of the cargo holds of ships intended for the carriage of dry cargoes in bulk.

2.2 Net thickness of corrugation

2.2.1 Cold and hot formed corrugations

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is not to be taken less than:

$$t = 0,0149 b_p \sqrt{\frac{1,05\ P_R}{R_{eH}}}$$

where:

b_p : Plate width, in mm, taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, see Ch 4, Sec 5, Fig 27

P_R : Resultant pressure, in kN/m^2, as defined in Ch 5, Sec 6, [4.1.7].

The net thickness is also to comply with the requirements given in [1.2.1].

2.2.2 Built-up corrugations

Where the thicknesses of the flange and web of built-up corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds are different, the net plate thicknesses are not to be taken less than that obtained from the following formula.

The net thickness t_N, in mm, of the narrower plating is not to be taken less than that calculated according to [2.2.1] with b_p taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, whichever is smaller.

The net thickness t_W, in mm, of the wider plating is not to be taken less than the greater of:

a) The thickness calculated according to [2.2.1] with b_p taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, whichever is greater.

b) $$t_W = \sqrt{\frac{4,62 b_W^2\ P_R 10^{-4}}{R_{eH}} - t_{NO}^2}$$

where:

t_{NO} : Net offered thickness of the narrower plating, in mm, not to be taken greater than that obtained in a)

b_W : Plate width, in mm, of the wider plating, taken as the width of the corrugation flange $b_{f\text{-}cg}$ or the web $b_{w\text{-}cg}$, whichever is greater, see Ch 4, Sec 5, Fig 27.

The net thickness is also to comply with the requirements given in [1.2.2].

2.2.3 Lower part of corrugation

The net thickness of the lower part of corrugations is to be maintained for a distance of not less than 0,15 ℓ_C measured from the top of the lower stool, or from the inner bottom where no lower stool is fitted. The span of the corrugations ℓ_C, in m, is to be taken as given in Ch 4, Sec 5, [10.3.5].

2.2.4 Middle part of corrugation

The net thickness of the middle part of corrugations is to be maintained for a distance not greater than 0,3 ℓ_C from the bottom of the upper stool, or from the deck if no upper stool is fitted. The net thickness is also to comply with the requirements in Ch 7, Sec 6, [4.7.2] and [1.2].

3 Strength check of plating supporting wheeled cargo

3.1 General

3.1.1 The requirements of this Article apply for the strength check of plating supporting wheeled cargo.

3.1.2 If deemed necessary, the Society may require a fatigue assessment of plating supporting wheeled cargo.

3.2 Load model

3.2.1 General

Static and dynamic forces induced by relevant types of wheeled cargo are to be considered.

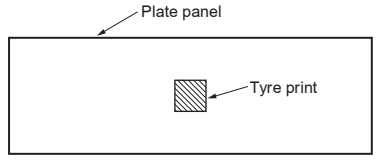
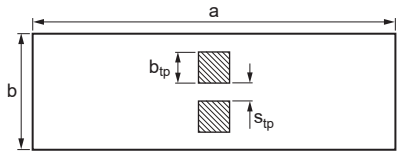
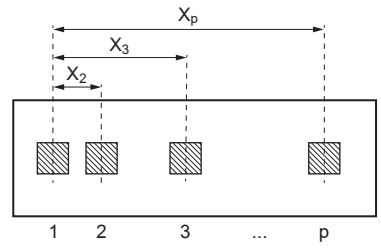
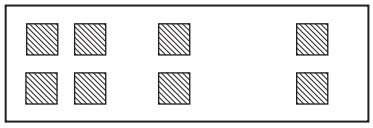
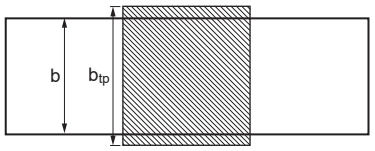
3.2.2 Tyre print

For the purpose of applying the requirements in [3.3], a single tyre print is to be considered for wheels that belong to the same axle and are separated from each other by not more than half of their individual width.

3.2.3 Forces due to wheeled cargo

The wheel force P_0 induced by a single wheel, in kN, is to be taken as defined in Ch 5, Sec 6, [7.2] considering dynamic forces in the vertical direction only.

Table 3 : Tyre print arrangements on plate panel

Tyre print arrangement	Total load on plate panel	m	α	δ	C_l
	$n\ P_0$	1	$\frac{A_T}{ab}10^6$	1	1
	$2\ n\ P_0$	2	$\frac{A_T}{ab}10^6$	$\frac{\delta_1 + \delta_2}{2}$	1
	$p\ n\ P_0$ $p \geq 2$	1	$\frac{A_T}{ab}10^6$	1	$\max\left(1 + \sum_{\substack{i=1 \\ i \neq j}}^{p} \beta_i, j \in [1;p]\right)$
	$2\ p\ n\ P_0$ $p \geq 2$	2	$\frac{A_T}{ab}10^6$	$\frac{\delta_1 + \delta_2}{2}$	$\max\left(1 + \sum_{\substack{i=1 \\ i \neq j}}^{p} \beta_i, j \in [1;p]\right)$
	$\delta\ n\ P_0$	1	$\frac{A_T}{ab_{tp}}10^6$	$\frac{b}{b_{tp}}$	1

Note 1:

A_T : Tyre print area, in m^2, as defined in [3.3.2]

$$\delta_1 = 1 - \frac{s_{tp}}{b - b_{tp}}$$

$$\delta_2 = 1 - \frac{3s_{tp}^2 + 6s_{tp}b_{tp}}{3b^2 - 4b_{tp}^2}$$

s_{tp} : Distance, in mm, between the two tyre prints

b_{tp} : Tyre print breadth, in mm

βi : Coefficient for the considered tyre print:

- for $\alpha_i < 2$: $\beta_i = 0{,}8\ (1{,}2 - 2{,}02\ \alpha_i + 1{,}17\ \alpha_i^2 - 0{,}23\ \alpha_i^3)$
- for $\alpha_i \geq 2$: $\beta_i = 0$

with:

$$\alpha_i = \frac{x_i}{b}$$

x_i : Distance, in mm, from the considered tyre print (i) to the reference tyre print (j)

p : Number of tyre prints along the panel length.

Note 2: For multiple tyre prints arrangements, all tyre prints are to be identical.Tyre prints with various characteristics acting simultaneously on a plate panel are considered by the Society on a case by case basis.

3.3 Plating

3.3.1 Net thickness

The net thickness t, in mm, of plate panels supporting wheeled cargo is to be not less than the value obtained from the following formula:

$$t = 13,8 C_{WL} \sqrt{\frac{mn|P_0|}{C_a R_{eH}} \delta C_l}$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - 0,05\frac{a}{b} + 0,02\left(4 - \frac{a}{b}\right)\alpha^{0,5} - 1,75\alpha^{0,25}$$

where a/b is to be taken not greater than 3

α : Coefficient to be taken as given in Tab 3

m : Number of tyre prints over the panel breadth, to be taken as given in Tab 3

n : Number of wheels per tyre print

P_0 : Wheel force, in kN, as defined in [3.2.3].

C_a : Permissible bending stress coefficient for plate, as defined in [1.1.1].

δ : Coefficient to be taken as given in Tab 3

C_l : Coefficient to be taken as given in Tab 3

3.3.2 Tyre print area

The tyre print area, A_T, in m^2, is to be taken as indicated by the Designer but not greater than:

$$A_T = 9,81\frac{nQ_A}{n_W p_T}$$

where:

n : number of wheels per tyre print

Q_A : Axle load, in t

n_W : Number of individual wheels for the axle considered

p_T : Tyre pressure, in kN/m^2. When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 4.

When the tyre print consists of several wheels (see [3.2.2]), A_T is the total print area, including the area in between single wheels.

Table 4 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T, in kN/m^2	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	Not applicable
Vans	600	Not applicable
Trucks and trailers	800	Not applicable
Handling machines	1100	1600

4 Plating subject to impact loads

4.1 General

4.1.1 Unless otherwise specified, the net thickness of plate panels subject to impact is to be not less than the value obtained, in mm, from the following formula:

$$t = \frac{0,0158\alpha_p b}{C_d}\sqrt{\frac{P_I}{C_a R_{eH}}}$$

where:

C_d : Plate capacity correction coefficient:

- for impact on flat bottom forward, on flat area of the bottom aft and for berthing impact on the side shell:
  $C_d = 1,3$
- for sloshing:
  $C_d = 1,0$
- for impact on bow flare:
  $C_d = 1,2$

C_a : Permissible bending stress coefficient taken as: for acceptance criteria AC-4:
$C_a = 1,0$

P_I : Any impact pressure defined in the Rules, including:
- bottom impact pressure, as defined in Ch 5, Sec 5, [4.2.1]
- bow impact pressure, as defined in Ch 5, Sec 5, [4.3.1]
- sloshing impact pressure, as defined in Ch 5, Sec 6, [2.2.2]
- stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2]
- berthing impact pressure, as defined in Ch 5, Sec 5, [4.4]

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

5 Strength check of plating supporting steel coils on wooden dunnage

5.1 General

5.1.1 The net thickness of inner bottom plating, hopper side plating and inner hull plating for ships intended to carry steel coils is to comply with [5.2.1] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

5.2 Yielding check

5.2.1 The net thickness t, in mm, of plating of longitudinally framed inner bottom, bilge hopper sloping plate and inner hull is not to be taken less than:

$$t = K_1 \sqrt{\frac{F_{sc} \times 10^3}{C_a R_{eH}}}$$

where:

K_1 : Coefficient taken as:

$$K_1 = \sqrt{\frac{1,7 \frac{s}{1000} \ell K_2 - 0,73 \left(\frac{s}{1000}\right)^2 K_2^2 - (\ell - \ell_{lp})^2}{2 \ell_{lp} \left(2 \frac{s}{1000} + 2 \ell K_2\right)}}$$

K_2 : Coefficient taken as:

$$K_2 = -\frac{s}{1000 \ell} + \sqrt{\left(\frac{s}{1000 \ell}\right)^2 + 1,37 \left(\frac{1000 \ell}{s}\right)^2 \left(1 - \frac{\ell_{lp}}{\ell}\right)^2 + 2,33}$$

F_{sc} : Load due to steel coil cargoes, taken equal to $F_{sc\text{-}ib\text{-}s}$, $F_{sc\text{-}ib}$, $F_{sc\text{-}hs\text{-}s}$ or $F_{sc\text{-}hs}$ as defined in Ch 5, Sec 6, [5], depending on the considered design load set (see Ch 7, Sec 2, [2])

C_a : Permissible bending stress coefficient, as defined in [1.1.1].

6 Special requirements

6.1 Minimum thickness of keel plating

6.1.1 The net thickness of the keel plating is not to be taken less than the offered net thickness of the adjacent 2 m width bottom plating, measured from the edge of the keel strake.

The width of the keel is defined in Ch 4, Sec 5, [7.2.1].

6.2 Bilge plating

6.2.1 Thickness of transversely stiffened bilge plating

a) The net thickness of transversely stiffened bilge plating is not to be taken less than the offered net required thickness for the adjacent bottom shell plating and adjacent side shell plating, by Part B, Chapter 7 and Part B, Chapter 9, whichever is greater. When bilge plating is divided into two or more strakes, in accordance with this requirement, the net thicknesses of lower and upper strakes are to be determined in comparison with the net required thicknesses of adjacent bottom shell plating and side shell plating respectively.

b) The net thickness of transversely stiffened rounded bilge plating t, in mm, is not to be taken less than:

$t = 6,45 \cdot 10^{-4} (P_{ex}\, s_b)^{0,4}\, R^{0,6}$

where:

P_{ex} : Sea pressure for the design load set SEA-1 as defined in Ch 7, Sec 2, [2.1.3], calculated at the lower turn of the bilge, in kN/m^2

R : Effective bilge radius in mm:

$R = R_0 + 0,5\ (\Delta s_1 + \Delta s_2)$

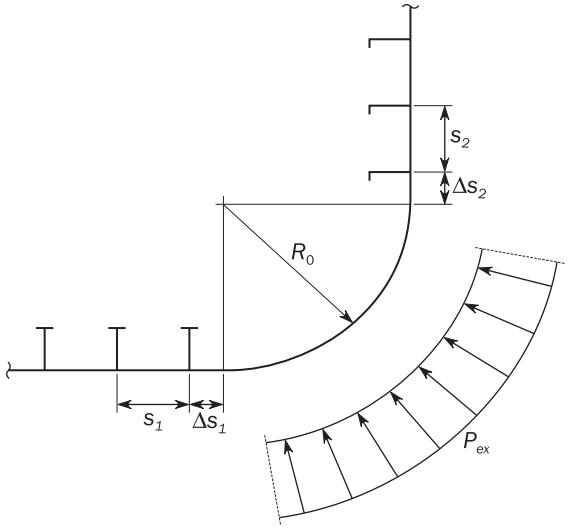
R_0 : Radius of curvature, in mm (see Fig 1)

Δs_1 : Distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see Fig 1. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero

Δs_2 : Distance between the upper turn of bilge and the lowest side longitudinal, in mm, see Fig 1. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero

s_b : Distance between transverse stiffeners, webs or bilge brackets, in mm.

Figure 1 : Transverse stiffened bilge plating



6.2.2 Thickness of longitudinally stiffened bilge plating

The net thickness of longitudinally stiffened bilge plating is not to be less than the value obtained according to [1.1.1].

A bilge keel is not considered as an effective 'longitudinal stiffening' member.

6.2.3 Transverse extension of bilge minimum plate thickness

Where a plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to be extended to the adjacent plate above the bilge, provided the plate seam is not more than $s_2/4$ below the lowest side longitudinal. Similarly, for the flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be extended to the adjacent plate, provided the plate seam is not more than $s_1/4$ beyond the outboard bottom longitudinal. For definition of s_1 and s_2, see Fig 1.

6.2.4 Hull envelope framing in bilge area

For transversely stiffened bilge plating, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The scantling of those longitudinals is to be not less than the one of the closer adjacent stiffener. The distance Δs_1 between the lower turn of bilge and the outermost bottom longitudinal is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals s_1. Similarly, the distance Δs_2 between the upper turn of the bilge and the lowest side longitudinal is generally not to be greater than one-third of the spacing between the two lowest side longitudinals s_2. See Fig 1.

6.3 Inner bottom of cargo holds intended to carry dry cargo

6.3.1 For ships with one of the following service notations:

- **general cargo ship**, intended to carry dry bulk cargo in holds
- **bulk carrier**
- **bulk carrier ESP**
- **self-unloading bulk carrier ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP**
- **combination carrier/OOC ESP**

the inner bottom net thickness is to be increased by 2 mm unless it is protected by a continuous wooden ceiling.

6.4 Sheer strake

6.4.1 General

The minimun witdth of the sheer strake is defined in Ch 4, Sec 5, [8.1.4].

6.4.2 Welded sheer strake

The net thickness of a welded sheer strake is not to be less than the offered net thickness of the adjacent side plating, provided this adjacent side plating is located entirely within the top wing tank or the double side tank, as the case may be.

6.4.3 Rounded sheer strake

The net thickness of a rounded sheer strake is not to be less than:

- the offered net thickness of the adjacent 2 m width deck plating, or
- the offered net thickness of the adjacent 2 m width side plating,

whichever is greater.

6.5 Deck stringer plating

6.5.1 The minimum width of deck stringer plating is defined in Ch 4, Sec 5, [9.1.2].

6.5.2 Within 0,6 L amidships, the net thickness of the deck stringer plate is not to be less than the offered net thickness of the adjacent deck plating.

6.6 Deck plating protected by wood sheathing or deck composition

6.6.1 The net thickness of deck plating protected by wood sheathing, deck composition or other arrangements deemed suitable by the Society may be reduced on a case by case basis. In no case this net thickness is to be less than the minimum value as given in Ch 7, Sec 3.

6.6.2 The sheathing is to be secured to the deck to the satisfaction of the Society.

6.7 Supporting structure in way of corrugated bulkheads

6.7.1 General

Requirements for the arrangement of bulkhead as given in Ch 4, Sec 5, [10.3] are to be considered together with [6.7.2] to [6.7.4].

6.7.2 Lower stool

a) The net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the stool side plate, within the region of the corrugation depth from the stool top plate, is not to be less than the greater of the following:

   - the net thickness obtain from [1.1]
   - the corrugated bulkhead flange net actual thickness at the lower end.

   If material of different yield strength are used, the required thickness is to be adjusted by the ratio of the two material factors as defined in Ch 4, Sec 1, [2.2].

c) Continuity between corrugation web and lower stool supporting brackets is to be maintained inside the stool.

d) The net thickness of supporting bracket is not to be less than 80% of the required net thickness of the corrugation webs and is to be of at least the same material yield strength.

e) The net thickness of supporting floors or girders is not to be less than the net required thickness of the stool side plating connected to the inner bottom and is to be of at least the same material yield strength. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors k, as defined in Ch 4, Sec 1, [2.2].

f) Where a lower stool is fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see Ch 4, Sec 1, [2.6].

6.7.3 Upper stool

a) The net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

b) The net thickness of the lower portion of stool side plating is not to be less than the greater of the following
   - the net thickness obtain from [1.1]
   - 80% of the upper part of the bulkhead plating as required by [1.2]
   - the corrugated bulkhead flange net actual thickness at the upper end.

   If material of different yield strength are used, the required thickness is to be adjusted by the ratio of the two material factors as defined in Ch 4, Sec 1, [2.2].

6.7.4 Local supporting structure in way of corrugated bulkheads without a lower stool

a) The net thickness of the supporting floors or girders and pipe tunnel beams in way of a corrugated bulkhead are not to be less than the required net thickness of the corrugation flanges and are to be of at least the same material yield strength. The inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and Z grade steel as defined in Ch 4, Sec 1, [2.6.1] is to be used unless through thickness properties are documented for approval.

b) Brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength. Where support is provided by gussets with shedder plates instead of brackets/carlings, the height of the gusset plate is to be at least equal to the corrugation depth. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates is not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flange and is to be of at least the same material yield strength.

6.8 Aft peak bulkhead

6.8.1 The net thickness of the aft peak bulkhead plating in way of the stern tube penetration is to be at least 1,6 times the required thickness for the bulkhead plating.

Section 5 Stiffeners

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

d_{shr} : Effective shear depth, in mm, as defined in Ch 4, Sec 6, [1.4.4]

f_{bdg} : Bending moment factor taken as:

- for continuous stiffeners with fixed ends, f_{bdg} is to be taken equal to:
  - for horizontal stiffeners and upper end of vertical stiffeners:

    $f_{bdg} = 12$
  - for lower end of vertical stiffeners:

    $f_{bdg} = 10$
- for non-continuous stiffeners which may be considered as simply supported at both ends:

  $f_{bdg} = 8$
- for stiffeners with end fixity other than above, variable load or being part of grillage, the requirements in [1.7] apply

f_{shr} : Shear force distribution factor taken as:

- for continuous stiffeners with fixed ends, or for non-continuous stiffeners which may be considered as simply supported at both ends, f_{shr} is to be taken equal to:
  - for horizontal stiffeners and upper end of vertical stiffeners:

    $f_{shr} = 0,5$
  - for lower end of vertical stiffeners:

    $f_{shr} = 0,7$
- for stiffeners with reduced end fixity or being part of grillage, the requirements in [1.7] apply.

K_{corr} : Coefficient to take into account the corrosion:

- in general:

  $K_{corr} = 1,0$
- for tank testing at construction stage:

  $K_{corr} = 1,1$

$K_{R,s}$: Coefficient to take into account the curvature of the associated plating, taken equal to:

- for curved associated plating:

  $$K_{R,s} = e^{-\left(6 \cdot 10^{-8} \cdot \left(\frac{s^2}{2Rt_{p,gr_off}}\right)^2\right)}$$

  to be taken not less than 0,7
- for flat associated plating:

  $K_{R,s} = 1$

ℓ_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6, [1.1.2]

ℓ_{shr} : Effective shear span, in m, as defined in Ch 4, Sec 6, [1.1.3]

ℓ_{lp} : Distance, in m, between outermost dunnage per EPP in the ship X direction, as defined in Ch 5, Sec 6

P : Design pressure for the design load set being defined in Ch 7, Sec 2 and calculated at the load calculation point defined in Ch 4, Sec 6, [3.2], in kN/m^2

R : Radius of curvature of the attached plating, in m, measured in a plane perpendicular to the stiffener axis

t_{p,gr_off} : Gross thickness offered, in mm, of the attached plating

χ : Coefficient as defined in Ch 7, Sec 4.

1 General

1.1 Yielding check of stiffeners subject to lateral pressure

1.1.1 Web plating

The net web thickness t_w, in mm, of stiffeners subject to lateral pressure is not to be taken less than the greatest of the values calculated for all applicable design load sets as defined in Ch 7, Sec 2, [2], as obtained from the following formulae:

$$t_w = \frac{f_{shr} K_{R,s} |P| s \ell_{shr}}{d_{shr} K_{corr} \chi C_t \tau_{eH}}$$

with χ C_t not to be taken greater than 1,0

where:

C_t : Permissible shear stress coefficient for the design load set being considered, as defined in Tab 1.

Table 1 : Coefficients β_s , α_s , $C_{s\text{-}max}$, C_t and C_{comb}

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$	C_t	C_{comb}
AC-1	Longitudinal strength members	0,85	1,0	0,75	0,75	0,75
	Other members	0,75	0			
AC-2	Longitudinal strength members	1,00	1,0	0,9	0,9	0,9
	Other members	0,90	0			
AC-3	Longitudinal strength members	1,10	1,0	1,0	1,0	1,0
	Other members	1,00	0			

1.1.2 Section modulus

The net section modulus, Z in cm^3, of stiffeners subject to lateral pressure is not to be taken less than the greatest of the values calculated for all applicable design load sets as defined in Ch 7, Sec 2, [2.1.3], as obtained from the following formulae:

$$Z = \frac{K_{R,s} |P| s \ell_{bdg}^{\ 2}}{f_{bdg} \chi C_s R_{eH}}$$

with χ C_s not to be taken greater than K_{corr}

where:

C_s : Permissible bending stress coefficient as defined in Tab 2 for the design load set being considered

σ_L : Hull girder normal stress, in N/mm^2, as defined in Ch 7, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 4, Sec 6, [2.2]

β_s , α_s , $C_{s\text{-}max}$: Coefficients as defined in Tab 1.

Table 2 : Definition of C_s

Sign of hull girder bending stress σ_L	Lateral pressure acting on	Coefficient C_s
Tension (positive)	stiffener side	$C_s = K_{corr}\beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ but not to be takengreater than K_{corr} $C_{s\text{-}max}$
Compression (negative)	plate side	
Tension (positive)	plate side	$C_s = K_{corr}$ $C_{s\text{-}max}$
Compression (negative)	stiffener side	

1.1.3 Group of stiffeners

Where stiffeners of equal scantlings are sequentially placed on a single stiffened panel, between primary supporting members, the scantling of every stiffener of the designated group may alternatively be taken as the greatest of the following:

- the average of the scantlings individually required for every stiffener within the group according to [1.1.1] and [1.1.2]
- 90% of the maximum scantling individually required for any of the stiffeners within the group according to [1.1.1] and [1.1.2].

1.2 Yielding check of stiffeners supporting wheeled cargo

1.2.1 General

Static and dynamic forces induced by relevant types of wheeled cargo are to be considered.

1.2.2 Forces due to wheeled cargo

The wheel force P_0 induced by a single wheel, in kN, is to be taken as defined in Ch 5, Sec 6, [7.2] considering dynamic forces only in the vertical direction.

1.2.3 Web plating

The net web thickness t_w, in mm, of stiffeners supporting wheeled cargo is not to be taken less than the greatest of the values calculated for all applicable design load sets, as obtained from the following formulae:

$$t_w = \frac{\alpha_w K_T |P_0|}{d_{shr} C_t \tau_{eH}} 10^3$$

where:

α_w : Coefficient taking into account the number of individual wheels per axle considered as acting on the stiffener, defined in Tab 3, without being taken less than 1,0

K_S, K_T : Coefficients taking account of the number of axles considered as acting on the stiffener, defined in Tab 4

C_t : Permissible shear stress coefficient defined in [1.1.1].

Table 3 : Wheeled cargo - Coefficient α_w

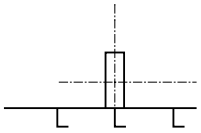
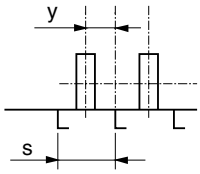
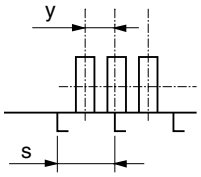
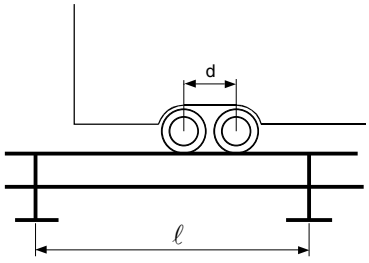
Single wheel configuration	Double wheels configuration	Triple wheels configuration
		
$\alpha_W = 1$	$\alpha_W = 2\left(1 - \frac{y}{s}\right)$	$\alpha_W = 3 - 2\frac{y}{s}$
Note 1: y : Distance, in mm, from the external wheel to the stiffener under consideration, to be taken equal to half the distance between the middle of the external wheels.		

Table 4 : Wheeled cargo - Coefficients K_S and K_T

Configuration		
Single axle	Double axles	
$K_S = 1$	if $d \le \ell/\sqrt{3}$	$K_S = \frac{172}{81} - \frac{4d}{3\ell} - \frac{d^2}{\ell^2} + \frac{d^4}{\ell^4}$
	if $d > \ell/\sqrt{3}$	$K_S = \frac{4}{3} - \frac{4d}{3\ell} + \frac{3d^2}{\ell^2} - \frac{8d^3}{3\ell^3}$
$K_T = 1$	$K_T = 2 - \frac{d}{2\ell} - \frac{3d^2}{2\ell^2} + \frac{d^3}{\ell^3}$	
Note 1: d : Distance, in m, between two axles (see Fig 1)		

Figure 1 : Wheeled cargo on stiffeners - Double axles



1.2.4 Section modulus

The minimum net section modulus, Z in cm³, of stiffeners supporting wheeled cargo is not to be taken less than the greatest of the values calculated for all applicable design load sets, as obtained from the following formulae:

$$Z = \frac{\alpha_w K_S |P_0| \ell_{bdg}}{6 C_S R_{eH}} 10^3$$

where:

C_s : Permissible bending stress coefficient defined in [1.1.2]

α_w, K_S, K_T: Coefficients defined in [1.2.3]

1.2.5 Multispan stiffeners

For multispan stiffeners supporting wheeled cargo and for stiffeners supporting more than 2 axles, it is to be checked that the normal stress σ and the shear stress τ, determined by a direct calculation, are in compliance with the requirements in [1.7].

1.3 Net section modulus and net shear sectional area of ordinary stiffeners subject to impact loads

1.3.1 Single span longitudinal, transverse and vertical ordinary stiffeners

Unless otherwise specified, the net plastic section modulus Z_{pl}, in cm³, as defined in Ch 4, Sec 6, [1.4.8] and the net web thickness t_w, in mm, of stiffeners subject to impact loads are to be not less than the values obtained from the following formulae:

$$Z_{pl} = \frac{P_I s \ell_{bdg}^2}{8(1 + n_s/2) C_s R_{eH}}$$

$$t_w = \frac{P_I s \ell_{shr}}{2 d_{shr} C_t \tau_{eH}}$$

where:

C_s : Permissible bending stress coefficient taken equal to 0,9 for acceptance criteria set AC-4

C_t : Permissible shear stress coefficient taken equal to 1,0 for acceptance criteria set AC-4

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 5, Sec 5, [4.2.1]
- bow impact pressure, as defined in Ch 5, Sec 5, [4.3.1]
- sloshing impact pressure, as defined in Ch 5, Sec 6, [2.2.2]
- stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2]
- berthing impact pressure, as defined in Ch 5, Sec 5, [4.4.1]

n_s : End fixation factor taken as:

- for both ends with low end fixity (simply supported):
  $n_s = 0$
- for one end fixed and one end simply supported:
  $n_s = 1$
- for continuous members or members with bracketed fitted at both ends:
  $n_s = 2$

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

1.4 Yielding check of stiffeners supporting steel coils on wooden dunnage

1.4.1 General

The net section modulus and the net shear sectional area of longitudinal stiffeners on inner bottom, bilge hopper sloping plate and inner hull for ships intended to carry steel coils are to comply with [1.4.2] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

1.4.2 Yielding check

The net section modulus Z, in cm³, and the net web thickness, t_w, in mm, of single span stiffeners located on inner bottom, bilge hopper sloping plate and inner hull are not to be taken less than:

$$Z = K_3 \frac{F_{sc}}{8\ C_s\ R_{eH}} 10^3$$

$$t_w = \frac{0,5\ F_{sc}}{d_{shr} C_t \tau_{eH}} 10^3$$

where:

K_3 : Span parameter, in m, as defined in Tab 5

n_2 : Number of load points per EPP of the inner bottom, see Ch 5, Sec 6, [5.1.3]

F_{sc} : Load due to steel coil cargoes, taken equal to $F_{sc\text{-}ib\text{-}s}$, $F_{sc\text{-}ib}$, $F_{sc\text{-}hs\text{-}s}$ or $F_{sc\text{-}hs}$ as defined in Ch 5, Sec 6, [5], depending on the considered design load set (see Ch 7, Sec 2, [2])

C_s : Permissible bending stress coefficient defined in [1.1.2]

C_t : Permissible shear stress coefficient for the design load set being considered, to be taken as:

- for acceptance criteria set AC-1:
  $C_t = 0,85$
- for acceptance criteria set AC-2:
  $C_t = 1,00$

1.5 Deck stiffeners in way of launching appliances used for survival craft or rescue boat

1.5.1 The scantlings of deck stiffeners are to be determined by direct calculations.

1.5.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

1.5.3 The combined stress, in N/mm², is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$ where R_m is the ultimate minimum tensile strength of the stiffener material, in N/mm².

Table 5 : Coefficient K_3

$n_2 = 1$	$n_2 = 2$	$n_2 = 3$	$n_2 = 4$	$n_2 = 5$	$n_2 = 6$
$K_3 = \ell_{bdg}$	$K_3 = \ell_{bdg} - \frac{\ell_{fp}^2}{\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{2\ell_{fp}^2}{3\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{5\ell_{fp}^2}{9\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{\ell_{fp}^2}{2\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{7\ell_{fp}^2}{15\ell_{bdg}}$

$n_2 = 7$	$n_2 = 8$	$n_2 = 9$	$n_2 = 10$	$n_2 > 10$	
$K_3 = \ell_{bdg} - \frac{4\ell_{fp}^2}{9\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{3\ell_{fp}^2}{7\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{5\ell_{fp}^2}{12\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{11\ell_{fp}^2}{27\ell_{bdg}}$	$K_3 = 2\ell_{bdg} / 3$	

1.6 Plate and stiffener of different materials

1.6.1 When the minimum specified yield stress of a stiffener exceeds the minimum specified yield stress of the attached plate by more than 35%, the following criterion is to be satisfied:

$$R_{eH\text{-}S} \leq \left(R_{eH\text{-}P} - \frac{\alpha_S |\sigma_L|}{\beta_S}\right) \frac{Z_P}{Z} + \frac{\alpha_S |\sigma_L|}{\beta_S}$$

where:

$R_{eH\text{-}S}$: Minimum specified yield stress of the material of the stiffener, in N/mm²

$R_{eH\text{-}P}$: Minimum specified yield stress of the material of the attached plate, in N/mm²

σ_L : Hull girder normal stress, in N/mm², as defined in Ch 7, Sec 2, [1.1] with $|\sigma_L|$ not to be taken less than $0,4\ R_{eH\text{-}P}$

Z : Net section modulus, in cm³, in way of face plate/free edge of the stiffener

Z_P : Net section modulus, in cm³, in way of the attached plate of stiffener

α_s , β_s : Coefficients defined in Tab 1.

1.7 Beam analysis

1.7.1 Model definition

The maximum normal bending stress σ and shear stress τ in a stiffener using net properties with reduced end fixity, variable load or being part of grillage are to be determined by direct calculations taking into account:

- the distribution of static and dynamic pressures and forces, if any
- the distribution of static and dynamic hull girder stresses, if any
- the number and position of intermediate supports (e.g. decks, girders, etc)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

1.7.2 Stress criteria

The stress is to comply with the following criteria:

a) for isolated beam analysis:

$\tau \leq \chi\ K_{corr}\ C_t\ \tau_{eH}$

$\sigma \leq \chi\ C_S\ R_{eH}$

b) for grillage analysis:

$$\sigma_{eq} \leq \chi \, K_{corr} \, C_{comb} \, R_{eH}$$

where:

C_t , C_S : Permissible shear and bending stress coefficients defined in [1.1]

C_{comb} : Permissible combined stress coefficient for the design load set being considered, as defined in Tab 1

σ_{eq} : Equivalent Von Mises stress, in N/mm^2:

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

1.8 Buckling check

1.8.1 The buckling check of stiffeners is to be performed according to Ch 9, Sec 1.

Section 6 Primary Supporting Members and Pillars

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

K_{corr} : Coefficient to take into account the corrosion as defined in Ch 7, Sec 4

P : Design pressure, in kN/m^2, for the design load set being considered as defined in Ch 7, Sec 2 and calculated at the load calculation point as defined in Ch 4, Sec 6, [4.1.1]

ℓ_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6, [1.1.6]

ℓ_{shr} : Effective shear span, in m, as defined in Ch 4, Sec 6, [1.1.7]

χ : Coefficient as defined in Ch 7, Sec 4

C_t : Permissible shear stress coefficient for the acceptance criteria set being considered, as given in Tab 2

C_s : Permissible bending stress coefficient for the acceptance criteria set, as given in Tab 2

ϕ_H : Depth of the opening measured in the direction parallel to the web height, in m

α : The greater of a or S1, in m, where a and S1 are defined in [4.4.1].

1 Application

1.1 Application

1.1.1 General requirements

The requirements in Article [2] apply to primary supporting members other than those covered by Article [3] and Article [4] subject to lateral pressure and/or concentrated loads, and to pillars subject to compressive and tensile axial loads.

The yielding and buckling checks are also to be carried out for members subject to any other specific loads.

1.1.2 Type of structural models

Depending on the service notation, ship type, structural arrangement and length, the supporting members are to be verified according to the requirements specified in Tab 1.

1.1.3 Requirements for holds intended to carry liquid cargo

The requirements in Article [3] apply to primary supporting members and vertical corrugations of bulkheads in holds intended to carry liquid cargo.

Table 1 : Primary supporting members applicable requirements

Ship type / length / structural arrangement		Structural models	Applicable requirements
general cargo ship **ro-ro cargo ship** **PCTC** **PCC** **ro-ro passenger ship** **passenger ship**	L < 150 m	Over whole ship length: Prescriptive or beam models (isolated beam model or grillage as applicable)	Part B, Chapter 7 **(1)**
	L ≥ 150 m	Over whole ship length: Complete ship model	Ch 8, App 3 or NI 640 **(1)**
All other cargo ships	L < 150 m	Over whole ship length: Prescriptive or beam models (isolated beam model or grillage as applicable)	Part B, Chapter 7 **(1)**
	L ≥ 150 m	• Within cargo area: cargo hold models • Outside cargo area: Prescriptive or beam model	Part B, Chapter 7 and Ch 8, App 1 **(1)**
	L ≥ 230 m with large deck openings	• Within cargo area: cargo hold models • Over whole ship length: Complete ship model	Ch 8, App 1 and Ch 8, App 3 **(1)**
(1) Specific prescriptive requirements in [4.7] and [4.8] applicable to dry bulk cargo holds are to be verified in addition to any direct strength analysis.			

Table 2 : Permissible bending and shear stress coefficients for primary supporting members

Acceptance criteria set	Structure attached to PSM	C_s	C_t	C_{comb}
AC-1	All boundaries, including decks and flats	0,70	0,70	0,70
AC-2		0,85	0,85	0,85
AC-3		0,90	0,90	0,90

1.1.4 Requirements for holds intended to carry dry bulk cargo

The requirements in Article [4] apply to primary supporting members and vertical corrugations of bulkheads in holds intended to carry dry bulk cargo.

1.1.5 Alternative to prescriptive requirements

Primary supporting members verified by direct strength analysis need not to comply with the requirements of this Section for all the design load scenarios already covered by such direct analysis (see typical design load scenarios for strength assessment in Ch 5, Sec 7, [2.1]).

However, the specific requirements in [4.7] and [4.8] related to the strength of corrugated bulkheads and double bottom in flooded conditions are to be applied for any hold intended to carry dry bulk cargo, irrespective of the achievement of direct strength analysis.

2 General

2.1 Scantling requirements

2.1.1 Net section modulus

The net section modulus Z_{n50}, in cm^3, of primary supporting members subject to lateral pressure is not to be taken less than the greatest value given by the following formula for all applicable design load sets defined in Ch 7, Sec 2, [2]:

$$Z_{n50} = 1000 \frac{|P| \; S \; \ell_{bdg}^2}{\chi \; f_{bdg} \; C_s \; R_{eH}}$$

where:

f_{bdg} : Bending moment distribution factor, as given in Tab 3

2.1.2 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of primary supporting members subject to lateral pressure is not to be taken less than the greatest value given by the following formula for all applicable design load sets defined in Ch 7, Sec 2, [2]:

$$A_{shr-n50} = 10 \frac{f_{shr} \; |P| \; S \; \ell_{shr}}{\chi \; C_t \; \tau_{eH}}$$

where:

f_{shr} : Shear force distribution factor, as given in Tab 3.

2.2 Wheeled loads

2.2.1 For primary supporting members subject to wheeled loads, the yielding check may be carried out according to [2.1] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles is located on the same primary supporting member according to Fig 1 to Fig 3, is to be considered.

The equivalent static pressure $P_{w\text{-}s}$, in kN/m^2, is to be obtained from the following formula:

$$P_{w-s} = 10 \frac{n_V Q_A}{\ell S} \left(3 - \frac{X_1 + X_2}{S}\right)$$

where:

n_V : Maximum number of vehicles possible located on the primary supporting member

Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, [7.2.2]

X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3)

X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3)

ℓ : Length of the primary supporting members (see Fig 1)

S : Primary supporting member spacing (see Fig 2)

The corresponding dynamic pressure P_{w-d}, in kN/m², is to be calculated for the HVM and FVM load cases by using the following formula:

$$P_{w-d} = \alpha P_{w-s}\frac{a_Z}{g}$$

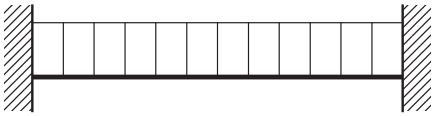
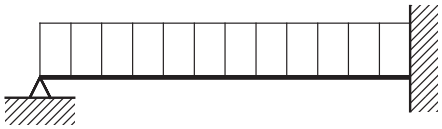
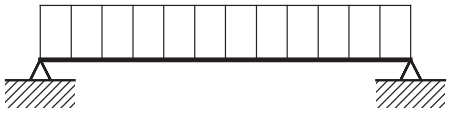
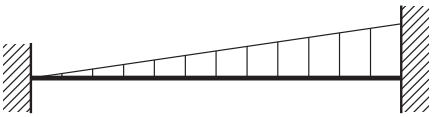
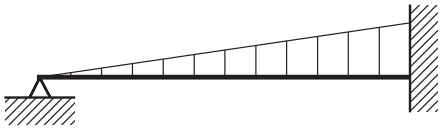
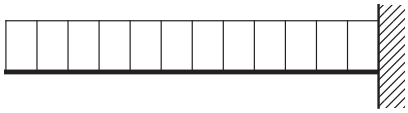
where:

α : Coefficient taken equal to:

- 0,5 in general
- 1,0 for landing gears of trailers.

For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation analysis according to the requirements of Ch 7, App 1.

Table 3 : Bending moment and shear force distribution factors f_{bdg} and f_{shr}

Load and boundary condition				Bending moment and shear force distribution factors (based on load at mid-span, where load varies)		
Load model	Position 1 Support	Position 2 Field	Position 3 Support	Position 1	Position 2	Position 3
A				$f_{bdg1} = 12,0$ $f_{shr1} = 0,50$	$f_{bdg2} = 24,0$ –	$f_{bdg3} = 12,0$ $f_{shr3} = 0,50$
B				– $f_{shr1} = 0,38$	$f_{bdg2} = 14,2$ –	$f_{bdg3} = 8,0$ $f_{shr3} = 0,63$
C				– $f_{shr1} = 0,50$	$f_{bdg2} = 8,0$ –	– $f_{shr3} = 0,50$
D				$f_{bdg1} = 15,0$ $f_{shr1} = 0,30$	$f_{bdg2} = 23,3$ –	$f_{bdg3} = 10,0$ $f_{shr3} = 0,70$
E				– $f_{shr1} = 0,20$	$f_{bdg2} = 16,8$ –	$f_{bdg3} = 7,50$ $f_{shr3} = 0,80$
F				– –	– –	$f_{bdg3} = 2,0$ $f_{shr3} = 1,0$

Note 1: The bending moment distribution factor f_{bdg} for the support positions is applicable for a distance of 0,2 ℓ_{bdg} from the end of the effective bending span of the primary supporting member.

Note 2: The shear force distribution factor f_{shr} for the support positions is applicable for a distance of 0,2 ℓ_{shr} from the end of the effective shear span of the primary supporting member.

Note 3: Application of f_{bdg} and f_{shr} :

The section modulus requirement within 0,2 ℓ_{bdg} from the end of the effective span is to be determined using the applicable f_{bdg1} and f_{bdg3} , however f_{bdg} is not to be taken greater than 12.

The section modulus of mid-span area is to be determined using $f_{bdg} = 24$, or f_{bdg2} from the Table if lesser.

The shear area requirement of end connections within 0,2 ℓ_{shr} from the end of the effective span is to be determined using $f_{shr} = 0,5$ or the applicable f_{shr1} or f_{shr3} , whichever is greater.

For models A through F, the value of f_{shr} may be gradually reduced outside of 0,2 ℓ_{shr} towards 0,5 f_{shr} at mid-span, where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

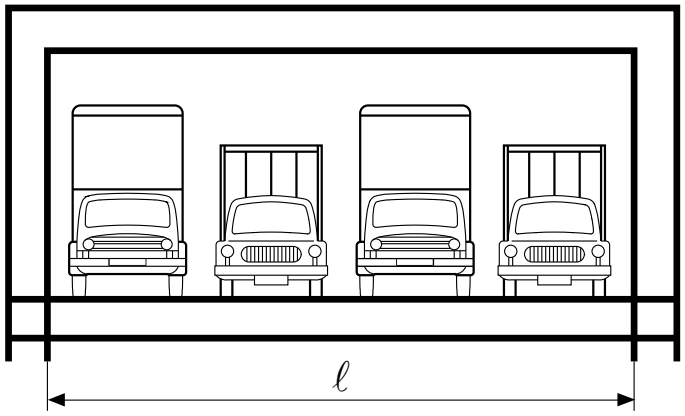


Figure 2 : Wheeled loads Distance between two consecutive axles

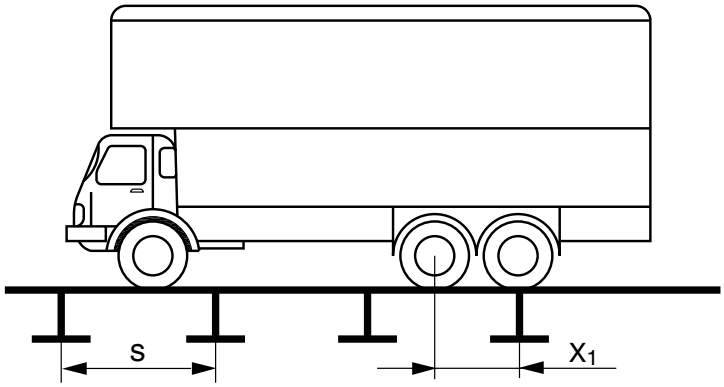
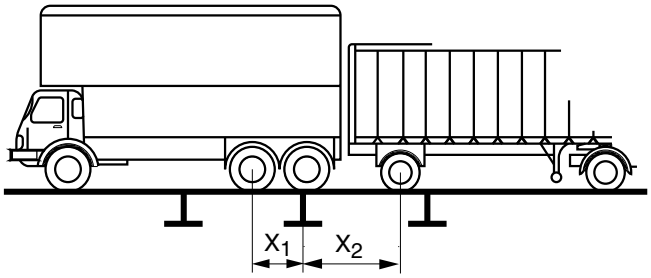


Figure 3 : Wheeled loads Distance between axles of two consecutive vehicles



2.3 Primary members subject to impact loads

2.3.1 The net section modulus Z_{n50}, in cm^3, of primary supporting members and their net shear area $A_{shr\text{-}n50}$, in cm^2, at any position along their span are not to be less than the values obtained from the following formulae:

$$Z_{n50} = \frac{f_{cb} P_l f_{pb} \ell_{bdg}^2 b_l}{f_{bdg} C_s R_{eH}} 10^3$$

$$A_{shr-n50} = 10 \frac{\sqrt{3} Q_l}{0,9 R_{eH}}$$

where:

f_{cb} : Correction factor for the bending moment at the ends and considering the patch load, taken as:

$$f_{cb} = 3f_{pb}^3 - 8f_{pb}^2 + 6f_{pb}$$

C_s : 0,8 for acceptance criteria AC-4

P_l : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 5, Sec 5, [4.2.1]
- bow impact pressure, as defined in Ch 5, Sec 5, [4.3.1]
- sloshing impact pressure, as defined in Ch 5, Sec 6, [2.2.2]
- stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2]

f_{pb} : Patch load modification factor for bending, taken as:

$$f_{pb} = \frac{\ell_l}{\ell_{bdg}}$$

Q_l : Shear force, in kN, taken as: $Q_l = f_{cs}\, f_{dist}\, P_l\, \ell_l\, b_l$

ℓ_l : Extent of impact load area, in m, along the span:

$$\ell_l = \sqrt{A_l}$$

not to be taken greater than:

- $0,5\, \ell_{shr}$ for the calculation of Q_l
- ℓ_{bdg} for the calculation of f_{pb}

f_{cs} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as:

$$f_{cs} = 0,5(f_{ps}^3 - 2f_{ps}^2 + 2)$$

f_{dist} : Coefficient for shear force distribution along the span, as defined in Fig 4

f_{ps} : Patch load modification factor for shear, taken as:

$$f_{ps} = 0,5\frac{b_l}{S}$$

f_{bdg} : Bending moment distribution factor, as given in Tab 3

b_l : Breadth of impact area supported by primary supporting member, in m, taken as:

$$b_l = \sqrt{A_l}$$

not to be taken greater than S

$A_l = 1,1\ L\ B\ C_B\ 10^{-3}$

For complex arrangements of primary supporting members, especially where grillage effect may not be ignored, for primary supporting members having variable cross sections, or for primary supporting members subject to berthing impact pressure as defined in Ch 5, Sec 5, [4.4], direct calculation is to be performed.

It is to be checked that the maximum obtained equivalent stress is not greater than $0,85\ R_{eH}$ when applying:

- in general: the load Q_l on a square area A_l to various locations on the model
- in case of berthing impact pressure: the pressure P_{Bl} on an area corresponding to the fender contact zone, as specified in Tab 4.

Figure 4 : Distribution of f_{dist} along the span of simple primary supporting members

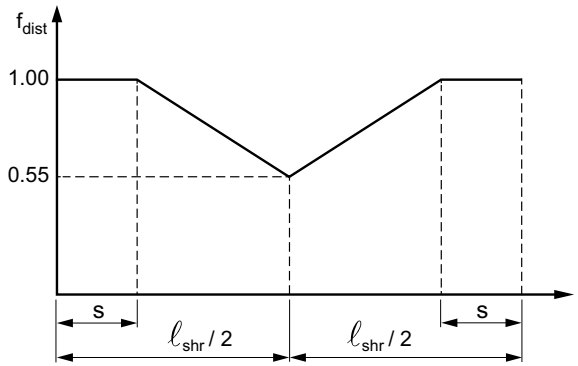


Table 4 : Berthing impact area

Ship moulded displacement Δ at T_{SC}, in t	Patch dimensions (m)	
	Length	Height
8000 < Δ ≤ 15000	2	1,4
15000 < Δ ≤ 20000	2,5	1,6
20000 < Δ ≤ 35000	3	1,8
35000 < Δ ≤ 40000	3	2
40000 < Δ ≤ 70000	3,5	2,4
70000 < Δ ≤ 150000	4	3
150000 < Δ ≤ 250000	5,5	3
250000 < Δ ≤ 400000	6,5	4
Δ > 400000	10,6	4

2.4 Deck primary members in way of launching appliances used for survival craft or rescue boat

2.4.1 The scantlings of deck primary supporting members are to be determined by direct calculations.

2.4.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.4.3 The combined stress, in N/mm^2, is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$ where R_m is the ultimate minimum tensile strength of the primary supporting member material, in N/mm^2.

2.5 Buckling check

2.5.1 The buckling check of primary supporting members is to be performed according to Ch 9, Sec 1.

2.6 Pillars subject to compressive axial load

2.6.1 Criteria

The maximum applied compressive axial load on a pillar F_{pill}, in kN, is to be taken as the greatest value calculated for all the applicable design load sets defined in Ch 7, Sec 2, [2], and is given by the following formula:

$$F_{pill} = P\, b_{a\text{-}sup}\, \ell_{a\text{-}sup} + \sum r_i F_{pill\text{-}i}$$

where:

$b_{a\text{-}sup}$: Mean breadth of area supported, in m

$\ell_{a\text{-}sup}$: Mean length of area supported, in m

$F_{pill\text{-}i}$: Axial load from the ith pillar above the pillar considered, in kN, if any

r_i : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to $0,9^i$ for the ith pillar of the line above the pillar considered, to be taken not less than 0,478

$A_{pill\text{-}n50}$: Net cross-section area of the pillar, in cm^2.

2.6.2 Buckling check

The buckling check of pillars is to be performed according to Ch 9, Sec 1, with σ_{av}, in N/mm^2, taken equal to:

$$\sigma_{av} = 10\frac{F_{pill}}{A_{pill\text{-}n50}}$$

2.7 Pillars subject to tensile axial load

2.7.1 Criteria

Pillars and PSM members subject to tensile axial load are to satisfy the criteria given in [5.1.4].

3 Primary supporting members in holds intended to carry liquid cargo

3.1 Floors in double bottom

3.1.1 Structural arrangement

Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

3.1.2 Net shear area

The net shear area,

$A_{shr\text{-}n50}$ in cm^2, of the floors at any position in the floor is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t\, \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = f_{shr}\, P\, S\, \ell_{shr}$$

f_{shr} : Shear force distribution factor, taken as:

$$f_{shr} = f_{shr-i}\left(1 - \frac{2y_i}{\ell_{shr}}\right)$$

without being taken less than 0,2

$f_{shr\text{-}i}$: Shear force distribution factor at the end of the span, ℓ_{shr}, as given in Tab 5

Table 5 : Shear force distribution factors of floors

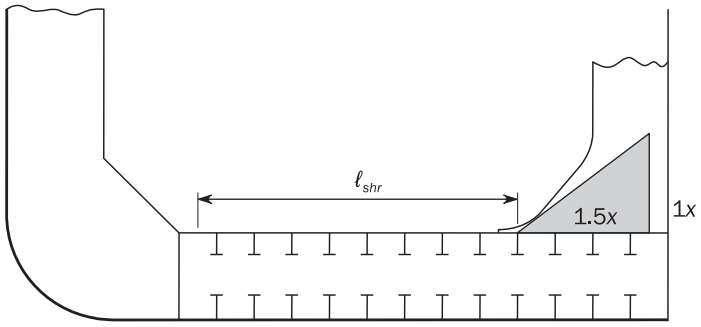
Structural configuration	Centre tank (f_{shr3} in Fig 6)	Wing tank	
		At inboard end (f_{shr2} in Fig 6)	At hopper knuckle end (f_{shr1} in Fig 6)
Ships with centreline longitudinal bulkhead	–	0,40	0,60
Ships with two longitudinal bulkheads	0,50	0,50	0,65

ℓ_{shr} : Effective shear span, of the double bottom floor, in m, as shown in Fig 5. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in Ch 4, Sec 6, [1.1.7]. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in Fig 5

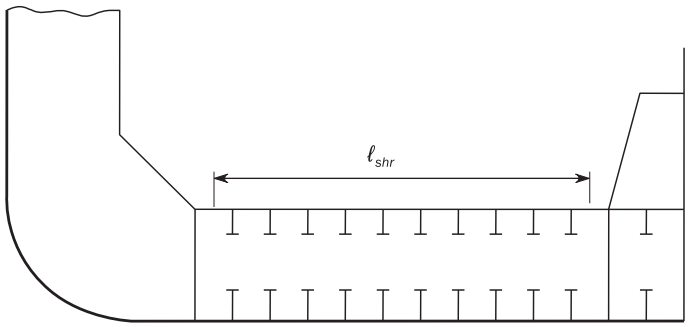
y_i : Distance from the considered cross section of the floor to the nearest end of the effective shear span, ℓ_{shr} in m.

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid point of effective shear span, ℓ_{shr} of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2.

Figure 5 : Effective shear span of floors

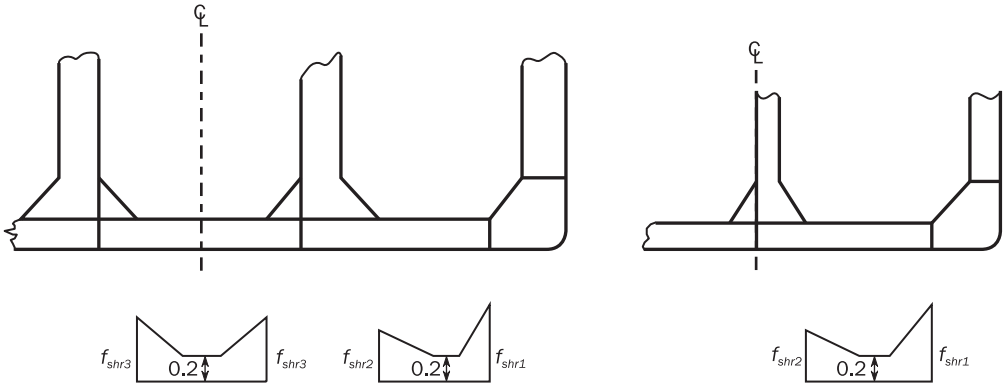


Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

Figure 6 : Shear force distribution factors of floors



3.2 Girders in double bottom

3.2.1 Structural arrangement

Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side, in way of longitudinal bulkheads and bulkhead stools and in way of flanges of vertically corrugated bulkheads without stools.

3.2.2 Net shear area of centre girders

For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}n50}$ in cm^2, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t\ \tau_{eH}}$$

where:

Q : Design shear force, in kN, taken as:

$$Q = 0,21\ n_1\ n_2\ P\ \ell_{shr}^2$$

ℓ_{shr} : Effective shear span as defined in [3.1.2]

P : Design pressure, in kN/m^2, as defined in [3.1.2]

n_1 : Coefficient taken as:

$$n_1 = 0,00935\left(\frac{\ell_{shr}}{S}\right)^2 - 0,163\left(\frac{\ell_{shr}}{S}\right) + 1,289$$

n_2 : Coefficient taken as:

$$n_2 = 1,3 - \left(\frac{S}{12}\right)$$

S : Double bottom floor spacing, in m, as defined in Ch 4, Sec 6, [1.2.2].

3.2.3 Net shear area of side girders

For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr\text{-}n50}$ in cm^2, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t\ \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = 0,14\ n_3\ n_4\ P\ \ell_{shr}^2$$

n_3 : Coefficient taken as:

$$n_3 = 1,072 - 0,0357\left(\frac{\ell_{shr}}{S}\right)$$

n_4 : Coefficient taken as:

$$n_4 = 1,2 - \left(\frac{S}{18}\right)$$

S : Double bottom floor spacing, in m, as defined in Ch 4, Sec 6, [1.2.2]

ℓ_{shr} : Effective shear span as defined in [3.1.2]

P : Design pressure, in kN/m^2, as defined in [3.1.2].

3.3 Deck transverses

3.3.1 Web depth

The web depth of deck transverses fitted under the deck is not to be less than:

- 0,20 $\ell_{bdg\text{-}dt}$ for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads
- 0,13 $\ell_{bdg\text{-}dt}$ for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank
- 0,10 $\ell_{bdg\text{-}dt}$ for the deck transverses of ships with a centreline longitudinal bulkhead
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

The web depth of deck transverses fitted above the deck is not to be less than:

- 0,10 $\ell_{bdg\text{-}dt}$
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

where:

$\ell_{bdg\text{-}dt}$: Effective bending span, in m, as defined in [3.3.2].

3.3.2 Net section modulus of deck transverses fitted below the upper deck

The net section modulus of deck transverses fitted below the upper deck, in cm^3, is not to be less than $Z_{in\text{-}n50}$ and $Z_{ex\text{-}n50}$ as given by the following formulae.

The net section modulus of the deck transverses fitted below the upper deck in the wing cargo tanks is also not to be less than required for the deck transverses fitted below the upper deck in the centre tanks.

$$Z_{in-n50} = \frac{850\, M_{in}}{C_s\, R_{eH}}$$

$$Z_{ex-n50} = \frac{850\, M_{ex}}{C_s\, R_{eH}}$$

where:

M_{in} : Design bending moment due to cargo pressure, in kNm, taken as:

- For deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

  $$M_{in} = 0,042\, \varphi_t\, P_{in-dt}\, S\, \ell_{bdg-dt}^2 + M_{st}$$

  without being taken less than M_0

- For deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

  $$M_{in} = 0,042\, \varphi_t\, P_{in-dt}\, S\, \ell_{bdg-dt}^2 + M_{vw}$$

  without being taken less than M_0

M_{st} : Bending moment transferred from the side transverse, in kNm:

$$M_{st} = c_{st}\, \beta_{st}\, P_{in-st}\, S\, \ell_{bdg-st}^2$$

where a cross tie is fitted in a wing cargo tank and $\ell_{bdg\text{-}st\text{-}ct}$ is greater than 0,7 $\ell_{bdg\text{-}st}$, then $\ell_{bdg\text{-}st}$ in the above formula may be taken as $\ell_{bdg\text{-}st\text{-}ct}$

M_{vw} : Bending moment transferred from the vertical web frame on the longitudinal bulkhead, in kNm:

$$M_{vw} = c_{vw}\, \beta_{vw}\, P_{in-vw}\, S\, \ell_{bdg-vw}^2$$

where $\ell_{bdg\text{-}vw\text{-}ct}$ is greater than 0,7 $\ell_{bdg\text{-}vw}$, then $\ell_{bdg\text{-}vw}$ in the above formula may be taken as $\ell_{bdg\text{-}vw\text{-}ct}$. For vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses

M_0 : Minimum bending moment, in kNm

$$M_0 = 0,083\, P_{in-dt}\, S\, \ell_{bdg-dt}^2$$

M_{ex} : Design bending moment due to green sea pressure, in kNm

$$M_{ex} = 0,067\, P_{ex-dt}\, S\, \ell_{bdg-dt}^2$$

$P_{in\text{-}dt}$: Design cargo pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, $\ell_{bdg\text{-}dt}$ of the deck transverse located at mid tank, in kN/m^2

$P_{in\text{-}st}$: Corresponding design cargo pressure in wing cargo tank for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at the mid-point of effective bending span, $\ell_{bdg\text{-}st}$ of the side transverse located at mid-tank, in kN/m^2

$P_{in\text{-}vw}$: Corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, $\ell_{bdg\text{-}vw}$ of the vertical web frame on the longitudinal bulkhead located at mid-tank, in kN/m^2

$P_{ex\text{-}dt}$: Design green sea pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, $\ell_{bdg\text{-}dt}$ of the deck transverse located at mid tank, in kN/m^2

φ_t : Coefficient taken as:

$$\varphi_t = 1 - 5\left(\frac{y_{toe}}{\ell_{bdg-dt}}\right)$$

without being taken less than 0,6

y_{toe} : Distance from the end of effective bending span, $\ell_{bdg\text{-}dt}$ to the toe of the end bracket of the deck transverse, in m

β_{st} : Coefficient taken as:

$$\beta_{st} = \left(0,9\left(\frac{\ell_{bdg-st}}{\ell_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{st-n50}}\right)\right)$$

without being taken less than 0,10 or greater than 0,65

β_{vw} : Coefficient taken as:

$$\beta_{vw} = 0,9 \left(\frac{\ell_{bdg-vw}}{\ell_{bdg-dt}} \right) \left(\frac{I_{dt-n50}}{I_{vw-n50}} \right)$$

without being taken less than 0,10 or greater than 0,50

ℓ_{bdg-dt} : Effective bending span of the deck transverse, in m, see Ch 4, Sec 6, [1.1.6] and Fig 7, but is not to be taken as less than 60% of the breadth of the tank at the location being considered

ℓ_{bdg-st} : Effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see Ch 4, Sec 6, [1.1.6] and Fig 7

$\ell_{bdg-st-ct}$: Effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see Ch 4, Sec 6, [1.1.6]

ℓ_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see Ch 4, Sec 6, [1.1.6] and Fig 7

$\ell_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see Ch 4, Sec 6, [1.1.6]

I_{dt-n50} : Net moment of inertia of the deck transverse at mid-span with an effective breadth of attached plating specified in Ch 4, Sec 6, [1.3.2], in cm^4

I_{st-n50} : Net moment of inertia of the side transverse at mid-span with an effective breadth of attached plating specified in Ch 4, Sec 6, [1.3.2], in cm^4

I_{vw-n50} : Net moment of inertia of the longitudinal bulkhead vertical web frame at mid-span with an effective breadth of attached plating specified in Ch 4, Sec 6, [1.3.2], in cm^4

c_{st} : Coefficient given in Tab 6

c_{vw} : Coefficient given in Tab 6.

Figure 7 : Definition of spans of deck, side transverses, vertical web frames on longitudinal bulkheads and horizontal stringers on transverse bulkheads

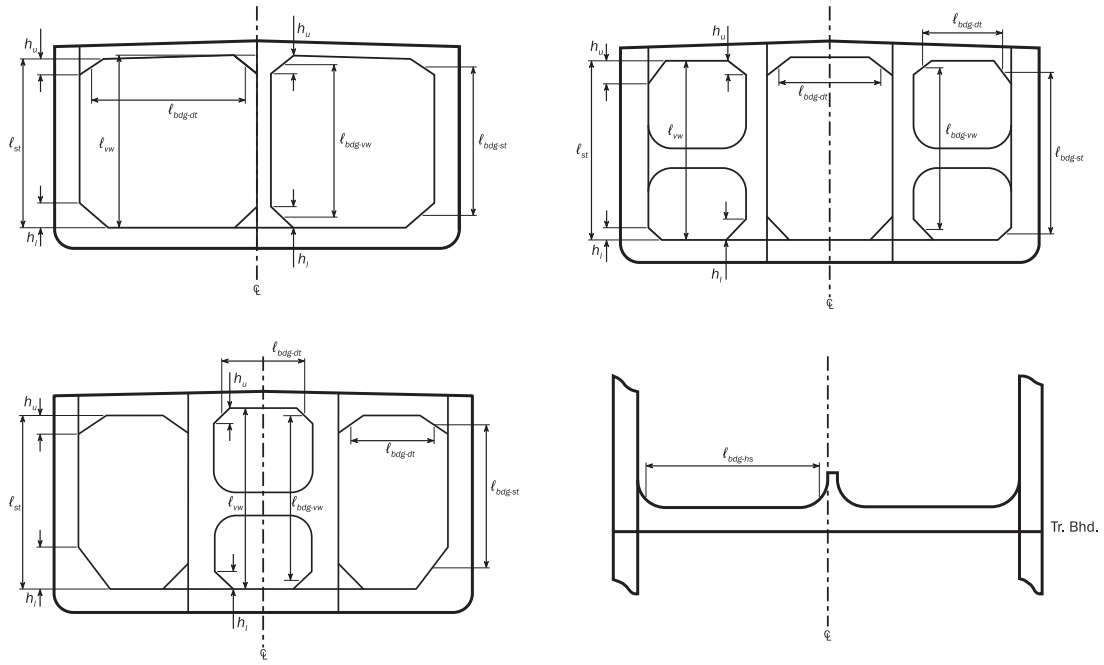


Table 6 : Values of c_{st} and c_{vw} for deck transverses

Structural configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0,056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $\ell_{bdg-vw-ct}$	-	0,044
		M_{st} based on ℓ_{bdg-st} or M_{vw} based on ℓ_{bdg-vw}	0,044	0,016
	Cross ties in wing cargo tanks	M_{st} based on $\ell_{bdg-st-ct}$ or M_{vw} based on $\ell_{bdg-vw-ct}$	0,044	0,044
		M_{st} based on ℓ_{bdg-st} or M_{vw} based on ℓ_{bdg-vw}	0,041	0,015

3.3.3 Net shear area of deck transverses fitted below the upper deck

The net shear area of deck transverses fitted below the upper deck, in cm^2, is not to be less than $A_{shr\text{-}in\text{-}n50}$ and $A_{shr\text{-}ex\text{-}n50}$ as given by:

$$A_{shr-in-n50} = \frac{8,5 Q_{in}}{C_t \tau_{eH}}$$

$$A_{shr-ex-n50} = \frac{8,5 Q_{ex}}{C_t \tau_{eH}}$$

where:

Q_{in} : Design shear force due to cargo pressure, in kN

$$Q_{in} = 0,65 P_{in-dt} S \ell_{shr} + c_1 D b_{ctr} S \rho_L g$$

Q_{ex} : Design shear force due to green sea pressure, in kN

$$Q_{ex} = 0,65 P_{ex-dt} S \ell_{shr}$$

$P_{in\text{-}dt}$: Design pressure in kN/m^2, defined in [3.3.2]

$P_{ex\text{-}dt}$: Design pressure in kN/m^2, defined in [3.3.2]

$\ell_{bdg\text{-}dt}$: Effective span, in m, defined in [3.3.2]

ℓ_{shr} : Effective shear span, of the deck transverse, in m, see Ch 4, Sec 6, [1.1.7]

c_1 : Coefficient taken as:

- c_1 = 0,04 in way of wing cargo tanks of ships with two longitudinal bulkheads
- c_1 = 0,00 in way of centre tank of ships with two longitudinal bulkheads
- c_1 = 0,00 for ships with a centreline longitudinal bulkhead

b_{ctr} : Breadth of the centre tank, in m.

3.3.4 Deck transverses fitted above the upper deck

When deck transverses are fitted above the upper deck, the net section modulus and shear area of deck transverses are not to be less than Z_{n50} and $A_{shr\text{-}n50}$, in cm^3 and cm^2 respectively, as given by the following formulae. The required section modulus and shear area are to be maintained over the full length of span.

$$z_{n50} = \frac{850 |P| S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

$$A_{shr-n50} = \frac{8,5 f_{shr} |P| S \ell_{shr}}{C_t \tau_{eH}}$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at midpoint of effective bending span, ℓ_{bdg} of the deck transverse located at mid tank, in kN/m^2

f_{bdg} : Coefficient taken as:

f_{bdg} = 12 for design load set LC-1, LC-2, LC-3 and LC-4 as defined in Ch 7, Sec 2, Tab 4

f_{bdg} = 15 for design load set SEA-1 as defined in Ch 7, Sec 2, Tab 4

f_{shr} : Coefficient taken as: f_{shr} = 0,5

ℓ_{bdg} : Effective bending span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

ℓ_{shr} : Effective shear span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

As an alternative, the required section modulus and shear area may be obtained by finite element method in accordance with Part B, Chapter 8 considering the following loading patterns with draught equal to T_{sc} and cargo density of 1,025 t/m^3:

- For ships with two longitudinal oil-tight bulkheads:
  - aft-holds and fore-holds full, mid-holds empty on both sides and full on center
  - aft-holds and fore-holds full, mid-holds full on sides and empty on center
- For ships with one centerline oil-tight bulkhead:
  - aft-holds and fore-holds full, mid-holds empty on portside and full on starboard
  - aft-holds and fore-holds full, mid-holds full on portside and empty on starboard.

3.3.5 Deck transverse adjacent to transverse bulkhead

The scantling of deck transverse adjacent to the transverse bulkhead is to comply with the requirements of [3.3.2] to [3.3.4] for design green sea pressure only.

3.4 Side transverses

3.4.1 Net shear area

The net shear area, $A_{shr-n50}$, in cm^2, of side transverses is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t\ \tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:
$Q = Q_u$ for upper part of the side transverse
$Q = Q_l$ for lower part of the side transverse

Q_u : Shear force, in kN, taken as:

$$Q_u = S\,[c_u\ \ell_{st}\,(P_u + P_l) - h_u\ P_u]$$

where a cross tie is fitted in a wing cargo tank and ℓ_{st-ct} is greater than 0,7 ℓ_{st}, then ℓ_{st} in the above formula is taken as ℓ_{st-ct}

Q_l : Shear force, in kN, taken as the greater of the following:

- $S\,[c_l\ \ell_{st}\,(P_u + P_l) - h_l\ P_l]$
- $0,35 c_l\ S\ \ell_{st}\ (P_u + P_l)$
- $1,2\ Q_u$

where a cross tie is fitted in a wing cargo tank and ℓ_{st-ct} is greater than 0.7 ℓ_{st}, then ℓ_{st} in the above formula is taken as ℓ_{st-ct}

P_u : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, in kN/m^2, calculated at mid length of tank and at mid height of h_u

P_l : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid height h_l located at mid length of tank, in kN/m^2

ℓ_{st} : Length of the side transverse, in m, taken as follows:

- where deck transverses are fitted below deck, ℓ_{st} is the length between the flange of the deck transverse and the inner bottom, see Fig 7
- where deck transverses are fitted above deck, ℓ_{st} is the length between the elevation of the deck at side and the inner bottom

ℓ_{st-ct} : Length of the side transverse, in m, taken as follows:

- where deck transverses are fitted below deck, ℓ_{st-ct} is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank
- where deck transverses are fitted above deck, ℓ_{st-ct} is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank

h_u : Effective length of upper bracket of the side transverse, in m, taken as follows:

- where deck transverses are fitted below deck, h_u is as shown in Fig 7
- where deck transverses are fitted above deck:
  - when an inner hull longitudinal bulkhead is arranged with a top wing structure as follows, h_u is taken as the distance between the deck at side and the lower end of slope plate of the top wing structure:
    - the breadth at top of the wing structure is greater than 1,5 times the breadth of the double side and
    - the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 deg or more to vertical
  - in the other cases: h_u is taken as 0

h_l : Height of bilge hopper, in m, as shown in Fig 7

c_u : Coefficient defined in Tab 7

c_l : Coefficient defined in Tab 7.

Table 7 : Values of c_u and c_l for side transverses

Structural configuration			c_u		c_l	
Number of side stringers			< three	≥ three	< three	≥ three
Ships with a centreline longitudinal bulkhead			0,12	0,09	0,29	0,21
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank					
	Cross ties in wing cargo tanks	Q_u or Q_l based on ℓ_{st-ct}				
		Q_u or Q_l based on ℓ_{st}	0,08		0,20	

3.4.2 Shear area over the length of the side transverse

The shear area over the length of the side transverse is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0,2 ℓ_{shr}.

b) The required shear area for the lower part is to be maintained over the lower 0,2 ℓ_{shr}.

c) Where Q_u and Q_l are determined based on $\ell_{st\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie.

d) For ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.

e) For ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

ℓ_{shr} : Effective shear span of the side transverse, in m

$$\ell_{shr} = \ell_{st} - h_u - h_l$$

where Q_u and Q_l are determined based on ℓ_{st}

$$\ell_{shr} = \ell_{st-ct} - h_u$$

where Q_u and Q_l are determined based on $\ell_{st\text{-}ct}$

ℓ_{st}, $\ell_{st\text{-}ct}$, h_u, h_l, Q_u, Q_l : Parameters defined in [3.4.1].

3.5 Vertical web frames on longitudinal bulkhead

3.5.1 Web depth

The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

- 0,14 $\ell_{bdg\text{-}vw}$ for ships with a centreline longitudinal bulkhead
- 0,09 $\ell_{bdg\text{-}vw}$ for ships with two longitudinal bulkheads
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

where:

$\ell_{bdg\text{-}vw}$: Effective bending span, in m, defined in [3.5.2].

3.5.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the vertical web frame is not to be less than:

$$Z_{n50} = \frac{850M}{C_s R_{eH}}$$

where:

M : Design bending moment, in kNm, as follows:

$$M = c_u P S \ell_{bdg-vw}^2$$

- for upper part of the web frame:

$$M = c_l P S \ell_{bdg-vw}^2$$

- for lower part of the web frame:

where a cross tie is fitted and $\ell_{bdg\text{-}vw\text{-}ct}$ is greater than 0,7 $\ell_{bdg\text{-}vw}$, then $\ell_{bdg\text{-}vw}$ in the above formula is to be taken as $\ell_{bdg\text{-}vw\text{-}ct}$.

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of the effective bending span, $\ell_{bdg\text{-}vw}$ of the vertical web frame located at mid tank, in kN/m^2

$\ell_{bdg\text{-}vw}$: Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see Fig 7

$\ell_{bdg\text{-}vw\text{-}ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid-depth of the cross tie on ships with two longitudinal bulkheads, in m

c_u : Coefficient defined in Tab 8

c_l : Coefficient defined in Tab 8.

Table 8 : Values of c_u and c_l for vertical web frame on longitudinal bulkheads

Structural configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0,057	0,071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $\ell_{bdg\text{-}vw\text{-}ct}$	0,057	0,071
		M based on $\ell_{bdg\text{-}vw}$	0,012	0,028
	Cross ties in wing cargo tanks	M based on $\ell_{bdg\text{-}vw\text{-}ct}$	0,057	0,071
		M based on $\ell_{bdg\text{-}vw}$	0,016	0,032

3.5.3 Section modulus over the length of the vertical web frame

The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required section modulus for the upper part is to be maintained over the upper 0,2 $\ell_{bdg\text{-}vw}$ or 0,2 $\ell_{bdg\text{-}vw\text{-}ct}$ as applicable.

b) The required section modulus for the lower part is to be maintained over the lower 0,2 $\ell_{bdg\text{-}vw}$ or 0,2 $\ell_{bdg\text{-}vw\text{-}ct}$ as applicable.

c) Where the required section modulus is determined based on $\ell_{bdg\text{-}vw\text{-}ct}$, the required section modulus for the lower part is also to be maintained below the cross tie.

d) The required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid-span.

where:

$\ell_{bdg\text{-}vw}$, $\ell_{bdg\text{-}vw\text{-}ct}$: Effective bending span, in m, defined in [3.5.2].

3.5.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the vertical web frame is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t\ \tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:
$Q = Q_u$ for upper part of the web frame
$Q = Q_l$ for lower part of the web frame

Q_u : Shear force, in kN, taken as:

$$Q_u = S\,[c_u\ \ell_{vw}\,(P_u + P_l) - h_u\ P_u]$$

where a cross tie is fitted in a centre or wing cargo tank and $\ell_{vw\text{-}ct}$ is greater than 0,7 ℓ_{vw}, then ℓ_{vw} in the above formula is to be taken as $\ell_{vw\text{-}ct}$

Q_l : Shear force, in kN, taken as the greater of the following:

- $S\,[c_l\ \ell_{vw}(P_u + P_l) - h_l\ P_l]$
- $c_w\ S\ c_l\ \ell_{vw}(P_u + P_l)$
- $1,2Q_u$

where a cross tie is fitted in a centre or wing cargo tank and $\ell_{vw\text{-}ct}$ is greater than 0,7 ℓ_{vw}, then ℓ_{vw} in the above formula is to be taken as $\ell_{vw\text{-}ct}$

P_u : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-height of upper bracket of the vertical web frame, h_u located at mid tank, in kN/m^2

P_l : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-height of lower bracket of the vertical web frame, h_l located at mid tank, in kN/m^2

ℓ_{vw} : Length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see Fig 7

$\ell_{vw\text{-}ct}$: Length of the vertical web frame, in m, between the flange of the deck transverse and mid-depth of the cross tie, where fitted

h_u : Effective length of upper bracket of the vertical web frame, in m, as shown in Fig 7

h_l : Effective length of lower bracket of the vertical web frame, in m, as shown in Fig 7

c_u : Coefficient defined in Tab 9

c_l : Coefficient defined in Tab 9

c_w : Coefficient taken as:

- $c_w = 0,57$ for ships with a centreline longitudinal bulkhead,
- $c_w = 0,50$ for ships with two longitudinal bulkheads.

Table 9 : Values of c_u and c_l for vertical web frame on longitudinal bulkhead

Structural configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0,17	0,28
Ships with two longitudinal bulkheads	Q_u or Q_l based on ℓ_{vw-ct}		
	Q_u or Q_l based on ℓ_{vw}	0,075	0,18

3.5.5 Shear area over the length of the vertical web frame

The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

a) The required shear area for the upper part is to be maintained over the upper 0,2 ℓ_{shr}.

b) The required shear area for the lower part is to be maintained over the lower 0,2 ℓ_{shr}.

c) Where Q_u and Q_l are determined based on ℓ_{vw-ct}, the required shear area for the lower part is also to be maintained below the cross tie.

d) For ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.

e) For ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

ℓ_{shr} : Effective shear span of the vertical web frame, in m.

$$\ell_{shr} = \ell_{vw} - h_u - h_l$$

where Q_u and Q_l are determined based on ℓ_{vw}

$$\ell_{shr} = \ell_{vw-ct} - h_u$$

where Q_u and Q_l are determined based on ℓ_{vw-ct}

ℓ_{vw}, ℓ_{vw-ct}, h_u, h_l, Q_u, Q_l : Parameters defined in [3.5.4].

3.6 Horizontal stringers on transverse bulkheads

3.6.1 Web depth

The web depth of horizontal stringers on transverse bulkhead is not to be less than:

- 0,28 ℓ_{bdg-hs} for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads
- 0,20 ℓ_{bdg-hs} for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks
- 0,20 ℓ_{bdg-hs} for horizontal stringers of ships with a centreline longitudinal bulkhead
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

where:

ℓ_{bdg-hs} : Effective bending span, in m, defined in [3.6.2].

3.6.2 Net section modulus

The net section modulus, Z_{n50} in cm^3, of the horizontal stringer over the end 0,2 ℓ_{bdg-hs} is not to be less than:

$$Z_{n50} = \frac{850M}{C_s R_{eH}}$$

where:

M : Design bending moment, in kNm

$$M = c\ P\ S\ \ell_{bdg-hs}^2$$

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, ℓ_{bdg-hs} and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2

ℓ_{bdg-hs} : Effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see Fig 7

c : Coefficient taken as:

- c = 0,073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead
- c = 0,083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads
- c = 0,063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads.

3.6.3 Section modulus over the length of horizontal stringers

The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

3.6.4 Net shear area

The net shear area, $A_{shr\text{-}n50}$ in cm^2, of the horizontal stringer over the end 0,2 ℓ_{shr} is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t\ \tau_{eH}}$$

where:

Q : Design shear force, in kN

$$Q = 0,5P\ S_{hs}\ \ell_{shr}$$

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, $\ell_{bdg\text{-}hs}$ and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2

S_{hs} : Spacing, in m, defined in [3.6.2]

ℓ_{shr} : Effective shear span of the horizontal stringer, in m.

3.6.5 Shear area at mid effective shear span

The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

3.7 Cross ties

3.7.1 Maximum applied design axial load

The maximum applied design axial load on cross ties, W_{ct} is to be less than or equal to the permissible load, $W_{ct\text{-}perm}$ as given by:

$$W_{ct} \leq W_{ct-perm}$$

where:

W_{ct} : Applied axial load, in kN.

$$W_{ct} = P\ b_{ct}\ S$$

$W_{ct\text{-}perm}$: Permissible load, in kN.

$$W_{ct-perm} = 0,12\ A_{ct-n50}\ \eta_{all}\ \sigma_{cr}$$

P : Maximum design pressure for all the applicable design load sets being considered as defined in Ch 7, Sec 2, Tab 4, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m^2

b_{ct} : Span, in m, taken as:

- Cross tie fitted in centre cargo tank:

  $b_{ct} = 0,5\ \ell_{bdg\text{-}vw}$
- Cross ties fitted in wing cargo tanks:
  - $b_{ct} = 0.5\ \ell_{bdg\text{-}vw}$ for design cargo pressure from the centre cargo tank
  - $b_{ct} = 0.5\ \ell_{bdg\text{-}st}$ for design sea pressure

$\ell_{bdg\text{-}vw}$: Effective bending span, in m, defined in [3.3.2]

$\ell_{bdg\text{-}st}$: Effective bending span, in m, defined in [3.3.2]

η_{all} : Allowable buckling utilisation factor as defined in Ch 9, Sec 1, [1.2]

σ_{cr} : Critical buckling stress in compression of the cross tie, in N/mm^2, as calculated using the net sectional properties in accordance with NR615, Sec 5, [3.1.1]

$A_{ct\text{-}n50}$: Net cross sectional area of the cross tie, in cm^2.

3.7.2 Welded connections

Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs.

Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

3.7.3 Horizontal stiffeners

Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

3.8 Vertically corrugated bulkheads separating liquid cargo holds

3.8.1 Application

In addition to the requirements of Ch 7, Sec 4, [1.2], vertically corrugated bulkheads separating liquid cargo holds are also to comply with the requirements of [3.8.2] to [3.8.5].

3.8.2 Net plate thickness over the height

The net plate thicknesses as required by [3.8.4] is to be maintained for two thirds of the corrugation length, ℓ_{cg} from the lower end. Above that, the net plate thickness may be reduced by 20% from the net thickness required in [3.8.4] for the mid part of the corrugation provided that the net section modulus of the upper end of the corrugation complies with [3.8.5].

3.8.3 Net web plating thickness over the height

The net web plating thickness of the lower 15% of the corrugation, t_w in mm, is to be taken as the greatest value calculated for all applicable design load sets, as given in Ch 7, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_w = \frac{1000|Q_{cg}|}{d_{cg}K_{corr}\chi C_{t\text{-}cg}\tau_{eH}}$$

where:

Q_{cg} : Design shear force imposed on the web plating at the lower end of the corrugation, in kN

$$Q_{cg} = \frac{s_{cg}\,\ell_{cg}|3P_l + P_u|}{8000}$$

P_l : Design pressure given in Ch 7, Sec 2, Tab 1 for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2

P_u : Design pressures given in Ch 7, Sec 2, Tab 1 for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2

d_{cg} : Depth of corrugation, in mm, see Fig 8

$C_{t\text{-}cg}$: Permissible shear stress coefficient:

- $C_{t\text{-}cg}$ = 0,75 for acceptance criteria set AC-1
- $C_{t\text{-}cg}$ = 0,90 for acceptance criteria set AC-2
- $C_{t\text{-}cg}$ = 0,95 for acceptance criteria set AC-3.

3.8.4 Net thicknesses of the flanges over the height

The net thicknesses of the flanges of corrugated bulkheads, t_f in mm, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in Ch 7, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_f = \frac{6,57\,b_{f\text{-}cg}\sqrt{\sigma_{bdg-max}}}{C_f}10^{-3}$$

where:

$\sigma_{bdg\text{-}max}$: Maximum value of the vertical bending stresses in N/mm^2 in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length:

$$\sigma_{bdg-max} = \frac{M_{cg}}{Z_{cg-act}}10^3$$

M_{cg} : Vertical bending moment, in kNm, as defined in [3.8.5]

$Z_{cg\text{-}act}$: Actual net section modulus at the lower end and at the mid length of a unit corrugation, in cm^3

$b_{f\text{-}cg}$: Breadth of flange plating, in mm. See Fig 8

$b_{w\text{-}cg}$: Breadth of web plating, in mm. See Fig 8

C_f : Coefficient taken as:

$$C_f = 7,65 - \left(0,26\left(\frac{b_{w-cg}}{b_{f-cg}}\right)^2\right)$$

3.8.5 Net section modulus over the height

The net section modulus at the lower and upper ends and at the mid length of the corrugation (ℓ_{cg} / 2) of a unit corrugation of vertically corrugated bulkheads separating liquid cargo holds, Z_{cg} are to be taken as the greatest value calculated for all applicable design load sets, as given in Ch 7, Sec 2, [2] and given by the following.

$$Z_{cg} = \frac{1000M_{cg}}{K_{corr}C_{s\text{-}cg}R_{eH}}$$

where:

M_{cg} : Vertical bending moment in kNm

$$M_{cg} = \frac{C_i |P| s_{cg} \ell_0^2}{12000}$$

C_i : Bending moment coefficient given in Tab 10

P : Averaged pressure in kN/m^2

$$P = \frac{P_u + P_l}{2}$$

P_l, P_u : Design pressure given in Ch 7, Sec 2, Tab 1 for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2:

- for transverse corrugated bulkheads, the pressures are to be calculated at a section located at b_{tk} / 2 from the longitudinal bulkheads of each tank
- for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead.

b_{tk} : Maximum breadth of tank under consideration measured at the bulkhead, in m

ℓ_o : Effective bending span of the corrugation, in m, measured from the mid depth of the lower stool to the mid depth of the upper stool. Where no lower or upper stool is fitted, ℓ_o is to be measured to lower or upper end. See Fig 8

$C_{s\text{-}cg}$: Permissible bending stress coefficient at the mid-length of the corrugation length, ℓ_{cg}:

- $C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0,75 for acceptance criteria set AC-1
- $C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0,90 for acceptance criteria set AC-2
- $C_{s\text{-}cg} = c_e$ but not to be taken as greater than 0,95 for acceptance criteria set AC-3

At the lower and upper ends of the corrugation length, ℓ_{cg}:

- $C_{s\text{-}cg}$ = 0,75 for acceptance criteria set AC-1
- $C_{s\text{-}cg}$ = 0,90 for acceptance criteria set AC-2
- $C_{s\text{-}cg}$ = 0,95 for acceptance criteria set AC-3

c_e : Coefficient taken as:

- for $\beta \geq 1,25$:

$$c_e = \frac{2,25}{\beta} - \frac{1,25}{\beta^2}$$

- for $\beta < 1,25$:

$$c_e = 1,0$$

β : Coefficient taken as:

$$\beta = \frac{b_{f\text{-}cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

$b_{f\text{-}cg}$: Breadth of flange plating, in mm, see Fig 8

t_f : Net thickness of the corrugation flange, in mm

Table 10 : Values of C_i

Bulkhead	At lower end of ℓ_{cg}	At mid-length of ℓ_{cg}	At upper end of ℓ_{cg}
Transverse bulkhead	C_1	C_{m1}	0,65 C_{m1}
Longitudinal bulkhead	C_3	C_{m3}	0,65 C_{m3}
Note 1: C_1, C_3, C_{m1}, and C_{m3} are defined in Tab 11			

Table 11 : Values of C_1, C_3, C_{m1}, and C_{m3}

C_1 and C_{m1}		C_3 and C_{m3}	
In general	for transverse bulkhead with no lower stool	In general	for longitudinal bulkhead with no lower stool
$C_1 = a_1 + b_1 \sqrt{\frac{A_{dt}}{b_{dk}}}$ without being taken less than 0,60, where: $a_1 = 0,95 - \frac{0,41}{R_{bt}}$ $b_1 = -0,20 + \frac{0,078}{R_{bt}}$	$C_1 = a_1 - b_1 \sqrt{\frac{A_{dt}}{b_{dk}}}$ without being taken less than 0,55, where: $a_1 = 1,0$ $b_1 = 0,13$	$C_3 = a_3 + b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ without being taken less than 0,60, where: $a_3 = 0,86 - \frac{0,35}{R_{bl}}$ $b_3 = -0,17 + \frac{0,10}{R_{bl}}$	$C_3 = a_3 - b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ without being taken less than 0,55, where: $a_3 = 1,0$ $b_3 = 0,13$
$C_{m1} = a_{m1} + b_{m1} \sqrt{\frac{A_{dt}}{b_{dk}}}$ without being taken less than 0,55, where: $a_{m1} = 0,63 + \frac{0,25}{R_{bt}}$ $b_{m1} = -0,25 - \frac{0,11}{R_{bt}}$	$C_{m1} = a_{m1} - b_{m1} \sqrt{\frac{A_{dt}}{b_{dk}}}$ without being taken less than 0,60, where: $a_{m1} = 0,85$ $b_{m1} = 0,34$	$C_{m3} = a_{m3} + b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ without being taken less than 0,55, where: $a_{m3} = 0,32 + \frac{0,24}{R_{bl}}$ $b_{m3} = -0,12 - \frac{0,10}{R_{bl}}$	$C_{m3} = a_{m3} - b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ without being taken less than 0,60, where: $a_{m3} = 0,85$ $b_{m3} = 0,19$

Note 1:

A_{dt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m². See Fig 8
$A_{dt} = 0$ if no upper stool is fitted

b_{dk} : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See Fig 8

R_{bt} : Coefficient for transverse bulkheads, taken as:

$$R_{bt} = \frac{A_{bt}}{b_{ib}} \left(1 + \frac{\ell_{ib}}{b_{ib}}\right) \left(1 + \frac{b_{av-t}}{h_{st}}\right)$$

A_{dl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m². See Fig 8
$A_{dl} = 0$ if no upper stool is fitted

ℓ_{dk} : Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See Fig 8.

R_{bl} : Coefficient for longitudinal bulkheads, taken as:

$$R_{bl} = \frac{A_{bl}}{\ell_{ib}} \left(1 + \frac{\ell_{ib}}{b_{ib}}\right) \left(1 + \frac{b_{av-l}}{h_{sl}}\right)$$

A_{bt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m². See Fig 8

A_{bl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m². See Fig 8

b_{ib} : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See Fig 8

ℓ_{ib} : Length of cargo tank at the inner bottom level between transverse lower stools, in m. See Fig 8

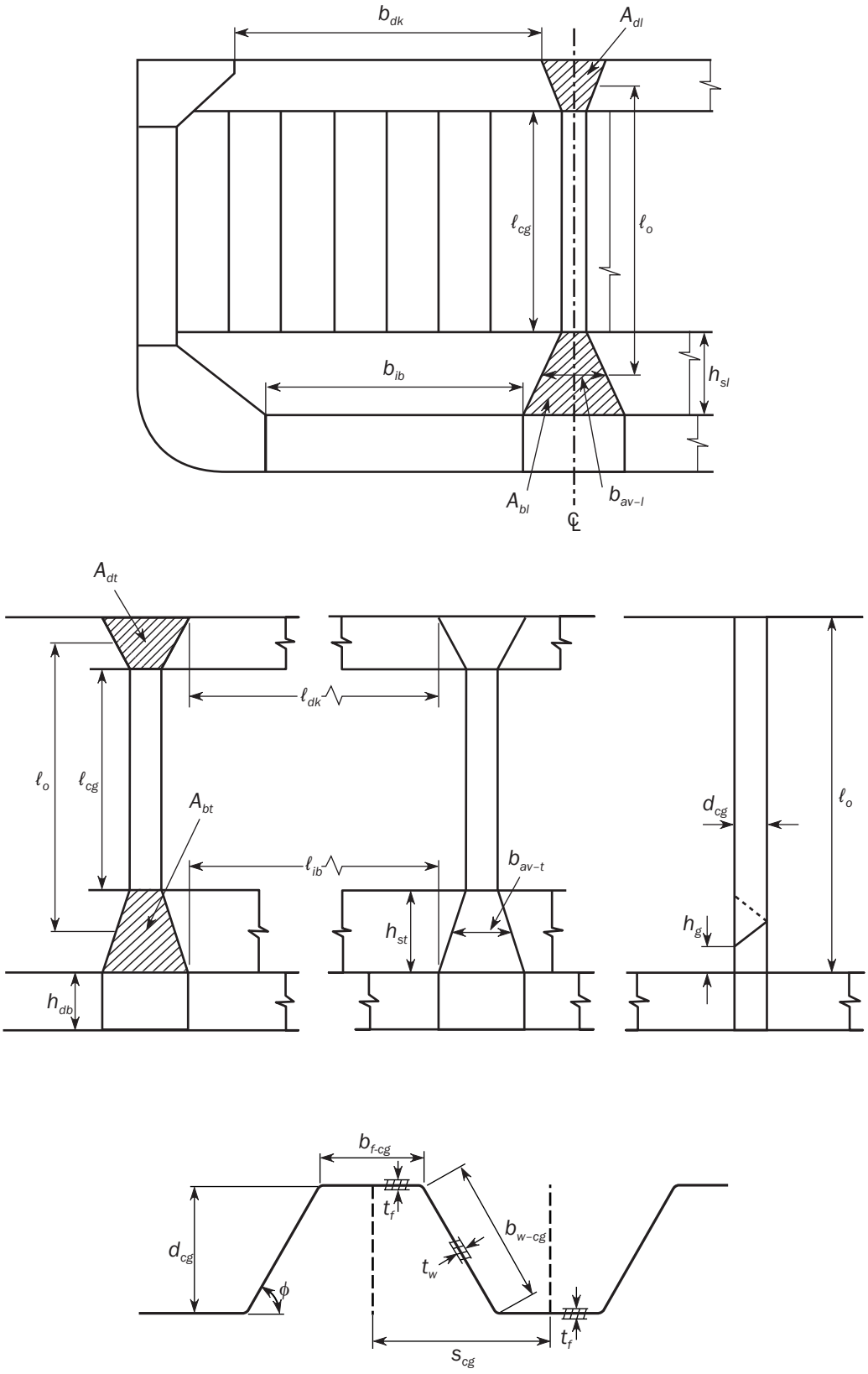
b_{av-t} : Average width of transverse bulkhead lower stool, in m. See Fig 8

b_{av-l} : Average width of longitudinal bulkhead lower stool, in m. See Fig 8

h_{st} : Height of transverse bulkhead lower stool, in m. See Fig 8

h_{sl} : Height of longitudinal bulkhead lower stool, in m. See Fig 8

Figure 8 : Definition of parameters for corrugated bulkhead (Tankers with longitudinal bulkhead at centreline



4 Primary supporting members in holds intended to carry dry bulk cargo

4.1 Centre girders and side girders

4.1.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_1 \frac{|P|\ S\ |x - x_c|}{(d_0 - d_1)\ C_t\ \tau_{eH}} \left\{1 - 4\left(\frac{y}{B_{DB}}\right)^2\right\}$$

where $|x - x_c|$ is less than 0,25 ℓ_{DB}, $|x - x_c|$ is to be taken as 0,25 ℓ_{DB}.

$$t_2 = 1,75 \sqrt[3]{\frac{H^2\ a^2\ C_t\ \tau_{eH}}{C'_1}}\ t_1$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted

S : Distance between the centres of the two spaces adjacent to the centre or side girder under consideration, in m

d_0 : Depth of the centre or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

C_1 : Coefficient given in Tab 12 depending on B_{DB}/ℓ_{DB}. For intermediate values of B_{DB}/ℓ_{DB}, C_1 is to be obtained by linear interpolation.

a : Depth of girders at the point under consideration, in m. However, where longitudinal stiffeners are fitted on the girder, a is the breadth of the EPP under consideration

S_1 : Spacing, in m, of vertical stiffeners or floors

C'_1 : Coefficient given in Tab 13 depending on S_1 /a

For intermediate values of S_1 /a, C'_1 is to be determined by linear interpolation

H : Value obtained from the following formulae:

- where the girder is provided with an unreinforced opening:

$$H = 1 + 0,5\ \frac{\phi_H}{\alpha}$$

- in other cases:

H = 1,0.

Table 12 : Coefficient C_1

B_{DB}/ℓ_{DB}	0,4 and under	0,6	0,8	1,0	1,2	1,4	1,6 and over
C_1	0,5	0,71	0,83	0,88	0,95	0,98	1,00

Table 13 : Coefficient C'$_1$

S_1/a	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_1	64	38	25	19	15	12	10	9	8	7

4.2 Floors

4.2.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 and t_2 specified in the following according to each location:

$$t_1 = C_2 \frac{|P|\ S\ B_{DB}}{(d_0 - d_1)\ C_t\ \tau_{eH}} \left(\frac{2\ |y|}{B'_{DB}}\right) \left\{1 - 2\left(\frac{x - x_c}{\ell_{DB}}\right)^2\right\}$$

where $|x - x_c|$ is less than 0,5 ℓ_{DB}, $|x - x_c|$ is to be taken as 0,25 ℓ_{DB} and where $|y|$is less than $B'_{DB}/4$, $|y|$ is to be taken as $B'_{DB}/4$.

$$t_2 = 1,75 \sqrt[3]{\frac{H^2\ a^2\ C_t\ \tau_{eH}}{C'_2}} t_1$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted

S : Spacing of solid floors, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m

C_2 : Coefficient given in Tab 14 depending on B_{DB}/ℓ_{DB}. For intermediate values of B_{DB}/ℓ_{DB}, C_2 is to be obtained by linear interpolation

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the breadth of the EPP under consideration

S_1 : Spacing, in m, of vertical stiffeners or girders

C'_2 : Coefficient given in Tab 15 depending on S_1/d_0. For intermediate values of S_1/d_0, C'_2 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

- where openings with reinforcement or no opening are provided on solid floors:
  - where slots without reinforcement are provided:

$$H = \sqrt{4,0\ \frac{d_2}{S_1} - 1,0}$$

    without being taken less than 1,0.
  - where slots with reinforcement are provided: H = 1,0.
- where openings without reinforcement are provided on solid floors:
  - where slots without reinforcement are provided:

$$H = \left(1 + 0,5\ \frac{\phi_H}{d_0}\right) \sqrt{4,0\ \frac{d_2}{S_1} - 1,0}$$

    without being taken less than:

$$1 + 0,5\ \frac{\phi_H}{d_0}$$

  - where slots with reinforcement are provided:

$$H = 1 + 0,5\ \frac{\phi_H}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater.

Table 14 : Coefficient C_2

B_{DB}/ℓ_{DB}	0,4 and under	0,6	0,8	1,0	1,2	1,4	1,6 and over
C_2	0,48	0,47	0,45	0,43	0,40	0,37	0,34

Table 15 : Coefficient C'_2

S_1/d_0	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_2	64	38	25	19	15	12	10	9	8	7

4.3 Stringer of double side structure

4.3.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_3\ \frac{|P\ |S\ |x - x_c|}{(d_0 - d_1)\ C_t\ \tau_{eH}}$$

where $|x - x_c|$ is under $0,25\ \ell_{DS}$, $|x - x_c|$ is to be taken as $0,25\ \ell_{DS}$

$$t_2 = 1,75 \sqrt[3]{\frac{H^2\ a^2\ C_t\ \tau_{eH}}{C'_3}}\ t_1$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}

S : Breadth of part supported by stringer, in m

d_0 : Depth of stringers, in m

d_1 : Depth of opening, if any, at the point under consideration, in m

ℓ_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m

h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank located midway between transverse bulkheads of hold under consideration, in m

C_3 : Coefficient given in Tab 16 depending on h_{DS}/ℓ_{DS}. For intermediate values of h_{DS}/ℓ_{DS}, C_3 is to be obtained by linear interpolation

a : Depth of stringers at the point under consideration, in m. However, where longitudinal stiffeners are fitted on the stringer, a is the breadth of the EPP under consideration

S_1 : Spacing, in m, of transverse stiffeners or web frames

C'_3 : Coefficient given in Tab 17 depending on S_1/a. For intermediate values of S_1/a, C'_3 is to be obtained by linear interpolation

H : Value obtained from the following formulae:

- where the stringer is provided with an unreinforced opening:

$$H = 1 + 0,5 \frac{\phi_H}{\alpha}$$

- in other cases:

H = 1,0

Table 16 : Coefficient C_3

h_{DS}/ℓ_{DS}	0,5 and under	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3 and over
C_3	0,16	0,23	0,30	0,36	0,41	0,44	0,47	0,50	0,54

Table 17 : Coefficient C'$_3$

S_1/a	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_3	64	38	25	19	15	12	10	9	8	7

4.4 Transverse web in double side structure

4.4.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_4 \frac{|P|\ S h_{DS}}{(d_0 - d_1)\ C_t\ \tau_{eH}} \left(1 - 1,75 \frac{z - z_{BH}}{h'_{DS}}\right)$$

where

$z - z_{BH}$ is greater than $0,4\ h'_{DS}$, $z - z_{BH}$ is to be taken as $0,4\ h'_{DS}$.

$$t_2 = 1,75 \sqrt[3]{\frac{H^2\ a^2\ C_t\ \tau_{eH}}{C'_4}}\ t_1$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}

S : Breadth of part supported by transverses, in m

d_0 : Depth of transverses, in m

d_1 : Depth of opening at the point under consideration, in m

C_4 : Coefficient given in Tab 18 depending on h_{DS}/ℓ_{DS}. For intermediate values of h_{DS}/ℓ_{DS}, C_4 is to be obtained by linear interpolation

z_{BH} : Z coordinate, in m, of the upper end of hopper tank with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

h_{DS} : As defined in the requirements of [4.3.1]

h'_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank at the position under consideration, in m

ℓ_{DS} : As defined in the requirements of [4.3.1]

a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration

S_1 : Spacing, in m, of horizontal stiffeners or stringers

C'_4 : Coefficient given in Tab 19 depending on S_1 /a. For intermediate values of S_1 /a, C'_4 is to be obtained by linear interpolation

H : Value obtained from the following formulae:

- where the transverse is provided with an unreinforced opening:

$$H = 1 + 0,5 \frac{\phi_H}{\alpha}$$

- in other cases:

H = 1,0.

α : The greater of a or S_1, in m.

Table 18 : Coefficient C_4

h_{DS}/ℓ_{DS}	0,5 and under	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3 and over
C_4	0,62	0,61	0,59	0,55	0,52	0,49	0,46	0,43	0,41

Table 19 : Coefficient C'_4

S_1 /a	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_4	64	38	25	19	15	12	10	9	8	7

4.5 Primary supporting member in bilge hopper tanks and topside tanks

4.5.1 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case-by-case basis.

4.5.2 Net section modulus, net shear sectional area and web thickness

The net section modulus Z, in cm^3, the net shear sectional area A_{shr}, in cm^2, and the net web thickness t_w, in mm, subject to lateral pressure are not to be less than the values obtained from the following formulae:

$$Z = \frac{|P|\ S \ell_{bdg}^{\ 2}}{f_{bdg}\ C_s\ R_{eH}}\ 10^3$$

$$A_{shr} = \frac{5\ |P|\ S \ell_{shr}}{C_t\ \tau_{eH}}$$

$$t_w = 1,75 \sqrt[3]{\frac{h_w\ C_t\ \tau_{eH}}{10^4\ C_5}\ A_{shr}}$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, calculated at the mid-point of span ℓ of a web frame located midway between transverse bulkheads of holds

S : Spacing of primary supporting members, in m

ℓ_{bdg} : Effective bending span, in m, of primary supporting members, measured between the supporting members as defined in Ch 4, Sec 6, [1.1.6]

ℓ_{shr} : Effective shear span, in m, of primary supporting members, measured between the supporting members as defined in Ch 4, Sec 6, [1.1.7]

f_{bdg} : Bending moment factor:

- For continuous primary supporting members and where end connections are fitted consistent with idealisation of the primary supporting members as having fixed ends and is not to be taken higher than:

$f_{bdg} = 10$

- For primary supporting members with reduced end fixity, the yield check is to be considered on a case-by-case basis

C_s : Permissible bending stress coefficient for primary supporting members taken equal to:

$C_s = 0,70$ for AC-1

$C_s = 0,85$ for AC-2

h_w : Web height, in mm

C_5 : Coefficient defined in Tab 20 according to s_1 and d_0. For intermediate values of s_1 /d_0, coefficient C_5 is to be obtained by linear interpolation

s_1 : Spacing of stiffeners or tripping brackets on web plate, in m

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m.

Table 20 : Coefficient C_5

s_1/d_0	0,3 and less	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,5	2,0 and over
C_5	60,0	40,0	26,8	20,0	16,4	14,4	13,0	12,3	11,1	10,2

4.6 Transverse vertically corrugated bulkheads separating holds assigned as ballast holds and separating hopper wells on dredgers

4.6.1 Application

These requirements apply to:

- transverse vertically corrugated watertight bulkheads of the cargo holds of ships of less than 150m in length intended for the carriage of dry cargoes in bulk and assigned as ballast holds
- transverse vertically corrugated bulkheads fitted on dredgers and forming the boundary of hopper wells subjected to spoil pressure, as detailed in Pt D, Ch 13, Sec 2, [6.4.1].

4.6.2 Section modulus

The net section modulus Z at the lower and upper ends, in cm^3, of transverse vertically corrugated bulkheads subject to lateral pressure are not to be less than the values obtained from the following formula:

$$Z = K \frac{P s_{cg} \ell^2}{f_{bdg} C_s R_Y}$$

where:

K : Coefficient given in Tab 21 and Tab 22, according to the type of end connection. When $d_H < 2,5\ d_0$ (see Fig 9), both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated

P : Design pressure, in kN/m^2, for:

- the WB design load sets as defined in Ch 7, Sec 2, Tab 3, or
- the HW-N or HW-Di design load sets as defined in Pt D, Ch 13, Sec 2, Tab 8,

and calculated at the load calculation point defined in Ch 4, Sec 6, [3.2]

s_{cg} : Half pitch length, in mm, of the corrugation, as defined in Ch 4, Sec 5, Fig 27

ℓ : Length, in m, between the supports, as indicated in Fig 9

C_s : Coefficient defined in Ch 7, Sec 5, [1.1.2]

f_{bdg} : Coefficient defined in Ch 7, Sec 5 for lower and upper ends of corrugation.

The effective width of the corrugation flange in compression is to be considered according to [4.6.3] when the net section modulus of corrugated bulkhead is calculated.

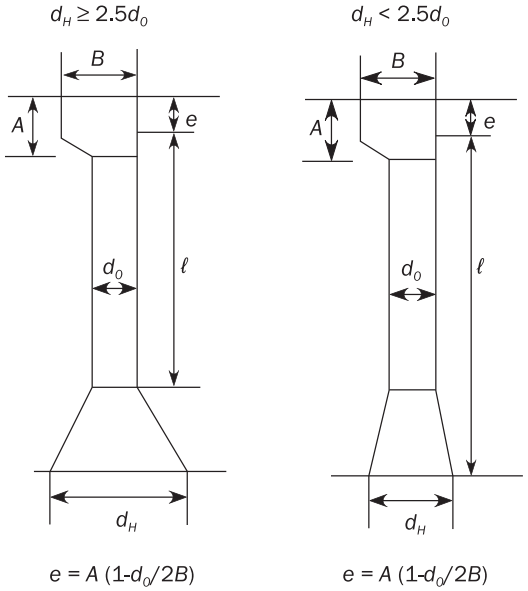
Table 21 : Values of K, in case $d_H \geq 2,5d_0$

Upper end support	
Welded directly to deck	Welded to stool efficiently supported by ship structure
1,00	0,83

Table 22 : Values of K, in case $d_H < 2,5d_0$

Section modulus of	Upper end support	
	Connected to deck	Connected to stool
Corrugated bulkhead	0,71	0,65
Stool at bottom	1,25	1,13

Figure 9 : Measurement of ℓ



4.6.3 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} not larger than the following formula:

$$b_{eff} = C_E\ b_{f-cg}$$

where:

C_E : Coefficient taken equal to:

- for $\beta \geq 1,25$:

$$C_E = \frac{2,25}{\beta} - \frac{1,25}{\beta^2}$$

- for $\beta < 1,25$:

$$C_E = 1,0$$

β : Coefficient to be taken equal to:

$$\beta = \frac{b_{f-cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

$b_{f\text{-}cg}$: Width, in mm, of the corrugation flange as shown in Ch 4, Sec 5, Fig 27

t_f : Net flange thickness, in mm.

4.7 Transverse vertically corrugated bulkheads in flooded conditions

4.7.1 Application

These requirements apply to vertically corrugated transverse watertight bulkheads of the cargo holds of ships intended for the carriage of dry cargoes in bulk.

4.7.2 Bending capacity and shear capacity

The bending capacity and the shear capacity of the corrugations of transverse watertight corrugated bulkheads separating cargo holds are to comply with the following formulae:

$$0,5W_{LE} + W_M \geq \frac{M}{0,95\ R_{eH}}\ 10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

where:

M : Bending moment in a corrugation, in kNm, taken as:

$$M = \frac{F_R\ \ell_C}{8}$$

F_R : Resultant force, in kN, given in Ch 5, Sec 6, [4.1.7]

ℓ_C : Span of the corrugations, in m, as given in Ch 4, Sec 5, [10.3.5]

W_{LE} : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [4.6.3], not to be taken greater than:

$$W_{LE,M} = W_G + \frac{Q\ h_G 10^3 - 0,5\ h_G^2\ s_{cg}\ P_R}{R_{eH}}$$

W_G : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [4.6.3]

Q : Shear force, in kN, at the lower end of a corrugation, to be taken as:

$$Q = 0,8\ F_R$$

h_G : Height, in m, of shedders or gusset plates, as applicable as shown in Fig 11 to Fig 13

P_R : Resultant pressure, in kN/m^2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Ch 5, Sec 6, [4.1.7]

W_M : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [4.6.3] without being taken greater than $1,15\ W_{LE}$

s_{cg} : Half pitch, in mm, of the corrugation flange as defined in Ch 4, Sec 5, [10.3.2]

τ : Shear stress, in N/mm^2, in the corrugation to be taken as:

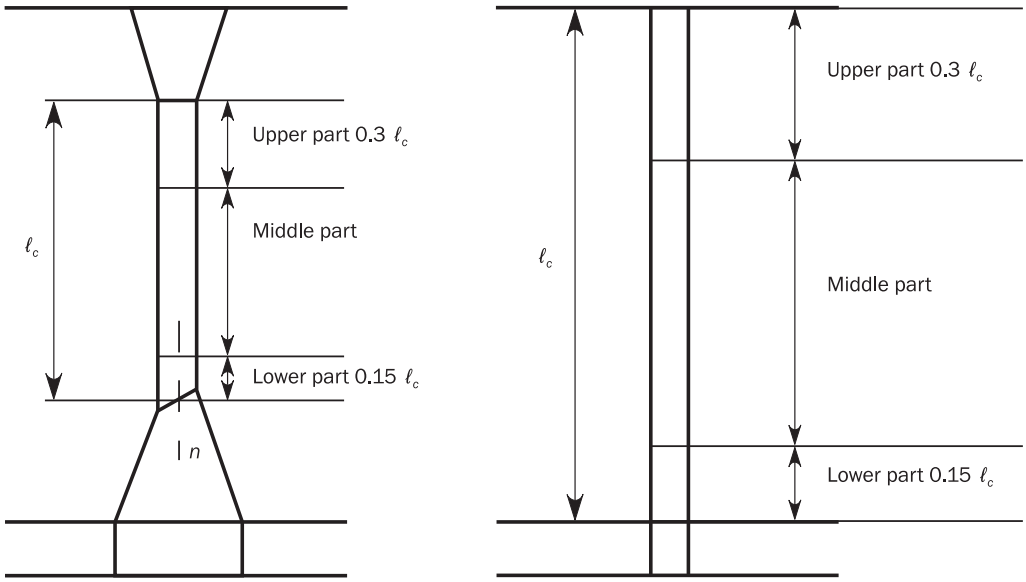
$$\tau = 10\ \frac{Q}{A_{shr}}$$

A_{shr} : Net shear area, in cm^2, of one half pitch corrugation. The calculated net shear area is to consider possible reduced shear efficiency due to non-straight angles between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by sin ϕ

ϕ : Angle between the web and the flange, see Ch 4, Sec 5, Fig 27.

The net section modulus of the corrugations in the upper part of the bulkhead, as defined in Fig 10, is not to be taken less than 75% of that of the middle part complying with this requirement and Ch 7, Sec 4, [1.2], corrected for different minimum yield stresses.

Figure 10 : Parts of corrugation



4.7.3 Shear buckling check of the bulkhead corrugation webs

This requirement is to be applied in lieu of the shear buckling strength criteria for corrugated bulkheads given in NR615, Section 3.

The shear stress τ, calculated according to [4.7.2], is to comply with the following formula:

$\tau \leq \tau_C$

where:

τ_C : Critical shear buckling stress, in N/mm^2, to be taken as:

- $\tau_C = \tau_E$

  for

  $$\tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

- $\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\ \tau_E}\right)$

  for

  $\tau_E > \frac{R_{eH}}{2\sqrt{3}}$

τ_E : Euler shear buckling stress, in N/mm^2, to be taken as:

$$\tau_E = 0,9 k_t\ E \left(\frac{t_w}{b_{w\text{-}cg}}\right)^2$$

k_t : Coefficient, to be taken equal to 6,34

t_w : Net thickness, in mm, of the corrugation webs

$b_{w\text{-}cg}$: Width, in mm, of the corrugation webs as shown in Ch 4, Sec 5, Fig 27.

4.7.4 Webs not supported by local brackets

Unless welded to a sloping stool top plate as defined in [4.7.7], if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

4.7.5 Effective shedder plates

Provided that effective shedder plates are fitted as shown in Fig 11, when calculating the section modulus at the lower end of the corrugations ("Sections 1" in Fig 11), the net area, in cm^2, of flange plates may be increased by I_{SH} to be taken as:

$$I_{SH} = 2,5 \cdot 10^{-3} b_{f\text{-}cg} \sqrt{t_f\ t_{SH}}$$

without being taken greater than $2,5\ b_{f\text{-}cg}\ t_f\ 10^{-3}$

where:

$b_{f\text{-}cg}$: Width, in mm, of the corrugation flange as shown in Ch 4, Sec 5, Fig 27.

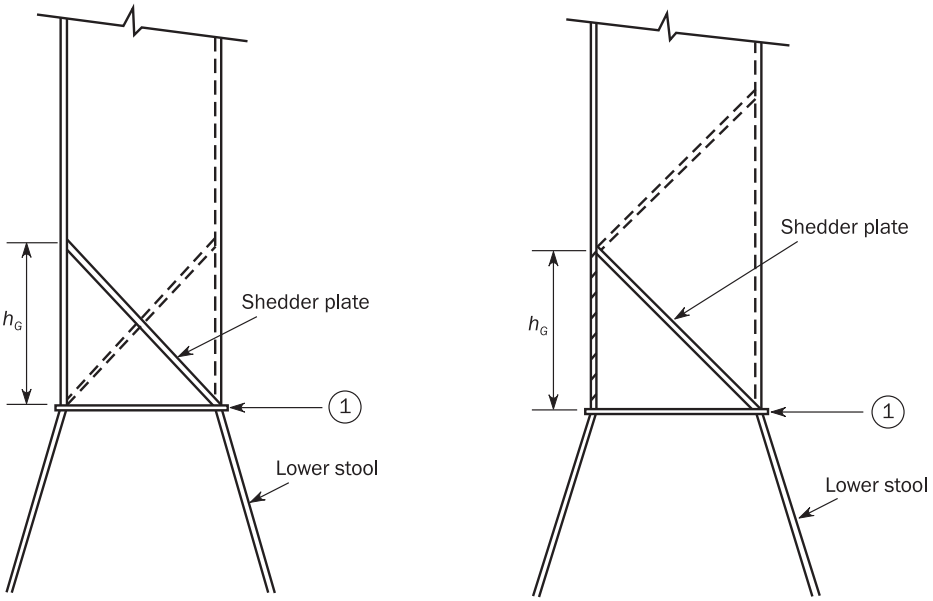
t_{SH} : Net shedder plate thickness, in mm.

t_f : Net flange thickness, in mm.

Effective shedder plates are those which:

- are not knuckled
- are welded to the corrugations and the lower stool top plate according to Ch 13, App 2
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating
- have net thickness not less than 75% of the net required for the corrugation flanges
- have material properties not less than those required for the flanges.

Figure 11 : Symmetrical and unsymmetrical shedder plates



4.7.6 Effective gusset plates

Provided that effective gusset plates are fitted, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Fig 12 and Fig 13), the net area, in cm^2, of flange plates may be increased by I_G to be taken as:

$I_G = 7\ h_G\ t_f$

where:

h_G : Height, in m, of gusset plates as shown in Fig 12 and Fig 13 but not to be taken greater than:

$$\frac{10\ S_{GU}}{7}$$

S_{GU} : Width, in m, of gusset plates.

t_f : Net flange thickness, in mm.

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [4.7.5]
- have a height not less than half of the flange width
- are fitted in line with the lower stool side plating
- are welded to the lower stool top plate, corrugations and shedder plates according to Ch 13, App 2
- have net thickness and material properties not less than those net required for the flanges.

Figure 12 : Symmetrical and unsymmetrical gusset / shedder plates

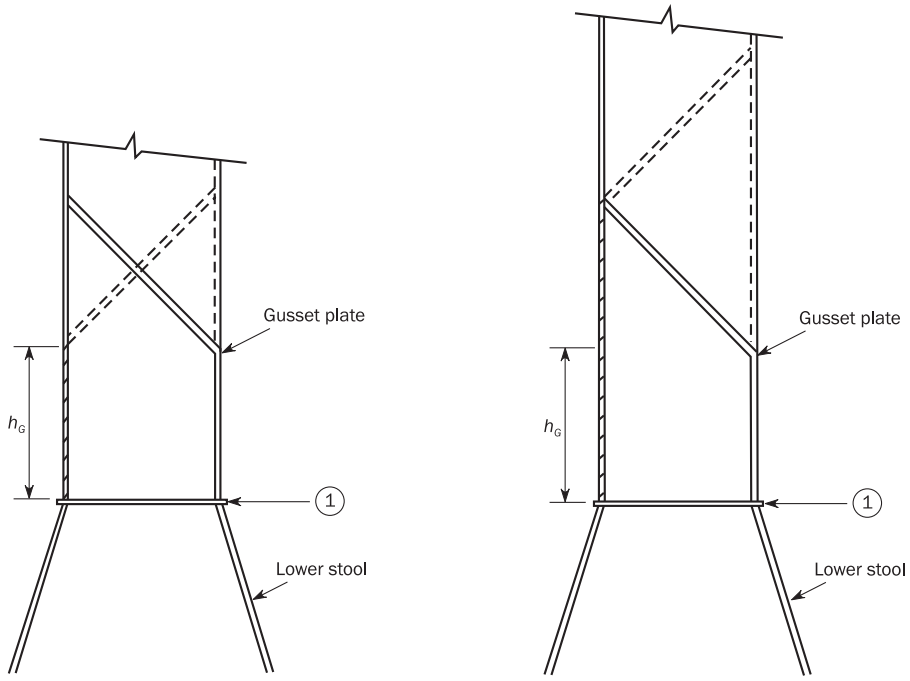
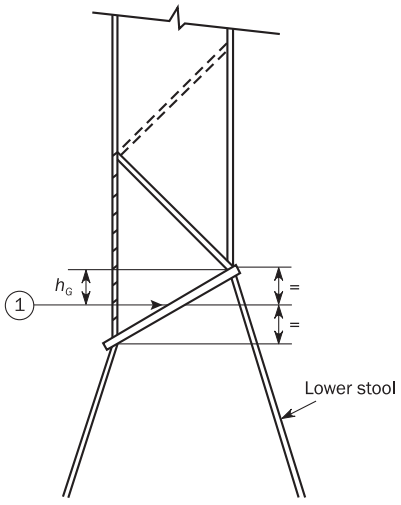


Figure 13 : Asymmetrical gusset / shedder plates



4.7.7 Sloping stool top plate

Where the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45° with the horizontal plane, the section modulus at the lower end of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% efficient for 0° and 100% efficient for 45°.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations, the net area of flange plates may be increased as specified in [4.7.6]. No credit may be given to shedder plates only.

4.7.8 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} as defined in [4.6.3].

4.8 Double bottom capacity in flooded conditions

4.8.1 Application

These requirements apply to the double bottom in cargo holds of ships intended for the carriage of dry cargoes in bulk.

4.8.2 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

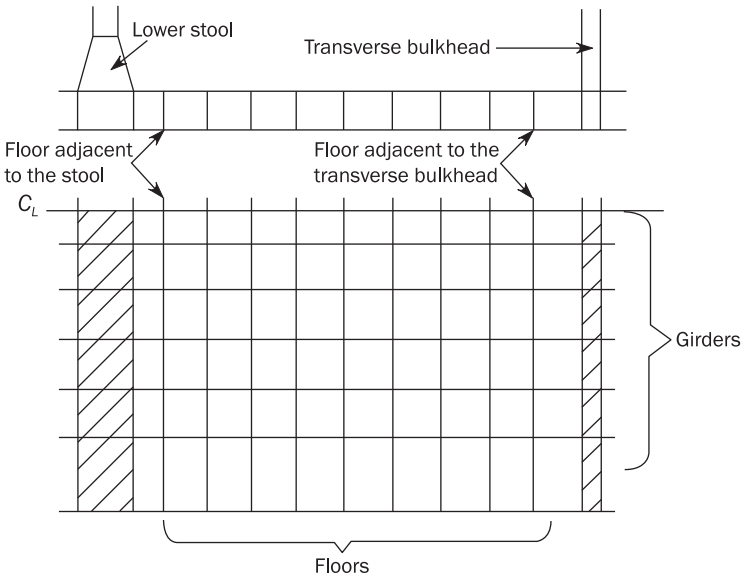
- Floors connected to hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted as shown in Fig 14. The shear strength of floors is to be calculated according to [4.8.3]
- Double bottom girders connected to stools, or transverse bulkheads if no stool is fitted. The shear strength of girders is to be calculated according to [4.8.4].

The floors and girders to be considered when calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools or transverse bulkheads if no stool is fitted. Where both ends of girders or floors are not directly connected to the hold boundaries, their strength is to be evaluated for the connected end only.

The hopper tank side girders and the floors directly below the connection of the stools or transverse bulkheads if no stool is fitted to the inner bottom may not be included.

For special double bottom designs, the shear capacity of the double bottom is to be calculated by means of direct calculations carried out in accordance with requirements specified in [5] Part B, Chapter 8, as applicable.

Figure 14 : Double bottom structure



4.8.3 Floor shear strength

The floor shear strength, in kN, is to be taken as given in the following formulae:

- in way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the openings in the outermost bay (i.e., that bay which is closer to the hopper tank):

$$S_{f2} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_f : Net sectional area, in mm², of the floor panel adjacent to the hopper tank

$A_{f,h}$: Net sectional area, in mm², of the floor panels in way of the openings in the outermost bay (i.e., the bay which is closer to the hopper tank)

τ_A : Allowable shear stress, in N/mm², to be taken as the lesser of:

$$\tau_A = 0,645 \frac{R_{eH}^{0,6}}{(s/t)^{0,8}}$$

and

$$\tau_A = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, τ_A is taken as:

$$\frac{R_{eH}}{\sqrt{3}}$$

t : Floor web net thickness, in mm

s : Spacing, in m, of stiffening members of the panel considered

η_1 : Coefficient to be taken equal to 1,1

η_2 : Coefficient to be taken equal to 1,2. It may be reduced to 1,1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

4.8.4 Girder shear strength

The girder shear strength, in kN, is to be taken as given in the following formulae:

- in way of the girder panel adjacent to the stool or transverse bulkhead, if no stool is fitted:

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the largest opening in the outermost bay (i.e., that bay which is closer to the stool) or transverse bulk-head, if no stool is fitted:

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

A_g : Net sectional area, in mm², of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted)

$A_{g,h}$: Net sectional area, in mm², of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool) or transverse bulkhead, if no stool is fitted

τ_A : Allowable shear stress, in N/mm², as defined in [4.8.3] where t is the girder web net thickness

η_1 : Coefficient to be taken equal to 1,1

η_2 : Coefficient to be taken equal to 1,15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

4.8.5 Allowable hold loading

The allowable hold loading, in t, is to be taken as:

$$W = \rho_C V \frac{1}{F}$$

where:

ρ_C : Density of the dry bulk cargo, in t/m³, as defined Ch 5, Sec 6, [3.3.3]

V : Volume, in m³, occupied by the cargo up to the level h_B

F : Coefficient to be taken as:

F = 1,1 in general.

F = 1,05 for steel mill products.

h_B : Level of cargo, in m, to be taken as:

$$h_B = \frac{P}{\rho_C g}$$

P : Pressure, in kN/m², to be taken as:

- For dry bulk cargoes, the lesser of:

$$P = \frac{Z + \rho g (z_F - (0,1 D_1) - h_F)}{1 + \frac{\rho}{\rho_C} (perm - 1)}$$

$$P = Z + \rho g (z_F - (0,1\ D_1) - h_F\ perm)$$

- For steel mill products:

$$P = \frac{Z + \rho g\ (z_F - (0,1\ D_1) - h_F)}{1 - \frac{\rho}{\rho_{ST}}}$$

D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships

h_F : Inner bottom flooded height, in m, measured vertically with the ship in the upright position, from the inner bottom to the flooded level z_F

z_F : Flooded level, in m, as defined in Ch 5, Sec 6, [4.1.3]

perm : Permeability of cargo, which need not be taken greater than 0,3.

ρ_{ST} : Density of steel, in t/m^3, to be taken as 7,85.

Z : Pressure, in kN/m^2, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

C_H : Shear capacity of the double bottom, in kN, to be calculated according to [4.8.2], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} as defined in [4.8.3] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.8.4]

$A_{DB,H}$: Area, in m^2, taken as:

$$A_{DB,H} = \sum_{i=1}^{n} S_i\ B_{DB,i}$$

C_E : Shear capacity of the double bottom, in kN, to be calculated according to [4.8.2], considering, for each floor, the shear strength S_{f1} as defined in [4.8.3] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.8.4]

$A_{DB,E}$: Area, in m^2, taken as:

$$A_{DB,E} = \sum_{i=1}^{n} S_i\ (B_{DB} - s)$$

n : Number of floors between stools or transverse bulkheads, if no stool is fitted.

S_i : Space of i-th floor, in m.

$B_{DB,i}$: Length, in m, to be taken equal to:

$B_{DB,i} = B_{DB} - s$ for floors for which $S_{f1} < S_{f2}$.

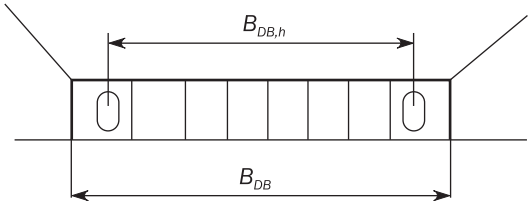
$B_{DB,i} = B_{DB,h}$ for floors for which $S_{f1} \geq S_{f2}$.

B_{DB} : Breadth, in m, of double bottom between the hopper tanks as shown in Fig 15

$B_{DB,h}$: Distance, in m, between the two openings considered as shown in Fig 15

s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

Figure 15 : Dimensions B_{DB} and $B_{DB,h}$



5 Grillage structure

5.1 General

5.1.1 Application

Where the structure is arranged as a grillage, the scantlings are to be checked using beam models in 2 or 3 dimensions, taking into account the requirements in [5.1.2] to [5.1.4].

5.1.2 Structural modelling

The model is to be built considering:

- the number and
  position of intermediate supports (e.g. decks, girders, pillars, etc)
- the conditions of fixity at the model boundaries and at intermediate supports
- the geometrical characteristics of the primary supporting members on the intermediate spans
- corrosion additions as defined in Ch 4, Sec 2, Tab 1.

5.1.3 Design loads

The distribution of static pressures and forces and of still water hull girder stresses, as applicable, are to be applied to the model for all the loading conditions defined in Ch 5, Sec 8 and considered relevant for the assessment of the modeled structure.

Unless otherwise specified by the Society, for each of the considered seagoing loading conditions, the still water and static loads are to be combined with the dynamic pressures and forces and with the wave hull girder stresses, if any of all the dynamic load cases defined in Ch 5, Sec 2.

5.1.4 Analysis criterion

The calculated stress values are to comply with the following criterion:

a) For isolated beam analysis:

$\tau \leq \chi \, K_{corr} \, C_t \, \tau_{eH}$

$\sigma \leq \chi \, K_{corr} \, C_s \, R_{eH}$

b) For grillage analysis: $\sigma_{eq} \leq \chi \, K_{corr} \, C_{comb} \, R_{eH}$

where:

σ_{eq} : Equivalent Von Mises stress, in N/mm^2:

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

C_t, C_s, C_{comb}:Permissible stress coefficients defined in Tab 2 for the acceptance criteria selected according to Tab 23

Table 23 : Acceptance criterias for grillage structure analysis

Acceptance criteria	Loading condition
AC-1	Harbour condition
AC-2	Any seagoing condition
AC-3	Tank testing condition Flooded condition

Appendix 1 Analyses of Primary Supporting Members Subject to Wheeled Loads

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply to the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subject to wheeled loads.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects,

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case by case basis, taking into account the ship's structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in Ch 8, App 3, as far as applicable.

1.3 Information required

1.3.1 To perform these structural analyses, the following characteristics for every vehicle to be loaded are necessary:

- load per axle
- arrangement of wheels on axles
- tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case by case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analyses

2.1.1 General

Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through local FE models according to Ch 8, App 2.

2.1.2 Criteria

Primary supporting members analyzed through FE models are to comply with the criteria in Ch 8, App 1, [5] or Ch 8, App 3, [5] as relevant.

2.2 Beam model analyses

2.2.1 General

Beam models, built according to Ch 7, Sec 6, [5.1], may be adopted in lieu of the finite element models, provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, FE models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

2.2.2 Criteria

Primary supporting members analyzed through beam models are to comply with the criteria in Ch 7, Sec 6, [5.1.4].

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2.

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

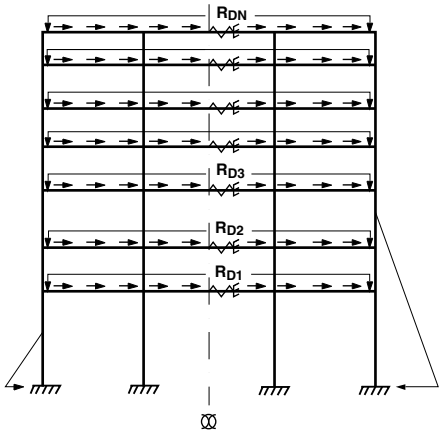
3.3.3 Additional boundary conditions at the fore and aft ends of models subject to transverse loads

When the model is subject to transverse loads, i.e. when load cases corresponding to beam and oblique sea (as defined in Ch 5, Sec 2) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions **(1)**:			ROTATION around axes **(1)**:		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 3, [2.6].					

Figure 1 : Springs at the fore and aft ends of models subject to transverse loads



For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (see Fig 1). The stiffness of each spring, simulating the effects of the deck in way of which it is modelled, is to be obtained, in kN/m, from the following formula:

$$R_{D,i} = \frac{24EJ_{D,i}s_a10^3}{2x^4 - 4L_Dx^3 + L_D^2\left(x^2 + 15{,}6\frac{J_{D,i}}{A_{D,i}}\right) + L_D^3x}$$

where:

$J_{D,i}$: Net moment of inertia, in m^4, of the average cross-section of the deck i, with the attached side shell plating, about its vertical neutral axis

$A_{D,i}$: Net area, in m^2, of the average cross-section of deck i plating

s_a : Spacing of side vertical primary supporting members, in m

x_i : Longitudinal distance, in m, measured from the transverse section at mid-length of the model to any end of deck i

$L_{D,i}$: Length of the deck i, in m, to be taken equal to the ship's length. Special cases in which such value may be reduced will be considered by the Society on a case by case basis.

4 Load model

4.1 General

4.1.1 Hull girder and local loads

Only local loads are to be directly applied to the structural model.

The stresses induced by hull girder loads are to be calculated separately and added to the stresses induced by local loads.

4.1.2 Loading conditions and load cases: wheeled cargoes

The still water and dynamic loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view on maximising the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The dynamic local loads and hull girder loads are to be calculated for the following sets of dynamic load cases defined in Ch 5, Sec 2, maximizing the vertical and transverse accelerations a_x and a_y according to Ch 5, Sec 3, [3.3]:

- BP2-P, BP2-S, OVA2-P and OVA2-S load cases for maximum vertical acceleration (OVA2-P and OVA2-S load cases are only relevant for models extending forward of 0,6L)
- BR2-P and BR1-S load cases for maximum transverse acceleration.

Other load cases may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship's decks are also designed to carry dry uniform cargoes, the loading conditions foreseeing the transportation of such cargoes are also to be considered. The still water and dynamic loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximising the stresses in primary supporting members.

The dynamic local loads and hull girder loads are to be calculated for the dynamic load cases specified in [4.1.2].

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1.2]
- the static forces defined in Ch 5, Sec 6, [7] and Ch 5, Sec 6, [6] for wheeled cargoes and dry uniform cargoes when relevant.

Dynamic loads include:

- the dynamic pressures, defined in Ch 5, Sec 5, [1], Ch 5, Sec 5, [3] and Ch 5, Sec 5, [5]
- the dynamic forces defined in Ch 5, Sec 6, [7] and Ch 5, Sec 6, [6] for wheeled cargoes and dry uniform cargoes when relevant.

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

5 Stress calculation

5.1 Normal stress induced by hull girder loads

5.1.1 The normal stress σ_L, in N/mm², induced by the hull girder loads is to be calculated according to Ch 6, Sec 1, [2.1] for the relevant load cases and added to the stresses induced by local loads as calculated by the direct strength analysis.

5.2 Analyses based on beam models

5.2.1 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of primary supporting members of decks

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members due to the forces induced by the vertical accelerations acting on wheeled cargoes (the racking effect is not to be considered), the simplified two dimensional analysis described in [6.2] may be considered.

This analysis is generally considered as being acceptable for standard structural typology where there are neither pillar lines nor longitudinal bulkheads, but sufficient transverse bulkheads to prevent racking effect.

6.2 Structural model

6.2.1 Members to be modelled

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [6.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(\ell_1 + \ell_2)}{\ell_1^2 + \ell_2^2 - \ell_1 \ell_2} 10^{-5}$$

- for the uppermost deck:

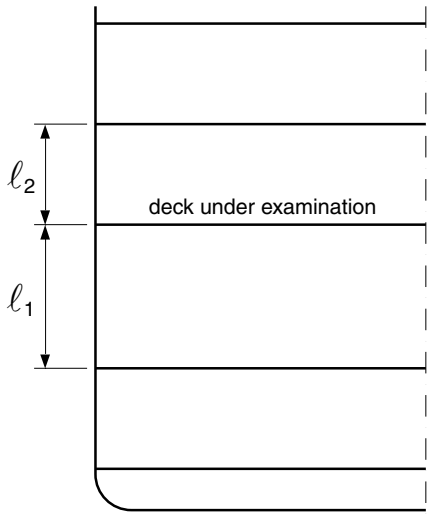
$$R_F = \frac{6EJ_1}{\ell_1} 10^{-5}$$

where:

ℓ_1, ℓ_2 : Height, in m, of the 'tweendecks, respectively below and above the deck under examination (see Fig 2)

J_1, J_2 : Net moments of inertia, in cm^4, of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

Figure 2 : Heights of 'tweendecks for grillage analysis of deck primary supporting members



6.4 Load model

6.4.1 Hull girder and local loads are to be calculated and applied to the model according to [4].

The dynamic local loads and hull girder loads are to be calculated for the load cases maximizing the vertical acceleration according to Ch 5, Sec 3, [3.3], and are to be applied to the model according to [4].

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.2].

CHAPTER 8
DIRECT STRENGTH ANALYSIS

Section 1 Direct Strength Assessment

Appendix 1 Cargo Hold Structural Strength Analysis

Appendix 2 Local Structural Strength Analysis

Appendix 3 Full Length Structural Strength Analysis

Section 1 Direct Strength Assessment

1 General

1.1 Application

1.1.1 This Chapter provides requirements to assess the scantlings of the hull structure using finite element analysis, mandatory only for ships defined in Ch 7, Sec 6, [1.1.1].

1.1.2 Direct strength assessment may cover the following types of analysis:

a) cargo hold analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and bulkheads, performed according to Ch 8, App 1

b) complete ship structural analysis to assess the primary supporting members, performed according to Ch 8, App 3

c) fine mesh analysis to assess detailed stress levels in local structural details, performed according to Ch 8, App 2

d) very fine mesh analysis to assess the fatigue capacity of the structural details according to Part B, Chapter 10.

1.1.3 The analysis is to verify that:

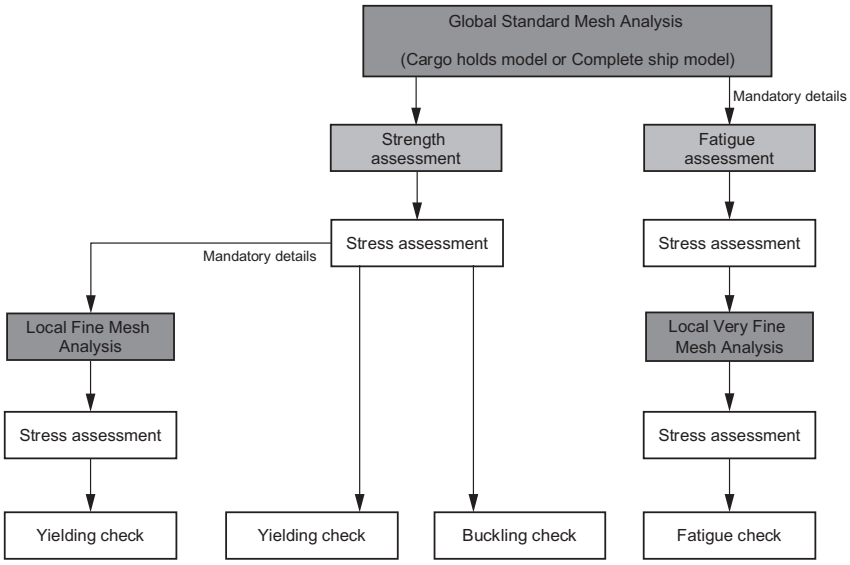
a) stress levels are within the acceptance criteria for yielding

b) buckling capability of plates and stiffened panels are within the acceptance criteria for bucking defined in Ch 9, Sec 1

c) fatigue capacity of the structural details is within the acceptance criteria defined in Ch 10, Sec 1.

1.1.4 A flow diagram showing the minimum requirement of finite element analysis is shown in Fig 1.

Figure 1 : Flow diagram of finite element analysis



2 Net scantling

2.1 Net scantling application

2.1.1 Models for cargo hold FE analyses, local fine mesh FE analyses and very fine mesh FE analyses are to be based on the net scantling approach, applying the corrosion addition as defined in Ch 4, Sec 2, Tab 1.

All the buckling capacity assessments are to be based on the net scantling approach, applying the corrosion addition as defined in Ch 4, Sec 2, Tab 1.

3 Finite element types

3.1 Finite element types to be used

3.1.1 The structural assessment is to be based on linear finite element analysis of three-dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in Tab 1.

Table 1 : Types of finite elements

Type of finite element	Description
Rod (or truss) element	Line element with axial stiffness only and constant cross-sectional area along the length of the element
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element
Shell (or plate) element	Shell element with in-plane stiffness and out-of-plane bending stiffness with constant thickness

3.1.2 Two node line elements and four node shell elements are, in general, considered sufficient for the representation of the hull structure. The mesh requirements given in this Chapter are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

4 Acceptance criteria

4.1 Definition

4.1.1 Acceptance criteria are to be selected as defined in Tab 2.

Table 2 : Acceptance criteria

Acceptance criteria	Design load scenario / Loading condition **(1)**
AC-1	Harbour condition
AC-2	Any seagoing condition
AC-3	Tank testing condition Flooded condition **(2)** Static heel 30° condition Collision condition
(1) The detailed loading conditions are defined in Ch 5, Sec 8. **(2)** In this Chapter, flooded condition is to be considered for watertight boundaries of compartments not intended to carry liquid (except for corrugated bulkheads.	

5 Submission of results

5.1 Detailed report

5.1.1 A detailed report of the structural analysis is to be submitted by the designer/builder to demonstrate compliance with the specified structural design criteria. This report is to include the following information:

a) list of plans used including dates and versions

b) detailed description of structural modeling including all modeling assumptions and any deviations in geometry and arrangement of structure compared with plans

c) plots to demonstrate correct structural modeling and assigned properties

d) details of material properties, plate thickness, beam properties used in the model

e) details of boundary conditions

f) details of all loading conditions reviewed with calculated hull girder shear force, bending moment and torsional moment distributions

g) details of applied loads and confirmation that individual and total applied loads are correct

h) plots and results that demonstrate the correct behaviour of the structural model under the applied loads

i) summaries and plots of global and local deflections

j) summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member

k) plate and stiffened panel buckling analysis and results

l) tabulated results showing compliance, or otherwise, with the design criteria

m) proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria

n) reference of the finite element computer program, including its version and date.

6 Computer programs

6.1 Use of computer programs

6.1.1 Any finite element computation program may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

Appendix 1 Cargo Hold Structural Strength Analysis

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

M_{sw} : Permissible vertical still water bending moment, in kN·m, as defined in Ch 5, Sec 4

M_{wv} : Vertical wave bending moment, in kN·m, in hogging or sagging condition, as defined in Ch 5, Sec 4

M_{wh} : Horizontal wave bending moment, in kN·m, as defined in Ch 5, Sec 4

M_{wt} : Wave torsional moment in seagoing condition, in kNm, as defined in Ch 5, Sec 4.

Q_{sw} : Permissible still water shear force, in kN, at the considered bulkhead position, as provided in Ch 5, Sec 4

Q_{wv} : Vertical wave shear force, in kN, as defined in Ch 5, Sec 4

$x_{b\text{-}aft}$, $x_{b\text{-}fwd}$: X-coordinate, in m, of, respectively, the aft and forward bulkheads of the mid-hold

x_{aft} : X-coordinate, in m, of the aft end support of the FE model

x_{fore} : X-coordinate, in m, of the fore end support of the FE model

x_i : X-coordinate, in m, of web frame station i

Q_{aft} : Vertical shear force, in kN, at the aft bulkhead of the mid-hold, as defined in [4.4.6]

Q_{fwd} : Vertical shear force, in kN, at the forward bulkhead of the mid-hold, as defined in [4.4.6]

$Q_{targ\text{-}aft}$: Target shear force, in kN, at the aft bulkhead of the mid-hold, as defined in [4.3.3]

$Q_{targ\text{-}fwd}$: Target shear force, in kN, at the forward bulkhead of the mid-hold, as defined in [4.3.3].

1 Objective and scope

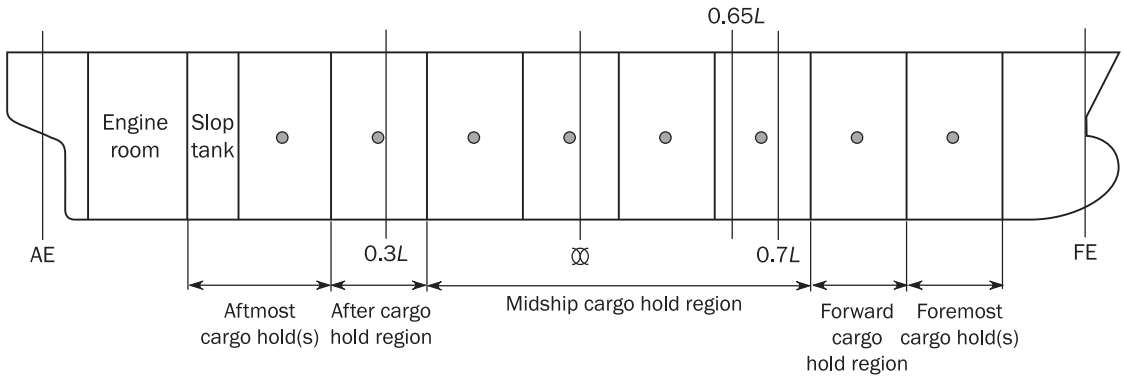
1.1 General

1.1.1 This Section gives the requirements for cargo hold structural strength analysis used for the assessment of scantlings of longitudinal hull girder structural members, primary supporting members and bulkheads within the cargo hold region.

1.1.2 For the purpose of FE structural assessment and load application, the cargo hold region contains the following cargo hold regions, which may vary depending on the ship length and cargo hold arrangement, as defined in Fig 1:

- midship cargo hold region
- forward cargo hold region
- after cargo hold region
- foremost cargo hold(s)
- aftmost cargo hold(s).

Figure 1 : Definition of the cargo hold regions for FE structural assessment



Holds in the forward cargo hold region are defined as holds having their longitudinal centre of gravity position located forward of 0.7 L from AE, except foremost cargo hold.

Holds in the midship cargo hold region are defined as holds having their longitudinal centre of gravity position located at or forward of 0.3 L from AE and at or aft of 0.7 L from AE.

Holds in the after cargo hold region are defined as holds having their longitudinal centre of gravity position located aft of 0.3 L from AE, except aftmost cargo hold.

Foremost cargo hold(s) is (are) defined as hold(s) in the foremost location of the cargo hold region.

Aftmost cargo hold(s) is (are) defined as hold(s) in the aftmost location of the cargo hold region.

1.1.3 Cargo hold structural strength analysis is mandatory for each typical cargo tank or cargo hold representative of the cargo hold regions defined in [1.1.2] including the aft bulkhead of the aftmost cargo hold and the collision bulkhead.

The evaluation areas are defined in [5.1].

1.2 Cargo hold structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- model: three cargo hold model with:
  - extent as given in [2.2]
  - finite element types as given in [2.3]
  - structural modeling as defined in [2.4]
- boundary conditions as defined in [2.5]
- FE load combinations as defined in [3]
- load application as defined in [4]
- evaluation area as defined in [5.1]
- strength assessment as defined in [5.2] and [5.3].

1.2.2 Mid-hold definition

For the purpose of the FE analysis, the mid-hold is defined as the middle hold(s) of the three cargo hold length FE model.

1.2.3 Scantling assessment

The scantling assessment is carried out according to Ch 8, Sec 1 for each individual cargo hold of the covered regions using the FE load combinations defined in [3] applicable to the considered cargo hold. The FE analysis results are applicable to the evaluation area, as defined in [5.1.1], of the considered cargo hold.

The individual transverse bulkhead structural elements, including plating, stiffeners and horizontal stringers, are to be assessed considering two cargo hold finite element analyses, i.e. the analysis for the hold forward and the one for the hold aft of the considered transverse bulkhead.

For ships having the service notation **container ship,** when the results of the full length model are not deemed sufficient by the Society, in particular to account for conditions with one bay empty, results from the midship cargo hold region analysis may also be extrapolated with special care to the other cargo hold areas.

2 Structural model

2.1 Members to be modeled

2.1.1 All the main longitudinal and transverse structural elements are to be modeled. These ones include:

- inner and outer shell
- upper deck
- double bottom floors and girders
- transverse and vertical web frames
- hatch coamings
- stringers and lower decks
- transverse and longitudinal bulkheads structures
- other primary supporting members
- other structural members which contribute to hull girder strength.

All plates and stiffeners on the structure, including web stiffeners, are to be modeled. Brackets which contribute to the primary supporting member strength and the size of which is not less than the typical mesh size (s-by-s) described in [2.4.2] are to be modeled.

2.2 Extent of model

2.2.1 Longitudinal extent

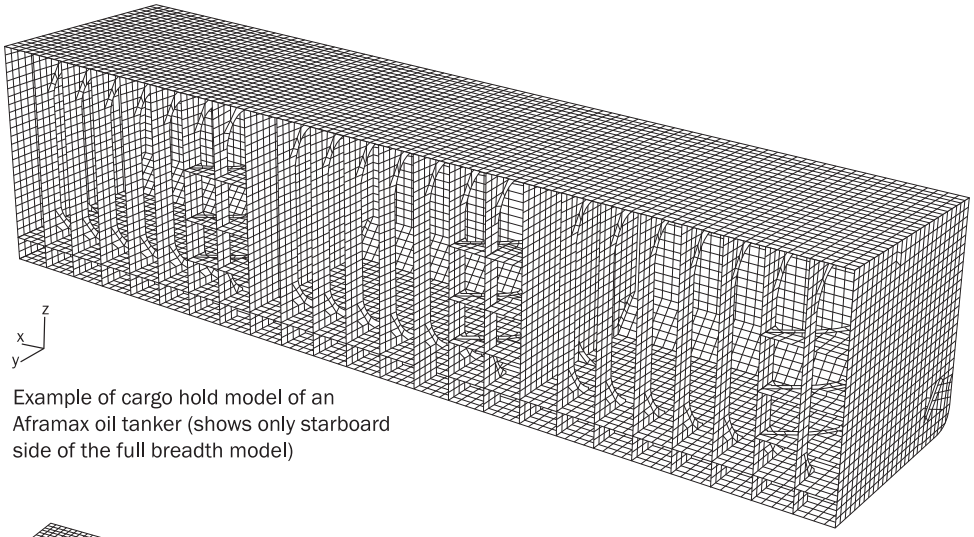
Except the foremost and aftermost cargo hold models, the longitudinal extent of the cargo hold FE model is to cover three cargo hold lengths. The transverse bulkheads at the ends of the model are to be modeled. Where corrugated bulkheads are fitted, the model is to include the extent of the bulkhead steel structure forward and aft of the tanks/holds at the model ends. Typical finite element models representing the midship cargo hold region are shown in Fig 2 to Fig 4.

The foremost and the aftmost cargo holds are located at the middle of the FE models as follows:

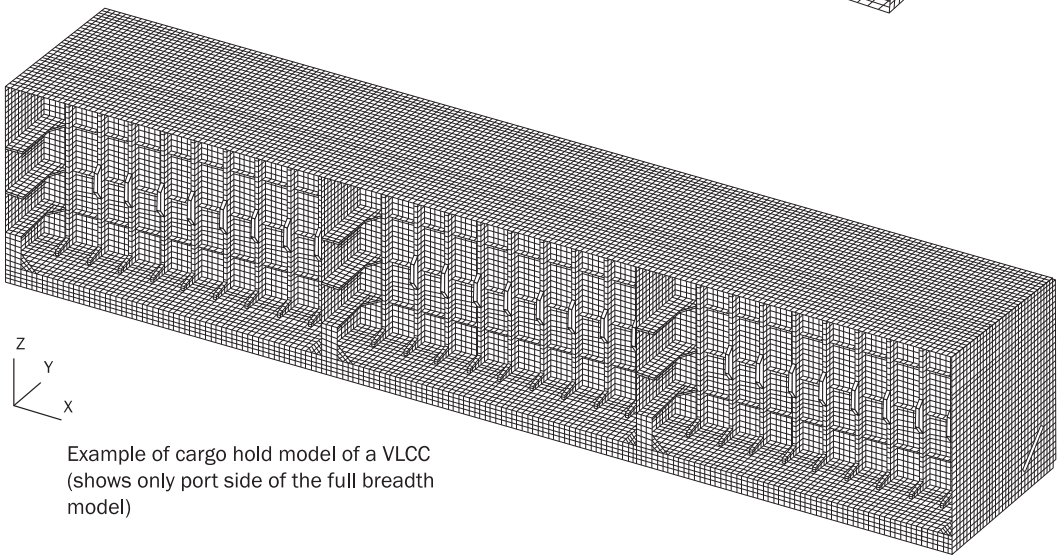
- foremost cargo hold: from the after bulkhead of the cargo hold no. 2 to the ship's foremost cross section where the reinforced ring or web frame remains continuous from the base line to the strength deck
- aftermost cargo hold: from the after bulkhead of the engine room to the forward bulkhead of no. N-1 cargo hold, where N is the number of holds or sets of holds numbered from forward to aft.

Examples of finite element models representing the foremost and aftermost cargo holds of different ship type configurations are shown in Fig 5 and Fig 6

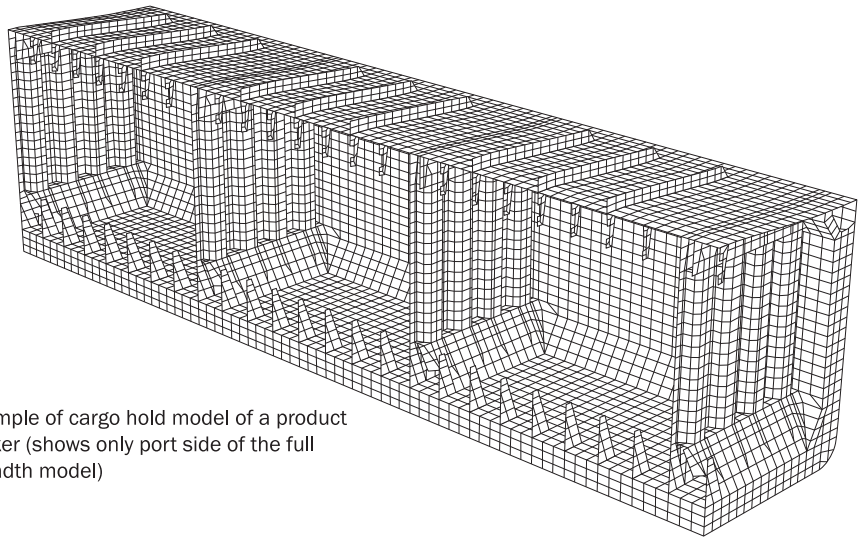
Figure 2 : Example of 3 cargo hold model within midship region of oil tankers



Example of cargo hold model of an Aframax oil tanker (shows only starboard side of the full breadth model)

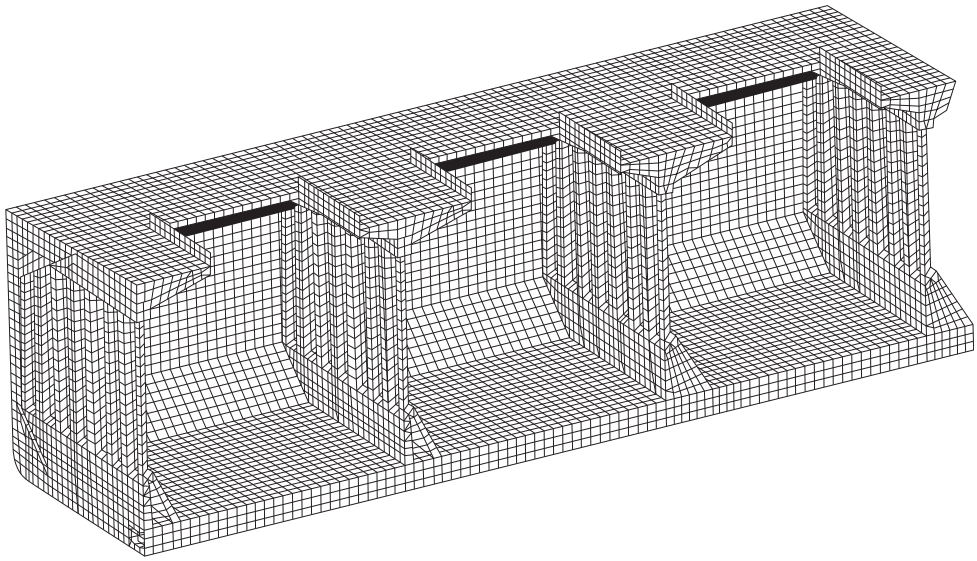


Example of cargo hold model of a VLCC (shows only port side of the full breadth model)



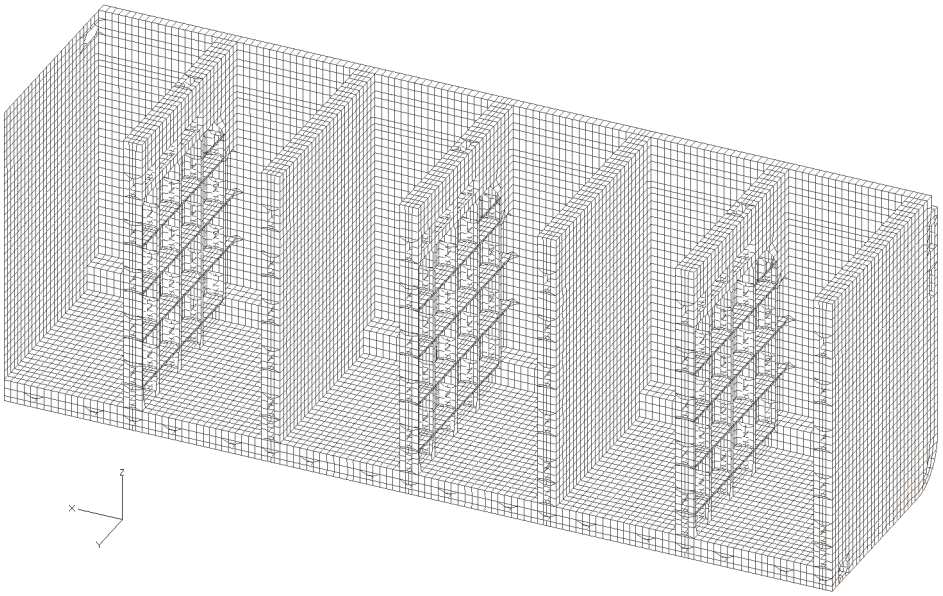
Example of cargo hold model of a product tanker (shows only port side of the full breadth model)

Figure 3 : Example of 3 cargo hold model within midship region of a bulk carrier



Example of cargo hold model of a bulk carrier (shows only port side of the full breadth model)

Figure 4 : Example of 3 cargo hold model within midship region of container ship



Example of cargo hold model of a container ship (shows only port side of the full breadth model)

Figure 5 : Example of FE model for the foremost cargo hold structure of an oil tanker

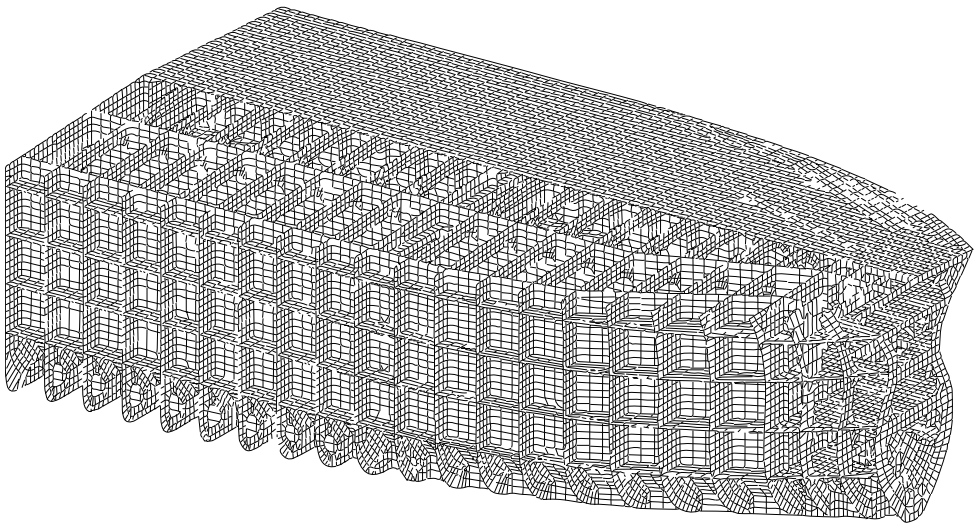
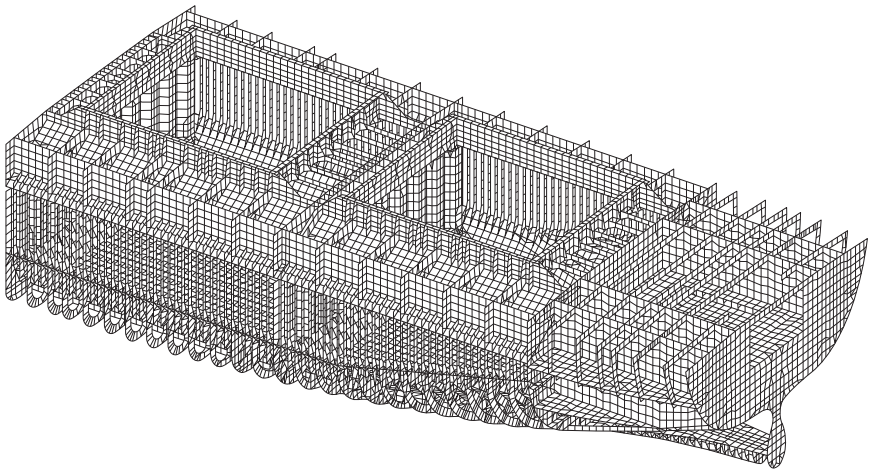


Figure 6 : Example of FE model for the aftermost cargo hold structure of a bulk carrier



2.2.2 Hull form modeling

In general, the finite element model is to represent the geometry of the hull form. In the midship cargo hold region, the finite element model may be prismatic, provided the mid-hold has a prismatic shape.

In the foremost cargo hold model, the hull form forward of the transverse section at the middle of the fore part up to the model end as defined in [2.2.1] may be modeled with a simplified geometry. The transverse section at the middle of the fore part up to the model end may be extruded out to the fore model end.

In the aftmost cargo hold model, the hull form aft of the middle of the machinery space may be modeled with a simplified geometry. The section at the middle of the machinery space may be extruded out to its aft bulkhead.

2.2.3 Transverse extent

Both port and starboard sides of the ship are to be modeled.

2.2.4 Vertical extent

The full depth of the ship is to be modeled including primary supporting members above the upper deck, trunks, forecastle and/or cargo hatch coaming, if any.

The superstructure or deck house in way of the machinery space, if any, and the bulwark are not required to be included in the model.

2.3 Finite element types

2.3.1 Shell elements are to be used to represent plating.

2.3.2 All the stiffeners are to be modeled with beam elements. The eccentricity of the neutral axis is to be modeled.

2.3.3 Face plates of primary supporting members and brackets are to be modeled using rod or beam elements.

2.4 Structural modeling

2.4.1 Aspect ratio

The aspect ratio of the shell elements is in general not to exceed 3. The use of triangular shell elements is to be kept to a minimum. Where possible, the aspect ratio of the shell elements, in areas where there are likely to be high stresses or a high stress gradient, is to be kept close to 1 and the use of triangular elements is to be avoided.

2.4.2 Mesh

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the shell element mesh is to satisfy the following requirements:

a) One element between every ordinary stiffener, see Fig 7 and Fig 8. Longitudinally, the element length is not to be greater than two longitudinal spaces, with a minimum of three elements between primary supporting members

b) At least three elements over the height of primary supporting members webs, see Fig 7 and Fig 8

   For primary supporting members with a small web depth, modeling using two elements over the depth is acceptable provided that there is at least one element between every web stiffener. The mesh size of adjacent structure is to be adjusted accordingly

c) The curvature of the free edge on large brackets of primary supporting members is to be modeled to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point, provided that the modeled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, as shown in Fig 9. The modeling of the tapering part of the flange is to be in accordance with [2.4.8]. An example of acceptable mesh is shown in Fig 9. A finer mesh is to be used for the determination of detailed stress at the bracket toe, as given in Ch 8, App 2.

Figure 7 : Typical finite element mesh on web frame of an oil tanker and a bulk carrier

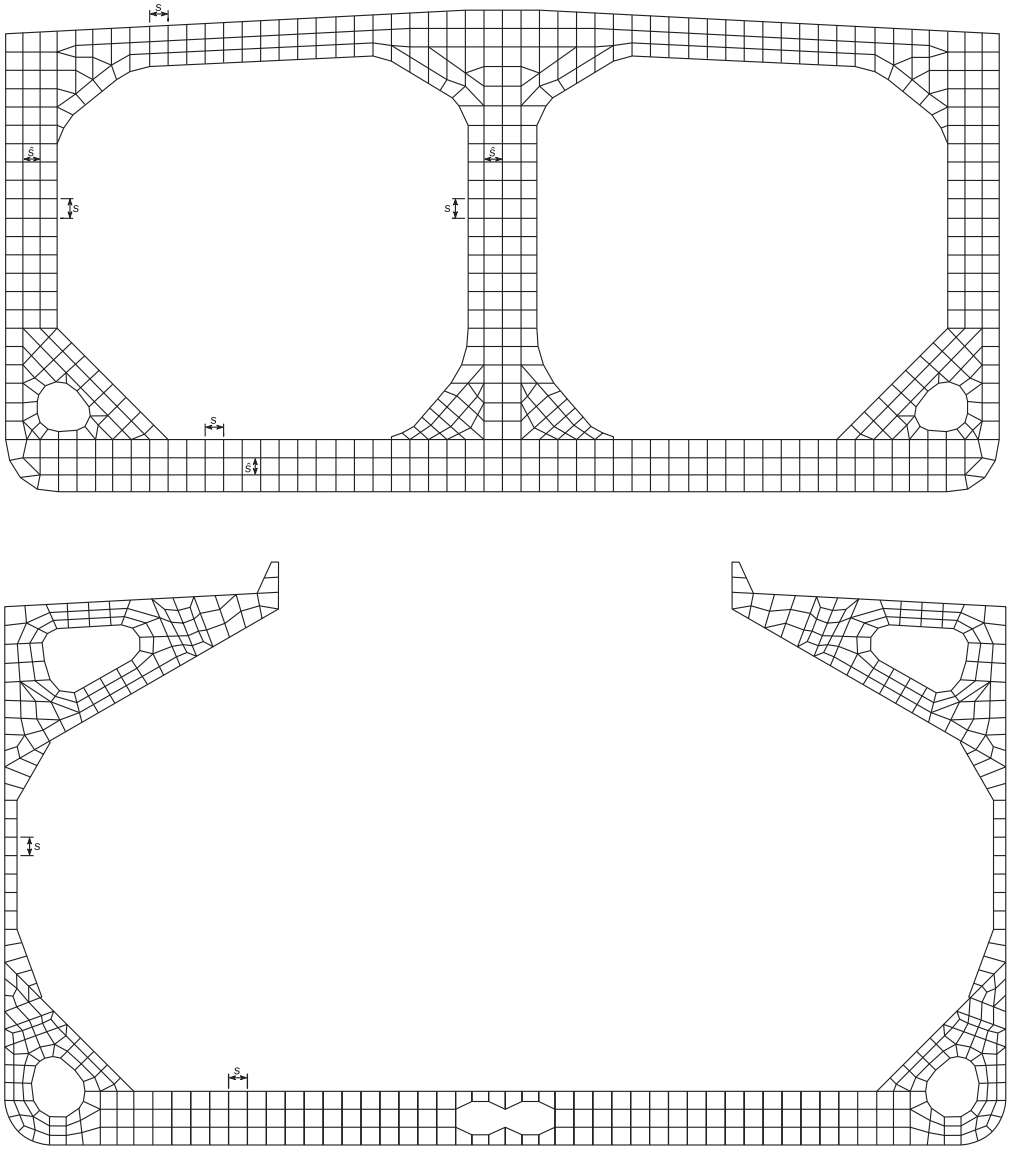


Figure 8 : Typical finite element mesh on web frame of a container ship

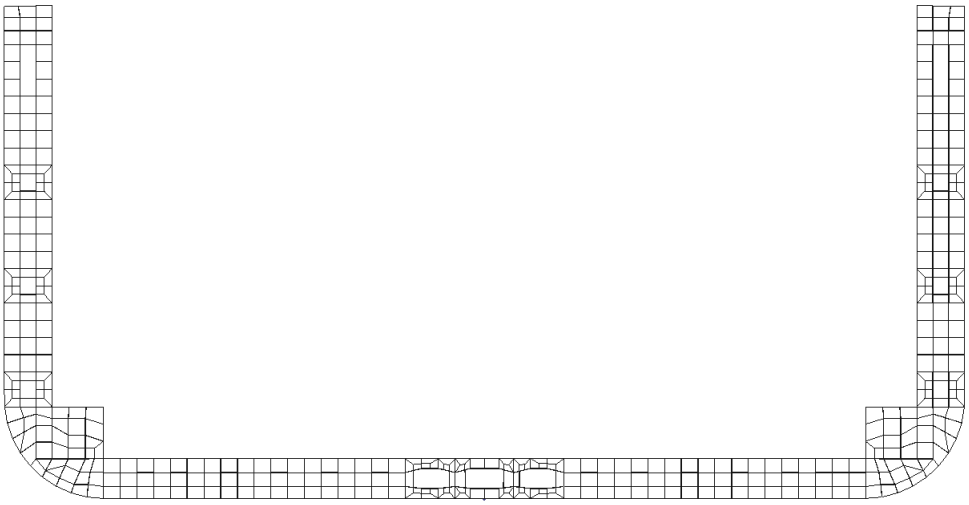
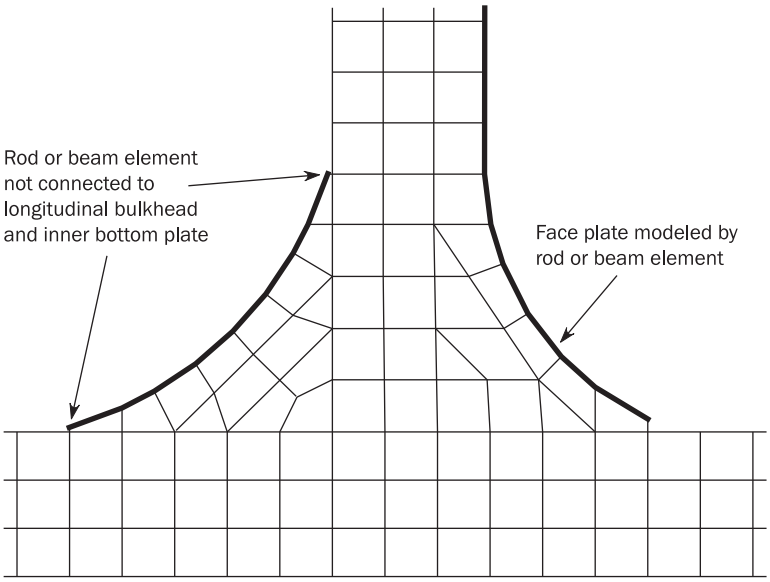


Figure 9 : Typical finite element mesh on large brackets of primary supporting member



2.4.3 Finer mesh

Where the geometry cannot be adequately represented in the cargo hold model and the stress exceeds the cargo hold mesh acceptance criteria, a finer mesh may be used for such geometry, to demonstrate satisfactory scantlings. The mesh size required for such analysis can be governed by the geometry. In such cases, the average stress within an area equivalent to that specified in [2.4] is to comply with the requirements given in [5.2].

2.4.4 Corrugated bulkhead

Diaphragms in the stools, supporting structure of corrugated bulkheads and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modeling is to be carried out as follows:

a) the corrugation is to be modeled with its geometric shape

b) the mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool

c) the mesh on the longitudinal corrugated bulkhead is to follow longitudinal positions of transverse web frames where the orrections to hull girder vertical shear forces are applied in accordance with [4.4.7]

d) the aspect ratio of the mesh in the corrugation is not to exceed 2 with a minimum of 2 elements for the flange breadth and the web height

e) where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stool in way of the corrugations

f) for a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in the model. The adjustment is to be made such that the shape and position of the corrugations and primary supporting members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary

g) when corrugated bulkhead is subjected to liquid cargo or ballast, dummy rod elements with a cross sectional area of 1 mm^2 are to be modeled at the corrugation knuckle between the flange and the web. Dummy rod elements are to be used as minimum at the two corrugation knuckles closest to the intersection between:
   - transverse and longitudinal bulkheads
   - transverse bulkhead and inner hull
   - transverse bulkhead and side shell.

h) manholes in diaphragms are to be modeled according to [2.4.9].

2.4.5 Examples of mesh arrangement of the cargo hold structure are shown in Fig 10 to Fig 13.

2.4.6 Sniped stiffener

Non continuous stiffeners are to be modeled as continuous stiffeners, i.e. the height web reduction in way of the sniped ends are not to be modeled.

2.4.7 Web stiffeners of primary supporting members

Web stiffeners of primary supporting members are to be modeled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points, provided that the adjusted distance does not exceed 0,2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modeled. These stiffeners may be modeled using rod elements.

Figure 10 : Example of FE cargo hold structure mesh arrangements for a container ship

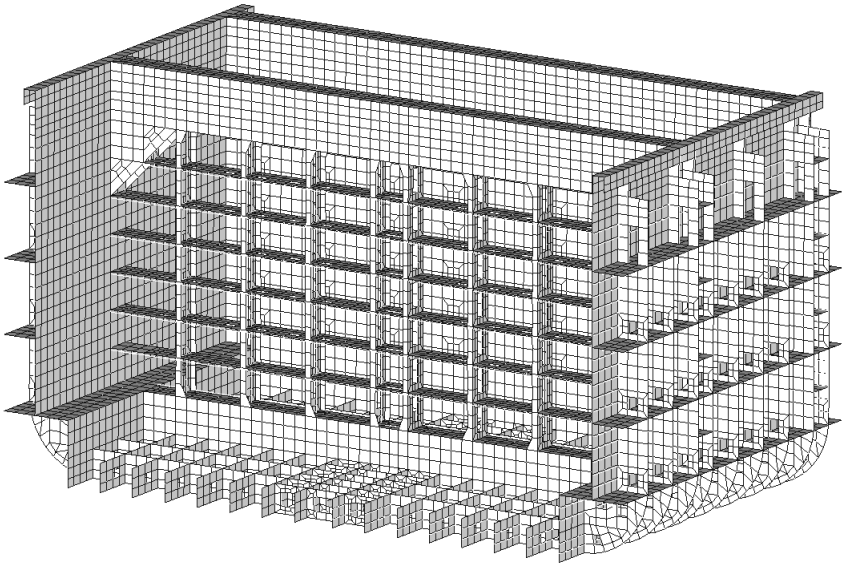


Figure 11 : Example of FE mesh arrangements of cargo hold structure for a bulk carrier

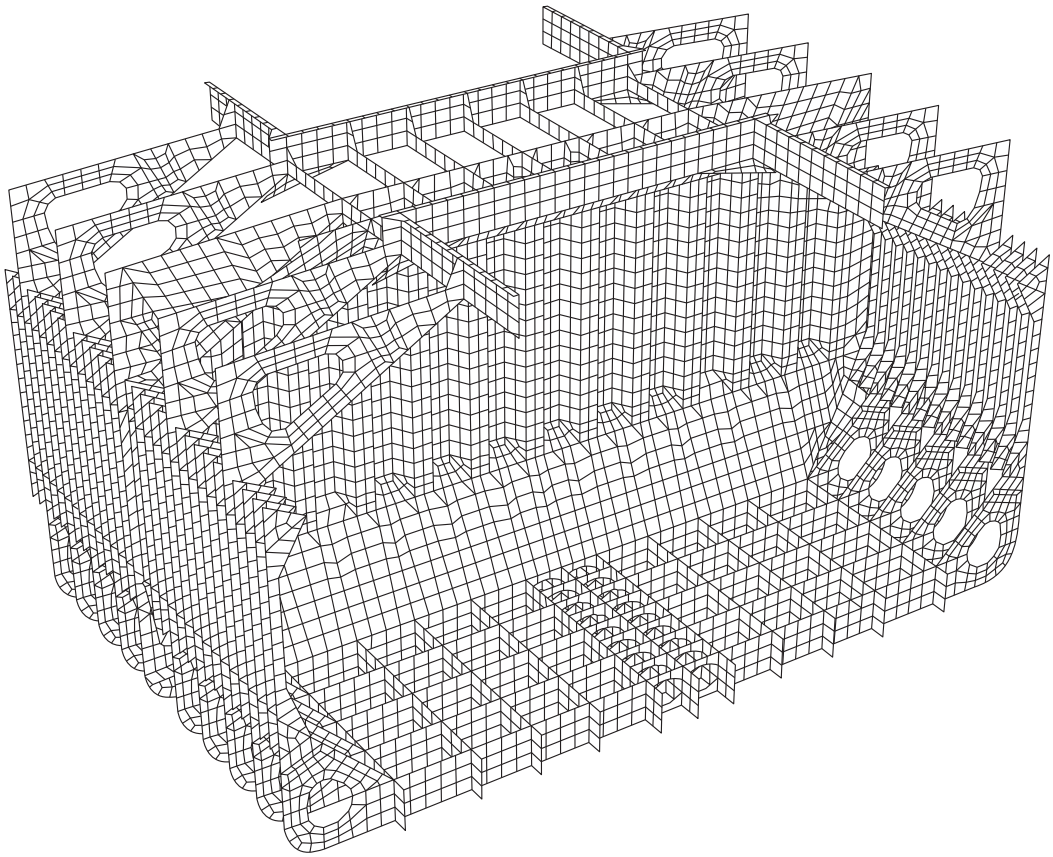


Figure 12 : Example of FE mesh on transverse corrugated bulkhead structure

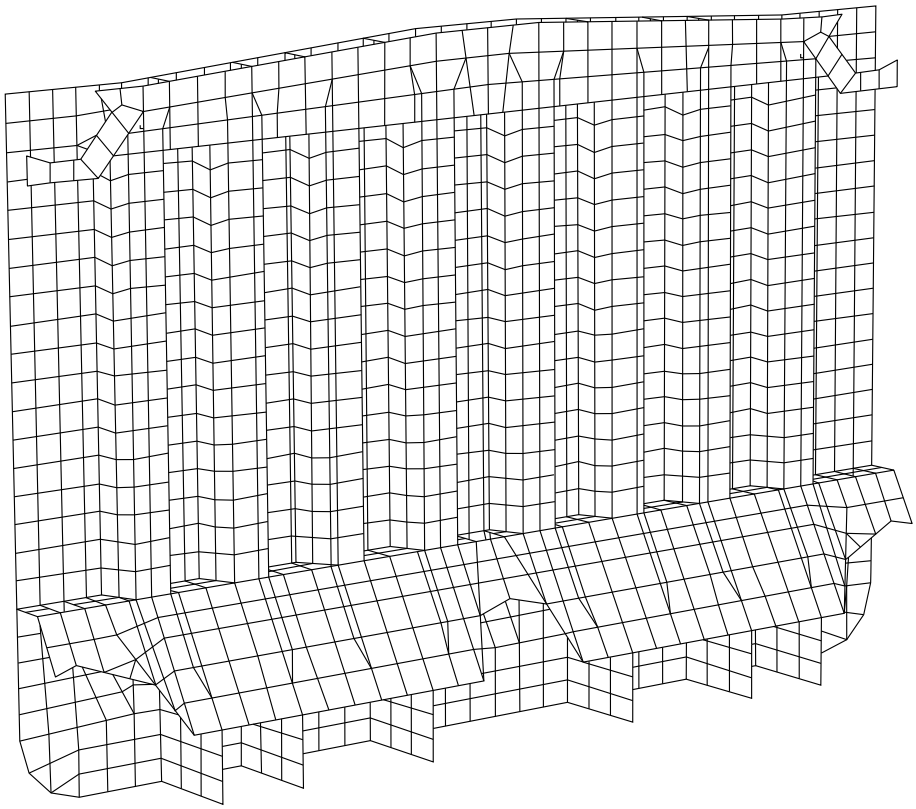
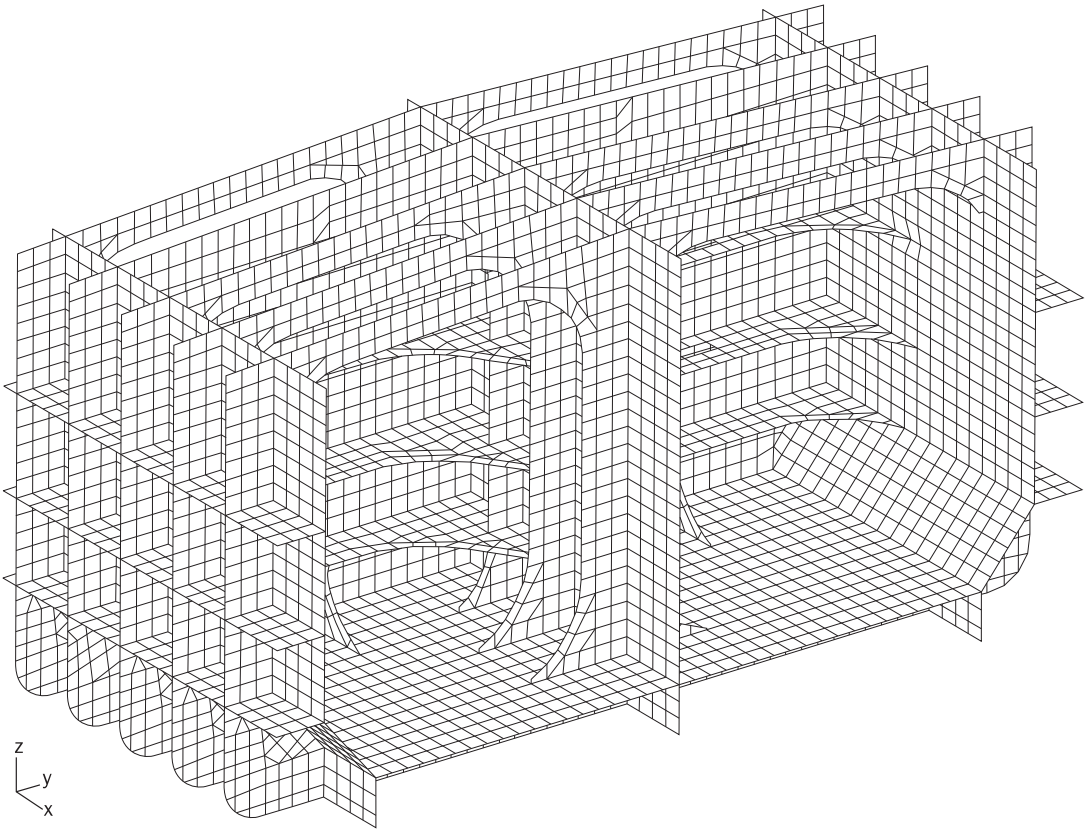


Figure 13 : Example of FE mesh arrangements of cargo tank structure for an aframax tanker



2.4.8 Face plate of primary supporting member

The effective cross-sectional area at the curved part of the face plate of primary supporting members and brackets is to be calculated in accordance with Ch 4, Sec 6. The cross-sectional area of a rod or beam element representing the tapering part of the face plate is to be based on the average cross-sectional area of the face plate in way of the element length.

2.4.9 Openings

Methods of representing openings and manholes in webs of primary supporting members are to be in accordance with Tab 1. Regardless of size, manholes are to be modeled by removing the appropriate elements.

Figure 14 : Openings in web

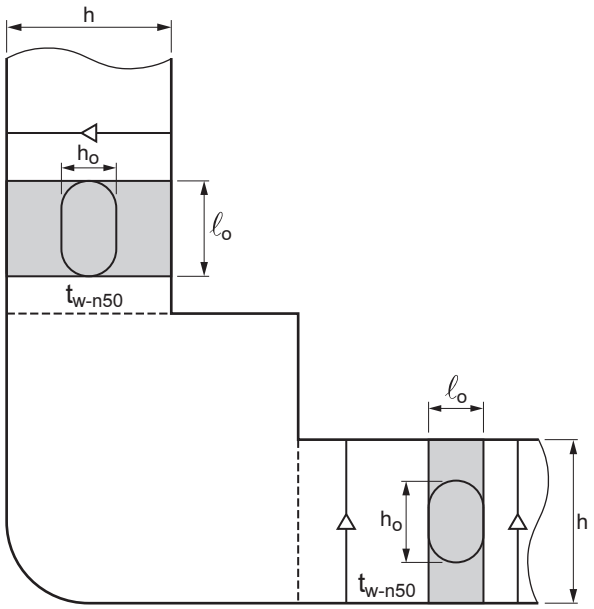


Figure 15 : Length ℓ_o for sequential openings with d_o < h/4

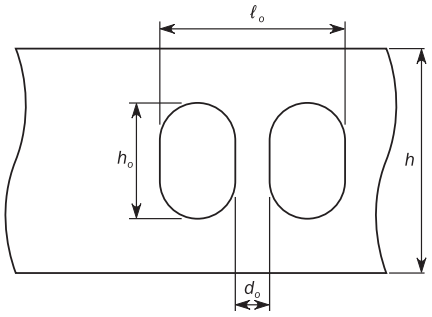


Table 1 : Representation of openings in primary supporting member webs

Criteria	Modeling decision	Analysis
$h_o/h < 0,5$ and $g_o < 2,0$	Openings do not need to be modeled	–
Manholes	The geometry of the opening is to be modeled by removing the adequate elements	To be evaluated by fine mesh if listed in Ch 8, App 2, [1.2.1]
$h_o/h \geq 0,5$ or $g_o \geq 2,0$	The geometry of the opening is to be modeled	

Note 1:

$$g_o = \left(1 + \frac{\ell_o^2}{2,6(h - h_o)^2}\right)$$

ℓ_o : Length, in m, of the opening parallel to the primary supporting member web direction, see Fig 14. For sequential openings where the distance d_o between openings is less than (0,25 h), ℓ_o is to be taken as the length across openings, as shown in Fig 15

h_o : Height of the opening parallel to the web depth, in m, see Fig 14 and Fig 15

h : Web height of the primary supporting member in way of the opening, in m, see Fig 14 and Fig 15.

2.5 Boundary conditions

2.5.1 General

All boundary conditions described in this Section are in accordance with the global coordinate system defined in Ch 5, Sec 1.

2.5.2 Application

The boundary conditions given in [2.5.3] are applicable to cargo hold finite element model analyses in cargo hold region.

2.5.3 Boundary conditions

The boundary conditions consist of rigid links, point constraints and end-beams at model ends. The rigid links connect the nodes on the longitudinal members at the model ends to an independent point at neutral axis in centreline.

The boundary conditions to be applied at the ends of the cargo hold FE model are given in Tab 2, except for the foremost cargo hold model, for which they are given in Tab 3.

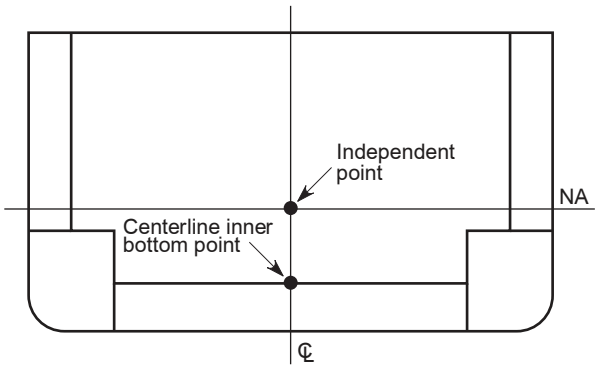
Table 2 : Boundary constraints at model ends except the foremost cargo hold model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Independent point **(1)** at aft end	–	fix	fix	$M_{T\text{-end}}$	–	–
Independent point **(1)** at fore end	–	fix	fix	fix	–	–
Intersection of centerline and inner bottom **(1)** at fore end	fix	–	–	–	–	–
Cross section at both ends	–	rigid link	rigid link	rigid link	–	–
	End beam, see [2.5.4]					
Note 1: [–] means no constraint applied (free). **(1)** See Fig 16.						

Table 3 : Boundary constraints at model ends of the foremost cargo hold model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Independent point **(1)** at aft end	–	fix	fix	fix	–	–
Intersection of centerline and inner bottom **(1)** at aft end	fix	–	–	–	–	–
Independent point **(1)** at fore end	–	fix	fix	$M_{T\text{-end}}$	–	–
Cross section at aft end	–	rigid link	rigid link	rigid link	–	–
	End beam, see [2.5.4]					
Cross section at fore end	–	rigid link	rigid link	rigid link	–	–
Note 1: [–] means no constraint applied (free). **Note 2:** The fore end constraints are to be located at the most forward reinforced ring or web frame which remains continuous from the base line to the strength deck. **(1)** See Fig 16.						

Figure 16 : Boundary conditions applied at the model end sections



NA : neutral axis of the model end sections

2.5.4 End constraint beams

End constraint beams are to be modeled at both end sections of the model along all longitudinally continuous structural members and along the cross deck plating of ships with large deck openings. An example of end beams at one end for a double hull bulk carrier is shown in Fig 17.

The properties of beams are calculated at fore and after sections separately and all beams at each end section have identical properties as follows:

- Net moment of inertia: $I_{yy\text{-}n50} = I_{zz\text{-}n50} = I_{xx\text{-}n50}$ (J) = 1/25 of the vertical hull girder moment of inertia of fore/aft end cross sections based on the net FE model
- Net cross sectional area: $A_{y\text{-}n50}$ and $A_{z\text{-}n50}$ = 1/80 of the fore/aft end cross sectional areas based on the net FE model.

where:

$I_{yy\text{-}n50}$: Moment of inertia about local beam Y axial, in m^4

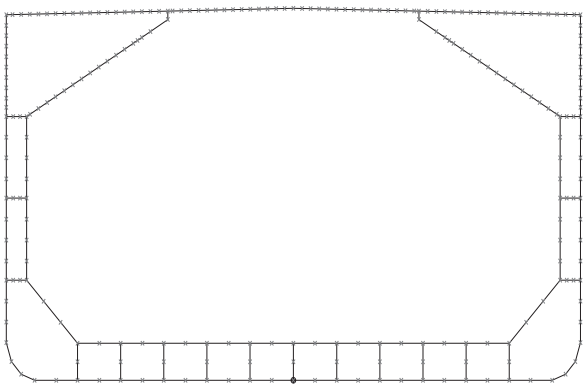
$I_{zz\text{-}n50}$: Moment of inertia about local beam Z axial, in m^4

$I_{xx\text{-}n50}$ (J) : Torsional inertia, in m.

$A_{y\text{-}n50}$: Shear area in local beam Y direction, in m^2

$A_{z\text{-}n50}$: Shear area in local beam Z direction, in m^2.

Figure 17 : End constraint beams



3 FE load combinations

3.1 Design load combinations

3.1.1 FE load combination definition

A FE load combination is defined as a loading pattern, a draught, a roll radius of gyration, a metacentric height, a value of still water bending moment and of still water shear force, associated with a given dynamic load case.

3.1.2 Mandatory load combinations

For cargo hold structural strength analysis, the design load combinations specified in the applicable Part D or Part E chapter are to be used for the considered ship type and cargo hold regions.

Each load combination requires the application of the structural weight, internal and external loads and hull girder loads. For seagoing condition, both static and dynamic load components are applied. For tank testing and flooding condition, only the static load components are applied.

3.1.3 Additional loading conditions

Where the loading conditions specified by the designer are not covered by the load combinations given the applicable Part D or Part E chapter, these additional loading conditions are to be examined according to the procedure in [4].

4 Load application

4.1 General

4.1.1 Structural weight

Effect of the weight of hull structure is to be included in the static loads, but is not to be included in the dynamic loads. Density of steel is to be taken as given in Ch 5, Sec 6.

4.1.2 Sign convention

Unless otherwise mentioned in this Section, the sign of the moments and shear forces is to be in accordance with the sign convention defined in Ch 5, Sec 1.

4.2 External and internal loads

4.2.1 External loads

The external pressures are to be calculated for each load case in accordance with Ch 5, Sec 5. They include static sea pressure, wave pressure and green sea pressure.

The effect of the hatch cover self weight is to be ignored in the loads applied to the ship structure.

4.2.2 Internal loads

The internal loads are to be calculated for each load case in accordance with Ch 5, Sec 6 for design load scenarios given in Ch 5, Sec 7, Tab 1. They include static dry and liquid cargo (including containers on deck if any), ballast and other liquid pressure, setting pressure on relief valve and dynamic pressure of dry and liquid cargo (including containers on deck if any), ballast and other liquid pressure due to acceleration.

4.2.3 Pressure application on FE element

A constant pressure, calculated at the element's centroid, is applied to the shell element of the loaded surfaces, e.g. outer shell and deck for the external pressure and tank/hold boundaries for the internal pressure. Alternately, the pressure can be calculated at the element nodes applying linear pressure distribution within the elements.

4.3 Hull girder loads

4.3.1 General

Each loading condition is to be associated with the corresponding hull girder loads to be applied to the model according to the procedure described in [4.4] for shear force and bending moment and in [4.5]for torsional moment.

The hull girder loads are the combinations of the still water hull girder loads and the wave induced hull girder loads as specified in Ch 5, Sec 8.

For each required FE load combination:

- the combination between still water bending moment and still water shear force may be adjusted by the use of relevant coefficients, in line with the loading manual and to the satisfaction of the Society
- the wave induced hull girder loads are to be calculated with the load combination factors (LCFs) specified in Ch 5, Sec 2.

4.3.2 Target hull girder vertical bending moment

The target hull girder vertical bending moment $M_{v\text{-}targ}$, in kN·m, at a longitudinal position for a given FE load combination, is taken as: $M_{v\text{-}targ} = M_{sw} + M_{wv\text{-}LC}$

where:

M_{sw} : Maximum and minimum permissible vertical still water bending moments at the considered longitudinal position, in seagoing conditions, in kN·m, as defined in Ch 5, Sec 4

$M_{wv\text{-}LC}$: Vertical wave bending moment, in kN·m, for the dynamic load case under consideration, calculated in accordance with Ch 5, Sec 4, [3.6.1].

Within the midship cargo hold region, the value of $M_{v\text{-}targ}$ is taken as the maximum hull girder bending moment within the mid-hold, for each given FE load combination.

Outside the midship cargo hold region, the values of $M_{v\text{-}targ}$ are taken at all web frames and transverse bulkhead positions of the FE model under consideration.

4.3.3 Target hull girder vertical shear forces

The target hull girder vertical shear forces $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$ at the aft and forward transverse bulkheads of the mid-hold, in kN, for a given FE load combination, are taken as:

- if $Q_{fwd} \geq Q_{aft}$:

  $Q_{targ\text{-}aft} = Q_{sw\text{-}aft} - \Delta Q_{sw\text{-}aft} + |C_{QV}|\, Q_{wv\text{-}neg}$

  $Q_{targ\text{-}fwd} = Q_{sw\text{-}fwd} + \Delta Q_{sw\text{-}fwd} + |C_{QV}|\, Q_{wv\text{-}pos}$
- if $Q_{fwd} < Q_{aft}$:

  $Q_{targ\text{-}aft} = Q_{sw\text{-}aft} + \Delta Q_{sw\text{-}aft} + |C_{QV}|\, Q_{wv\text{-}pos}$

  $Q_{targ\text{-}fwd} = Q_{sw\text{-}fwd} - \Delta Q_{sw\text{-}fwd} + |C_{QV}|\, Q_{wv\text{-}neg}$

where:

Q_{fwd}, Q_{aft} : Vertical shear forces, in kN, due to the local loads, respectively at the forward and aft bulkhead positions of the mid-hold, as defined in [4.4.6]

$Q_{sw\text{-}aft}$, $Q_{sw\text{-}fwd}$: Aft and forward permissible still water shear forces, in kN, at any longitudinal position for seagoing conditions as defined in Ch 5, Sec 4

C_{QV} : Load combination factor for vertical wave shear force, as given in Ch 5, Sec 2

$Q_{wv\text{-}pos}$, $Q_{wv\text{-}neg}$: Positive and negative vertical wave shear forces, in kN, as defined in Ch 5, Sec 4, [3.2.1].

$\Delta Q_{sw\text{-}fwd}$: Shear force correction, in kN, for the considered FE loading pattern at the forward bulkhead taken as:

- For bulk carriers:

  Minimum of the absolute values of $\Delta Q_{md\text{-}fwd}$ as defined in [4.3.4] calculated at forward bulkhead for the mid-hold and the value calculated at aft bulkhead of the forward cargo hold taken as:

  $$\Delta Q_{sw-fwd} = Min(|\Delta Q_{md-fwd}|_{Mid}, |\Delta Q_{md-fwd}|_{Fwd})$$

- For other ships:

  $$\Delta Q_{sw-fwd} = 0$$

$\Delta Q_{sw\text{-}aft}$: Shear force correction, in kN, for the considered FE loading pattern at the aft bulkhead taken as:

- For bulk carriers:

  Minimum of the absolute values of $\Delta Q_{md\text{-}fwd}$ as defined in [4.3.4] calculated at aft bulkhead for the mid-hold and the value calculated at forward bulkhead of the aft cargo hold taken as:

  $$\Delta Q_{sw-aft} = Min(|\Delta Q_{md-fwd}|_{Mid}, |\Delta Q_{md-fwd}|_{Aft})$$

- For other ships:

  $$\Delta Q_{sw-aft} = 0$$

The values of $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$ are to be taken at the aft and forward transverse bulkheads of the mid-hold under consideration.

4.3.4 Shear force correction for bulk carriers

For bulk carriers, shear force correction, which takes into account the portion of loads transmitted by the double bottom longitudinal girders to the transverse bulkheads, is to be considered.

For the considered cargo hold, the shear force correction at the considered transverse section is to be obtained, in kN, from the following formula:

$$\Delta Q_{md-fwd} = C_d \alpha \left(\frac{M}{B_H \, \ell_H} - \rho T_{LC,mh} \right)$$

where:

C_d : Distribution coefficient taken as:

- C_d = -1 at the aft end of the considered cargo hold except for aftmost cargo hold
- C_d = 1 at the fore end of the considered cargo hold except for foremost cargo hold
- C_d = 0 at mid-length of the cargo hold
- C_d = 0 at the aft bulkhead of the aftmost cargo hold
- C_d = 0 at the fore bulkhead of the foremost cargo hold
- C_d : Linearly distributed at other locations

α : Coefficient taken as:

$$\alpha = g \, \frac{\ell_0 \, b_0}{2 + \varphi \frac{\ell_0}{b_0}}$$

M : Mass, in t, in the hold in way of the considered transverse section for the considered loading condition. M is to include the mass of ballast water and fuel oil located directly below the flat portion of the inner bottom, if any, excluding the portion under the bulkhead stool

φ : Coefficient taken as:

$$\varphi = 1,38 + 1,55 \frac{\ell_0}{b_0}$$

without being taken greater than 3,7

B_H : Breadth of the cargo hold, in m, as defined in Ch 5, Sec 6

ℓ_H : Length of the cargo hold, in m, as defined in Ch 5, Sec 6

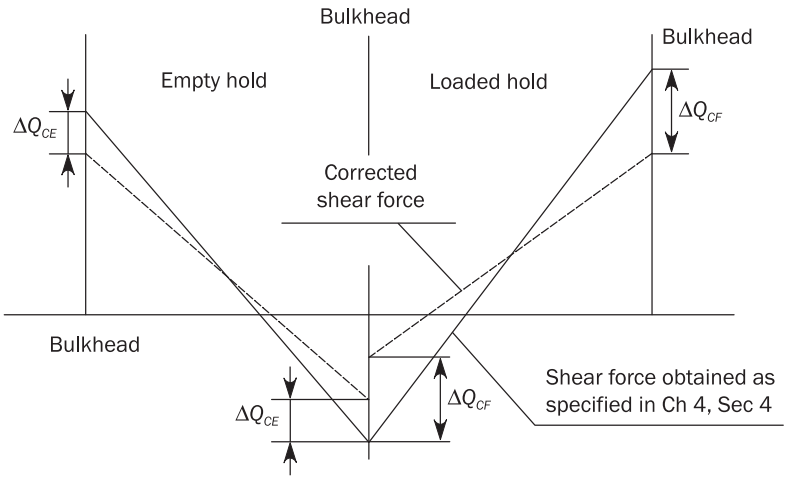
ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold

$T_{LC,mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered

ΔQ_{CF} : Shear force correction for the full hold (see Fig 18)

ΔQ_{CE} : Shear force correction for the empty hold (see Fig 18).

Figure 18 : Shear force correction, ΔQ_C



4.3.5 Target hull girder horizontal bending moment

The target hull girder horizontal bending moment $M_{h\text{-}targ}$, in kN·m, for a given FE load combination is taken as:

$$M_{h\text{-}targ} = M_{wh\text{-}LC}$$

where:

$M_{wh\text{-}LC}$: Horizontal wave bending moment, in kN·m, for the dynamic load case under consideration, calculated in accordance with Ch 5, Sec 4, [3.6.3].

Within the midship cargo hold region, the value of $M_{wh\text{-}LC}$ is taken as the maximum hull girder bending moment within the mid-hold(s) for each individual cargo hold for each given FE load combination.

Outside the midship cargo hold region, the values of $M_{wh\text{-}LC}$ are taken at all web frames and transverse bulkhead positions of the FE model under consideration.

4.3.6 Target hull girder torsional moment

For ships with large deck openings only, the target hull girder torsional moment, $M_{wt\text{-}targ}$, in kNm, for the dynamic load cases OHM, OHS and OVA is the value at the target location taken as:

$$M_{wt-targ} = M_{wt-LC}\ (x_{targ})$$

where:

$M_{wt\text{-}LC}$ (x): Wave torsional moment, in kNm, for the dynamic load cases OHM, OHS and OVA, defined in Ch 5, Sec 4, [3.6.5], calculated at x position

x_{targ} : Target location for hull girder torsional moment taken as:

- For midship cargo hold region:
  - If $x_{mid} \leq 0{,}5$ L: after bulkhead of the mid-hold
  - If $x_{mid} > 0{,}5$ L: forward bulkhead of the mid-hold
- Outside midship cargo hold region:

  The transverse bulkhead of mid-hold where the following formula is minimum:

$$\frac{M_{wt-LC}(x_{bhd})}{|M_{wt-LC}(x_{bhd})|} \cdot [M_{wt-LC}(x_{bhd}) - M_{T-FEM}(x_{bhd})]$$

x_{mid} : X-coordinate, in m, of the mid-hold centre

x_{bhd} : X-coordinate, in m, of the after or forward transverse bulkhead of mid-hold.

For dynamic load cases of ships with large deck openings other than OHM, OHS and OVA and for all dynamic load cases of other types of ships, the hull girder torsional moment $M_{wt\text{-}targ}$ at middle of mid-hold is to be adjusted to zero.

4.4 Procedure to adjust hull girder shear forces and bending moments

4.4.1 General

The procedure given in this sub-article describes how to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distribution on the three cargo hold FE model, in order to achieve the required target values defined in [4.3] at the following target locations:

- at the transverse bulkheads of the mid-hold for vertical shear force
- at the centre of the mid-hold, in general, for hull girder bending moments.

The final adjusted loads at the target location should not exceed the target loads.

4.4.2 Local load distribution

The following local loads are to be applied:

a) ship structural steel weight distribution over the length of the cargo hold model (static loads)

b) static sea pressure, dynamic wave pressure and, where applicable, green sea load

c) weight of cargo/containers, ballast and fuel oil (static loads)

d) dynamic loads for cargo/containers, ballast and fuel oil in seagoing operation.

The 3D nodal forces obtained by applying the above local loads to the FE model are lumped to each longitudinal station, in order to generate the one dimension local load distribution.

The longitudinal stations are located at transverse bulkheads/frames and typical nodal locations in between the frames according to the cargo hold model mesh size requirement.

Any intermediate nodes created for modeling structural details are not treated as longitudinal stations for the purpose of local load distribution.

The nodal forces are to be lumped to the nearest longitudinal station, the lumping process being done separately for vertical and horizontal nodal forces in order to obtain both vertical and horizontal local loads f_{vi} and f_{hi} at each longitudinal station i.

4.4.3 Hull girder forces and bending moments due to local loads

The model is considered simply supported at both ends. The reaction forces at model ends and the hull girder shear forces and bending moments induced by local loads at any longitudinal station are determined by the following formulae:

$$R_{V_fore} = -\frac{\sum_i (x_i - x_{aft})\ f_{vi}}{x_{fore} - x_{aft}}$$

$$R_{V_aft} = \sum_i f_{vi} + R_{V_fore}$$

$$R_{H_fore} = \frac{\sum_i (x_i - x_{aft})\ f_{hi}}{x_{fore} - x_{aft}}$$

$$R_{H_aft} = -\sum_i f_{hi} + R_{H_fore}$$

$$F_l = \sum_i f_{li}$$

and, when $x_i < x_j$:

$$Q_{V_FEM}\ (x_j) = R_{V_aft} - \sum_i f_{vi}$$

$$Q_{H_FEM}\ (x_j) = R_{H_aft} + \sum_i f_{hi}$$

$$M_{V_FEM}\ (x_j) = (x_j - x_{aft})\ R_{V_aft} - \sum_i (x_j - x_i)\ f_{vi}$$

$$M_{H_FEM}\ (x_j) = (x_j - x_{aft})\ R_{H_aft} + \sum_i (x_j - x_i)\ f_{hi}$$

where:

R_{V_aft}, R_{V_fore}, R_{H_aft}, R_{H_fore}: Vertical and horizontal reaction forces at the aft and fore ends, in kN

x_{aft} : X-coordinate of the aft end support, in m

x_{fore} : X-coordinate of the fore end support, in m

f_{vi} : Lumped vertical local load at longitudinal station i, in kN, as defined in [4.4.2]

f_{hi} : Lumped horizontal local load at longitudinal station i, in kN, as defined in [4.4.2]

F_l : Total longitudinal force of the model, in kN

f_{li} : Lumped longitudinal local load at longitudinal station i, in kN, as defined in [4.4.2]

x_j : X-coordinate, in m, of the considered longitudinal station j

x_i : X-coordinate, in m, of longitudinal station i

$Q_{V_FEM}\ (x_j)$, $Q_{H_FEM}\ (x_j)$, $M_{V_FEM}\ (x_j)$, $M_{H_FEM}\ (x_j)$: Vertical and horizontal shear forces, in kN, and bending moments, in kN·m, at longitudinal station x_j created by the local loads applied on the FE model. According to the sign convention, positive reaction forces create a positive shear force.

4.4.4 Longitudinal unbalanced force

In case the total longitudinal force of the model F_l is not equal to zero, the counter longitudinal force $(F_x)_j$ is to be applied at the model end where the translation in X-direction δ_x is fixed. $(F_x)_j$ is to be distributed among all the bending effective hull girder longitudinal elements, as follows:

$$(F_x)_j = \frac{F_l}{A_{x\text{-}n50}} \frac{A_{j\text{-}n50}}{n_j}$$

where:

$(F_x)_j$: Axial force, in kN, applied to a node of the j-th element

F_l : Total longitudinal force of the model, in kN, as defined in [4.4.3]

$A_{j\text{-}n50}$: Net cross-sectional area of the j-th element, in m^2

$A_{x\text{-}n50}$: Net cross-sectional area of the fore end section, in m^2:

$$A_{x\text{-}n50} = \sum_j A_{j\text{-}n50}$$

n_j : Number of nodal points of the j-th element on the cross-section:

$n_j = 1$ for beam element

$n_j = 2$ for 4-node shell element.

4.4.5 Hull girder shear force adjustment procedure

The hull girder shear force adjustment procedure defined in this requirement applies to all the FE load combinations. The FE load combinations not directly covered by the applicable Part D or Part E chapter are to be considered on a case-by-case basis.

The two following methods are used for shear force adjustment:

- method 1 (M1): shear force adjustment at one of the mid-hold bulkheads, as given in [4.4.6]
- method 2 (M2): shear force adjustment at both mid-hold bulkheads, as given in [4.4.7]

The method to be applied for one given FE load combination is to be selected as follows:

- no shear force adjustment is requested when the shear forces at both bulkheads are lower than, or equal to, the target values. This applies to cargo hold analysis in whole cargo area except for aft most and foremost cargo hold.

  For aft most and foremost cargo hold analyses, the shear force adjustment is to be applied with method 1. The target hull girder vertical shear force at the aft and forward transverse bulkheads, $Q_{targ\text{-}aft}$ and $Q_{targ\text{-}fwd}$, are to be set to values of vertical shear force due to local loads Q_{aft} and Q_{fwd} accordingly:

  $Q_{targ\text{-}fwd} = Q_{fwd}$

  $Q_{targ\text{-}aft} = Q_{aft}$
- method 1 applies when the shear force exceeds the target value at one bulkhead. At the other bulkhead, the shear force adjusted according to method 1 is not to exceed the target value, otherwise method 2 is to be applied
- method 2 applies when the shear forces exceed the target values at both bulkheads.

4.4.6 Method 1 for vertical shear force adjustment at one bulkhead

The required adjustments in shear force at aft or forward transverse bulkhead of the mid-hold are to be made by applying vertical bending moments, M_{Y_aft}, M_{Y_fore} at model ends. For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Tab 7:

- for aft most cargo hold model: $\delta w'_1$
- for foremost cargo hold model: $\delta w'_3$

The required adjustments in shear force at mid-hold aft and forward bulkheads are given by:

- aft bulkhead:

  $$M_{Y_aft} = M_{Y_fore} = \frac{(x_{fore} - x_{aft})}{2}(Q_{targ\text{-}aft} - Q_{aft}) - M'_{1\text{-}aft}$$

  $$\Delta Q_{aft} = \Delta Q_{fwd} = 0$$

  - for aftmost cargo hold model only:

    $$\delta w'_1 = \frac{Q_{targ\text{-}aft} - Q_{aft} + R_{v_aft}}{(n_1 - 1)}$$

  - for foremost cargo hold model only:

    $$\delta w'_3 = \frac{Q_{targ\text{-}aft} - Q_{aft} + R_{v_fore}}{(n_3 - 1)}$$
- forward bulkhead:

  $$M_{Y_aft} = M_{Y_fore} = \frac{(x_{fore} - x_{aft})}{2}(Q_{targ\text{-}fwd} - Q_{fwd}) - M'_{1\text{-}fwd}$$

$\Delta Q_{aft} = \Delta Q_{fwd} = 0$

- for aftmost cargo hold model only:

$$\delta w'_1 = \frac{Q_{targ_fwd} - Q_{fwd} + R_{v_aft}}{(n_1 - 1)}$$

- for foremost cargo hold model only:

$$\delta w'_3 = \frac{Q_{targ_fwd} - Q_{fwd} + R_{v_fore}}{(n_3 - 1)}$$

where:

M_{Y_aft} , M_{Y_fore} : Vertical bending moments, in kN·m, to be applied at the aft and fore ends in accordance with [4.4.10], in order to enforce the hull girder vertical shear force adjustment as shown in Tab 4. The sign convention is that of the FE model.

Q_{aft} : Vertical shear force, in kN, due to the local loads at mid-hold aft bulkhead location x_{b_aft} resulting from the local loads calculated according to [4.4.3]

Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{aft} is the maximum absolute shear force between the stations located right after and right forward the mid-hold aft bulkhead

Q_{fwd} : Vertical shear force, in kN, due to the local loads at mid-hold forward bulkhead location x_{b_fwd} resulting from the local loads calculated according to [4.4.3]

Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{fwd} is the maximum absolute shear force between the stations located right after and right forward the mid-hold forward bulkhead.

$M'_{1\text{-}aft}$, $M'_{1\text{-}fwd}$: Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- aft most cargo hold model:

$$M'_{1-aft} = \frac{\ell_1}{4}(Q_{targ-aft} - Q_{aft} + R_{v_aft})$$

$$M'_{1-fwd} = \frac{\ell_1}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v_aft})$$

- foremost cargo hold model:

$$M'_{1-aft} = \frac{\ell_3}{4}(Q_{targ-aft} - Q_{aft} + R_{v_fore})$$

$$M'_{1-fwd} = \frac{\ell_3}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v_fore})$$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Tab 7

$\delta w'_3$: Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Tab 7

ΔQ_{aft} , ΔQ_{fwd}: Shear force adjustments, as given in Tab 7

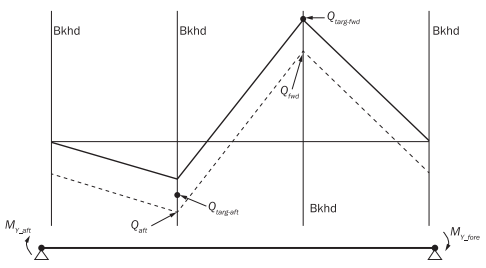
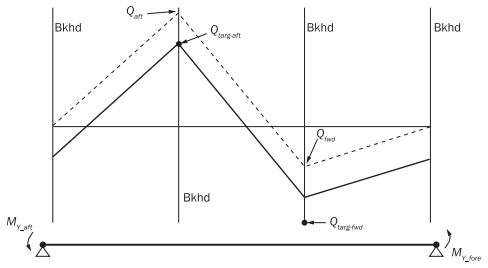
R_{v_aft} , R_{v_fore} : Reaction forces at the aft and fore end, in kN, as defined in [4.4.3]

ℓ_1 : Length of the modelled engine room in aftmost cargo hold model, in m. (see also Tab 7)

ℓ_3 : Length of the modelled forepeak in foremost cargo hold model, in m. (see also Tab 7)

n_1, n_3 : Number of frame spaces (see also Tab 7)

Table 4 : Vertical shear force adjustment by application of vertical bending moments M_{Y_aft} and M_{Y_fore} for method

Vertical shear force diagram	
	
Target position at mid-hold	
Forward bulkhead	Aft bulkhead

Note 1:

———— Vertical shear force after adjustment

- - - - - - - - Vertical shear force due to local loads

4.4.7 Method 2 for vertical shear force adjustment at both bulkheads

The required adjustments in shear force at both mid-hold transverse bulkheads are to be made by applying:

- vertical bending moments M_{Y_aft} and M_{Y_fore} at model ends, and
- vertical loads at the transverse frame positions as shown in Tab 6, in order to generate vertical shear forces ΔQ_{aft} and ΔQ_{fwd} at the transverse bulkhead positions.
- for aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Tab 6:
  - for aft most cargo hold model: $\delta w'_1$
  - for foremost cargo hold model: $\delta w'_3$

Tab 5 shows application examples of the shear force adjustment by means of vertical bending moments and vertical loads.

$$M_{Y_aft} = M_{Y_fore} = \frac{(x_{fore} - x_{aft})}{2}\frac{(Q_{targ\text{-}fwd} - Q_{fwd} + Q_{targ\text{-}aft} - Q_{aft})}{2} - M'_2$$

$$M_{Y_fore} = M_{Y_aft}$$

$$\Delta Q_{fwd} = \frac{Q_{targ\text{-}fwd} - Q_{fwd} - (Q_{targ\text{-}aft} - Q_{aft})}{2}$$

$$\Delta Q_{aft} = -\Delta Q_{fwd}$$

For aft most cargo hold model:

$$\delta w'_1 = \frac{\left[\frac{(Q_{targ-aft} - Q_{aft})(\ell - \ell_2 - \ell_1) + (Q_{targ-fwd} - Q_{fwd})(\ell - \ell_2 - \ell_3)}{2\ell - \ell_1 - 2\ell_2 - \ell_3} + R_{Vaft}\right]}{n_1 - 1}$$

For foremost cargo hold model:

$$\delta w'_3 = \frac{\left[\frac{(Q_{targ-fwd} - Q_{fwd})(\ell - \ell_2 - \ell_3) + (Q_{targ-aft} - Q_{aft})(\ell - \ell_2 - \ell_1)}{2\ell - \ell_1 - 2\ell_2 - \ell_3} + R_{Vfore}\right]}{n_3 - 1}$$

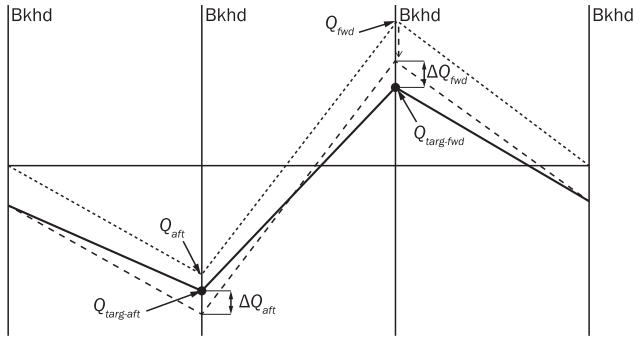
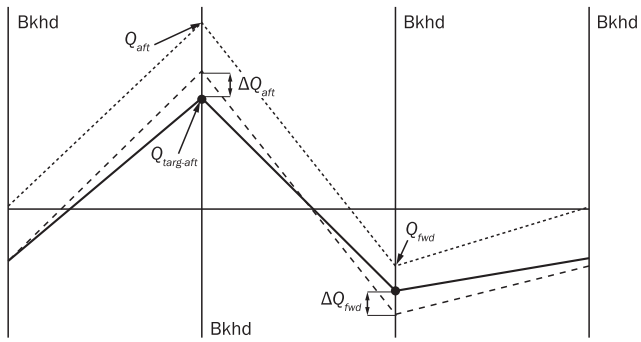
where:

M_{Y_aft}, M_{Y_fore} : Vertical bending moments, in kN·m, to be applied at the aft and fore ends in accordance with [4.4.10], in order to enforce the hull girder vertical shear force adjustment. The sign convention is that of the FE model

ΔQ_{aft} : Shear force adjustment, in kN, at mid-hold aft bulkhead

ΔQ_{fwd} : Shear force adjustment, in kN, at mid-hold forward bulkhead.

Table 5 : Target and required shear force adjustment by applying vertical forces

Vertical shear force diagram	Aft bulkhead	Forward bulkhead
	Target shear force	Target shear force
	$Q_{targ\text{-}aft}$ (–ve)	$Q_{targ\text{-}fwd}$ (+ve)
	$Q_{targ\text{-}aft}$ (+ve)	$Q_{targ\text{-}fwd}$ (–ve)
	Note 1: –ve means negative, +ve means positive. Vertical shear force after both adjustments Vertical shear force after adjustment by use of M_{Y_aft} and M_{Y_fore} Vertical shear force due to local loads	

M'_2 : Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- aftmost cargo hold model

$$M'_2 = \frac{\ell_1(n_1-1)\delta w'_1}{4}$$

- foremost cargo hold model

$$M'_2 = \frac{\ell_3(n_3-1)\delta w'_3}{4}$$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Tab 7

$\delta w'_3$: Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Tab 7

R_{v_aft}, R_{v_fore} : Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3]

ℓ_1 : Length of the modelled engine room in aftmost cargo hold model, in m. (see also Tab 7)

ℓ_3 : Length of the modelled forepeak in foremost cargo hold model, in m. (see also Tab 7)

n_1, n_3 : Number of frame spaces (see also Tab 7)

The shear force adjustments ΔQ_{aft} and ΔQ_{fwd} are to be generated at transverse bulkhead positions by applying vertical loads at the transverse frame positions, as shown in Tab 6.

Vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward cargo hold nor any frames aft of the aft cargo hold of the FE model.

The vertical loads applied to each transverse frame in order to generate the increase/decrease in shear force at bulkheads may be calculated as shown in Tab 6.

In case of uniform frame spacing, the amount of vertical force to be distributed at each transverse frame may be calculated in accordance with Tab 7.

Where non-uniform frame spacing is used within a hold i, the average frame spacing $\ell_{av\text{-}i}$ is used to calculate the average frame load $\delta w_{av\text{-}i}$ according to Tab 7. $\delta w_{av\text{-}i}$ is then redistributed among the non-uniform frames, as follows:

$$\delta w_i^k = \delta w_{av\text{-}i} \frac{\ell^k_{av\text{-}i}}{\ell_{av\text{-}i}}$$

where:

k = 1, 2, ..., n_i –1, for each frame in cargo hold i, with i = 1, 2, 3

$\ell_{av\text{-}i}$: Average frame spacing, in m, equal to: $\ell_{av\text{-}i} = \ell_i / n_i$, in cargo hold i, with i = 1, 2, 3

ℓ_i : Length, in m, of the cargo hold i, with i = 1, 2, 3, as defined in Tab 7

n_i : Number of frame spacings in cargo hold i, with i = 1, 2, 3, as defined in Tab 7

$\delta w_{av\text{-}i}$: Average frame load calculated, according to Tab 7, with the average frame spacing $\ell_{av\text{-}i}$ in cargo hold i, with i = 1, 2, 3

δw_i^k : Distributed load, in kN, for non-uniform frame k in cargo hold i

$\ell^k_{av\text{-}i}$: Equivalent frame spacing, in m, for each frame k, with k = 1, 2,..., n_i –1, in cargo hold i, taken equal to:

- for k = 1 (first frame), in cargo hold i:

$$\ell^k_{av\text{-}i} = \ell_i^1 - \frac{\ell_{av\text{-}i}\,\ell_i^1}{\ell_i^1 + \ell_i^{n_i}} + \frac{\ell_i^2}{2}$$

- for k = 2, 3, …, n_1 –2, in cargo hold i:

$$\ell^k_{av\text{-}i} = \frac{\ell_i^k}{2} + \frac{\ell_i^{k+1}}{2}$$

- for k = n_i –1 (last frame), in cargo hold i:

$$\ell^k_{av\text{-}i} = \ell_i^{n_i} - \frac{\ell_{av\text{-}i}\,\ell_i^{n_i}}{\ell_i^1 + \ell_i^{n_i}} + \frac{\ell_i^{n_i-1}}{2}$$

ℓ_i^k : Frame spacing, in m, between the frames k–1 and k, in the cargo hold i.

The vertical correction loads, δw_i for a uniform frame spacing or δw_i^k for a non-uniform frame spacing, are to be applied, following the shear flow distribution at the considered cross-section, as described in Ch 6, App 1. For a frame section under the vertical load δw_i, the shear flow q_f, at the middle point of the element, is calculated as follows:

$$q_{f\text{-}k} = \frac{\delta w_i}{I_{y\text{-}n50} \cdot 10^{12}} Q_{k\text{-}n50}$$

where:

$q_{f\text{-}k}$: Shear flow calculated at the middle of the k-th element of the transverse frame, in N/mm

δw_i : Distributed load at each transverse frame location, in N, for the i-th cargo hold (i = 1, 2, 3), as defined in Tab 7

$Q_{k\text{-}n50}$: First moment, about the neutral axis, of the accumulative section area starting from the open end (shear stress free end) of the cross-section to the point s_k for shear flow $q_{f\text{-}k}$, in mm^3, taken as:

$$Q_{k\text{-}n50} = \int_0^{S_k} z_{neu}\ t_{n50}\ ds$$

z_{neu} : Vertical distance, in mm, from the integral point s to the vertical neutral axis

t_{n50} : Net thickness, in mm, of the plate at the integral point of the cross-section

The distributed shear force $F_{j\text{-}grid}$ at the j-th FE grid of the transverse frame, in N, is obtained from the shear flow of the connected elements, as follows:

$$F_{j\text{-}grid} = \sum_{k=1}^{n} q_{f\text{-}k}\ \frac{\ell_k}{2}$$

where:

ℓ_k : Length, in mm, of the k-th element of the transverse frame connected to grid j

n : Total number of elements connected to grid j.

The shear flow has direction along the cross-section and therefore the distributed force $F_{j\text{-}grid}$ is a vector force. For vertical hull girder shear correction, the vertical and horizontal force components calculated with the above mentioned shear flow method need to be applied to the cross-section.

4.4.8 Procedure to adjust vertical and horizontal bending moments for midship cargo hold region

In case the target vertical bending moment needs to be reached, an additional vertical bending moment $M_{v\text{-}end}$ is to be applied at both FE model ends, according to [4.4.10], in order to generate this target value within the mid-hold. This additional vertical bending moment is to be taken, in kN·m, equal to:

$$M_{v\text{-}end} = M_{v\text{-}targ} - M_{v\text{-}peak}$$

where:

$M_{v\text{-}targ}$: Hogging (positive) or sagging (negative) vertical bending moment, in kN·m, as specified in [4.3.2]

$M_{v\text{-}peak}$: Maximum or minimum bending moment, in kN·m, within the mid-hold length induced by the local loads as described in [4.4.3] and the shear force adjustment as defined in [4.4.5].

$M_{v\text{-}peak}$ is to be taken as the maximum bending moment if $M_{v\text{-}targ}$ is hogging (positive) and as the minimum bending moment if $M_{v\text{-}targ}$ is sagging (negative).

$M_{v\text{-}peak}$ is to be calculated as follows, based on a simply supported beam model:

$$M_{v\text{-}peak} = \text{Extremum}\left\{M_{V_FEM}(x) + M_{lineload} + M_{Y_aft}\left(2\frac{x - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right\}$$

$M_{V_FEM}(x)$: Vertical bending moment, in kN·m, at position x, induced by the local loads as described in [4.4.3]

M_{Y_aft} : Aft bending moment, in kN·m, to be taken equal to:

- when method 1 is applied: the value defined in [4.4.6]
- when method 2 is applied: the value defined in [4.4.7]
- otherwise: $M_{Y_aft} = 0$

$M_{lineload}$: Vertical bending moment, in kN·m, at position x, induced by the application of vertical loads at frames according to method 2, to be taken equal to:

$$M_{lineload} = -(x - x_{aft})F - \sum_i (x - x_i)\delta w_i \text{ when } x_i < x$$

F : Reaction force, in kN, at model ends induced by the application of vertical loads to frames as defined in Tab 6

x : X-coordinate, in m, of frame in way of the mid-hold

δw_i : Vertical load, in kN, at web frame station i applied to generate required shear force.

In case the target horizontal bending moment needs to be reached, an additional horizontal bending moment $M_{h\text{-}end}$ is to be applied at both FE model ends, according to [4.4.10], in order to generate this target value within the mid-hold. The additional horizontal bending moment, in kN·m, is to be taken equal to: $M_{h\text{-}end} = M_{h\text{-}targ} - M_{h\text{-}peak}$

where:

$M_{h\text{-}targ}$: Horizontal bending moment, as defined in [4.3.5]

$M_{h\text{-}peak}$: Maximum or minimum horizontal bending moment, in kN·m, within the mid-hold length induced by the local loads described in [4.4.3].

$M_{h\text{-}peak}$ is to be taken as the maximum horizontal bending moment if $M_{h\text{-}targ}$ is positive (starboard side in tension) and as the minimum horizontal bending moment if $M_{h\text{-}targ}$ is negative (port side in tension).

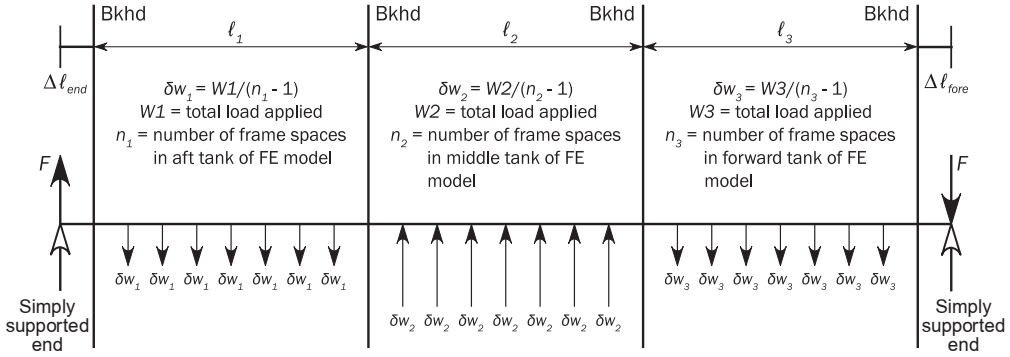
$M_{h\text{-}peak}$ is to be calculated as follows, based on a simply supported beam model:

$M_{h\text{-}peak} = \text{Extremum}\ \{M_{H_FEM}(x)\}$

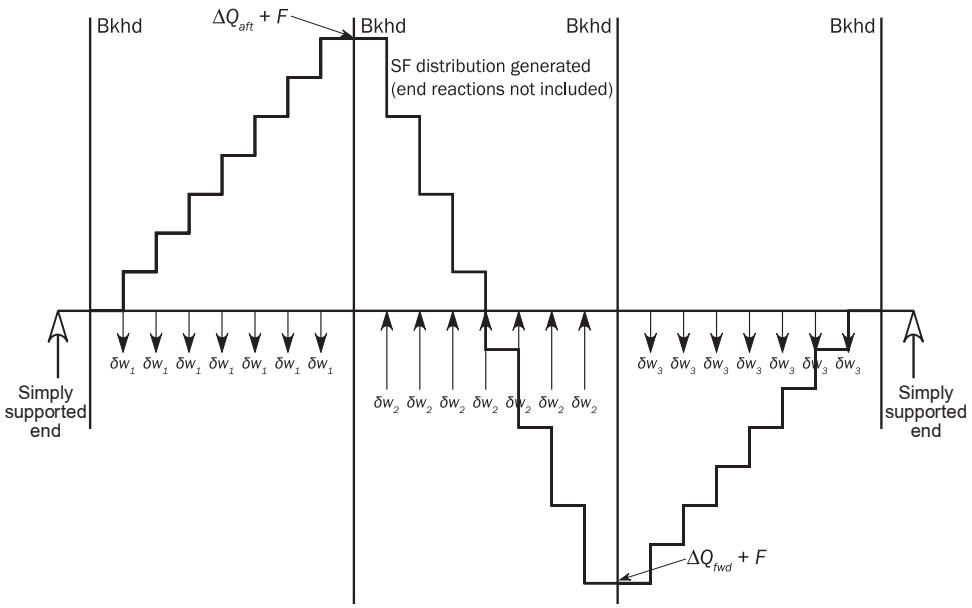
$M_{H_FEM}(x)$: Horizontal bending moment, in kN·m, at position x, induced by the local loads as described in [4.4.3].

The vertical and horizontal bending moments are to be calculated over the mid-hold length in order to identify the position and value of each maximum/minimum bending moment.

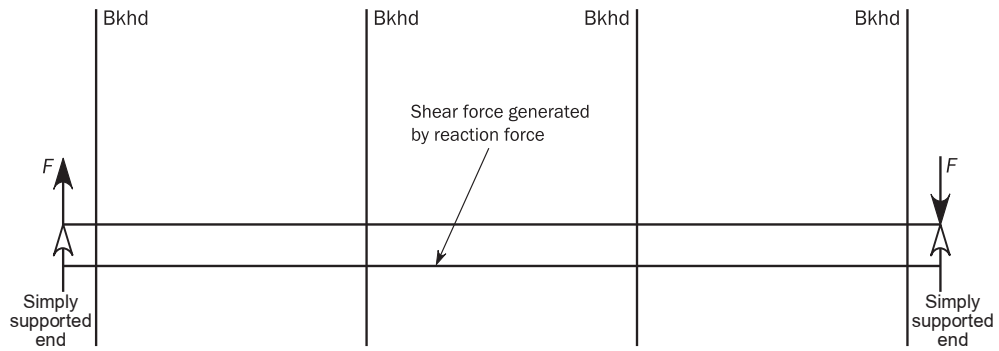
Table 6 : Distribution of adjusting vertical force at frames and resulting shear force distributions



Note: Transverse bulkhead frames not loaded
Frames beyond aft transverse bulkhead of aft most tank and forward bulkhead of forward most tank not loaded
F = Reaction load generated by supported ends



Shear force distribution due to adjusting vertical force at frames



Note: $F = 0$ if $\ell_1 = \ell_3$ and $\Delta\ell_{fore} = \Delta\ell_{end}$, and loads are symmetrical about mid-length of model

Note 1: For definition of the symbols, see Tab 7.

Table 7 : Formulae for calculation of vertical loads for adjusting vertical shear forces

δw_1 : Distributed load, in kN, at frame in the aft cargo hold of the FE model

$$\delta w_1 = \frac{\Delta Q_{aft}\ (2\ell - \ell_2 - \ell_3) + \Delta Q_{fwd}\ (\ell_2 + \ell_3)}{(n_1 - 1)\ (2\ell - \ell_1 - 2\ell_2 - \ell_3)} + \delta w'_1$$

δw_2 : Distributed load, in kN, at frame in the mid-hold of the FE model

$$\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$$

δw_3 : Distributed load, in kN, at frame in the forward cargo hold of the FE model

$$\delta w_3 = \frac{-\Delta Q_{fwd}\ (2\ell - \ell_1 - \ell_2) - \Delta Q_{aft}\ (\ell_1 + \ell_2)}{(n_3 - 1)\ (2\ell - \ell_1 - 2\ell_2 - \ell_3)} = \delta w'_3$$

F : End reactions, in kN, due to application of vertical loads to frames:

- In general

$$F = F_{aft} = F_{fwd} = 0,5\left(\frac{W1\ \ell_2 + \ell_1 - W3\ \ell_2 + \ell_3}{\ell}\right)$$

- For aftmost and foremost cargo hold FE model

$$F = F_{aft} = \frac{W1(\Delta\ell_{fore} + \ell_3 + \ell_2 + 0,5\ell_1) + W2(\Delta\ell_{fore} + \ell_3 + 0,5\ell_2) + W3(\Delta\ell_{fore} + 0,5\ell_3)}{\ell}$$

where:

ΔQ_{aft} : Required adjustment in shear force, in kN, at the aft bulkhead of the mid-hold, see [4.4.7]

ΔQ_{fwd} : Required adjustment in shear force, in kN, at fore bulkhead of the mid-hold, see [4.4.7]

ℓ : Total length, in m, of FE model including portions beyond end bulkheads:
$\ell = \ell_1 + \ell_2 + \ell_3 + \Delta\ell_{end} + \Delta\ell_{fore}$

ℓ_1 : Length of the aft cargo hold of the model, in m

ℓ_2 : Length of the mid-hold of the model, in m

ℓ_3 : Length of the forward cargo hold of the model, in m

n_1 : Number of frame spaces in the aft cargo hold of the FE model

n_2 : Number of frame spaces in the mid-hold of the FE model

n_3 : Number of frame spaces in the forward cargo hold of the FE model

$\delta w'_1$: Additional distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model. Formulae of $\delta w'_1$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly

$\delta w'_3$: Additional distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model. Formulae of $\delta w'_3$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly

W1 : Total evenly distributed vertical load, in kN, applied to the aft hold of the FE model: $W1 = (n_1 - 1)\ \delta w_1$

W2 : Total evenly distributed vertical load, in kN, applied to the mid-hold of the FE model: $W2 = (n_2 - 1)\ \delta w_2$

W3 : Total evenly distributed vertical load, in kN, applied to the forward hold of the FE model: $W3 = (n_3 - 1)\ \delta w_3$

$\Delta\ell_{end}$: Distance, in m, between the aft bulkhead of the aft cargo hold to the aft end of the FE model
$\Delta\ell_{end} = 0$ in the aftmost cargo hold model

$\Delta\ell_{fore}$: Distance, in m, between the forward bulkhead of the forward cargo hold to the forward end of the FE model
$\Delta\ell_{fore} = 0$ in the foremost cargo hold model

Note 1: In the above formulae, positive direction of loads, shear forces and adjusting vertical forces is in accordance with Tab 5 and Tab 6.

Note 2: W1 + W3 = W2 (not applicable for aftmost and foremost cargo FE model)

Note 3: The above formulae are applicable only if a uniform frame spacing is used within each hold. The length and frame spacing of individual cargo holds may be different.

4.4.9 Procedure to adjust vertical and horizontal bending moments outside midship cargo hold region

To reach the vertical hull girder target values at each frame and transverse bulkhead position, as defined in [4.3.2], the vertical bending moment adjustments, m_{vi}, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Fig 19. The vertical bending moment adjustment at each longitudinal location, i, is to be calculated as follows:

$$f(i) = M_{v-targ}(i) - M_{V-FEM}(i) - M_{lineload}(i) - M_{Y-aft} \cdot \left(\frac{2(x_i - x_{aft})}{x_{fore} - x_{aft}} - 1\right)$$

$$m_{vi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{vj}$$

$$m_{v_end} = -\sum_{j=0}^{n_t} m_{vj}$$

where:

i : Index corresponding to the i-th station, starting from i=1 at the aft end section up to n_t

n_t : Total number of longitudinal stations where the vertical bending moment adjustment, m_{vi}, is applied

m_{vi} : Vertical bending moment adjustment, in kN.m, to be applied at transverse frame or bulkhead at station i

m_{v_end} : Vertical bending moment adjustment, in kN.m, to be applied, at the fore end section (n_t+1 station)

m_{vj} : Argument of summation to be taken as:

- $m_{v0} = 0$ when j = 0
- $m_{vj} = m_{vi}$ when j = i

$M_{v\text{-}targ}(i)$: Required target vertical bending moment, in kN.m, at station i, calculated in accordance with [4.3.2]

$M_{V\text{-}FEM}(i)$: Vertical bending moment distribution, in kN.m, at station i due to local loads as given in [4.4.3]

$M_{lineload}(i)$: Vertical bending moment, in kN.m, at station i, due to the line load for the vertical shear force correction as required in [4.4.8].

To reach the horizontal hull girder target values at each frame and transverse bulkhead position as defined in [4.3.4], the horizontal bending moment adjustments, m_{hi}, are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Fig 19. The horizontal bending moment adjustment at each longitudinal location, i, is to be calculated as follows:

$$f(i) = M_{h-targ}(i) - M_{H-FEM}(i)$$

$$m_{hi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{hj}$$

$$m_{h_end} = -\sum_{j=0}^{n_t} m_{hj}$$

where:

i : Longitudinal location for bending moment adjustments, m_{hi}.

n_t : Total number of longitudinal stations where the horizontal bending moment adjustment, m_{hi}, is applied.

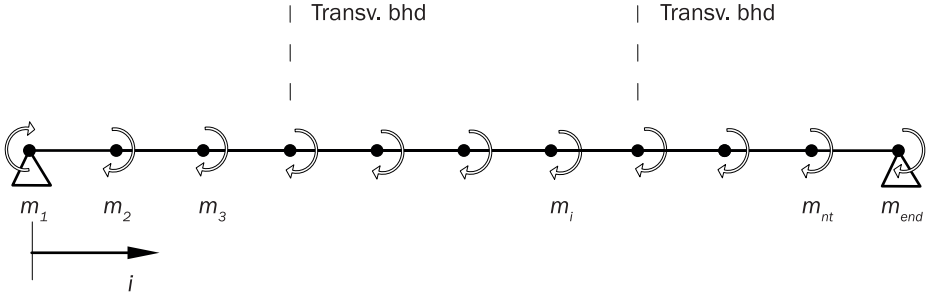
m_{hi} : Horizontal bending moment adjustment, in kN.m, to be applied at transverse frame or bulkhead at station i.

m_{h_end} : Horizontal bending moment adjustment, in kN.m, to be applied at the fore end section (n_t+1 station).

m_{hj} : Argument of summation to be taken as:

- $m_{h0} = 0$ when j = 0
- $m_{hj} = m_{hi}$ when j = i

Figure 19 : Adjustments of bending moments outside midship cargo hold region.



m_{hi} can be substituted to m_{vi} in this figure and m_i is the positive bending moment in FE coordinate system.

$M_{h\text{-}targ}(i)$: Required target horizontal bending moment, in kN.m, at station i, calculated in accordance with [4.3.5].

$M_{H\text{-}FEM}(i)$: Horizontal bending moment distribution, in kN.m, at station i due to local loads as given in [4.4.3].

The vertical and horizontal bending moment adjustments, m_{vi} and m_{hi}, are to be applied at all web frames and bulkhead positions of the FE model. The adjustments are to be applied in FE model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements in accordance with [4.4.10].

4.4.10 Application of bending moment adjustments on the FE model

The required vertical and horizontal bending moment adjustments are to be applied by distributing the longitudinal axial nodal forces among all the bending effective hull girder longitudinal elements of the considered FE model cross-section according to Ch 6, Sec 1, [1.2], as follows:

- for vertical bending moment:

$$(F_x)_i = \frac{M_v}{I_{y\text{-}n50}} \frac{A_{i\text{-}n50}}{n_i} z_i$$

- for horizontal bending moment:

$$(F_x)_i = \frac{M_h}{I_{z\text{-}n50}} \frac{A_{i\text{-}n50}}{n_i} y_i$$

where:

M_v : Vertical bending moment adjustment, in kN·m, to be applied to the considered cross-section of the model

M_h : Horizontal bending moment adjustment, in kN·m, to be applied to the considered cross-section of the model

$(F_x)_i$: Axial force, in kN, applied to a node of the i-th element

Z_i : Vertical distance, in m, from the neutral axis to the centre of the cross-sectional area of the i-th element

Y_i : Horizontal distance, in m, from the neutral axis to the centre of the cross-sectional area of the i-th element

$A_{i\text{-}n50}$: Cross-sectional area, in m^2, of the i-th element

n_i : Number of nodal points of the i-th element on the cross-section:

- $n_i = 1$ for a beam element
- $n_i = 2$ for a 4-node shell element.

For cross-sections not located at the model ends, the average area of the corresponding i-th elements forward and aft of the considered cross-section is to be used.

4.5 Procedure to adjust hull girder torsional moments

4.5.1 General

The procedure in this sub-article describes how to adjust the hull girder torsional moment distribution on the cargo hold FE model to achieve the target torsional moment at the target location. The hull girder torsional moment target values are given in [4.3.6].

4.5.2 Torsional moment due to local loads

Torsional moment, in kN.m, at longitudinal station i due to local loads, $M_{T\text{-}FEMi}$ in kN.m, is determined by the following formula (see Fig 20):

$$M_{T-FEMi} = \sum_k [f_{hik}(z_{ik} - z_T)] - \sum_k (f_{vik} y_{ik})$$

where:

$M_{T\text{-}FEMi}$: Lumped torsional moment, in kN.m, due to local load at longitudinal station i

z_T : Vertical coordinate from baseline, in m, of the horizontal shear centre at the transverse section under consideration , as defined in Ch 5, Sec 4, [3.5.1]

f_{hik} : Horizontal nodal force, in kN, of node k at longitudinal station i

f_{vik} : Vertical nodal force, in kN, of node k at longitudinal station i

y_{ik} : Y--coordinate, in m, of node k at longitudinal station i

z_{ik} : Z-coordinate, in m, of node k at longitudinal station i

$M_{T\text{-}FEM0}$: Lumped torsional moment, in kN.m, due to local load at aft end of the FE model (forward end for foremost cargo hold model), taken as:

- For the foremost cargo hold model:

$$M_{T-FEM0} = \sum_k [f_{h0k}(z_{0k} - z_T)] - \sum_k (f_{v0k} y_{0k}) + R_{H_fore}(z_{ind} - z_T)$$

- For the other cargo hold models:

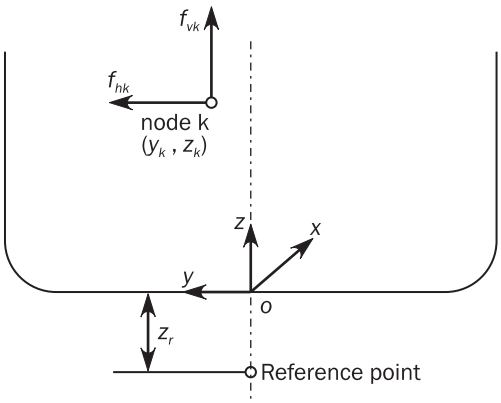
$$M_{T-FEM0} = \sum_k [f_{h0k}(z_{0k} - z_T)] - \sum_k (f_{v0k} y_{0k}) + R_{H_aft}(z_{ind} - z_T)$$

R_{H_fore} : Horizontal reaction forces, in kN, at the forward end, as defined in [4.4.3]

R_{H_aft} : Horizontal reaction forces, in kN, at the aft end, as defined in [4.4.3]

z_{ind} : Vertical coordinate, in m, of independent point as defined in [2.5.3].

Figure 20 : Station forces and acting location of torsional moment at section



4.5.3 Hull girder torsional moment

The hull girder torsional moment, $M_{T\text{-}FEM}(x_j)$, in kN.m, is obtained by accumulating the station torsional moment from the aft end section (forward end for foremost cargo hold model) as follows:

$$M_{T-FEM}(x_j) = \sum_i M_{T-FEMi}$$

- when $x_i \geq x_j$ for foremost cargo hold model,
- when $x_i < x_j$ otherwise.

where:

$M_{T\text{-}FEM}(x_j)$: Hull girder torsional moment, in kN.m, at longitudinal station x_j

x_j : X-coordinate, in m, of considered longitudinal station j.

The torsional moment distribution given in [4.5.2], has a step at each longitudinal station.

4.5.4 Procedure to adjust hull girder torsional moment to target value

The torsional moment is to be adjusted by applying a hull girder torsional moment $M_{T\text{-}end}$, in kN.m, at the independent point of the aft end section of the model (forward end for foremost cargo hold model), given as follows:

$$M_{T-end} = M_{wt-targ} - M_{T-FEM}(x_{targ})$$

where:

x_{targ} : X-coordinate, in m, of the target location for hull girder torsional moment, as defined in [4.3.6]

$M_{wt\text{-}targ}$: Target hull girder torsional moment, in kN.m, specified in [4.3.6], to be achieved at the target location

$M_{T\text{-}FEM}(x_{targ})$: Hull girder torsional moment, in kN.m, at target location due to local loads.

Due to the step of hull girder torsional moment at each longitudinal station, the hull girder torsional moment is to be selected from the values aft and forward of the target location as follows: Maximum value for positive torsional moment and minimum value for negative torsional moment.

4.6 Summary of hull girder load adjustments

4.6.1 The required methods of hull girder load adjustments for different cargo hold regions are given in Tab 8.

Table 8 : Overview of hull girder load adjustments in FE analyses

	Midship cargo hold region	After and Forward cargo hold region	Aft most cargo holds	Foremost cargo holds
Adjustment of Vertical Shear Forces	See [4.4.5]	See [4.4.5]	See [4.4.5]	See [4.4.5]
Adjustment of Bending Moments	See [4.4.8]	See [4.4.9]	See [4.4.9]	See [4.4.9]
Adjustment of Torsional Moment	See [4.5.4]	See [4.5.4]	See [4.5.4]	See [4.5.4]

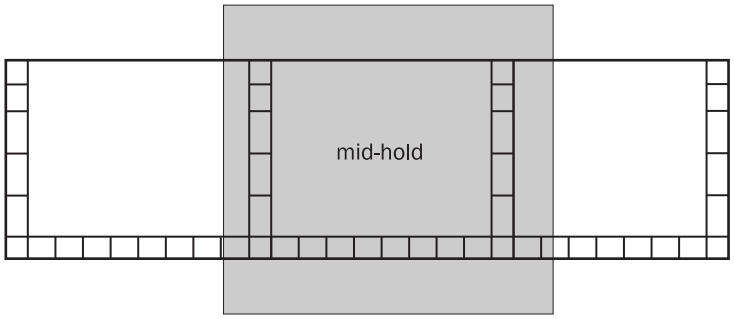
5 Analysis criteria

5.1 General

5.1.1 Evaluation areas

Verification of results against the acceptance criteria is to be carried out within the longitudinal extent of the mid-hold, as shown in Fig 21.

Figure 21 : Longitudinal extent of evaluation area



5.1.2 Structural members

The following structural elements within the evaluation area are to be verified with the criteria given in [5.2] and [5.3]:

- all the hull girder longitudinal structural members
- all the primary supporting structural members and bulkheads within the mid-hold
- all the structural members being part of the transverse bulkheads
- all structural members being part of the collision bulkhead and extending to one web frame spacing forward of the collision bulkhead
- all structural members being part of the forward transverse bulkhead of the machinery space and all hull girder longitudinal structural members aft of this transverse bulkhead within the extent of 15% of the aftmost cargo hold length excluding slop tanks if any.

5.2 Yield strength assessment

5.2.1 Von Mises stress

For all the plates of the structural members defined in [5.1.2], the Von Mises stress σ_{vm}, in N/mm^2, is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid-plane, as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where:

σ_x σ_y : Element normal membrane stresses, in N/mm^2

τ_{xy} : Element shear stress, in N/mm^2.

5.2.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress σ_{axial}, in N/mm^2, is to be calculated based on the axial force alone. The axial stress is to be evaluated at the middle of the element length.

5.2.3 Yield criteria

The structural elements given in [5.1.2] are to comply with the following criterion:

$$\lambda_y \leq \lambda_{yperm}$$

where:

λ_y : Yield utilisation factor:

$$\lambda_y = \frac{\sigma_{vm}}{R_Y} \quad \text{for shell elements}$$

$$\lambda_y = \frac{|\sigma_{axial}|}{R_Y} \quad \text{for rod or beam elements}$$

σ_{vm} : Von Mises stress, in N/mm^2

σ_{axial} : Axial stress in rod or beam element, in N/mm^2

λ_{yperm} : Standard mesh permissible yield utilisation factor defined in Tab 9.

5.2.4 Corrugation of corrugated bulkhead

The stress in corrugation of corrugated bulkheads is to be evaluated based on:

a) the von Mises stress, σ_{vm}, in shell elements on the flange and web of the corrugation

b) the axial stress, σ_{axial}, in dummy rod elements, modeled with unit cross sectional properties at the intersection between the flange and web of the corrugation.

5.3 Buckling strength assessment

5.3.1 All the structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 9, Sec 1.

Table 9 : Standard mesh permissible yield utilisation factor λ_{yperm}

Structural component	Acceptance criteria **(1)**	λ_{yperm}
Plating of all the longitudinal hull girder structural members, primary supporting structural members and bulkheads Face plate of the primary supporting members Dummy rod of corrugated bulkhead Independent tanks primary supporting members **(3)** Independent tanks supports and keys **(4)**	AC-1	0,8
	AC-2	1,0
	AC-3	$1,0 \cdot R_{eH} / R_y$
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only Supporting structure in way of lower end of corrugated bulkheads without lower stool **(2)**	AC-1	0,72
	AC-2	0,9
	AC-3	$0,9 \cdot R_{eH} / R_y$
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads and without lower stool, for shell elements only	AC-1	0,65
	AC-2	0,81
	AC-3	$0,81 \cdot R_{eH} / R_y$

(1) See Ch 8, Sec 1, [4] for the acceptance criteria definition.

(2) Supporting structure for a transverse corrugated bulkhead refers to the structure in the longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth.
Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within 3 longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.

(3) Not applicable to primary supporting members of Type B independent tanks.

(4) Not applicable to skirts of Type B independent tanks primarily constructed of bodies of revolution.

Appendix 2 Local Structural Strength Analysis

1 Objective and scope

1.1 General

1.1.1 The local strength analysis of structural details is to be in accordance with the requirements given in this Section.

1.1.2 Fine mesh analysis procedure

The details to be assessed by fine mesh analysis are to be modeled according to the requirements given in Article [2], under the FE load combinations defined in Article [3], and are to comply with the criteria given in Article [4].

1.2 Structural details to be assessed by fine mesh analysis

1.2.1 Mandatory structural details

Mandatory structural details subject to fine mesh analysis are listed in Ch 13, Sec 5, [2], as applicable depending on the assigned service notation.

For structural details having the same geometry and the same relative location inside the midship cargo region, one fine mesh model is required. The selection of the location of this fine mesh model is to be based on the detail which has the maximum yield utilisation factor λ_y as defined in Ch 8, App 1, [5.2.3].

Such analysis may also be considered for other details which are considered critical by the Society, or where the stresses can not be reliably assessed based on a standard mesh analysis (see Ch 8, App 1, [2.4.3]).

When local fine mesh analysis not complying with the criterion given in Article [4] has already been performed for a given detail, the screening criteria given in [1.2.2] may be used to determine where to perform this type of analysis on other details which can be considered by the Society as similar in terms of geometry, stress response and meshing.

1.2.2 Screening criteria

A stress concentration factor K_{SC} is determined as follows, based on the stress results from both theglobal strength analysis (cargo hold or full length as applicable) and local strength analysis:

$$K_{sc} = \frac{\sigma_{vm,f}}{\sigma_{vm,g}}$$

where:

$\sigma_{vm,f}$: Von Mises stress for the considered detail, in N/mm^2, obtained from the local strength analysis with a fine mesh model

$\sigma_{vm,g}$: Von Mises stress in way of the considered detail, in N/mm^2, obtained from the global strength analysis with a global standard mesh model.

Once the stress concentration factor has been determined for a given detail, each similar detail included in the global standard mesh model is to be checked against the following screening criterion:

$$\lambda_{sc} \leq \lambda_{fperm}$$

where:

λ_{sc} : Screening utilisation factor calculated as follows:

$$\lambda_{sc} = \frac{\sigma_{vm,g} K_{sc}}{R_Y}$$

λ_{fperm} : Fine mesh permissible yield utilisation factor as defined in Tab 1.

Where the screening criterion is not met, fine mesh analysis of the corresponding structural detail is to be performed according to [1.1.2].

Table 1 : Fine mesh permissible yield utilisation factor λ_{fperm}

Structural component		Acceptance criteria **(1)**	λ_{fperm}
• All hull structure components • Independent tanks primary supporting members **(2)** • Independent tanks supports and keys	Elements not adjacent to welding	AC-1	1,36 f_f
		AC-2	1,70 f_f
		AC-3	1,70 R_{eH} / R_y **(3)**
	Elements adjacent to welding	AC-1	1,20 f_f
		AC-2	1,50 f_f
		AC-3	1,50 R_{eH} / R_y **(3)**

(1) See Ch 8, Sec 1, [4] for the acceptance criteria definition.
(2) Not applicable to primary supporting members of Type B independent tanks.
(3) For antiflotation keys, λ_{fperm} is to be increased by 20%
Note 1: f_f : Fatigue factor, taken as:
- f_f = 1,0 in general, including the free edge of base material
- f_f = 1,2 for details assessed by very fine mesh analysis complying with the fatigue assessment criteria given in Ch 10, Sec 1.

2 Structural modeling

2.1 General

2.1.1 Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by fine mesh zones incorporated into the cargo hold model. Alternatively, separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo hold model may be used.

2.2 Extent of model

2.2.1 If a separate local fine mesh model is used, its extent is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions. The boundary of the fine mesh model is to coincide with primary supporting members in the cargo hold model, such as web frame, girders, stringers and floors.

2.3 Mesh size

2.3.1 The mesh size in the fine mesh zones is not to be greater than 50 x 50 mm.

2.4 Elements

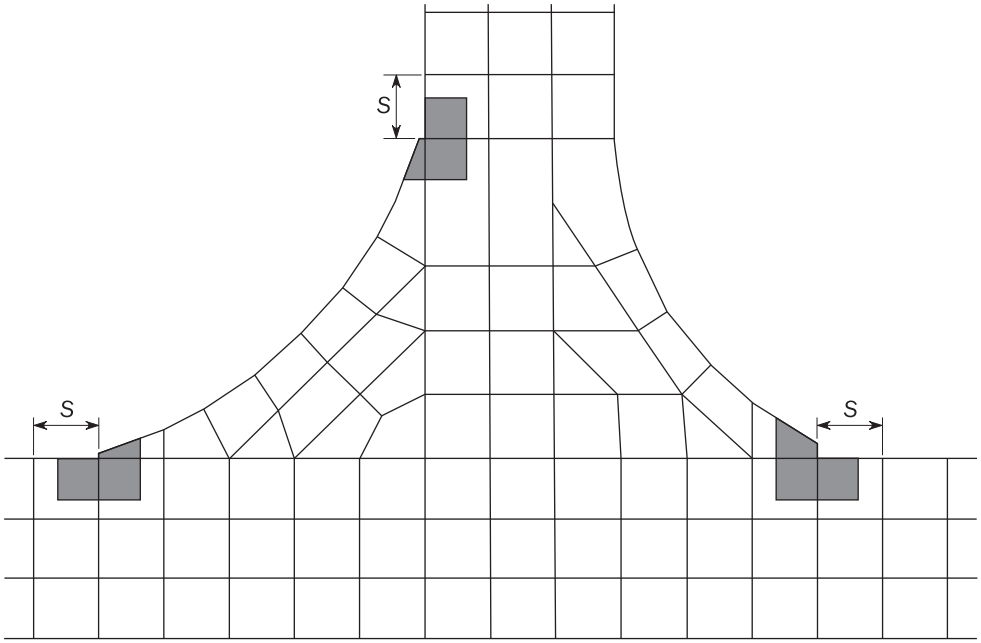
2.4.1 All plating within the fine mesh zone is to be represented by shell elements. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements within the fine mesh model are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angles less than 45° or greater than 135°, are to be avoided. Stiffeners inside the fine mesh zone are to be modeled using shell elements. Stiffeners outside the fine mesh zones may be modeled using beam elements.

2.4.2 The extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation. A smooth transition of mesh density from fine mesh zone to the boundary of the fine mesh model is to be maintained, see Fig 1 and Fig 2.

2.4.3 Where a fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modeled with mesh size not greater than 50 x 50 mm. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modeled with shell elements. Web stiffeners close to an opening may be modeled using rod or beam elements located at a distance of at least 50 mm from the edge of the opening. Example of fine mesh zone around an opening is shown in Fig 3.

2.4.4 Face plates of openings, primary supporting members and associated brackets are to be modeled with at least two elements across their width on either side.

Figure 1 : Fine mesh zone around bracket toes



Fine mesh zone
Element size ≤50 mm × 50 mm
Extent - at least 10 elements in all directions
Face plate modelled by plate elements

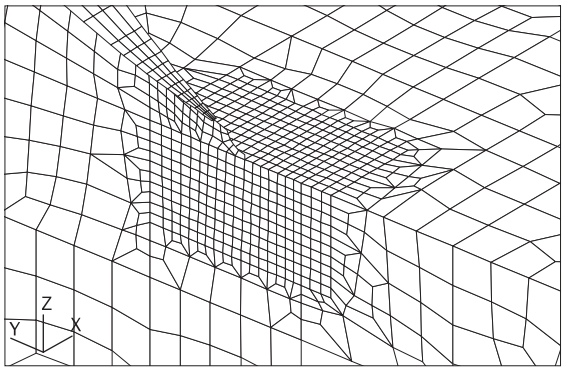


Figure 2 : Example of local model for the analysis of hatch opening structures

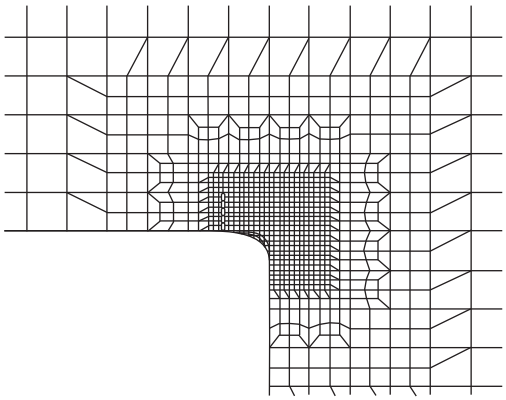
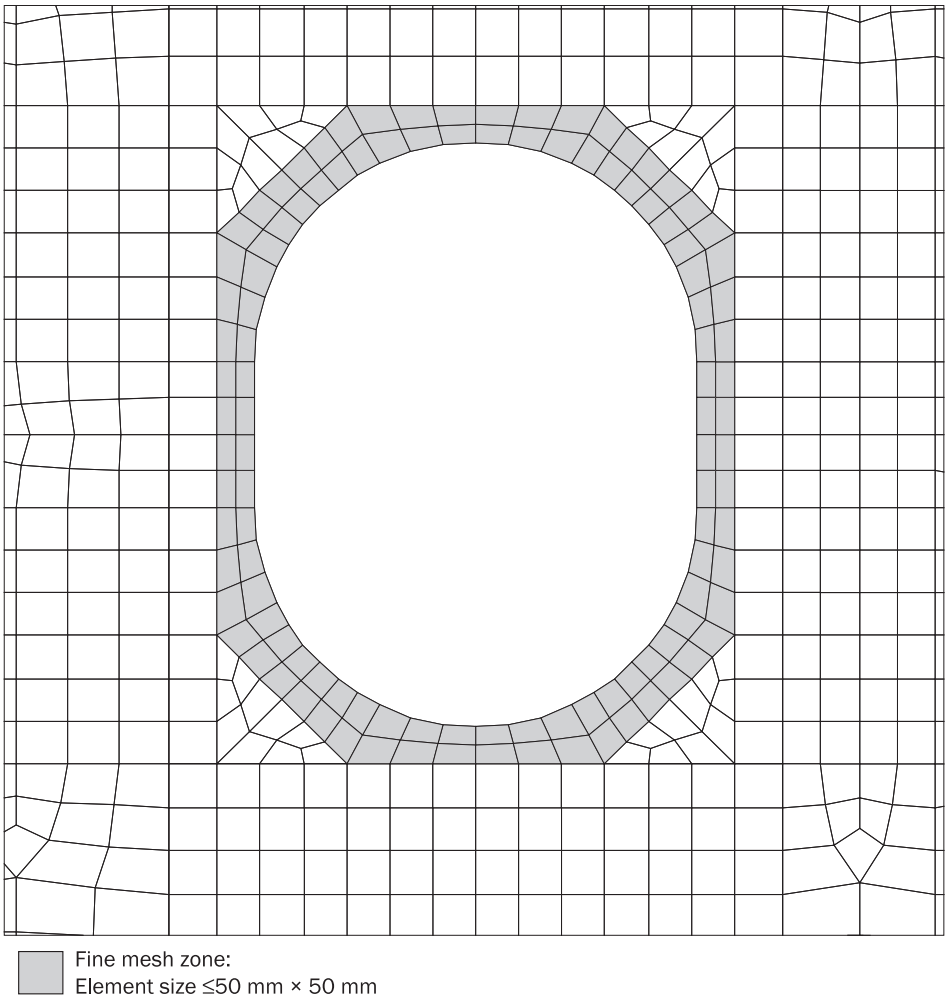


Figure 3 : Fine mesh zone around an opening



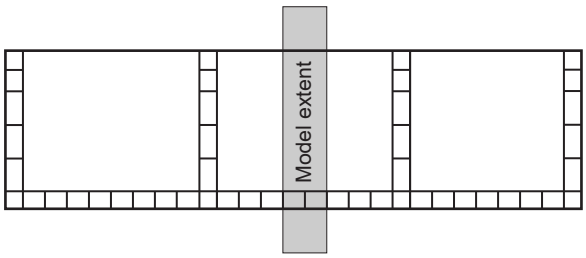
2.5 Transverse web frames

2.5.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-article are applicable to the analysis of a typical transverse web frame.

2.5.2 Where a FE sub-model is used, the model is to have an extent of at least 1+1 web frame spaces, i.e. one web frame space extending on either side of the transverse web frame under investigation. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub-model.

2.5.3 The full depth and full breadth of the ship are to be modeled, see Fig 4.

Figure 4 : Example of extent of local model for fine mesh analysis of web frame bracket connections and openings



2.6 Transverse bulkhead stringers, buttress and adjacent web frame

2.6.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-section are applicable to the analysis of transverse bulkhead structures and adjacent web frame.

2.6.2 Due to the structural interaction among the transverse bulkhead, horizontal stringers, web frames, deck and double bottom, it is recommended that the FE local model represents a full section of the hull. Longitudinally, the ends of the model should extend over at least one web frame space beyond the areas that require investigation, see Fig 5.

2.6.3 Alternatively, it is acceptable to use a number of local models, as shown in Fig 6, to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship are to be modeled. For the analysis of buttress structure, the local model width should be at least 4+4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

2.7 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

2.7.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners.

2.7.2 Where a local FE model is used, its length is to be of at least 2 web frame spaces on each side of the area under investigation. The model width is to extend over at least 2 longitudinal stiffeners spaces on each side the area under investigation.

2.7.3 The web of the longitudinal stiffeners outside of the fine mesh zone should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The flange of the longitudinal stiffeners and face plate of brackets should be modeled with at least 2 shell elements across its width at one side.

2.7.4 The mesh size and extent of the fine mesh zone is to be in accordance with [2.3] and [2.4].

Figure 5 : Example of local model for fine mesh analysis of transverse bulkhead and adjacent structure

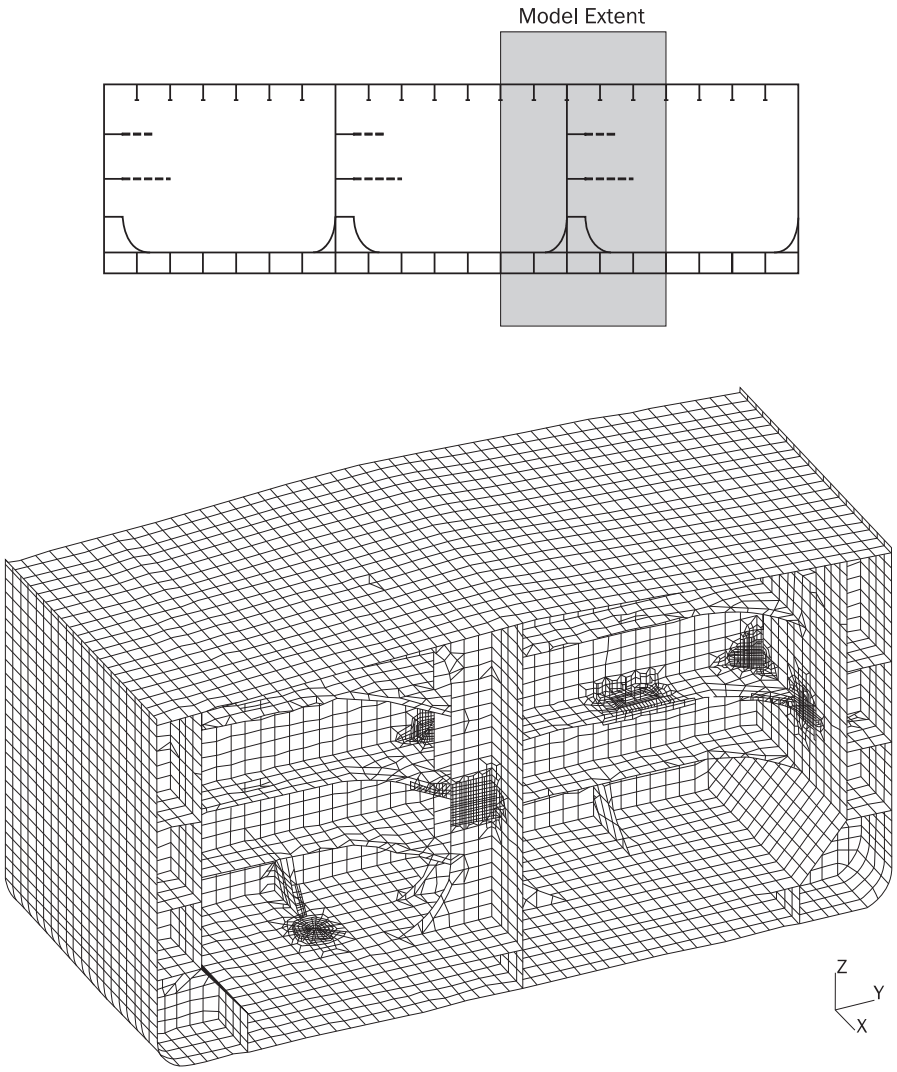
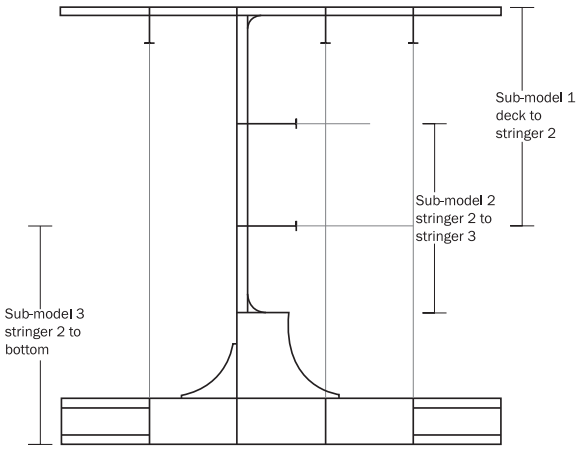


Figure 6 : Example of local analysis of transverse bulkhead structure using local models



2.8 Corrugated bulkheads

2.8.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-article are applicable to the analysis of connections of corrugated bulkheads to lower stool and the connection between lower stool and inner bottom.

2.8.2 The minimum extents of the local model are as follows, see also Fig 7:

a) Vertically, the model is to extend from the bottom of the ship to a level of at least 2 m above the connection between the corrugation and the lower stool.

b) For transverse corrugated bulkheads, the local model is to extend transversaly to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the local model covers two lower stool transverse web/diaphragm spaces). The end diaphragms do not need to be modeled.

c) For longitudinal corrugated bulkheads, the local model is to extend to the nearest web frame on each side of the fine mesh zone (i.e. the local model covers two frame spaces). The end web frames do not need to be modeled.

d) For connection between the corrugation and the lower stool located close to the intersection of transverse and longitudinal corrugated bulkheads (such as for product tankers), the local model is to cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever is relevant. In addition, the local model is to extend over at least one diaphragm/web frame outside the intersection between the transverse stool and the longitudinal stool.

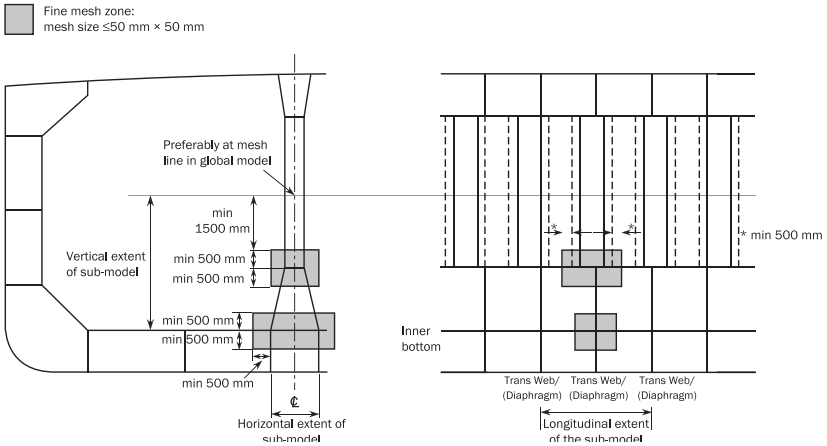
e) For lower stool to inner bottom connection, the connection between inner bottom, lower stool plate, diaphragm and double bottom girder, where applicable, is to be at the centre of the fine mesh zone.

2.8.3 The fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and at least 500 mm on each side of the corrugation webs (i.e. the fine mesh zone covers at least four corrugation knuckles, see Fig 7.

2.8.4 Diaphragm webs, brackets inside the lower stool and all stiffeners on the stool plate and diaphragm are to be modeled at their actual positions within the extent of the local model. Shell elements are to be used for the modeling of diaphragm, web and flange of vertically orientated stiffeners, and brackets in the fine mesh zone.

2.8.5 Horizontally orientated stiffeners within the fine mesh zone are to be represented by either shell or beam elements.

Figure 7 : Extent of local model and fine mesh zone for the analysis of corrugated bulkhead connection to lower stool and inner bottom



3 FE load combinations

3.1 General

3.1.1 The fine mesh detailed stress analysis is to be carried out for all the FE load combinations as defined in Ch 8, App 1, [3] required according to the applicable Part D or Part E chapter, except tank testing and flooding conditions, applied to the corresponding cargo hold analysis.

3.2 Application of loads and boundary conditions

3.2.1 General

Where a separate local model is used for the fine mesh detailed stress analysis, the nodal displacements from the global model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the global model may be applied to the boundary nodes.

Where there are nodes on the local model boundaries which are not coincident with the nodal points on the global model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

At the exception of flooding loads, all the local loads, including any loads applied for hull girder bending moment and/or shear force adjustments, in way of the structure represented by the separate local finite element model are to be applied to the model.

4 Analysis criteria

4.1 Yield strength assessment

4.1.1 Reference stress

Reference stress is Von Mises stress σ_{vm} as defined in Ch 8, App 1, [5.2.1], which is to be calculated based on the membrane normal and shear stresses of the shell element evaluated at the element centroid. The stresses are to be evaluated at the mid-plane of the element.

4.1.2 Permissible stress

The maximum permissible stresses are based on the mesh size of 50 x 50 mm, as specified in [2.1] to [2.4].

Where a smaller mesh size is used, an area weighted Von Mises stress $\sigma_{vm\text{-}av}$ calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area:

$$\sigma_{vm\text{-}av} = \frac{\sum_1^n A_i \ \sigma_{vm\text{-}i}}{\sum_1^n A_i}$$

The average stress is to be calculated based on stresses at the element centroid; stress values obtained by interpolation and/or extrapolation are not to be used.

Stress averaging is not to be carried across structural discontinuities and abutting structure.

4.1.3 Yield criteria

The structural assessment is to demonstrate that the stress complies with the following criterion: $\lambda_f \leq \lambda_{fperm}$

where:

λ_f : Fine mesh yield utilisation factor:

- for shell elements:

$$\lambda_f = \frac{\sigma_{vm}}{R_Y}$$

- for rod or beam elements:

$$\lambda_f = \frac{|\sigma_{axial}|}{R_Y}$$

σ_{vm} : Von Mises stress, in N/mm^2

σ_{axial} : Axial stress in rod element, in N/mm^2

λ_{fperm} : Fine mesh permissible yield utilisation factor as defined in Tab 1.

In addition, the average Von Mises stress over a standard mesh size as per Ch 8, App 1, [2.4.2] is not to exceed the permissible stress as defined in Ch 8, App 1, [5.2].

Appendix 3 Full Length Structural Strength Analysis

1 Objective and scope

1.1 General

1.1.1 This Section gives the requirements for full length structural strength analysis to be used for the assessment of primary supporting members.

1.1.2 The structural analysis aims at calculating the stresses in the primary supporting members and in the hull plating, to be used for yielding and buckling checks.

1.2 Full length structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- full length model with:
  - extent as given in [2.2]
  - finite element types as given in [2.3]
  - structural modeling as defined in [2.4]
- boundary conditions as defined in [2.5]
- loading conditions and load cases as defined in [3]
- load application as defined in [4]
- strength assessment as defined in [5].

2 Structural model

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements are to be modeled with their net scantlings according to Ch 4, Sec 3. Therefore, the hull girder stiffness and inertia to be reproduced by the model are also those obtained considering the net scantlings of the hull structures.

2.2 Extent of model

2.2.1 The complete ship is to be modeled so that the coupling between torsion and horizontal bending is properly taken into account in the structural analysis.

Superstructures are to be modeled in order to reproduce the correct lightweight distribution.

2.3 Finite element types

2.3.1 See Ch 8, App 1, [2.3].

2.4 Structural modeling

2.4.1 See Ch 8, App 1, [2.4].

Note 1: Openings modeling defined in Ch 8, App 1, Tab 1 are not applicable to complete ship models.

2.4.2 Lightweight and deadweight

The finite element model is to include both the lightweight and the deadweight mass and inertia distributions.

The lightweight can be adjusted using one of the following techniques:

- modification of the density properties of plate and beam elements
- additional nodal masses fitted on the structural model.

Massive items (main engine, hatch covers) are preferably be excluded of the lightweight distribution and modeled similarly to deadweight items.

Deadweight items (such as container stacks or liquids) are to be modeled as nodal masses linked to the model through additional elements designed in order to transfer loads without introducing artificial stiffness (interpolation elements). Nodal masses are also to include the inertia properties of the items they represent.

2.5 Boundary conditions of the model

2.5.1 General

All the boundary conditions described in this Section are in accordance with the global coordinate system defined in Ch 5, Sec 1.

2.5.2 Boundary conditions

In order to prevent the rigid body motions of the overall model, the constraints specified in Tab 1 are to be applied to full length finite element model analyses.

Table 1 : Boundary conditions to prevent rigid body motion of the model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
One node on the fore end of the ship	free	fixed	fixed	free	free	free
One node on the port side shell at aft end of the ship **(1)**	fixed	free	fixed	free	free	free
One node on the starboard side shell at aft end of the ship **(1)**	free	fixed	fixed	free	free	free
(1) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship's longitudinal plane of symmetry.						

3 Load combinations

3.1 General

3.1.1 The combination of loading conditions and load cases to be considered are given in Part D and Part E depending on the ship type.

4 Load application

4.1 General

4.1.1 Design wave method

The various load components which occur simultaneously may be combined by setting the characteristics of waves defined in [4.2.4] that maximise the dominant load effects given in [4.2.2].

Any other method may be used, provided relevant documentation is submitted to the Society for review.

4.1.2 Model loading

The loads are applied to the finite element model according to the following indications:

a) Still water loads include:
   - The still water sea pressure, defined in Ch 5, Sec 5, [1]
   - The still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast

b) Wave loads, determined by means of hydrodynamic calculations, include:
   - The wave pressure
   - The inertial loads

c) The fluid pressure in tanks is affected by the change of direction of the total acceleration vector defined in Ch 5, Sec 3

d) For dry unit cargoes, inertial forces are computed at the centre of mass, taking into account the mass moment of inertia

e) Inertial loads for structure weight and dry uniform cargo are computed using local accelerations calculated at their location.

4.1.3 Equilibrium check

The convergence of the displacement, trim and vertical bending moment is deemed satisfactory within the following tolerances:

- 2% of the displacement
- 0,1 degree of the trim angle
- 10% of the still water bending moment.

4.2 Procedure for the selection of design waves

4.2.1 Summary of the loading procedure

The determination of the design wave characteristics for each load case includes the following steps:

- computation of the response operators (amplitude and phase) of the dominant load effect
- selection of the wave length and heading according to [3]
- determination of the wave phase such that the dominant load effect reaches its maximum
- computation of the wave amplitude corresponding to the design value of the dominant load effect.

4.2.2 Dominant load effects

Each load case maximises the value of one of the following load effects having a dominant influence on the strength of some parts of the structure:

- vertical wave bending moment in hogging and sagging condition amidships
- horizontal wave bending moment amidships
- wave torsional moment around 0,25L and 0,75L
- vertical acceleration at fore body sections
- roll motion
- wave pressure at the waterline amidships.

Additional loads might be investigated when deemed relevant by the Society.

4.2.3 Response Amplitude Operators

The Response Amplitude Operators (RAO's) and associated phase characteristics are to be computed for wave periods between 4 and 22 seconds, using a seakeeping program, for the following motions and load effects:

- heave, sway, pitch, roll and yaw motions
- vertical wave bending moment at 0,5L or at the longitudinal position where the bending moment RAO is maximum
- vertical wave shear force at 0,25L and 0,75L
- horizontal wave bending moment at 0,5L
- wave torsional moment at 0,25L and 0,75L.

The response amplitude operators are to be calculated for wave headings ranging from 0° (following seas) to 180° (head seas) by increment of 15°, using a ship speed of 5 knots.

The amplitude and phase of other dominant load effects may be computed at relevant wave period, using the RAO's listed above.

4.2.4 Design waves

For each load case, the ship is considered to encounter a Response Conditioned Wave (RCW). The RCW is an irregular wave train composed by at least 60 uni-directional waves. For each wave, the range of time is to be taken between $-\pi/\Delta\omega$ and $\pi/\Delta\omega$, where $\Delta\omega$ is the wave frequency step as defined in [4.2.6].

4.2.5 Design wave amplitude and phase

For each wave contributing to the RCW, the amplitude A_i and phase φ_i can be computed from the RAO and the wave spectrum, using the following relationships:

$$A_i = S(\omega_i)|RAO(\omega_i, \beta)|\frac{D}{m_0}\Delta\omega_i$$

$$\varphi_i = -RAO_\varphi(\omega_i, \beta)$$

where:

D : Design value of the dominant load effect

RAO : Response amplitude operator of the dominant load effect computed for the relevant wave heading and wave frequency

RAO_φ : Phase of the response amplitude operator of the dominant load effect for the relevant wave heading and wave frequency

ω_i : Wave frequency

β : Wave heading

S : Wave spectrum (Pierson-Moskowitz) with the peak period T_p

m_0 : Spectral moment of order 0, defined as:

$$m_0 = \int_0^\infty S(\omega)RAO(\omega_i, \beta)^2 d\omega$$

$\Delta\omega_i$: Wave frequency step.

The wave heading β, peak period T_p and design value D of the dominant load effect are given, for each load case, in [3].

When positioning the finite element model of the ship on the design wave, the amplitude of the wave is to be corrected to obtain the design value of the dominant load effect in order to take into account the non linear effects due to the hull shape and to the pressure distribution above the mean waterline.

4.2.6 Seakeeping assumptions

When a direct seakeeping analysis is used to derive long-term values of hull girder loads, Response Amplitude Operators are to be computed, considering:

- a linear analysis
- a ship speed of 5 knots
- at least 36 headings (10° steps)
- frequencies in the range [0,1:2] rad/s
- a frequency step $\Delta\omega$ equal to:

$$\Delta\omega = 0,3\sqrt{\frac{g}{L}}$$

5 Analysis criteria

5.1 Yield strength assessment

5.1.1 Von Mises stress

The Von Mises stress σ_{vm}, in N/mm^2, is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid plane, as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\,\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where:

σ_x, σ_y : Element normal membrane stresses, in N/mm^2

τ_{xy} : Element shear stress, in N/mm^2.

5.1.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress σ_{axial}, in N/mm^2, is to be calculated based on the axial force alone. The axial stress is to be evaluated at mid-length of the element.

5.1.3 Yield criteria

The structural elements are to comply with the following criterion: $\lambda_y \leq \lambda_{yperm}$

where:

λ_y : Yield utilisation factor:

$$\lambda_y = \frac{\sigma_{vm}}{R_Y} \quad \text{for shell elements}$$

$$\lambda_y = \frac{|\sigma_{axial}|}{R_Y} \quad \text{for rod or beam elements}$$

σ_{vm} : Von Mises stress, in N/mm^2

σ_{axial} : Axial stress in rod or beam element, in N/mm^2

λ_{yperm} : Permissible yield utilisation factor defined in Ch 8, App 1, Tab 9.

Where the Von Mises stress of the elements under investigation by fine mesh exceeds the yield criteria, the average Von Mises stress obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the full length finite element model, is to satisfy the yield criterion above.

5.2 Buckling strength assessment

5.2.1 All the structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 9, Sec 1.

6 Refined analysis

6.1 Application

6.1.1 When a refined analysis is deemed necessary on a given detail, the requirements of this Article are to be applied.

6.2 Structural modeling

6.2.1 See Ch 8, App 2, [2].

6.3 Loading conditions and load cases

6.3.1 The loading conditions and load cases considered are to be similar to those applied for the full length model.

6.4 Load application

6.4.1 See Ch 8, App 2, [3.2].

6.5 Analysis criteria

6.5.1 See Ch 8, App 2, [4].

Part B
Hull and Stability

CHAPTER 9
BUCKLING

Section 1 Buckling

Section 1 Buckling

Symbols

For symbols not defined in this Section, refer to Ch 5, Sec 4.

1 General

1.1 Application

1.1.1 The buckling check of plating, stiffeners, primary supporting members and other structures such as pillars and brackets is to be performed according to the applicable requirements of NR615 Buckling Assessment of Plated Structures, taking into account, in addition, the requirements of this Section.

1.2 Allowable buckling utilisation factor

1.2.1 General structural elements

The allowable buckling utilisation factor η_{all} is defined in Tab 1.

Table 1 : Allowable buckling utilisation factor η_{all}

Structural component	Acceptance criteria	η_{all}
• Plates and stiffeners • Stiffened and unstiffened panels • Vertically stiffened side shell plating of single side skin ship • Web plate in way of openings • Web and flange of primary supporting members	AC-1	0,80
	AC-2 AC-3 AC-4	1,00
• Pillars	AC-1	0,75
	AC-2 AC-3	0,85
• Struts and cross ties	AC-1	0,65
	AC-2 AC-3	0,75
• Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only • Supporting structure in way of lower end of corrugated bulkheads without lower stool	AC-1	0,72
	AC-2 AC-3	0,90
• Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads, for shell elements only	AC-1	0,65
	AC-2 AC-3	0,81
Note 1: Supporting structure for a transverse corrugated bulkhead refers to the structure in longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth. **Note 2:** Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within three longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.		

2 Slenderness requirements

2.1 Application

2.1.1 The slenderness requirements defined in NR615, Sec 2 are to be applied to all structural members including plating, web and face plate, if any, of stiffeners and tripping brackets, web plating and flange of primary supporting members.

Slenderness requirements are not to be applied to corrugations of bulkheads.

When the buckling capacity of a plate element is assessed according to NR615, Sec 5, its associated slenderness requirement may be disregarded.

3 Prescriptive buckling requirements

3.1 Application

3.1.1 The requirements in this Article are to be taken into account for application of NR615, Sec 3.

3.1.2 Partial safety factor

The partial safety factor S, defined in NR615, Sec 5, is to be replaced by:

$$\frac{S}{K_{corr}}$$

where:

K_{corr} : Coefficient to take into account the corrosion:

- in general:
  $K_{corr} = 1,0$
- for tank testing at construction stage:
  $K_{corr} = 1,1$

3.2 Design load sets

3.2.1 General

Unless otherwise specified, the buckling checks are to be performed for all the design load sets defined in Ch 7, Sec 2, [2], with pressure combination defined in Ch 7, Sec 2, [1].

For each design load set defined in Ch 7, Sec 2, except the one associated to accidental design load scenario, the hull girder stress given in [3.3] is to be applied together with the lateral pressure determined according to Part B, Chapter 5, at the load calculation point defined in Ch 4, Sec 6.

Note 1: The still water loads Q_{sw} and M_{sw} need not be considered simultaneously but independently from each other when combined with wave loads, except in the following specific cases:

- where the minimum vertical still water bending moment $M_{sw\text{-}min}$ is positive, it is to be considered simultaneously with Q_{sw} when combined with the vertical wave bending moment in sagging condition $M_{wv\text{-}s}$
- where the minimum vertical still water shear force $Q_{sw\text{-}min}$ is positive, it is to be considered simultaneously with M_{sw} when combined with the negative vertical wave shear force $Q_{wv\text{-}neg}$
- where the maximum vertical still water shear force $Q_{sw\text{-}max}$ is negative, it is to be considered simultaneously with M_{sw} when combined with the positive vertical wave shear force $Q_{wv\text{-}pos}$.

3.2.2 Deckhouses side bulkheads

The buckling checks of structural members of deckhouses sides contributing to the longitudinal strength are to be performed for the design load set SEA-1 with a combined lateral pressure P_{ex} taken equal to 2,5 kN/m².

3.3 Hull girder stress

3.3.1 The hull girder bending stress σ_{hg}, in N/mm², is to be taken equal to σ_L as defined in Ch 6, Sec 1, [2.1.1] or Ch 6, Sec 1, [2.1.2] as applicable.

3.3.2 The hull girder shear stress τ_{hg}, in N/mm², is to be taken equal to τ_L as defined in Ch 6, Sec 1, [2.2.1] or Ch 6, Sec 1, [2.2.2] as applicable.

CHAPTER 10
FATIGUE

Section 1 Fatigue

Section 1 Fatigue

Symbols

T_{DF} : Design fatigue life, in year, specified by the designer, but not to be taken less than 25 years.
For ships granted with additional class notation **FAT xx years**, T_{DF} is to be taken equal to xx years

T_f : Calculated fatigue life, determined in accordance with NI611.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having a length equal to or greater than 150 m.

1.1.2 Fatigue assessment is performed on the applicable special structural details listed in Ch 13, Sec 5, [2] in order to prevent the following types of fatigue failure:

- fatigue cracks initiating from the weld toe and propagating into the base material
- fatigue cracks initiating from the free edge of non-welded details.

1.1.3 When the structural arrangement is such that some of the listed details listed are not relevant, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

1.2 Reference

1.2.1 When reference is made to NI611 "Guidelines for Fatigue Assessment of Steel Ships and Offshore Units", the latest version of this Guidance Note is applicable.

1.3 Fatigue due to loading and unloading

1.3.1 The additional fatigue damage that may be induced by the loading and unloading cycles is to be considered for ships assigned with one of the following service notations:

- **hopper dredger**
- **hopper unit**
- **split hopper unit**
- **split hopper dredger**.

1.3.2 Wave loads associated to loading and unloading fatigue assessment are to be obtained using the specific f_p coefficient defined in Ch 5, Sec 3.

1.3.3 The detailed operational loading / unloading sequence is to be provided by the Designer (loading/unloading cycle period, loading conditions involved, number of loading / unloading cycles per year).

2 Loading conditions

2.1 Design loading conditions for fatigue assessment

2.1.1 General

Loading conditions representative of the intended operation and the fraction of time spent in each condition are to be considered for fatigue analysis.

Unless otherwise specified, the following loading conditions are to be considered:

- full load condition 50% of the time
- normal ballast condition 50% of the time

Tanks filling levels associated to each loading condition are detailed in Tab 1.

2.1.2 Ro-ro and passenger ships

For ships with the service notation **ro-ro cargo ship**, **PCTC**, **PCC**, **passenger ship** or **ro-ro passenger ship**, the full load condition is to be considered 100% of the time.

Table 1 : Tanks filling levels for fatigue loading conditions

Type of tank	Filling level	
	Full load condition	Normal ballast condition
Cargo holds **(2)**	100 %	0 %
Ballast tanks	0 %	100 %
Consumable tanks **(1)**	50 %	50 %
(1) Consumable tanks are to be filled at 100% in case of FE fatigue analysis **(2)** If applicable		

2.1.3 Container ships

For ships with the service notation **container ship**, the loading condition to be considered for fatigue is defined in Pt D, Ch 2, Sec 2, [10.2].

2.1.4 Bulk carriers, ore carriers and combination carriers

For ships with the service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, the following loading conditions are to be considered:

- full load homogeneous condition: 25% of the time
- partially filled alternate loading condition: 25% of the time if allowed by the loading manual. Otherwise, the full load homogeneous condition is to be increased to 50%.
- normal ballast condition: 25% of the time
- heavy ballast 25% of the time.

3 Corrosion model

3.1 General

3.1.1 Corrosion model

The fatigue assessment is to be performed based on net thicknesses according to Ch 4, Sec 2.

Unless otherwise specified in Part D or Part E, the following values of stress correction factor as defined in NI611 are to be considered:

a) for analytical approach for longitudinal stiffeners:
   - $f_{c_a} = 0,95$
   - $f_{c_b} = 1,0$

b) for FEA calculations:

   $f_{c_FEA} = 0,95$

4 Fatigue assessment based on a deterministic approach

4.1 Longitudinal stiffener connections

4.1.1 Application

The fatigue strength of connections of longitudinal stiffeners with stiffeners of transverse primary supporting members is to be checked according to the methodology of NI611 as applicable to the “simplified rule based approach”.

For application of this methodology, requirements [4.1.2] to [4.1.6] are to be taken into account.

4.1.2 Loading conditions

The design fatigue loading conditions as defined in [2.1] are to be considered.

4.1.3 Hull girder loads

The vertical still water bending moment distribution defined in Ch 5, Sec 4, [2.1.3] is to be considered for the fatigue assessment.

The torsional still water moment is to be taken equal to zero.

4.1.4 Load cases

The dynamic load cases to be considered are given in Ch 5, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 5, Sec 7, [3].

For the loading conditions defined in [4.1.2], all the fatigue load cases are to be considered for fatigue assessment in accordance with NI611.

4.1.5 Fatigue damage calculation

The fatigue damage is to be calculated according to NI611 as applicable, considering:

- a simplified rule based approach
- a single period design life pattern
- the corrosion protection.

4.1.6 Acceptance criteria

The acceptance criteria is defined in [6].

4.2 Other structural details

4.2.1 Application

When the structural details other than longitudinal connections to primary supporting members are assessed by deterministic fatigue analysis, they are to be checked according to the methodology of NI611 as applicable to the "rule based approach", taking into account requirements [4.2.2] to [4.2.7].

4.2.2 Loading conditions

The design fatigue loading conditions as defined in [2.1] are to be considered.

4.2.3 Hull gider loads

The vertical still water bending moment and shear force distribution are to be taken as the maximum permissible value in seagoing operation.

The torsional still water moment is to be taken equal to zero.

4.2.4 Load cases

The dynamic load cases to be considered are given in Ch 5, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 5, Sec 7, [3].

For the loading conditions defined in [4.2.2], all the fatigue load cases are to be considered for fatigue assessment in accordance with NI611.

4.2.5 Hot spot stress calculation for welded details

For hot spot stress calculation of ordinary welded details as defined in NI611, the "hot spot stress without stress extrapolation" method is to be considered.

4.2.6 Fatigue damage calculation

The fatigue damage is to be calculated according to NI611 as applicable, considering:

- a simplified rule based approach
- a single period design life pattern
- the corrosion protection.

4.2.7 Acceptance criteria

The acceptance criterion is defined in [6].

5 Fatigue assessment based on spectral fatigue analysis

5.1 General

5.1.1 Fatigue strength of details subject to spectral fatigue analysis is to be assessed following the provisions of NI611 considering the assumptions given in [5.1.2] to [5.1.6].

5.1.2 Seakeeping assumptions

The seakeeping analysis necessary to the spectral fatigue assessment is to be based on:

- linear analysis
- ship speed, to be taken as 75% of the design speed
- at least 36 headings, 10° steps
- frequencies, to be taken in the range [0:2] rad/s
- frequency step, to be about $0,3\ (g / L)^{0,5}$
- intermittent wetting, to be accounted for, where relevant.

5.1.3 Loading conditions

The design fatigue loading conditions as defined in [2.1] are to be considered.

5.1.4 Environmental conditions

The long term analysis of stress RAOs is to be carried out considering the North Atlantic scatter diagram.

5.1.5 Fatigue damage calculation

The fatigue damage is to be calculated according to NI611 as applicable, considering:

- a spectral analysis
- a single period design life pattern
- the corrosion protection.

5.1.6 Acceptance criteria

The acceptance criterion is defined in [6].

6 Acceptance criteria

6.1 Fatigue life and acceptance criteria

6.1.1 General

For each considered detail, the calculated fatigue life T_f is to be greater than T_{DF}.

CHAPTER 11
OTHER STRUCTURES

Section 1 Fore Part
Section 2 Machinery Space
Section 3 Aft Part
Section 4 Tanks Subject to Sloshing
Section 5 Superstructures and Deckhouses
Section 6 Bow Doors and Inner Doors
Section 7 Side Doors and Stern Doors
Section 8 Watertight and Weathertight Doors
Section 9 Large Hatch Covers
Section 10 Small Hatches
Section 11 Movable Decks, Inner Ramps and External Ramps
Section 12 Arrangement of Hull and Superstructure Openings
Section 13 Helicopter Decks and Platforms

Section 1 Fore Part

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

b_I : Breadth of impact area supported by primary supporting member, in m, as defined in Ch 7, Sec 6, [2.3.1]

c_E : Coefficient to be taken equal to:

- for $L \leq 65$ m:

  $c_E = 1$

- for $65 \text{ m} < L < 90$ m:

  $c_E = 3 - L / 32,5$

- for $L \geq 90$ m:

  $c_E = 0$

c_F : Coefficient to be taken equal to:

- for forecastle sides:

  $c_F = 0,9$

- in other cases:

  $c_F = 1,0$

f_{bdg} : Bending moment factor taken as:

$$f_{bdg} = 8\left(1 + \frac{n_s}{2}\right)$$

n_s : End fixation factor taken as:

- for both ends with low end fixity (simply supported):

  $n_s = 0$

- for one end fixed and one end simply supported:

  $n_s = 1$

- for continuous members or members with brackets fitted at both ends:

  $n_s = 2$

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the following structures of the fore part as defined in Ch 1, Sec 1, [2.1.2]:

- fore peak structures
- stem.

In addition, the requirements of this Section apply to structure subjected to impact loads:

- flat bottom forward, according to [3.2]
- bow area, according to [3.3].

2 Structural arrangement

2.1 Bottom Structure

2.1.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values specified in Tab 1.

Table 1 : Scantling of bottom plating and ordinary stiffeners

Element	Minimum value
Plating	Net minimum thickness, in mm: • in general: $t = c_F (0,03 L_3 + 5,5) k^{1/2} - c_E$ • for inner bottom: $t = 2 + 0,017 L_3 k^{1/2} + 4,5 s$
Ordinary stiffeners	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_0^{1/3} k^{1/6}$ • the net thickness of the attached plating

2.1.2 Floors

In case of transverse framing, solid floors are to be fitted at each web frame location.

In case of longitudinal framing, the spacing of solid floors is not to be greater than 3,5 m or four transverse frame spaces, whichever is smaller.

The floors dimensions and scantlings are to be not less than those specified in Tab 2 and Tab 3.

Table 2 : Longitudinally framed bottom - Floors and girders dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0,085 D + 0,15$
Web net thickness,in mm	$t = \min(10mm; 1,5 L_0^{1/3} k^{1/6})$
Floor face plate net sectional area, in cm^2	$A_P = 3,15 D$
Floor face plate net thickness, in mm	• $t_p = 0,4 D + 5$ • t_p may be assumed not greater than 14 mm

Table 3 : Transversely framed bottom - Floors dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0,085 D + 0,15$
Web net thickness,in mm	$t = \min(10mm; 1,5 L_0^{1/3} k^{1/6})$
Floor face plate net sectional area, in cm^2	$A_P = 1,67 D$

2.1.3 Bottom girders

A supporting structure is to be provided at the centreline, either by extending the centreline girder to the stem, or by providing a deep girder or a centreline bulkhead.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

The spacing of bottom girders is not to exceed:

- 2,5 m in case of transverse framing
- 3,5 m in case of longitudinal framing.

The bottom girders dimensions are to be not less than those specified in Tab 2.

2.1.4 Alternative design verification

The spacing of solid floors and bottom girders, defined in [2.1.2] and [2.1.3] respectively, may be increased, if the designer performs a verification of the bottom structure by means of grillage analysis or FE analysis and provides the full corresponding documentation.

The acceptance criteria to be applied are defined in Ch 7, Sec 6, [5.1.4]. A FE analysis is to be performed, considering the requirements provided in Part B, Chapter 8.

2.2 Centreline wash bulkheads

2.2.1 General

Except for dry peaks, a centreline longitudinal wash bulkhead may be required in liquid compartments for which there is a risk of resonance in the transverse direction.

2.2.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.2.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in Tab 2 is to be not less than that required for the centre girder in [2.1.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula:

$t = 6,5 + 0,013\ L_1$

2.2.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$w = 3,5\ s\ \ell^2\ k\ (z_{TOP} - z_M)\ 10^{-3}$

where:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.2.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side transverse or side girder.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.2.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the total area of the bulkhead, and, in the zone above, to not less than 10% of the total area of the bulkhead. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.3 Side shell structure

2.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values specified in Tab 4.

Table 4 : Scantling of side plating and ordinary stiffeners

Element	Minimum value
Plating	Net minimum thickness, in mm: $t = c_F\ (0,03\ L_3 + 5,5)\ k^{1/2} - c_E$
Ordinary stiffeners	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5\ L_0^{1/3}\ k^{1/6}$ • the net thickness of the attached plating

2.3.2 Web frames

The spacing S of web frames, in m, as defined in Ch 1, Sec 3, Tab 4, is generally not to be taken greater than:

$S = 2,6 + 0,005\ L$

2.3.3 Stringers

Stringers are to have an effective span not greater than 10 m and are to be adequately supported by web frame structures.

Moreover, the depth b_A, in mm, and the net thickness t_A, in mm, of the stringer webs of transversely framed side are generally to be not less than the values obtained from the following formulae:

$b_A = 2,5\ (180 + L)$

$t_A = (6 + 0,018\ L)\ k^{1/2}$

2.3.4 Alternative design verification

The spacing of web frames and stringers may be increased, if the designer performs a verification of the side shell supporting structure by means of beam analysis or FE analysis and provides the full corresponding documentation.

The acceptance criteria to be applied are defined in Ch 7, Sec 6, [5.1.4]. A FE analysis is to be performed, considering the requirements provided in Part B, Chapter 8.

2.3.5 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames.

Each panting beam is to be connected to the side frames by means of brackets whose arms are generally to be not less than twice the panting beam depth.

Side frames not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

The net area A_B, in cm^2, and the net inertia J_B, in cm^4, of the panting beam section are to be not less than the values obtained from the following formulae:

$A_B = 0,5\ L - 18$

$J_B = 0,34\ (0,5\ L - 18)\ b_B^2$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.6.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

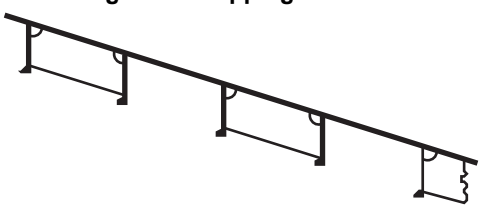
Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.4 Tripping brackets

2.4.1 For side shell and tank walls located forward of the collision bulkhead and vertically framed, tripping brackets spaced not more than 2,6 m are to be fitted, according to Fig 1, between primary supporting members, decks and/or platforms.

The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

Figure 1 : Tripping brackets



2.5 Decks

2.5.1 Plating and ordinary stiffeners

The net scantlings of deck plating and ordinary stiffeners, up to the bulkhead deck, are to be not less than the values obtained from the values specified in Tab 5.

Table 5 : Scantling of deck plating and ordinary stiffeners

Element	Minimum value
Plating	Net minimum thickness, in mm: $t = 2,1 + 0,013\ L_3\ k^{1/2} + 4,5\ s$
Ordinary stiffeners	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5\ L_0^{1/3}\ k^{1/6}$ • the net thickness of the attached plating.

2.6 Platforms

2.6.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.2] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case by case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.6.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm^2, from the following formula:

$$A = \frac{10 P_{ex} d_S h_S}{C_P R_y}$$

where:

P_{ex} : Sea pressure, defined in Ch 5, Sec 5, [1], acting at the ends of the platform transverse in the direction of its axis.

d_S : Half of the longitudinal distance between the two adjacent transverses, in m

h_S : Half of the vertical distance between the two adjacent platforms, in m

C_P : Coefficient, to be taken equal to:

$$C_P = 1 \quad \text{for} \quad \frac{d_P}{r_P} \leq 70$$

$$C_P = 1,7 - 0,01\frac{d_P}{r_P} \quad \text{for} \quad 70 < \frac{d_P}{r_P} \leq 140$$

When $d_P/r_P > 140$, the scantlings of the struts are considered by the Society on a case by case basis

d_P : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse

r_P : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

$$r_P = \sqrt{\frac{J}{A_E}}$$

A_E : Actual net sectional area, in cm^2, of the transverse section of the strut considered

J : Minimum net moment of inertia, in cm^4, of the strut considered

2.6.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

2.7 Bulbous bow

2.7.1 General

Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

2.7.2 Diaphragm plates

At the forward end of the bulb, the structure is generally to be supported by horizontal diaphragm plates, spaced about 1 m apart, in conjunction with a deep centreline web.

In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

2.7.3 Special bulbous bow designs

In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

2.7.4 Strengthening for anchor and chain cable contact

The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in [2.8.1].

2.8 Stems

2.8.1 Plate stem

The net thickness t_{Stm}, in mm, from keel line to T_{SC} + 0,6 m, is not to be less than:

$$t_{Stm} = (0,6 + 0,4\ S_B)\ (0,08\ L + 2,7)\ k^{0,5}$$

but need not be greater than:

$$t_{Stm} = 22\ k^{0,5} - 1$$

where:

S_B : Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.

Starting from 0,6 m above T_{SC} up to $(T_{SC} + C_w)$, the net thickness may gradually be reduced to 0,8 t_{Stm}.

The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

2.8.2 Bar stems

The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm^2, from the following formulae:

$$A_P = \left(0,40 + \frac{10T}{L}\right)(0,009L^2 + 20)\sqrt{k} \quad \text{for } L \le 90$$

$$A_P = \left(0,40 + \frac{10T}{L}\right)(1,8L - 69)\sqrt{k} \quad \text{for } 90 < L \le 200$$

where the ratio T/L in the above formulae is to be taken not less than 0,05 or greater than 0,075.

The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0,4L + 13)\sqrt{k}$$

The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 13, Sec 3, [5.6].

2.9 Thruster tunnel

2.9.1 General

The net thickness of the tunnel plating is not to be less than the net thickness required for the shell plating in the vicinity of the bow thruster.

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case-by-case basis.

3 Structures subject to impact loads

3.1 General

3.1.1 Application

This Article covers the strengthening requirements for local impact loads that may occur on the forward structures.

3.1.2 General scantling requirements

Local scantling increase due to impact loads is to be made with due consideration given to the details, provide effective continuity of strength and avoid hard spots, notches and other harmful stress concentrations.

3.1.3 Design to resist impact loads

a) The design of end connections of stiffeners in the impact regions is to provide end fixity, either by making the stiffeners continuous through supports, or by providing end brackets complying with Ch 4, Sec 5, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt}$, in cm^3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:

Z_{pl} : Net plastic section modulus, in cm^3, as required by Ch 7, Sec 5, [1.3.1].

b) Scantlings and arrangements of primary supporting members, including decks and bulkheads in way of the stiffeners, are to comply with Ch 7, Sec 6, [2.3]. In areas where impact load is maximum, the web stiffeners are to be arranged perpendicular to the hull envelope plating and double sided lug connections are to be provided.

c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

d) Tripping arrangements are to comply with Part B, Chapter 9. In addition, tripping brackets are to be fitted at the toe of end brackets and at locations where the primary supporting member flange is knuckled or curved.

3.1.4 Shell plating

The net thickness t, in mm, of the hull envelope plating subjected to bottom slamming or bow impact according to [3.2] and [3.3] is to comply with the requirements in Ch 7, Sec 4, [4], considering the impact pressure P_{SLI} or P_{FI} as applicable, defined respectively in Ch 5, Sec 5, [4.2] and in Ch 5, Sec 5, [4.3].

3.1.5 Shell stiffeners

The shell stiffeners subjected to bottom slamming or bow impact according to [3.2] and [3.3] are to comply with the requirements in Ch 7, Sec 5, [1.3] considering the impact pressure P_{SLI} or P_{FI} as applicable, defined respectively in Ch 5, Sec 5, [4.2] and in Ch 5, Sec 5, [4.3].

3.1.6 Primary supporting members

The primary supporting members subjected to bottom slamming or bow impact according to [3.2] and [3.3] are to comply with the requirements in Ch 7, Sec 6, [2.3], considering the impact pressure P_{SLI} or P_{FI} as applicable, defined respectively in Ch 5, Sec 5, [4.2] and in Ch 5, Sec 5, [4.3].

3.2 Bottom slamming

3.2.1 Application

Where the minimum forward draught T_F, as specified in Ch 1, Sec 2, [1.6.1], is less than 0,04 L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, as required in Ch 1, Sec 5.

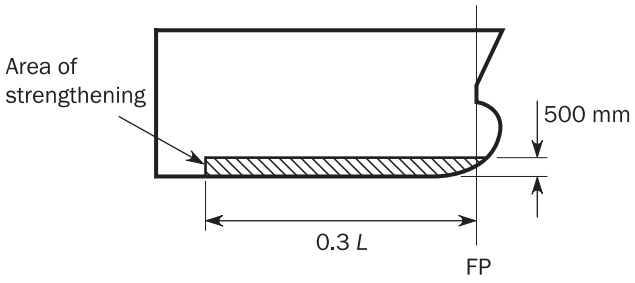
The load calculation point of the primary supporting members is specified in Ch 4, Sec 6, [4].

3.2.2 Extent of strengthening

The strengthening is to extend between 0,7L to the fore end, over the flat bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see Fig 2.

Outside the region strengthened to resist bottom slamming, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

Figure 2 : Extent of strengthening against bottom slamming



3.3 Bow impact

3.3.1 Application

The side structure in the ship forward area is to be strengthened against bow impact pressures. The strengthening is to extend as follows:

a) Area of strengthening A as indicated in Fig 3:

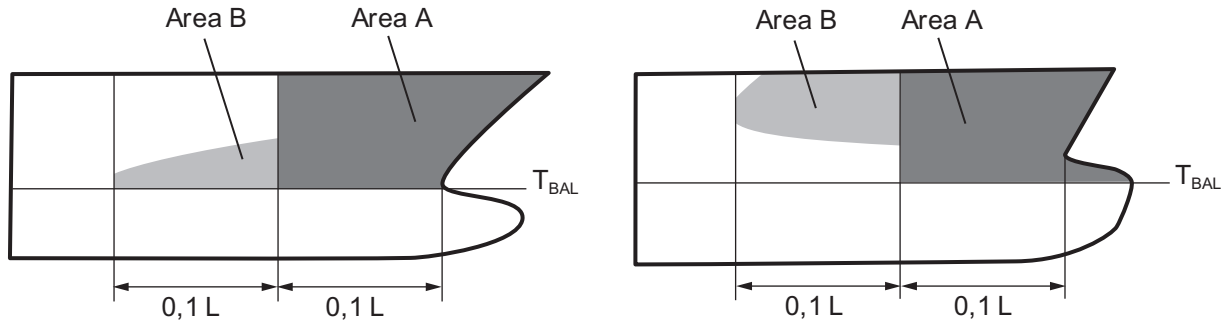
Forward of 0,1 L from the FP and, vertically, from the minimum design ballast draught T_{BAL}, up to the forecastle deck, if any, or to the level at which a knuckle with an angle greater than 15° is located on the side shell, where T_{BAL} is defined in Ch 1, Sec 3, [2.1.6]

b) Area of strengthening B as indicated in Fig 3:

Between 0,1 L and 0,2 L from the FP for areas with a flare angle α greater than 40°, where α is defined in Ch 5, Sec 5, [4.3.1].

Outside the strengthening area, scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

Figure 3 : Examples of extent of strengthening against bow impact



3.3.2 Buckling check of primary supporting members

The buckling check of the webs and flanges of primary members is to be performed according to the requirements for plate panels as defined in Ch 9, Sec 1. The normal stress σ and the shear stress τ as defined below are to be considered independently.

The normal bending stress σ, in N/mm^2, is to be taken equal to:

- In way of the attached plating:

$$\sigma = 0$$

- In way of the flange:

$$\sigma = \frac{f_{cb} P_{FI} f_{pb} \ell_{bdg}^{\ 2} b_l}{f_{bdg} Z_{n50}} 10^3$$

where:

f_{cb} : Correction factor for the bending moment at the ends considering the patch load, as defined in Ch 7, Sec 6, [2.3.1]

ℓ_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6, [1.1.6]

f_{pb} : Patch load modification factor for bending, as defined in Ch 7, Sec 6, [2.3.1]

The shear stress τ, in N/mm^2, is to be taken equal to:

$$\tau = 10 \frac{Q_l}{A_{shr-n50}}$$

where:

Q_l : Shear force in kN, as defined in Ch 7, Sec 6, [2.3.1].

When the structure is arranged as a grillage, direct analysis (finite element analysis or beam models) is to be applied. Plate panels are to be considered as simply supported along the edges, except for flanges free edges which are to be considered as free. The stresses obtained from direct analysis are to be mutually considered accounting for the following:

a) Beam model analysis:

- Normal bending stress σ is to be calculated in way of flange and attached plating.
- Shear stress τ is to be taken equal to the mean stress acting within the web.
- Stresses are to be calculated along the span of the primary supporting member at the point where the worst combination of σ and τ occurs and at least at the ends and the middle of the span.

b) Finite element analysis:

Normal stresses σ_x , σ_y and shear stress τ are to be taken as obtained from the finite element analysis.

3.3.3 Decks, bulkheads and webs of primary supporting members

Unless buckling check of primary supporting members and decks/bulkhead panels is performed according to 3.3.2 b), the net web thickness t_w, in mm, of each primary supporting member, including decks and bulkheads directly welded to the side shell, is not to be less than:

$$t_w = \frac{P_{FI} b_I}{\sin\varphi_w \sigma_{cr}}$$

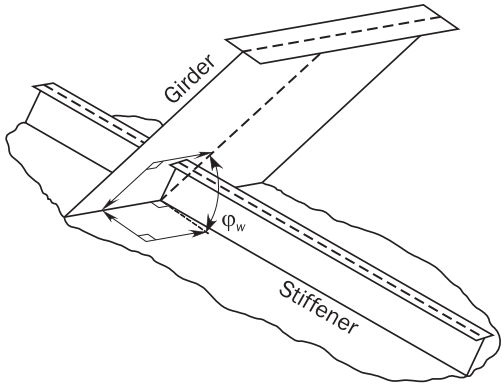
where:

φ_w : Angle, in deg, between the primary supporting member web and the shell plate, as shown in Fig 4

σ_{cr} : Critical buckling stress in compression, in N/mm^2, of the web of the primary supporting member or deck/bulkhead panel in way of the applied load, as given in Part B, Chapter 9. In the calculation, either σ_{cx}' or σ_{cy}' is to be considered, depending on the orientation of the normal stress induced in the plate panel by the lateral pressure acting on the side shell and UP-B or SP-B is to be applied respectively for webs of primary supporting members or for decks and bulkheads.

In addition, in case of longitudinal framing system, primary supporting members and bulkheads are to be fitted with web stiffeners according to Ch 4, Sec 5, [4.2] where the angle φ_w is smaller than 75°. The web stiffeners are to be connected, as far as practicable, to the longitudinal stiffeners.

Figure 4 : Angle between shell primary member and shell plate



3.3.4 Breasthooks and diaphragm plating

The net thickness of breasthooks/diaphragm plates in way of bow impact strengthening area defined in [3.3.1] t_w, in mm, is not to be less than:

$$t_w = \frac{s}{70}\sqrt{\frac{R_{eH}}{235}}$$

where:

s : Spacing of stiffeners on the web, in mm, as defined in Ch 1, Sec 3, Tab 4. Where no stiffeners are fitted, s is to be taken as the depth of the web.

Section 2 Machinery Space

Symbols

P : Maximum power, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantlings and arrangement of structures located in the machinery space. It is the shipyard responsibility to design the ship in accordance with the machinery manufacturer's requirements.

2 Machinery space arrangement

2.1 Structural arrangement

2.1.1 All parts of the machinery, shafting, etc, are to be supported to properly transfer the loads to the ship structure. The adjacent structure is to be suitably stiffened.

2.1.2 Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2.1.3 In case of change of framing system between machinery space and adjacent hull areas, abrupt structural discontinuities are to be avoided.

2.1.4 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces. Web frames are to be connected at the top and bottom to members of suitable stiffness.

Side transverses are to be aligned with floors.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4-frame spacing.

2.1.5 Side shell longitudinal stiffeners are to be efficiently connected to transverse bulkheads to provide proper fixity and lateral support. When the stiffener is not continuous through the bulkhead, a soft-toe bracket is to be fitted. Brackets lapped onto the longitudinals are not satisfactory.

2.1.6 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

2.1.7 Machinery casing

Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

2.1.8 The foundations of main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity in all anticipated loading conditions. The following drawings are to be submitted to the machinery manufacturer for review:

a) foundations of main propulsion units

b) foundations of reduction gears

c) foundations of thrust bearings

d) structures supporting a), b) and c).

2.1.9 Platforms

The location and extension of platforms in machinery spaces are preferably to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$t = 0,018\ L_0\ k^{1/2} + 4,5$

2.2 Double bottom

2.2.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.2.2 Minimum thicknesses

The net thicknses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

Table 1 : Double bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$3,0 + 0,024\ L\ k^{1/2} + 0,0045b$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case by case basis.	
Margin plate	$L^{1/2}\ k^{1/4} + 1$	$0,9\ L^{1/2}\ k^{1/4} + 1$
Centre girder	$1,8\ L^{1/3}\ k^{1/6} + 4$	$1,55\ L^{1/3}\ k^{1/6} + 3,5$
Floors and side girders	$1,7\ L^{1/3}\ k^{1/6} + 1$	
Girder bounding a duct keel	$0,8\ L^{1/2}\ k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

2.2.3 Lower net thickness values for floor and web girder web can be accepted, if based on direct calculations.

2.2.4 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 2, Sec 2, [3]. This depth may need to be considerably increased, depending on the type and depth of main machinery seatings.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be provided by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors. A lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

2.2.5 Centreline girder

The double bottom is to be arranged with a centreline girder. Manholes in the centreline girder are only to be fitted where absolutely necessary for double bottom access and maintenance. Local strengthening in way of such manholes is to be provided.

2.2.6 Side bottom girders

In the machinery space, the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to provide adequate rigidity of the structure. The side bottom girders, in longitudinal stiffened double bottom, are to be in line with bottom longitudinals in adjacent areas. The spacing of such girders is generally not to be greater than 3 times that of the longitudinals and in no case greater than 3 m.

2.2.7 Girders in way of machinery seatings

Bottom girders are to be fitted in way of machinery seatings.

Bottom girders arranged in way of main machinery seatings are to be extended over the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far as practicable and be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.2.8 Floors in longitudinally stiffened double bottom

Where the double bottom is longitudinally stiffened, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

2.2.9 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely stiffened, floors are to be arranged at every frame.

Boilers and other important machinery are to be supported by means of structural elements of adequate strength.

2.2.10 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2.11 Inner bottom plating

Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. The hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

2.2.12 Heavy equipment

Where an heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

2.3 Single bottom

2.3.1 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1-frame spacing in way of the main engine and thrust bearing
- 2-frame spacing in other areas of the machinery spaces.

Boilers and other important machinery are to be supported by means of structutal elements of adequate strength.

2.3.2 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Boilers and other important machinery are to be supported by means of structural elements of adequate strength.

2.3.3 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case by case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case by case basis.

2.3.4 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

2.3.5 Minimum thicknesses

The net thicknesses of floor and girder webs are to be not less than the values given in Tab 2.

Table 2 : Single bottom - Minimum net thicknesses of floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0,05\ L_0\ k^{1/2}$	$6 + 0,05\ L_0\ k^{1/2}$
Floors and side girder	$6,5 + 0,05\ L_0\ k^{1/2}$	$5 + 0,05\ L_0\ k^{1/2}$

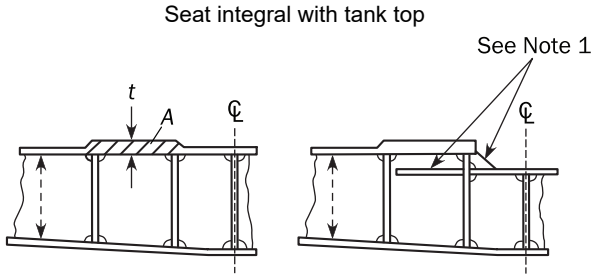
3 Machinery foundations

3.1 General

3.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by foundations having a strength sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

3.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integrated within the double bottom structure. Consideration is to be given to substantial increase of the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see Fig 1.

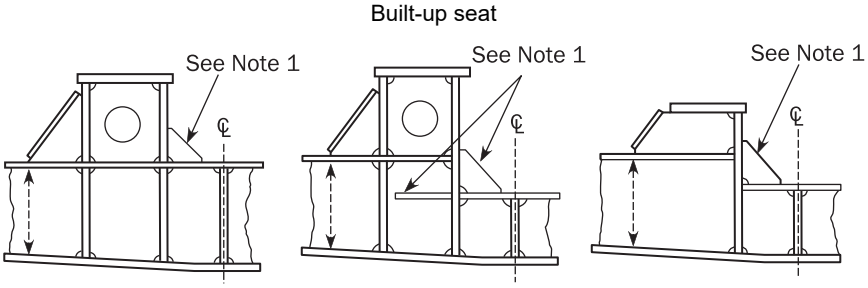
Figure 1 : Machinery foundations type 1



Note 1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with the recommendations of the engine manufacturer.

3.1.3 For main machinery supported on foundations of Type 2, as shown in Fig 2, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see Fig 2.

Figure 2 : Machinery foundations type 2



Note 1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with the recommendations of the engine manufacturer.

3.1.4 Supporting structure above the double bottom plating

Girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with supporting structures.

3.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

3.2 Scantlings

3.2.1 The net scantlings of the structural elements in way of the seatings of engines are to be determined by the engine manufacturer. They are to be checked on the basis of justificative calculations supplied by the engine manufacturer. If these calculations are not supplied, the net scantlings of the structural elements in way of the seatings of engines are to be not less than those obtained from the formulae in Tab 3.

3.3 Foundations for internal combustion engines and thrust bearings

3.3.1 The general rigidity of the engine is to be considered in the determination of the foundations scantlings, as it may have an incidence on the loads balance.

3.3.2 Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

3.3.3 Number of longitudinal members in way of seatings of engines

In general, at least two longitudinal members are to be fitted in way of seatings of main engines.

One longitudinal member may be fitted only where the following three formulae are complied with:

$L < 150$ m

$P < 7100$ kW

$P < 2,3\ n_R\ L_E$

3.4 Auxiliary machinery foundations

3.4.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

Table 3 : Scantlings of the structural elements in way of seatings of engines

Scantling	Minimum value
Net cross-sectional area, in cm^2, of each bedplate of the seatings	$40 + 70\frac{P}{n_r L_E}$
Net thickness, in mm, of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\sqrt{240 + 175\frac{P}{n_r L_E}}$ • Bedplate supported by one longitudinal member: $5 + \sqrt{240 + 175\frac{P}{n_r L_E}}$
Web net thickness, in mm, of girders fitted in way of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\frac{1}{n_G}\sqrt{320 + 215\frac{P}{n_r L_E}}$ where n_G is the number of longitudinal members in way of the bedplate considered • Bedplate supported by one longitudinal member: $\sqrt{95 + 65\frac{P}{n_r L_E}}$
Web net thickness, in mm, of transverse members fitted in way of bedplates of the seating **(1)**	$\sqrt{55 + 40\frac{P}{n_r L_E}}$
(1) When intermediate transverse members welded to the bedplate are fitted, the web minimum net thickness may be reduced on a case-by-case basis.	

Section 3 Aft Part

Symbols

F_C : Force, in kN, taken equal to:

$$F_C = \left(\frac{2\pi N}{60}\right)^2 R_P P$$

P : Mass of a propeller blade, in t

N : Number of revolutions per minute of the propeller

R_P : Distance, in m, of the centre of gravity of a blade in relation to the rotation axis of the propeller

σ_{ALL} : Allowable stress, in N/mm^2: $\sigma_{ALL} = 70 / k$

where:

k : Material factor, as defined in Ch 4, Sec 1, [2.2]

w_A : Section modulus, in cm^3, of the arm at the level of the connection to the hull with respect to a transversal axis

w_B : Section modulus, in cm^3, of the arm at the level of the connection to the hull with respect to a longitudinal axis

A : Sectional area, in cm^2, of the arm

A_S : Shear sectional area, in cm^2, of the arm

d_P : Propeller shaft diameter, in mm, measured inside the liner, if any

b : Breadth of the plate panel, in mm, as defined in Ch 4, Sec 6, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantlings and arrangement of structures located aft of the aft peak bulkhead.

In addition, the requirements of this Section apply to structures subjected to stern impact loads according to Article [5].

2 Aft peak

2.1 Structural arrangement

2.1.1 Floors

Floors are to be fitted at each frame space in the aft peak. They are to extend at least above the stern tube. Where floors do not extend up to a platform or a deck, they are to be stiffened by flanges at their upper end.

Heavy plate floors are to be fitted in way of, and near, the rudder post, propeller post and rudder horn. They are to extend up to the peak tank top or platform. In this area, cut outs, scallops and other openings are to be kept to a minimum.

2.1.2 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured with wide tapering brackets.

Where the aft peak is adjacent to a longitudinally framed side machinery space, the side girders in the aft peak are to be fitted with tapering brackets.

2.1.3 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted at the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

2.1.4 Alternative design verification

Spacings and arrangements other than those required in [2.1.1], [2.1.2] and [2.1.3] may be agreed, provided the designer performs a verification by means of grillage analysis or FE analysis and provides the full corresponding documentation. The acceptance criteria to be applied are defined in Ch 7, Sec 6, [5.1.4]. A FE analysis is to be performed under consideration of the requirements provided in Part B, Chapter 8.

2.2 Scantlings

2.2.1 Plating minimum net thickness

The minimum net thickness of plating are to be not less than values specified in Tab 1.

2.2.2 Shell plating connected with stern frame

The net thickness of shell plating connected with the stern frame is not to be less than the value obtained, in mm, from the following formula:

$t = 0,094 (L_3 - 43) + 0,009 b$

In way of the boss and heel plate, the net thickness t of shell plating, in mm, is not to be less than:

$t = 0,105 (L_3 - 47) + 0,011 b$

2.2.3 Heavy shell plates

Heavy shell plates are to be fitted locally in way of the heavy plate floors as required in [2.1.1]. The net thickness of heavy shell plates is not to be less than the value given in [2.2.1]. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the rudder horn plating is radiused into the shell plating, the radius r at the shell connection, in mm, is not to be less than: $r = 150 + 0,8 L_3$

2.2.4 Thruster tunnel plating

The net thickness t_{tun} of the tunnel plating, in mm, is to comply with the requirements in Ch 11, Sec 1, [2.9].

Table 1 : Net thickness of plating

Plating location	Net minimum thickness, in mm
Bottom and side	$c_F (0,03 L_3 + 5,5) k^{1/2} - c_E$
Inner bottom	$2 + 0,017 L_3 k^{1/2} + 0,0045 b$
Deck	For strength deck: $2,1 + 0,013 L_3 k^{1/2} + 0,0045 b$
Platform and wash bulkhead	• $1,3 + 0,004 L_3 k^{1/2} + 0,0045 b$ for $L < 120$ m • $2,1 + 2,2 k^{1/2} + 0,001b$ for $L \geq 120$ m
Note 1: Where cF and cE are coefficient defined in Ch 11, Sec 1.	

2.2.5 Web net minimum thicknesses

The web net minimum thickness of ordinary stiffeners are to be not less than values specified in Tab 2.

Table 2 : Net scantlings of ordinary stiffeners

Ordinary stiffener location	Minimum value
Bottom, side and deck Platform and wash bulkhead	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_0^{1/3} k^{1/6}$ • the net thickness of the attached plating.

2.3 Stiffening of floors and girders

2.3.1 Stiffeners on the floors and girders in aft peak ballast or fresh water tanks above propeller are to be designed in accordance with [2.3.2] and [2.3.3]. This applies for stiffeners located in an area extending longitudinally between the forward edge of the rudder and the after end of the propeller boss and transversely within the diameter of the propeller.

2.3.2 The height of stiffeners h_{stf}, in mm, on the floors and girders in aft peak is not to be less than:

- for flat bar stiffeners: $h_{stf} = 80 \ell_{stf}$
- for bulb profiles and flanged stiffeners: $h_{stf} = 70 \ell_{stf}$

where:

ℓ_{stf} : Stiffener length, in m, as shown in Fig 1. ℓ_{stf} need not be taken greater than 5 m.

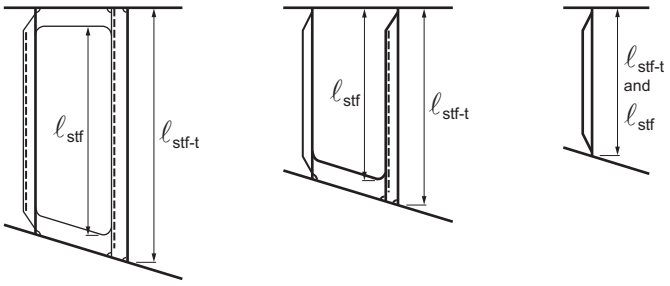
2.3.3 End brackets are to be provided as follows:

- at the lower and upper ends when $\ell_{stf\text{-}t}$ exceeds 4 m
- at the lower end when $\ell_{stf\text{-}t}$ exceeds 2,5 m

where:

$\ell_{stf\text{-}t}$: Total length of the stiffener, in m, as shown in Fig 1.

Figure 1 : Stiffening of floors and girders in the aft peak tank



$\ell_{sft-t} > 4,0$ m 4,0 m ≤ $\ell_{sft-t} > 2,5$ m $\ell_{sft-t} \leq 2,5$ m

3 Connection of hull structures with the rudder horn

3.1 Connection of after peak structures with the rudder horn

3.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

3.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 12, Sec 1, [8.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

3.1.3 Hull structures

Direct calculations are to be performed to check the connection of the rudder horn to the structure of the vessel, taking account of the reactions induced by the rudder on the rudder horn.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

3.2 Structural arrangement above the after peak

3.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2-frame spacing in way of the horn
- 4-frame spacing for and aft of the rudder horn
- 6-frame spacing in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop.

3.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

4 Stern frames

4.1 General

4.1.1 Stern frames are to be fabricated from steel plates or made of cast steel with a hollow section. For applicable material specifications and steel grades, see Ch 4, Sec 1. Stern frames of other material or construction will be specially considered.

4.1.2 Cast steel and fabricated stern frames are to be strengthened by adequately spaced horizontal plates. Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

4.1.3 In the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness of stern frames may be reduced to 80% of the applicable requirement in [4.2.1].

4.2 Propeller posts

4.2.1 Gross scantlings of propeller posts

The gross scantlings of propeller posts are not to be less than those obtained from the formulae in Tab 3 for single screw ships and in Tab 4 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable, provided the section modulus of the propeller post section about its longitudinal axis is not less than the value calculated with the propeller post scantlings in Tab 3 or Tab 4, as applicable.

4.2.2 Propeller shaft bossing

In single screw ships, the thickness of the propeller shaft bossing, over the whole shaft bearing length and included in the propeller post, is not to be less than 60% of the thickness b required in [4.2.1] for bar propeller posts with a rectangular section.

4.3 Connections

4.3.1 Connections with hull structure

Stern frames are to be effectively attached to the aft structure and the required scantling for the lower part of the propeller post is to be extended from the aft end of propeller post, at the centerline of the propeller shaft, to a length not less than $(1500 + 6\ L_3)$ mm, in order to provide an effective connection with the keel. However, the stern frame need not extend beyond the aft peak bulkhead.

Table 3 : Single screw ships - Gross scantlings of propeller posts

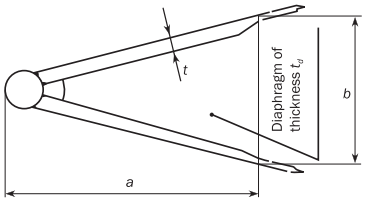
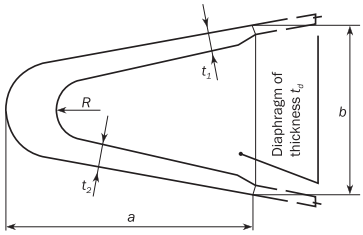
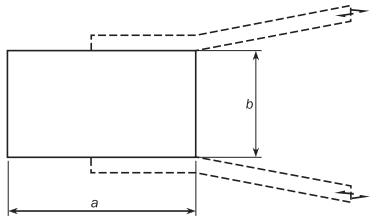
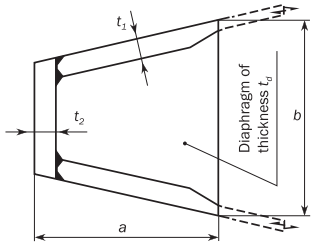
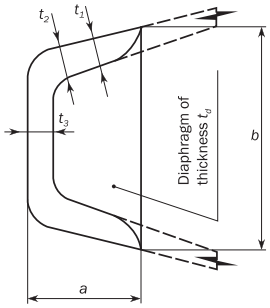
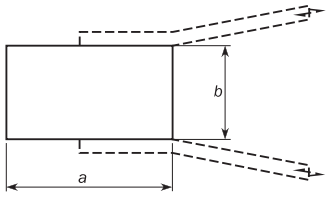
Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having a rectangular section
			
a	$50\ L_2^{1/2}$	$33\ L_2^{1/2}$	$10\sqrt{7,2L - 256}$
b	$35\ L_2^{1/2}$	$23\ L_2^{1/2}$	$10\sqrt{4,6L - 164}$
t_1	$2,5\ L_2^{1/2}$	$3,2\ L_2^{1/2}$	–
t_2	–	$4,4\ L_2^{1/2}$	–
t_d	$1,3\ L_2^{1/2}$	$2,0\ L_2^{1/2}$	–
R	–	50 mm	–

Table 4 : Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having a rectangular section
			
a	$25\ L_2^{1/2}$	$12,5\ L_2^{1/2}$	2,4 L + 6
b	$25\ L_2^{1/2}$	$25\ L_2^{1/2}$	0,8 L + 2
t_1	$2,5\ L_2^{1/2}$	$2,5\ L_2^{1/2}$	–
t_2	$3,2\ L_2^{1/2}$	$3,2\ L_2^{1/2}$	–
t_3	–	$4,4\ L_2^{1/2}$	–
t_d	$1,3\ L_2^{1/2}$	$2,0\ L_2^{1/2}$	–

4.3.2 Connection with keel plate

The thickness of the lower part of the stern frames is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the stern frame is to be designed to ensure an effective connection with the keel.

4.3.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having a height not less than the double bottom height and a net thickness not less than the value obtained, in mm, from the following formula:

$t = 9 + 0,023\ L_1$

4.3.4 Connection with centre keelson

Where the stern frame is made of cast steel, the lower part of the stern frame is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

4.4 Rudder gudgeons

4.4.1 In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

4.5 Sterntubes

4.5.1 The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

5 Structure subject to stern impact loads

5.1 General

5.1.1 Application

This Article covers the strengthening requirements for local impact loads that may occur on the flat area of the bottom aft structure having a maximum deadrise angle of 30° and located at a distance not greater than h_{SL} from the design waterline, for ships having a length L at least equal to 150 m, where:

h_{SL} : Maximum relative wave elevation, in m, for stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2].

5.1.2 General scantling requirements

Local scantling increase due to impact loads is to be made with due consideration given to the details, provide effective continuity of strength and avoid hard spots, notches and other harmful stress concentrations.

5.1.3 Design to resist impact loads

a) The design of end connections of stiffeners in the impact regions is to provide end fixity, either by making the stiffeners continuous through supports, or by providing end brackets complying with Ch 4, Sec 5, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt}$, in cm^3, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt} = \frac{16 Z_{pl}}{f_{bdg}}$$

where:

Z_{pl} : Net plastic section modulus, in cm^3, as required by Ch 7, Sec 5, [1.3.1].

b) Scantlings and arrangements of primary supporting members, including decks and bulkheads in way of the stiffeners, are to comply with Ch 7, Sec 6, [2.3]. In areas where impact load is maximum, the web stiffeners are to be arranged perpendicular to the hull envelope plating and double sided lug connections are to be provided.

c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

d) Tripping arrangements are to comply with Part B, Chapter 9. In addition, tripping brackets are to be fitted at the toe of end brackets and at locations where the primary supporting member flange is knuckled or curved.

5.1.4 Shell plating

The net thickness t, in mm, of the hull envelope plating subject to stern impact according to [5.1.1] is to comply with the requirements in Ch 7, Sec 4, [4], considering the impact pressure P_{SLI} defined in Ch 5, Sec 5, [4.2].

5.1.5 Shell stiffeners

The shell stiffeners subject to stern impact according to [5.1.1]are to comply with the requirements in Ch 7, Sec 5, [1.3] considering the impact pressure P_{SLI} defined in Ch 5, Sec 5, [4.2]

5.1.6 Primary supporting members

The primary supporting members subject to stern impact according to [5.1.1] are to comply with the requirements in Ch 7, Sec 6, [2.3], considering the impact pressure P_{SLI} defined in Ch 5, Sec 5, [4.2].

Section 4 Tanks subject to Sloshing

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1,2 - \frac{b}{2,1\ a}$$

but not to be taken greater than 1,0

a : Length of plate panel, in mm, as defined in Ch 4, Sec 6

b : Breadth of plate panel, in mm, as defined in Ch 4, Sec 6

ℓ_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6

ℓ_{shr} : Effective shear span, in m, as defined in Ch 4, Sec 6

H : Height of a tank, in m, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

ℓ_C : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead

b_C : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead

d_F : Filling level of a tank, in m, to be taken as the vertical distance, measured with the ship at rest, from the tank bottom to the free surface of the liquid

ℓ_S : Length, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F, as shown in Fig 1. In this figure, wash bulkheads are those satisfying the requirements in Ch 4, Sec 5, [10.4.1]

b_S : Breadth, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F, as shown in Fig 2 for ships without longitudinal watertight or wash bulkheads.

For ships fitted with longitudinal watertight or wash bulkheads (see Fig 3), b_S is delimited by these bulkheads (to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 5, [10.4.1])

σ_L : Hull girder normal stress, in N/mm^2, as defined in Ch 6, Sec 1, [2.1.2], calculated at the load calculation point as defined in Ch 4, Sec 6, [2.2] or Ch 4, Sec 6, [3.2].

1 Application

1.1 General

1.1.1 The requirements of this Section cover the strengthening requirements for localised loads that may occur in partly filled tanks intended for the carriage of liquid.

1.1.2 Sloshing and impact pressures are to be considered as applicable according to respectively [1.3] and [1.4].

Figure 1 : Length ℓ_S of the free surface of the liquid

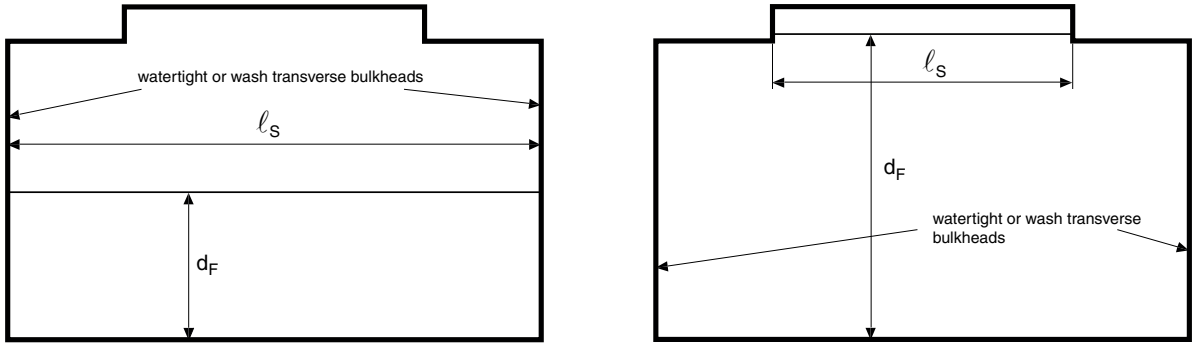


Figure 2 : Breadth b_S of the free surface of the liquid for ships without longitudinal bulkheads

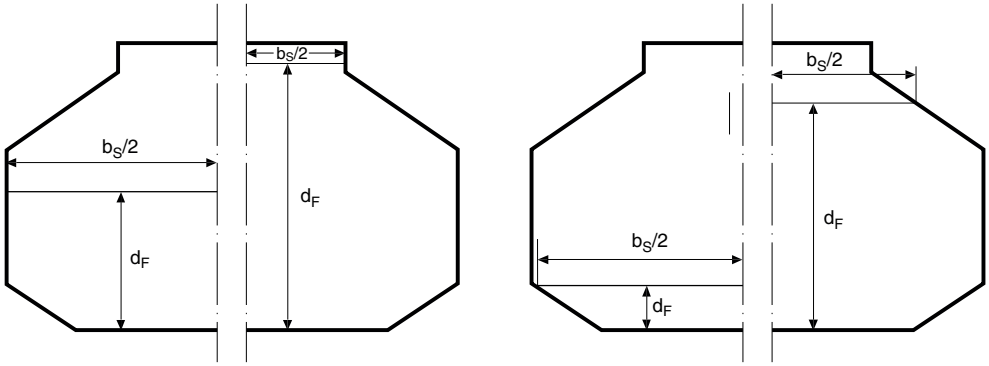
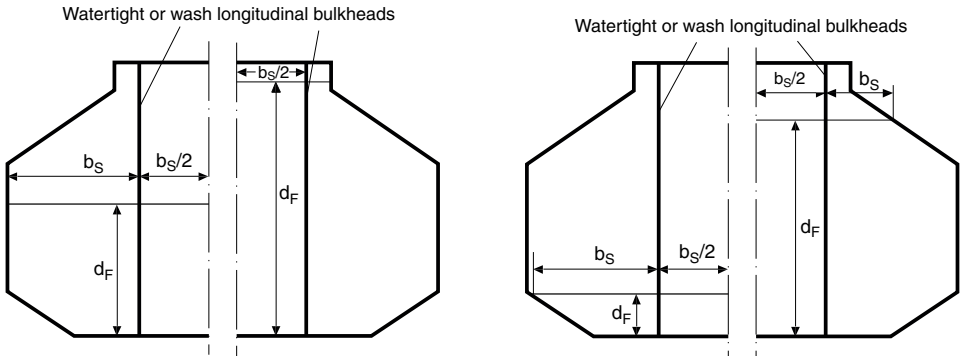


Figure 3 : Breadth b_S of the free surface of the liquid for ships with longitudinal bulkheads



1.2 Liquefied gas carriers

1.2.1 Sloshing in cargo containment tanks of liquefied gas carriers is to be checked according to Pt D, Ch 9, Sec 4, or Pt D, Ch 9, Sec 20, as applicable.

1.3 Sloshing loads

1.3.1 Longitudinal motion

Where there is a risk of longitudinal resonance according to [1.5] for a filling level d_F, the sloshing pressure P_{sl} calculated according to Ch 5, Sec 6, [2.2.1] is to be considered as acting on transverse bulkheads which form tank boundaries, in the area extended vertically 0,2 d_F above and below d_F (see Ch 5, Sec 6, Fig 2).

Where tank bottom transverses or wash transverse bulkheads are fitted, the sloshing pressure calculated according to Ch 5, Sec 6, [2.4.2] is to be considered as acting on them.

The Society may also require the sloshing pressure to be considered when there is no risk of resonance, but the tank arrangement is such that ℓ_C / L > 0,15.

1.3.2 Transverse motion

Where there is a risk of transverse resonance according to [1.5] for a filling level d_F, the sloshing pressure P_{sl} calculated according to Ch 5, Sec 6, [2.2.1] is to be considered as acting on longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically 0,2 d_F above and below d_F (see Ch 5, Sec 6, Fig 2).

If sloped longitudinal topsides are fitted, they are to be considered as subjected to the sloshing pressure if their height is less than 0,30 H.

Where wash longitudinal bulkheads are fitted, the sloshing pressure calculated according to Ch 5, Sec 6, [2.4.2] is to be considered as acting on them.

1.4 Impact loads

1.4.1 Longitudinal motion

Where there is a risk of longitudinal resonance in tanks with arrangements such that ℓ_s is greater than 0,13 L at any filling level d_F from 0,10 H to 0,95 H, the dynamic impact pressure P_{W-I} due to liquid motions calculated according to Ch 5, Sec 6, [2.5.1] is to be considered as acting on:

- transverse bulkheads which form tank boundaries, in the area extended vertically 0,15 H from the tank top
- the tank top in the area extended longitudinally 0,3 ℓ_C from the above transverse bulkheads.

Where the upper part of a transverse bulkhead is sloped, the impact pressure is to be considered as acting on the sloped part of the transverse bulkhead and the tank top (as the case may be) in the area extended longitudinally 0,3 ℓ_C from the transverse bulkhead.

1.4.2 Transverse motion

Where there is a risk of transverse resonance in tanks with arrangements such that b_s is greater than 0,56 B at any filling level d_F from 0,10 H to 0,95 H, the dynamic impact pressure P_{W-I} due to liquid motions calculated according to Ch 5, Sec 6, [2.5.1] is to be considered as acting on:

- longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically 0,15 H from the tank top
- the tank top in the area extended transversely 0,3 b_C from the above longitudinal bulkheads, inner sides or sides.

Where the upper part of a longitudinal bulkhead, inner side or side is sloped, the impact pressure is to be considered as acting on this sloped part and the tank top (as the case may be) in the area extended transversely 0,3 b_C from the longitudinal bulkhead, inner side or side.

1.4.3 Static pressure

The static pressure P_{S-I} , acting on the full tank boundary and calculated according to Ch 5, Sec 6, [2.3.2], is to be combined with P_{W-I} according to Ch 5, Sec 6, [2.2.2].

1.5 Evaluation of the risk of resonance

1.5.1 Where tanks are partly filled at a level d_F such as $0,10\ H \leq d_F \leq 0,95\ H$, the risk of resonance between:

- the ship pitch motion and the longitudinal motion of the liquid inside the tank
- the ship roll motion and the transverse motion of the liquid inside the tank,

is to be evaluated on the basis of the criteria specified in Tab 1

where:

T_X : Natural period, in s, of the liquid motion in the longitudinal direction:

$$T_X = \sqrt{\frac{4\pi\ell_S}{g\tanh\frac{\pi d_F}{\ell_S}}}$$

T_Y : Natural period, in s, of the liquid motion in the transverse direction:

$$T_Y = \sqrt{\frac{4\pi b_S}{g\tanh\frac{\pi d_F}{b_S}}}$$

T_φ : Pitch period, in s, defined in Ch 5, Sec 3, [2.1.2]

T_θ : Roll period, in s, defined in Ch 5, Sec 3, [2.2.1].

1.5.2 The Society may accept that the risk of resonance is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank dimensions and the ship characteristics. The calculations are to be submitted to the Society for approval.

Table 1 : Criteria for the evaluationof the risk of resonance

Liquid motion direction	Risk of resonance when:	Resonance due to:
Longitudinal	$0,6 < \frac{T_X}{T_\varphi} < 1,3$ and $\frac{d_F}{\ell_C} > 0,1$	Pitch
Transverse	$0,8 < \frac{T_Y}{T_\theta} < 1,2$ and $\frac{d_F}{b_C} > 0,1$	Roll

2 Scantling of elements subject to sloshing loads

2.1 Plating

2.1.1 Net thickness

The net thickness of plating t, in mm, subject to sloshing pressures is not to be less than:

$$t = 0,0158\alpha_p b\sqrt{\frac{P_{sl}}{C_a R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient to be taken as:

$$C_a = \beta_a - \alpha_a\frac{|\sigma_L|}{R_{eH}}$$

without being taken greater than $C_{a\text{-}max}$

with β_a, α_a and $C_{a\text{-}max}$ as defined in Tab 2

σ_L : Hull girder bending stress, in N/mm^2, corresponding to the greater of the still water sagging and hogging bending moments in absolute value

P_{sl} : Sloshing pressure, in kN/m^2, calculated according to Ch 5, Sec 6, [2.2.1].

Table 2 : Definition of β_a, α_a and $C_{a\text{-}max}$

Acceptance criteria set	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-1	Longitudinal strength members in the cargo hold region including, but not limited to: • deck • longitudinal bulkhead • longitudinal girders and stringers	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other strength members including: • transverse bulkhead • transverse stringers and web frames • plating of tank boundaries and primary supporting members		0,8	0	0,8

2.2 Stiffeners

2.2.1 Net section modulus of horizontal stiffeners

The net section modulus Z, in cm^3, of horizontal stiffeners subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{sl} S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} : Bending moment factor:

- $f_{bdg} = 12$

  for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners
- $f_{bdg} = 8$

  for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners

C_s : Permissible bending stress coefficient, to be taken as:

- For members subject to hull girder stress:

  coefficient to be taken as defined in Tab 3
- $C_s = C_{s\text{-}max}$

  for other cases

P_{sl} : Sloshing pressure, in kN/m^2, calculated according to Ch 5, Sec 6, [2.2.1].

$C_{s\text{-}max}$: Coefficient as defined in Tab 4.

2.2.2 Vertical stiffeners

Vertical stiffeners subject to sloshing loads are to be assessed by means of direct calculation according to Ch 7, Sec 5, [1.7] considering the permissible stress coefficient C_s as defined in [2.2.1].

2.3 Primary supporting members

2.3.1 Web plating

The web plating net thickness t of primary supporting members, in mm, is not to be less than:

$$t = 0,0158\alpha_p b\sqrt{\frac{P_{sl}}{C_a R_{eH}}}$$

where:

P_{sl} : Sloshing pressure, in kN/m^2, calculated according to Ch 5, Sec 6, [2.2.1]. The pressure is to be calculated at the load application point, defined in Ch 4, Sec 6, [4.1], taking into account the distribution over the height of the member

C_a : Permissible plate bending stress coefficient, as given in [2.1.1].

2.3.2 Stiffeners on web plating

The net section modulus Z, in cm^3, of each individual stiffener on the web plating of primary supporting members subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{sl} S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

P_{sl} : Sloshing pressure, in kN/m^2, calculated according to Ch 5, Sec 6, [2.2.1]. The pressure is to be calculated at the load application point, defined in Ch 4, Sec 6, [3.2], taking into account the distribution over the height of the member

C_s : Permissible bending stress coefficient, as given in Tab 3

f_{bdg} : Bending moment factor, as given in [2.2.1].

Table 3 : Permissible bending stress coefficient C_s

Sign of hull girder bending stress σ_L **(1)**	Lateral pressure acting on **(2)**	Stiffener boundary condition **(3)**	f_{bdg}	Coefficient C_s **(4)**
Tension (positive)	Stiffener side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ with $C_s \le C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ with $C_s \le C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ with $C_s \le C_{s\text{-}max}$
Compression (negative)	Stiffener side	F - F	12	$C_s = C_{s\text{-}max}$
		F - S	8	$C_s = C_{s\text{-}max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ with $C_s \le C_{s\text{-}max}$
	Plate side	F - F	12	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ with $C_s \le C_{s\text{-}max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_L\rvert}{R_{eH}}$ with $C_s \le C_{s\text{-}max}$
		S - S	8	$C_s = C_{s\text{-}max}$

(1) σ_L is to be considered for the hogging and sagging situations.

(2) For primary supporting members located inside the considered tank and for wash bulkheads, the sloshing pressure is to be applied on both stiffener side and plate side.

(3) F - F stands for both ends of the stiffener fixed against rotation
F - S stands for one end of the stiffener fixed and the other not fixed against rotation
S - S stands for both ends of the stiffener not fixed against rotation.

(4) See Tab 4 for definition of β_s, α_s and $C_{s\text{-}max}$.

Table 4 : Definition of β_s , α_s and $C_{s\text{-}max}$

Acceptance criteria set	Structural member		β_s	α_s	Cs-max
AC-1	Longitudinal strength members in the cargo hold region including, but not limited to: • deck stiffeners • stiffeners on longitudinal bulkheads • stiffeners on longitudinal girders and stringers	Longitudinal stiffeners	0,85	1,0	0,75
		Transverse or vertical stiffeners	0,70	0	0,70
	Other strength members including: • stiffeners on transverse bulkheads • stiffeners on transverse stringers and web frames • stiffeners on tank boundaries and primary supporting members		0,75	0	0,75

2.3.3 Tripping brackets supporting primary supporting members

The net section modulus Z, in cm^3, in way of the base within the effective length d of tripping brackets, and the net shear sectional area A_{shr}, in cm^2, after deduction of cut-outs and slots, of the tripping brackets supporting primary supporting members are not to be less than:

$$Z = \frac{1000 P_{sl} s_{trip} h_2}{2 C_s R_{eH}}$$

$$A_{shr} = 10 \frac{P_{sl} s_{trip} h}{C_t \tau_{eH}}$$

where:

P_{sl} : Sloshing pressure, in kN/m^2, calculated according to Ch 5, Sec 6, [2.2.1]. The average pressure may be calculated at mid-point of the tripping bracket, taking into account the distribution over the height of the bracket

s_{trip} : Mean spacing, in m, between tripping brackets or other primary supporting members or bulkheads

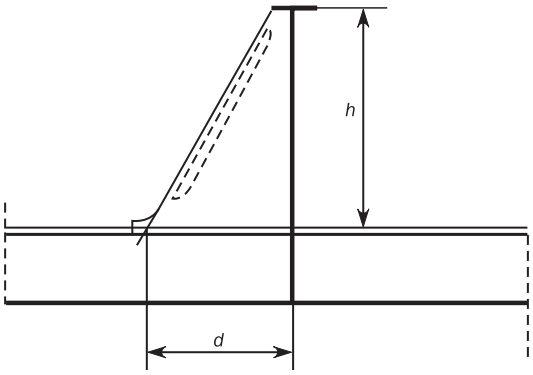
h : Height of tripping bracket, in m (see Fig 4)

C_s : Permissible bending stress coefficient for tripping brackets, to be taken as 0,75

C_t : Permissible shear stress coefficient for tripping brackets, to be taken as 0,75.

The effective breadth of the attached plate to be used for the calculation of the section modulus of the tripping bracket is to be taken as h / 3.

Figure 4 : Effective length d of tripping bracket



3 Scantling of elements subject to impact loads

3.1 Plating

3.1.1 Plate panels subject to impact loads according to [1.4] are to comply with the requirements of Ch 7, Sec 4, [4].

3.2 Ordinary stiffeners

3.2.1 Ordinary stiffeners subject to impact loads according to [1.4] are to comply with the requirements of Ch 7, Sec 5, [1.3].

3.2.2 Stiffeners partly located in the impact area

For stiffeners partly located within the application area defined in [1.4.1] and [1.4.2], the static pressure P_{S-I} and the dynamic impact pressure P_{W-I} are to be taken as follows:

- the static pressure P_{S-I} is to be considered as acting over the full span of the stiffener, and taken equal to $P_{S-I,eq}$
- the dynamic impact pressure P_{W-I} is to be considered as acting only on the portion of the stiffener span located within the application area, and taken equal to $P_{W-I,eq}$,

where

$$P_{S-I,eq} = \frac{(P_{S-1} + P_{S-2})}{2}$$

$$P_{W-I,eq} = \frac{\ell_1}{\ell} \cdot P_{W-I}$$

P_{S-1} , P_{S-2}: Static pressures, in kN/m², calculated at both ends of the stiffener span.

ℓ_1 : Portion of the stiffener span, in m, located within the application area.

3.3 Primary supporting members

3.3.1 Primary supporting members subject to impact loads according to [1.4] are to comply with the requirements of Ch 7, Sec 6, [2.3].

Section 5 Superstructures and Deckhouses

Symbols

k : Material factor, defined in Ch 4, Sec 1, [2.2] or Ch 4, Sec 1, [4.2] as applicable

P_{sd} : Lateral pressure, in kN/m^2, defined in Ch 5, Sec 5, [5.4] calculated at midpoint of stiffener span, or at the middle of the plate field.

s : Stiffener spacing, in mm

t_c : Corrosion addition, defined in Ch 4, Sec 3

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of fore, side and aft bulkheads and decks of superstructures and deckhouses.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, as amended, with regard to the strength of enclosed superstructures.

1.1.3 In addition to the requirements of this Section, structural elements of superstructures and deckhouses forming tank boundaries are to comply with the applicable requirements of Part B, Chapter 7.

1.2 Net scantlings

1.2.1 Except for the stiffeners section modulus in [3.3.1], and as specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 3, [1.2].

1.3 Definitions

1.3.1 Superstructures

Superstructures are defined in Ch 1, Sec 3.

1.3.2 Deckhouses

Deckhouses are defined in Ch 1, Sec 3.

1.3.3 Tiers of superstructures and deckhouses

Tiers of superstructures and deckhouses are defined in Ch 1, Sec 3, [2.2.10].

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when (D - T_{SC}) exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 3, Tab 5), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Fore and aft bulkheads of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case by case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of side bulkheads of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the side, fore and aft bulkheads of superstructures and deckhouses.

1.4.4 The side plating at fore and aft bulkheads of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least a 3-frame spacing.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5 B in breadth extending more than 0,15 L in length within 0,4 L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at fore and aft bulkheads of superstructures and deckhouses.

1.5.2 Strengthening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Ch 6, Sec 1, [1].

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

Unless otherwise permitted by the Society, doors open outwards to provide additional security against the impact of the sea.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Sides of deckhouses are to be strengthened in way of lifeboats and rescue boats and the top plating is to be reinforced in way of their lifting appliances.

1.5.6 Construction details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Unprotected front bulkheads of first tier superstructures or deckhouses are generally to be built of steel and not of aluminium alloy.

Aluminium alloys may be adopted for front bulkheads of superstructures or deckhouses above the first tier.

2 Superstructures side bulkheads

2.1 Plating

2.1.1 The net thickness of plating of superstructures side bulkheads is to be determined in accordance with the applicable requirements of Ch 7, Sec 4, considering the lateral pressure defined in Ch 5, Sec 5, [5.3].

2.2 Stiffeners

2.2.1 The net scantlings of stiffeners of superstructures side bulkheads are to be determined in accordance with the applicable requirements of Ch 7, Sec 5, considering the lateral pressure defined in Ch 5, Sec 5, [5.3].

2.3 Primary supporting members

2.3.1 The net scantlings of primary supporting members of superstructures side bulkheads are to be determined in accordance with the applicable requirements of Ch 7, Sec 6, using the lateral pressure defined in Ch 5, Sec 5, [5.3].

3 Fore and aft bulkheads of superstructures and deckhouses, side bulkheads of deckhouses

3.1 Application

3.1.1 Buckling

In addition to the requirements in [3.2.1] to [3.4.1], the structural members of deckhouses side bulkheads contributing to the longitudinal strength are to be check for buckling according to Ch 9, Sec 1, [3.2.2].

3.2 Plating

3.2.1 The net plating thickness of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses is to be not less than the value obtained, in mm, from the following formula:

$$t = 0{,}95 s \sqrt{k P_{sd}} \cdot 10^{-3} - t_c$$

This net thickness is to be not less than:

- the values given in Tab 1 for steel superstructures,
- the following values for aluminium superstructures:
  - 4 mm for rolled products
  - 2,5 mm for extruded products.

Table 1 : Minimum thicknesses of superstructures and deckhouses

Location	Minimum thickness, in mm
Lowest tier **(1)**	$(5 + 0{,}01\ L_3)\ k^{1/2} - t_c$
Second tier and above **(2)**	$(4 + 0{,}01\ L_4)\ k^{1/2} - t_c$
(1) L_3 : As defined in Ch 1, Sec 3, Tab 1 **(2)** L_4 : Rule length L, but not less than 100 m and not greater than 300 m	

3.3 Stiffeners

3.3.1 The gross section modulus of single span stiffeners of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses is to be not less than the value obtained, in cm^3, from the following formula:

$$Z = k \frac{P_{sd} s \ell^2}{f_{bdg} 235}$$

where:

ℓ : Span of the ordinary stiffener, in m.
For vertical stiffeners, ℓ is to be taken equal to the tweendeck height but not less than 2 m.

f_{bdg} : Coefficient depending on the stiffener end connections, and taken equal to:
- 12 for continuous horizontal stiffeners with at least one fixed end and for lower tier vertical stiffeners
- 8 for horizontal stiffeners simply supported at both ends
- value defined in Tab 2 for vertical stiffeners of upper tiers.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below considering spacing and span.

Table 2 : Coefficient n for vertical stiffeners of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses

Coefficient f_{bdg}	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	12	14	10
Bracketed lower end	14	14	12
Sniped lower end	10	12	10

3.4 Primary supporting members

3.4.1 It is to be checked that the stress values in primary supporting members of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses, calculated using the lateral pressure P_{sd}, in kN/m^2, defined in Ch 5, Sec 5, [5.4], comply with the following criterion:

$$\sigma_{eq} \leq \frac{235}{k}$$

where:

σ_{eq} : equivalent Von Mises stress, in N/mm²:

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

4 Decks

4.1 Plating

4.1.1 The net thickness of decks plating is to be determined in accordance with the applicable requirements of Ch 7, Sec 4, considering the loads defined in Ch 5, Sec 5, [3] or in Ch 5, Sec 6, [6] as applicable.

4.1.2 For decks sheathed with wood, the net thickness obtained from [4.1.1] may be reduced by 10 percent.

4.2 Stiffeners

4.2.1 The net scantlings of decks ordinary stiffeners are to be determined in accordance with the applicable requirements of Ch 7, Sec 5, considering the loads defined in Ch 5, Sec 5, [3] or in Ch 5, Sec 6, [6] as applicable.

4.3 Primary supporting members

4.3.1 The net scantlings of decks primary supporting members are to be determined in accordance with the applicable requirements of Ch 7, Sec 6, considering the loads defined in Ch 5, Sec 5, [3] or in Ch 5, Sec 6, [6] as applicable.

5 Additional requirements applicable to movable wheelhouses

5.1 General

5.1.1 The requirements of this Article apply in addition of those in [1] to [4].

5.1.2 The structures of movable wheelhouses are to be checked in low and in high position.

5.1.3 Mechanical locking devices are to be fitted in addition to hydraulic systems.

5.2 Supports and guides, connections with the deck, under deck reinforcements, locking devices

5.2.1 Still water and inertial forces

The supports or guides of movable wheelhouses, connections with the deck, under deck reinforcements and locking devices are to be checked considering the sum of the following forces:

- still water and inertial forces, determined according to Ch 5, Sec 6, [6.2]
- wind forces, corresponding to a lateral pressure of 1,2kN/m².

5.2.2 Checking criteria

It is to be checked that the calculated stress values comply with the following criterion:

$$\sigma_{eq} \leq \frac{235}{k\gamma_R\gamma_m}$$

where:

σ_{eq} : equivalent Von Mises stress, in N/mm²:

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

γ_R : Partial safety factor covering uncertainties regarding resistance, to be taken equal to:

- 1,10 in general
- 1,40 for checking locking devices

γ_m : Partial safety factor covering uncertainties regarding material, to be taken equal to 1,02.

Section 6 Bow Doors and Inner Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

The requirements apply to ships engaged on international voyages and also to ships engaged only in domestic (non international) voyages, except where specifically indicated otherwise in this Section.

1.1.2 Two types of bow door are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case by case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1.1.2], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per.

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [3.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 The design loads to be considered for the scantlings of bow doors are defined in Ch 5, Sec 5, [7.1].

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m^2, from the following formulae:

$p_E = 0,45\ L_1$

$p_E = 10\ h$

where:

h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_I to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m^2.

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship's structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Ch 11, Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 11, Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in Ch 5, Sec 5, [7.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

Members are to be considered to have simply supported end connections.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct strength calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Ch 11, Sec 11.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7] and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_Y, defined in Ch 5, Sec 5, [7.1.3], is in compliance with the following formula:

$M_Y > 0$

Moreover, the closing moment M_Y is to be not less than the value M_{Y0}, in kN.m, obtained from the following formula:

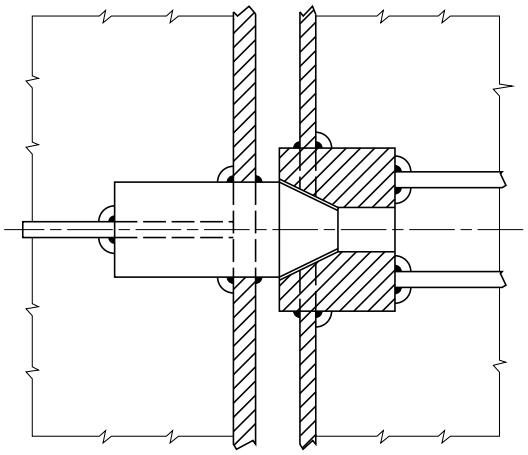
$$M_{Y0} = 10Wc + 0,1\sqrt{a^2 + b^2}\sqrt{F_X^2 + F_Z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 1).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 1 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X and F_Z
- Case 2: $0,7F_Y$ acting on each side separately together with $0,7F_X$ and $0,7F_Z$,

where F_X, F_Y and F_Z are to be calculated as indicated in Ch 5, Sec 5, [7.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X, F_Y and F_Z acting on both doors
- Case 2: $0,7F_X$ and $0,7F_Z$ acting on both doors and $0,7F_Y$ acting on each door separately,

where F_X, F_Y and F_Z are to be calculated as indicated in Ch 5, Sec 5, [7.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2] and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_X.

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula: $M_0 = 10\ W\ d + 5\ A_X\ a$

where:

d : Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Ch 5, Sec 5, Fig 6

a : Vertical distance, in m, defined in Ch 5, Sec 5, [7.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force ($F_Z - 10\ W$), in kN, within the allowable stresses defined in [6.1.1].

5.2.9 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

6 Strength criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \leq \sigma_{ALL}$

$\tau \leq \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \leq \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm^2, equal to: $\sigma_{ALL} = 120/k$

τ_{ALL} : Allowable shear stress, in N/mm^2, equal to: $\tau_{ALL} = 80/k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2, equal to: $\sigma_{VM,ALL} = 150/k$

k : Material factor, defined in Ch 4, Sec 1, [2.2], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 9, Sec 1.

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula: $\sigma_B \leq 0,8\ R_{e,HB}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

F : Design force, in kN, defined in Ch 5, Sec 5, [7.1.2]

A_B : Projected bearing area, in cm^2

$R_{e,HB}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula: $\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2, equal to: $\sigma_{T,ALL} = 125/k$

k : Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system for operating and closing doors is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply, e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.3 The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that an audible alarm is given on the navigation bridge if the ship leaves harbour with the bow door or the inner door not closed or with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of the doors and a sufficient number of their securing devices.

Special consideration is to be given for the lighting and contrasting colour of the objects under surveillance.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests required in Part D, Chapter 1 and/or Part D, Chapter 12.

7.2.7 A drainage system is to be arranged in the area between bow door and ramp or, where no ramp is fitted, between the bow door and the inner door.

The system is to be equipped with an audible alarm function to the navigation bridge being set off when the water levels in these areas exceed 0,5 m or the high water level alarm, whichever is lesser.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)

- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.8 For ro-ro passenger ships on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions or unauthorized access by passengers thereto, can be detected whilst the ship is underway.

8 Operating and Maintenance Manual

8.1 General

8.1.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain the necessary information on:

a) Main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer's recommended testing for equipment
   - description of equipment:
     - bow doors
     - inner bow doors
     - bow ramp/doors
     - central power pack
     - bridge panel
     - engine control room panel

b) Service conditions:
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - doors/ramps operating instructions
   - doors/ramps emergency operating instructions

c) Maintenance:
   - schedule and extent of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer's maintenance procedures

d) Register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance/rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

Section 7 Side Doors and Stern Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors located abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

The requirements apply to ships assigned with the service notation **ro-ro passenger ship** or **ro-ro cargo ship** engaged on international voyages and also in domestic (non-international) voyages, except where specifically indicated otherwise in this section.

Shell doors not covered by this Section are dealt with in Ch 11, Sec 8.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1.1.2], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case by case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 The design loads to be considered for the scantlings of side and stern doors are defined in Ch 5, Sec 5, [7.2].

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 4, for side plating, using the door stiffener spacing. It is in no case to be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Ch 11, Sec 11.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 5, for the side, using the door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Ch 11, Sec 11.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct strength calculations on the basis of the design forces in [2] and the strength criteria in Ch 11, Sec 6, [6.1.1] and Ch 11, Sec 6, [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

Members are to be considered to have simply supported end connections.

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [5.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [5.1.1] for normal or damaged conditions.

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \leq \sigma_{ALL}$

$\tau \leq \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \leq \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm^2: $\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm^2: $\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2: $\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.2], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

In case of damaged ship conditions assessment, the above allowable stresses are to be increased by 20%.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 9, Sec 1.

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula: $\sigma_B \leq 0,8\ R_{eH,B}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

with:

F : Design force, in KN, defined in Ch 5, Sec 5, [7.2.1]

A_B : Projected bearing area, in cm^2

$R_{eH,B}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula: $\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2: $\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in Ch 11, Sec 6, [6.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

6.2 Systems for indication / monitoring

6.2.1 The following requirements apply to doors in the boundary of special category spaces or ro-ro spaces, as defined in Pt D, Ch 12, Sec 2, [1.1], through which such spaces may be flooded.

For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than $6m^2$, then the requirements of this sub-article need not be applied.

6.2.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

6.2.3 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a backup power supply from the emergency source of power or secure power supply, e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

Note 1: See Ch 11, Sec 6, [7.2.2] for fail safe principal design.

6.2.4 The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that audible alarm is given on the navigation bridge if the ship leaves harbour with any side shell or stern door not closed or with any of the securing devices not in the correct position.

6.2.5 For passenger ships, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

For cargo ships, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

6.2.6 For ro-ro passenger ships, on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions and unauthorized access by passengers thereto, can be detected whilst the ship is underway.

7 Operating and Maintenance Manual

7.1 General

7.1.1 An Operating and Maintenance Manual for the side doors and stern doors is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
- special safety precautions
- details of ship
- equipment and design loading (for ramps)
- key plan of equipment (doors and ramps)
- manufacturer’s recommended testing for equipment
- description of equipment:
  - side doors
  - stern doors
  - central power pack
  - bridge panel
  - engine control room panel

b) service conditions:
- limiting heel and trim of ship for loading / unloading
- limiting heel and trim for door operations
- doors / ramps operating instructions
- doors / ramps emergency operating instructions

c) maintenance:
- schedule and extend of maintenance
- trouble shooting and acceptable clearances
- manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

Section 8 Watertight and Weathertight Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling of shell doors not covered by Ch 11, Sec 7 and doors in bulkheads that are required to be watertight or weathertight.

1.2 Definitions

1.2.1 Watertightness

The various degrees of watertightness are defined in NR 467 Ch 3, Sec 3, [3.3.2].

1.2.2 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges, or from sliding open.

1.2.3 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.2.4 Locking device

A locking device is a device locking the securing device in the closed position.

2 Design loads

2.1 General

2.1.1 Doors are to be designed to offer equivalent strength compared to the adjacent bulkhead in which they are fitted. Therefore, they are to be assessed considering the same design loads, as per the examples given in the following requirements.

2.2 Side shell doors

2.2.1 Doors fitted in side shell are to be checked with the outside sea pressures defined in Ch 5, Sec 5, and whenever relevant, with the internal flooding pressure defined in Ch 5, Sec 6, [1.4].

2.3 Internal bulkheads doors

2.3.1 Doors fitted in watertight bulkheads are to be checked with the flooding pressures defined in Ch 5, Sec 6, [1.4], for spaces on both sides of the bulkhead.

2.4 Superstructure doors

2.4.1 Doors fitted in superstructure walls are to be checked with the loads defined in Ch 5, Sec 5, [5].

3 Door leaf scantling

3.1 Plating

3.1.1 The net thickness of watertight and weathertight doors is to be not less than that calculated according to Ch 7, Sec 4 or to Ch 11, Sec 5, [2.1] or Ch 11, Sec 5, [3.2], as relevant.

3.2 Stiffeners

3.2.1 The net scantling of doors stiffeners is to be not less than that calculated according to Ch 7, Sec 5 or to Ch 11, Sec 5, [2.2] or Ch 11, Sec 5, [3.3], as relevant, considering that doors stiffeners are generally to be considered as simply supported at ends instead of clamped.

3.3 Glass

3.3.1 If permitted, when glazing is fitted in the door leaf, its thickness is to be in line with the requirements of Ch 11, Sec 12, [3.3].

4 Securing and supporting

4.1 General

4.1.1 Doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

In order to prevent damage to the packing material, the edges of the part of the door frame in contact with the seal should be rounded or chamfered.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2].

The number and distribution of securing and supporting devices is to be set to achieve the scantling criteria in [4.2] and the required degree of watertightness.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can comply with the checking criteria defined in Ch 7, Sec 6, [5.1.4] for primary members, using AC-2 or AC-3 acceptance criteria as relevant.

4.2.2 In addition to the requirements in [4.2.1], every element transmitting loads by means of direct contact must be checked against bearing. In that respect, the maximum normal compressive stress σ_c distributed over the contact area between the two elements is not to be higher than R_{eH}.

4.2.3 The distribution of the reaction forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the hull structure, the actual position of the supports and the design load pattern. In case of homogeneously distributed supports and uniform design pressure, the total force acting on the door may be considered as evenly divided amongst the supports.

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Inspection and testing

5.1 General

5.1.1 Watertight and semi-watertight doors which become immersed by an equilibrium or intermediate waterplane are to be subjected to a hydrostatic pressure test.

5.1.2 For large doors of more than 6 m^2 intended for use in the watertight subdivision boundaries of cargo spaces, structural analysis may be accepted in lieu of pressure testing. Where such doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis, is to be carried out.

5.1.3 Watertight doors above the freeboard or bulkhead deck which are not immersed by an equilibrium or intermediate waterplane but become intermittently immersed at angles of heel in the required range of positive stability beyond the equilibrium position may be only hose tested (required only to be weathertight according to Ch 3, Sec 3, [3.3.2].

5.2 Hydrostatic pressure testing

5.2.1 The head of water used for the pressure test shall correspond at least to the head measured from the lower edge of the door opening, at the location in which the door is to be fitted in the vessel, to the bulkhead deck or freeboard deck, as applicable, or to the most unfavourable damage waterplane, if that be greater. Testing may be carried out at the factory or other shore based testing facility prior to installation in the ship. The duration of the test is to be at least 30 min.

5.2.2 For cargo ships not covered by damage stability requirements, watertight doors are to be tested by water pressure to a head of water measured from the lower edge of the opening to one meter above the freeboard deck.

5.2.3 Leakage criteria for watertight doors

The following acceptable leakage criteria should apply:

- doors with gaskets: no leakage
- doors with metallic sealing: max leakage 1 litre/min.

Limited leakage may be accepted for pressure tests on large doors located in cargo spaces employing gasket seals or guillotine doors located in conveyor tunnels, in accordance with the following value, in litre/min:

$$\frac{(P + 4{,}572) \times h^3}{6568}$$

where:

P : Perimeter of door opening (m)

h : Test head of water (m).

However, in the case of doors where the water head taken for the determination of the scantling does not exceed 6,10 m, the leakage rate may be taken equal to 0,375 litre/min if this value is greater than that calculated by the above-mentioned formula.

5.2.4 Leakage criteria for semi-watertight doors

A leakage quantity of approximately 100 l/hour is to be considered as being acceptable for a 1,35 m^2 opening.

5.2.5 For doors on passenger ships which are used at sea or which become submerged by the equilibrium or intermediate waterplane, a prototype test shall be conducted, on each side of the door, to check the satisfactory closing of the door against a force equivalent to a water height of at least 1m above the sill on the centre line of the door.

5.3 Hose testing

5.3.1 All watertight, semi-watertight and weathertight doors shall be subject to a hose test after installation in a ship. Hose testing is to be carried out:

- from both sides of a watertight or semi-watertight door unless, for a specific application, exposure to floodwater is anticipated only from one side
- from both sides of internal bulkheads weathertight doors (fitted above bulkhead deck)
- from the exposed side of external weathertight doors (superstructures).

Where a hose test is not practicable because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by means such as an ultrasonic leak test or an equivalent test.

6 Type approval procedure

6.1 General

6.1.1 Type approval certificates of doors may be issued to applicant manufacturers to certify that the design of the door has been assessed against a given strength level.

6.1.2 The documents and information listed in [6.2.1] must allow for the door strength to be checked against the applied design load.

6.1.3 In case a type approved door is fitted onboard a vessel, the hull supporting structure in way of the door is to be checked to have adequate strength according to [4].

6.1.4 A type approved door fitted onboard a vessel is to be selected to have a design load at least equivalent to the adjacent bulkhead in which it is fitted.

6.2 Documents and information to be submitted

6.2.1 Prior to issuance of type approval certificate, the following documents and information must be submitted to the Society for review, for each door model and variant:

- maximum considered design load
- tightness level (weathertight, semi-watertight or watertight)
- door dimensions
- structural drawings of the door, including securing devices
- material and mechanical properties of each part of the door
- test and inspection procedure (if relevant, see [6.3]).

6.3 Prototype test

6.3.1 *Where testing of individual doors is not carried out because of possible damage to insulation or outfitting items, testing of individual doors may be replaced by a prototype pressure test of each type and size of door with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the door is fitted. The installation method and procedure for fitting the door on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the bulkhead, the frame and the door.*

The corresponding test reports are to be annexed to the type approval certificate.

6.3.2 In such a case, the test procedure is to be submitted to the Society for review and is to be in line with the relevant requirements in [5].

Section 9 Large Hatch Covers

Symbols

For symbols not defined in this section, refer to Ch 1, Sec 3.

A_{shr} : Net shear sectional area, in cm^2, of the stiffener or primary supporting member

b_p : Effective breadth, in mm, of the plating attached to the stiffener or primary supporting member, as defined in [3]

f_{bc} : Boundary coefficient for stiffeners and primary supporting members, taken equal to:

$f_{bc} = 8$, in the case of stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end

$f_{bc} = 12$, in the case of stiffeners and primary supporting members clamped at both ends

k_ℓ : Material coefficient, taken equal to:

$$k_\ell = \left(\frac{235}{R_{eH}}\right)^{\alpha}$$

where:

α : Coefficient taken equal to:

- for $R_{eH} > 235$ N/mm^2:

  $\alpha = 0,75$

- for $R_{eH} \leq 235$ N/mm^2:

  $\alpha = 1,0$

R_{eH} may not be taken greater than $0,7\ R_m$

P_C : Pressure acting on the hatch coaming, in kN/m^2, as defined in [6.2]

P_S : Still water pressure, in kN/m^2, as defined in [4.1]

P_W : Wave pressure, in kN/m^2, as defined in [4.1]

t_c : Total corrosion addition, in mm, as defined in [1.5]

σ_a, τ_a : Allowable stresses, in N/mm^2, as defined in [1.6].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to large cargo hatch covers and coamings on weather decks, as defined in Ch 1, Sec 3, [2.4].

1.2 Definitions

1.2.1 Large hatches

Large hatches are hatches with openings greater than 2,5 m^2.

1.2.2 ICLL

Where ICLL is referred to in the text, this is to be taken as the International Convention on Load Lines, 1966 as amended by the 1988 protocol, as amended in 2003.

1.2.3 Single skin cover

A hatch cover made of steel or equivalent material which has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is weathertight and fitted with gaskets and clamping devices unless such fittings are specifically excluded.

1.2.4 Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

1.2.5 Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices.

1.3 Materials

1.3.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

The materials used for construction of the steel large hatch covers, stoppers, securing devices and their weldings are to comply with the applicable requirements of Ch 4, Sec 1 and Part B, Chapter 13 respectively.

Specifications of the materials are to be shown in the drawings of the hatch covers.

1.3.2 Other materials

The use of materials other than steel is to be considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.4 Net scantlings

1.4.1 Corrosion additions for steel other than stainless steel

All scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

The corrosion additions are given in [1.5].

1.4.2 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_C is to be taken equal to 0.

1.5 Corrosion additions

1.5.1 The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in Tab 1.

1.6 Allowable stresses

1.6.1 The allowable stresses σ_a , in N/mm^2, is to be obtained from Tab 2.

The allowable buckling utilisation factors are given in Tab 3:

Table 1 : Corrosion additions t_c for hatch covers and hatch coamings

Application	Structure	t_C , in mm
Weather deck hatches of container ships, car carriers, paper carriers, passenger ships	Hatch covers	1,0
	Hatch coamings (including stays and stiffeners)	1,5
Hatch covers of ships having the service notation **bulk carrier**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**	Plating and stiffeners of single skin hatch cover	2,0
	Top and bottom plating of double skin hatch cover	2,0
	Internal structures of double skin hatch cover	1,5
Weather deck hatches of all other ship types covered by this Section	Hatch covers in general	2,0
	Weather exposed plating and bottom plating of double skin hatch covers	1,5
	Internal structure of double skin hatch covers and closed box girders	1,0
	Hatch coamings (including stays and stiffeners)	1,5

Table 2 : Allowable stresses

Members of	Subjected to	σ_a, in N/mm^2
Weathertight hatch cover	External pressure, as defined in [4.1.2]	0,80 R_{eH}
Weathertight hatch cover	Other loads, as defined in [4.1.4] to [4.1.8]	0,90 R_{eH} for load categories: S+D 0,72 R_{eH} for load categories: S

Table 3 : Allowable buckling utilisation factors

Structural component	Subject to	η_{all}, Allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in [4.1.2]	0,80 for load categories: S+D
	Other loads, as defined in [4.1.4] to [4.1.8]	0,90 for load categories: S+D 0,72 for load categories: S

2 Arrangements

2.1 Height of hatch coamings

2.1.1 The height of hatch coamings is not to be less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2 The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

2.2 Hatch covers

2.2.1 The stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.2 The spacing of primary supporting members parallel to the direction of stiffeners is not to be greater than 1/3 of the span of primary supporting members.

2.2.3 The breadth of the primary supporting member face plate is not to be less than 40% of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.

The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.2.4 Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.2.5 The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1 Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

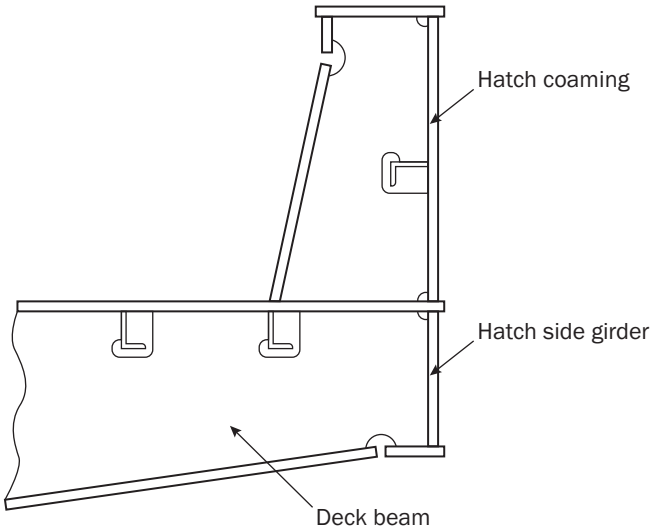
2.3.2 Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3 Longitudinal coamings are to be vertically extended at least to the lower edge of deck beams or hatch side girders below deck are to be fitted in line with longitudinal coamings. Extended coaming plates are to be flanged or fitted with face bars or half-round bars at the level of lower edge of the deck beams (see Fig 1).

- where they are not part of continuous deck girders, the lower edge of longitudinal coamings including below deck structure as an extension measure above are to extend for at least two frame spaces beyond the end of the hatch openings.
- where they are part of continuous deck girders, their scantlings are to be as required in Ch 7, Sec 6 and Ch 9, Sec 1.

2.3.4 A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

Figure 1 : Example of extension to lower edge of deck beams of longitudinal coaming by fitting a hatch side girder



3 Width of Attached Plating

3.1 Stiffeners

3.1.1 The width of the attached plating b_p, in mm, to be considered for the check of stiffeners is to be taken as:

- where the attached plating extends on both sides of the stiffener:

  $b_p = s$

- where the attached plating extends on one side of the stiffener:

  $b_p = 0,5\ s$

4 Load Model

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are given in [4.1.2] to [4.1.8]. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the green sea loads defined in [4.1.2] and [4.1.3] are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, or when the covered hold is intended to be loaded with ballast or liquid cargo, the pressures and forces defined in [4.1.4] to [4.1.8] are to be considered independently from the sea pressures.

4.1.2 Vertical weather design load

The vertical weather design load acting on exposed hatch covers is to be considered and is defined in Ch 5, Sec 5, [6.2.1].

4.1.3 Horizontal weather design load

The horizontal weather design load acting on coamings of exposed hatches is to be considered and taken as given in Tab 4.

4.1.4 Internal pressures due to ballast water or liquid cargo

If applicable, the internal static and dynamic lateral pressures due to ballast water or liquid cargo are to be considered and are defined in Ch 5, Sec 6, [1].

Table 4 : Horizontal weather loads

Application		P_A, in kN/m²
Ships having the service notation **bulk carrier**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**	Most forward transverse coaming of ships not fitted with a forecastle according to Pt D, Ch 4, Sec 2, [2]; Pt D, Ch 5, Sec 2, [3] and Pt D, Ch 6, Sec 2, [1] depending on the service notation.	290
	All other coamings	220
All other ship types covered by this Section		as defined in Ch 5, Sec 5, [6.2.2]

4.1.5 Pressures due to uniform or unit cargoes

If applicable, the static and dynamic pressures or forces due to uniform or unit cargoes are to be considered and are defined in Ch 5, Sec 6, [6].

4.1.6 Forces due to wheeled cargo

If applicable, the static and dynamic forces due to wheeled cargo are to be considered and are defined in Ch 5, Sec 6, [7].

4.1.7 Pressures or forces due to special cargoes

In the case of carriage of special cargoes (e.g. pipes, etc) on the hatch covers which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case-by-case basis.

4.1.8 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be considered and are defined in Ch 5, Sec 6, [9.2].

4.1.9 Self weight

The effect of the hatch cover structure weight is to be included in the static loads but not in the dynamic loads.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- Longitudinally, at the hatch cover mid-length.
- Transversely, on the longitudinal plane of symmetry of the ship.
- Vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated at the level of the tight boundary of the cover:

- In way of the geometrical centre of gravity of the plate panel, for plating.
- At mid-span, for stiffeners and primary supporting members.

5 Strength Check

5.1 General

5.1.1 Finite element analysis

In all cases, the stresses in the primary supporting members are to be determined by a finite element analysis and are to comply with the criteria in [5.4.4].

The hatch cover geometry shall be idealized as realistically as possible in the FE model, with elements not larger than stiffener spacing. In way of force transfer points and cutouts, the mesh is to be refined where applicable. The ratio of element length to width is not to exceed 3.

The element size along the height of webs of primary supporting member is not to exceed one-third of the web height. Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements or shell/plate elements. Anti-buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Fig 2 are to be assessed by means of FE analysis. The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

Wherever applicable the following boundary conditions are to be applied to the FE model:

- Boundary nodes in way of a bearing pad on the hatch coamings are to be fixed against displacement in the direction perpendicular to the pad.
- Lifting stoppers are to be fixed against displacements in the direction determined by the stoppers.
- For a folding type hatch cover, the FE nodes connected through a hinge are to have the same translational displacement in the direction perpendicular to the hatch cover top plating.

5.1.2 Hatch covers supporting containers

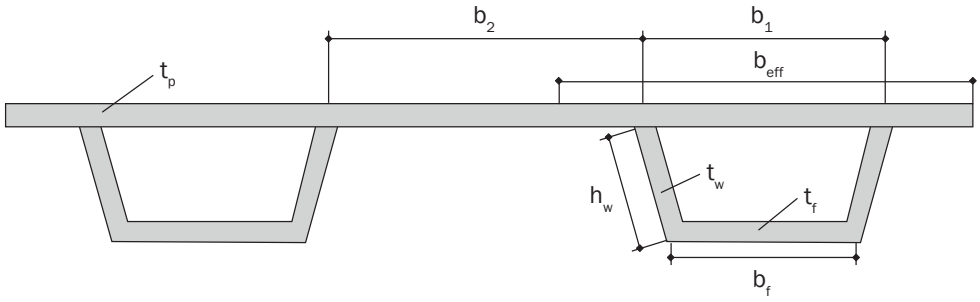
The scantlings of hatch covers supporting containers are to comply with the applicable requirements of the Society.

5.1.3 Hatch covers supporting wheel loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with the applicable requirements of:

- Ch 7, Sec 4, for plating
- Ch 7, Sec 5, or by direct calculations under consideration of the permissible stresses given in [5.4.4], for ordinary stiffeners
- Ch 7, Sec 6, for primary supporting members.

Figure 2 : Example of hatch cover fitted with U type stiffener



5.1.4 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in [5.4.4].

5.2 Plating

5.2.1 Net thickness

The net thickness, in mm, of steel hatch cover top plating is not to be taken less than:

$$t = 0,0158 F_p b \sqrt{\frac{F_s P_s + F_W P_W}{0,95 R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

- in general:

  $F_p = 1,5$

- for the attached plating of primary supporting members and for $\sigma \geq 0,8\ \sigma_a$:

  $$F_p = 1,9 \frac{\sigma}{\sigma_a}$$

σ : Normal stress, in N/mm^2, in the attached plating of primary supporting members, determined through a finite element analysis.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of the plating forming the top of the hatch cover is not to be taken less than the greater of the following values:

$$t = \frac{b}{100}$$

$t = 6$

5.2.3 Lower plating of double skin hatch covers and box girders

The thickness to fulfil the strength requirements is to be obtained from the calculations according to [5.4].

When the lower plating is taken into account as a strength member of the hatch cover, its net thickness, in mm, is not to be less than 5 mm.

When project cargo is intended to be carried on a hatch cover, the net thickness must not be less than: $t = 6,5\ s$

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is to be determined according to Ch 7, Sec 4.

Note 1: Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that can be considered as uniformly distributed over the hatch cover, e.g., timber, pipes or steel coils need not to be considered as project cargo.

5.3 Stiffeners

5.3.1 Stiffeners are to comply with the applicable slenderness and proportion requirements given in Ch 9, Sec 1.

5.3.2 Minimum net thickness of web

The net thickness, in mm, of the stiffener web is to be taken not less than 4 mm.

5.3.3 Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{shr}, in cm^2, of a stiffener subject to lateral pressure are to be taken not less than given by the following formulae:

$$Z = \frac{(F_S\ P_S + F_W\ P_W)\ s \cdot \ell_s^2}{f_{bc}\ \sigma_a}$$

$$A_{shr} = \frac{5(F_S\ P_S + F_W\ P_W)\ s\ \ell_s}{\tau_a} 10^{-3}$$

where:

ℓ_s : Stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.4 Primary supporting members

5.4.1 Application

Primary supporting members are to be checked by Finite Element analysis using the checking criteria in [5.4.4].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is not to be less than the greater of:

$t = 6{,}5\ s\ 10^{-3}$

$t = 5$

5.4.3 Edge girders (skirt plates)

Scantlings of edge girders are obtained from the calculations according to [5.4] under consideration of the permissible stresses defined in [1.6].

The net thickness, in mm, of the outer edge girders exposed to wash of sea is not to be less than the greatest of:

$$t = 15{,}8\ b \sqrt{\frac{p_A}{0{,}95 R_{eH}}}$$

$t = 8{,}5\ s\ 10^{-3}$

$t_{min} = 5$

where:

p_A : Horizontal pressure, in kN/m^2, as defined in Ch 5, Sec 5, [6.2.2].

The stiffness of edge girders is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia I, in cm^4, of edge girders is not to be less than:

$$I = 6 q s_{SD}^4$$

where:

q : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

s_{SD} : Spacing, in m, of securing devices.

5.4.4 Checking criteria

The Von Mises stress σ_{vm} determined through a finite element analysis, is to comply with the following formulae:

- For shell elements in general:

  $\sigma_{vm} \leq \sigma_a$

- For rod or beam elements in general:

  $\sigma_{axial} \leq \sigma_a$

where:

σ_{vm} : Von Mises stress, in N/mm^2, to be taken as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where indices x and y are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element, and:

σ_x : Normal stress, in N/mm^2, in x direction

σ_y : Normal stress, in N/mm^2, in y direction

τ_{xy} : Shear stress, in N/mm^2, in the x-y plane

σ_a : Allowable stress as defined in [1.6]

σ_{axial} : Axial stress in rod or beam elements, in N/mm^2

In case of finite element (FE) calculations using shell (or plate) elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges shall not exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

5.4.5 Deflection limit

The net moment of inertia of a primary supporting member, when loaded by sea pressure, excluding the self-weight of the structure, is to be such that the deflection does not exceed $\mu\ \ell_{max}$.

where:

μ : Coefficient taken equal to: $\mu = 0{,}0056$ for weathertight hatch covers.

ℓ_{max} : Greatest span, in m, of primary supporting members.

5.5 Buckling

5.5.1 Application

The buckling check of all hatch cover structures, including plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of NR615 "Buckling Assessment of Plated Structures", taking into account, in addition, the requirements of this sub-article, and considering the allowable buckling utilisation factors defined in [1.6].

5.5.2 Slenderness requirements

The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3,0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

6 Hatch Coamings

6.1 Stiffening

6.1.1 The stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2 Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

6.1.3 Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

6.1.4 When two hatches are close to each other, under deck stiffeners are to be fitted to connect the longitudinal coamings in order to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5 Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1 The wave lateral pressure, P_A in kN/m^2, to be considered as acting on the hatch coamings is defined in [4.1.3].

6.2.2 For cargo holds intended for the carriage of ballast water, the liquid internal pressures applied on hatch coaming is also to be determined according to Ch 5, Sec 6.

6.3 Scantlings

6.3.1 Plating

The net thickness, in mm, of the hatch coaming plate is not to be taken less than the greater value given by the following formulae:

$$t = 0,016b\sqrt{\frac{P_A}{0,95R_{eH}}}$$

$t = 9{,}5$

6.3.2 Stiffeners

The net section modulus, Z, in cm^3, of longitudinal or transverse stiffeners fitted on hatch coamings is not to be taken less than:

$$Z = 1,21 \frac{P_A \; s \; \ell^2}{f_{bc} \; c_p \; R_{eH}}$$

where:

f_{bc} : Coefficient taken equal to:

f_{bc} = 16 in general

f_{bc} = 12 for the end span of stiffeners sniped at the coaming corners

c_p : Ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to 40t, where t is the plate net thickness.

c_p = 1,16 in the absence of more precise evaluation.

6.3.3 Coaming stays

At the connection with deck, the net section modulus Z, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Fig 3) are to be taken not less than:

$$Z = \frac{s_C \; P_A \; H_C^2}{1,9 \; R_{eH}}$$

$$t_w = \frac{s_C \; P_A \; H_C}{0,5 \; h \; R_{eH}}$$

where:

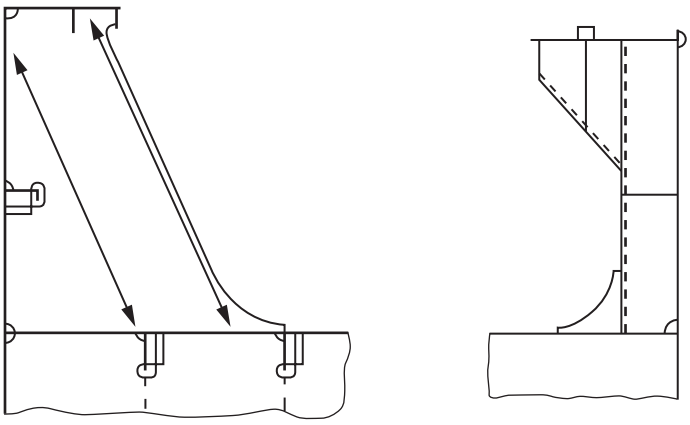
H_C : Stay height, in m

s_C : Stay spacing, in mm

h : Stay depth, in mm, at the connection with deck.

For calculating of offered section modulus of coaming stays, the face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and provided with adequate under deck structure supporting the coaming stay in the deck structure.

Figure 3 : Coaming stay (examples 1 and 2)

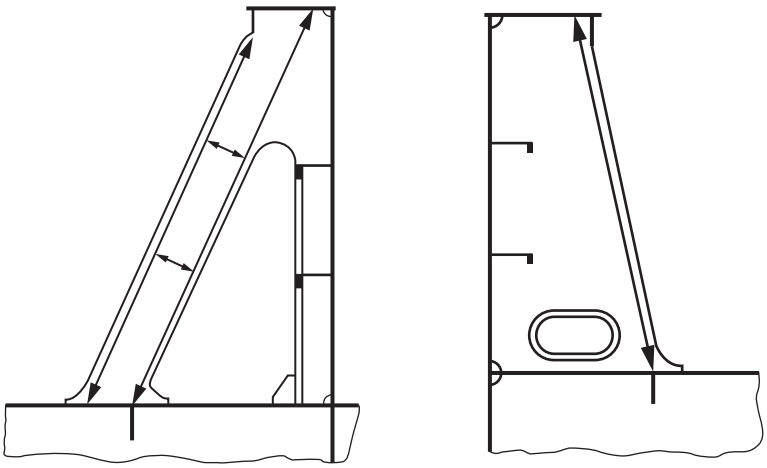


For other designs of coaming stays, such as those shown in Fig 4, the stress levels determined through a finite element analysis apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leq 0,95 \; R_{eH}$

$\tau \leq 0,5 \; R_{eH}$

Figure 4 : Coaming stay (examples 3 and 4)



6.3.4 Local details

The design of local details is to comply with the requirements in this section ensuring adequate structural continuity from the hatch covers into the supporting deck structure.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress τ, in N/mm^2, induced in the under deck structures by the loads transmitted by stays are to comply with the following formulae:

$$\sigma \leq 0,95\ R_{eH}$$

$$\tau \leq 0,5\ R_{eH}$$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements of the Society.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld leg length is not to be less than 0,62 t_w, where t_w is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with partial penetration double bevel welds extending over a distance not less than 15% of the stay width.

7 Container foundations on hatch covers

7.1 Strength requirements

7.1.1 The substructures of container foundations are to be designed for cargo and container loads according to Ch 5, Sec 6, [9.2], applying the permissible stresses according to [5.4.4].

8 Weathertightness, closing arrangement, securing devices, stoppers and supports

8.1 Weathertightness

8.1.1 Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured by means of tarpaulins.

8.1.2 In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

8.2 Gaskets

8.2.1 The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure.

8.2.2 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

8.2.3 The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

8.2.4 The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

8.2.5 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

8.2.6 Metallic contact is required to ensure earthing connection between the hatch cover and the hull structures.

8.2.7 Dispensation of weathertight gaskets

For hatch covers of cargo holds solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to [8.2.1] to [8.2.6] may be dispensed:

- the hatchway coamings are to be not less than 600 mm in height
- the exposed deck on which the hatch covers are located is situated above a depth H(x). H(x), in m, is to be shown to comply with the following criterion:

  $H(x) \geq T + f_b + h$

  where:

  f_b : Minimum required freeboard, in m, determined according to ICLL Reg.28, as amended

  h : Distance, in m, taken equal to:

  - for $x / L_{LL} \leq 0,75$: $h = 2\ h_s$
  - for $x / L_{LL} > 0,75$: $h = 3\ h_s$

  h_s : Standard height of superstructure, defined in Ch 1, Sec 3, Tab 5
- labyrinths, gutter bars or equivalent are to be fitted near the edges of each panel in way of the gaps to minimise the amount of water that can enter the container hold from the top surface of each panel
- the labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations
- the non-weathertight gaps between hatch cover panels are to be as small as possible commensurate with the capacity of the bilge system and expected water ingress, and the capacity and operational effectiveness of the fire-fighting system and, in general, not greater than 50 mm
- with regard to drainage of cargo holds and the necessary fire-fighting system, reference is made to applicable requirements in Part C, Chapter 1 and Part C, Chapter 4
- bilge alarms are to be provided in each hold fitted with non-weathertight covers
- scantlings of the hatch cover panels are to be equivalent to those for weathertight covers and in accordance with the applicable requirements of the present Section.

8.3 Closing arrangement, securing devices and stoppers

8.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced along the coamings and between cover elements.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height according to [2.1.2] are to be considered by the Society on a case-by-case basis.

8.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multi-panel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [8.3.5]. Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case by case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

8.3.3 Spacing

The spacing of the securing arrangements is not to be greater than 6 m.

8.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

8.3.5 Area of securing devices

The gross cross area of each securing device is not to be less than the value obtained, in cm^2, from the following formula:

$$A = 1,4\ S_S\ K_\ell$$

where:

S_S : Spacing, in m, of securing devices.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

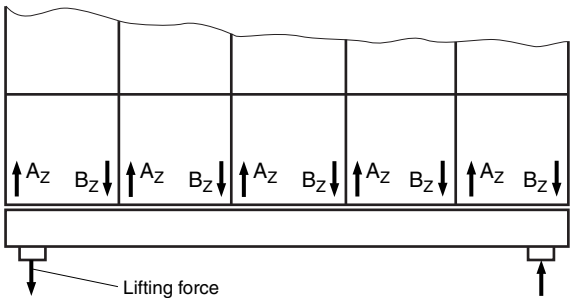
8.3.6 Anti lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to Ch 5, Sec 6, [9.2.4] (see Fig 5). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings, the equivalent stress, in N/mm^2, in the securing devices is not to exceed:

$$\sigma_v = 150/k_\ell$$

Note 1: The partial load cases given in Ch 5, Sec 6, Tab 15 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

Figure 5 : Lifting forces at a hatch cover



8.3.7 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is not to be less than the value obtained, in cm^4, from the following formula:

$$I = 6\ P_L\ S_S^4$$

where:

P_L : Packing line pressure, in N/mm, to be taken not less than 5

S_S : Spacing, in m, of securing devices.

8.3.8 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

8.3.9 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

With the exclusion of No. 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Ch 4, Sec 2, [3], Ch 5, Sec 2, [3] and Ch 6, Sec 2, [2] depending on the service notation.

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0,8 R_{eH}.

8.4 Cleats

8.4.1 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

8.4.2 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8.5 Tarpaulins

8.5.1 *Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.*

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0,65 kg/m^2 for waterproofing by tarring
- 0,60 kg/m^2 for waterproofing by chemical dressing
- 0,55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

8.6 Wedges, battens and locking bars

8.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally *to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.*

8.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

8.7 Hatch covers supports

8.7.1 Horizontal forces

For the design of hatch cover supports, the horizontal force F_h, in kN, to be considered is given by the following formula:

$F_h = m\,\alpha$

where:

α : Acceleration taken equal to:
- in longitudinal direction:
  $\alpha_X = 0,2$ g
- in transverse direction:
  $\alpha_Y = 0,5$ g

m : Sum of mass of cargo lashed on the hatch cover and mass of hatch cover, in t.

The accelerations in longitudinal and transverse direction do not need to be considered as acting simultaneously.

8.7.2 Allowable pressure

For the transmission of the support forces resulting from the load cases specified in [4] and of the horizontal mass forces specified in [8.7.1], supports are to be provided which are to be designed such that the nominal surface pressures, in N/mm^2, do not exceed in general the following values:

$p_{n\,max} = d\,p_n$

where:

d : Parameter taken equal to:
$d = 3,75 - 0,015\,L$,
to be taken not greater than $d_{max} = 3,0$ and not less than d_{min} whith:

d_{min} : Parameter defined as follows:

- in general:

  $d_{min} = 1,0$

- for partial loading conditions (see Ch 5, Sec 6, [9.2.5]):

  $d_{min} = 2,0\ f$

p_n : Permissible nominal surface pressure, in N/mm², as defined in Tab 5.

For metallic supporting surfaces not subjected to relative displacements, the nominal surface pressure, in N/mm², is to be taken equal to:

$p_{n\,max} = 3\ \pi_n$

Note 1: When the vertical hatch cover support material manufacturer can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed on a case-by-case basis, pending realistic long term distribution of spectra for vertical loads and relative horizontal motion.

Drawings of the supports are to be submitted, specifying the permitted maximum pressure given by the material manufacturer related to long time stress.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

The substructures of the supports are to be of such a design, that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h, in kN, in the longitudinal and transverse directions:

$$P_h = \mu_1 \frac{P_V}{\sqrt{d}}$$

where:

P_V : Vertical supporting force, in kN.

μ_1 : Frictional coefficient, taken equal generally to 0,5

For non-metallic, low-friction support materials on steel, μ_1 may be reduced, without being taken less than 0,35.

Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to [5.4.4] are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_h, fatigue strength may be checked.

Table 5 : Permissible nominal surface pressure p_n

Support material	p_n, in N/mm², when loaded by:	
	vertical force	horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Plastic materials on steel	50	–

9 Drainage

9.1 Arrangement

9.1.1 Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

9.1.2 Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

9.1.3 Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

9.1.4 If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

10 Testing

10.1 Initial test of watertight hatches

10.1.1 Watertight hatches are to be tested by water pressure to the maximum head of water they might sustain in a final or intermediate stage of flooding.

For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.

10.2 Prototype test

10.2.1 *Where testing of individual hatches is not carried out because of possible damage to insulation or outfitting items, testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the deck, the coaming and the hatch.*

Section 10 Small Hatches

1 General

1.1 Definition

1.1.1 Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m^2.

1.2 Application

1.2.1 The requirements in Article [2] apply to small hatch covers fitted on exposed decks.

1.2.2 The requirements in Article [3] apply to small hatch covers fitted on the exposed fore deck over the forward 0,25 L, for ships equal to or greater than 80 m in length, where the height of the exposed deck in way of the hatch is less than 0,1 L or 22 m above the summer load waterline, whichever is the lesser.

Small hatches fitted on ships assigned the service notation **container ship** and giving access to a cargo hold complying with the provisions of IACS UI LL64 are not required to be weathertight, and articles [3.3] and [3.5] need not to be complied with.

1.2.3 The requirements in Article [4] apply to small hatch covers fitted on non-exposed decks.

1.3 Materials

1.3.1 Steel

Materials used for the construction of steel small hatch covers are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 3 or Chapter 5, as applicable.

1.3.2 Other materials

The use of materials other than steel is considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

2 Small hatches fitted on exposed decks

2.1 General

2.1.1 Hatch covers on exposed decks are to be weathertight.

2.1.2 The height of small hatch coamings is to be not less than 600 mm if located in position 1, and 450 mm if located in position 2.

Where the closing appliances are secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.1.3 In any case the gross thickness of covers is to be not less than that of the adjacent plating, based on the same spacing and the same steel.

2.1.4 Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.

At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.1.5 Hatches of special design are considered by the Society on a case-by-case basis.

2.1.6 Hold access points located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to access points located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.1.7 Access points to cofferdams and ballast tanks are to be manholes-fitted with watertight covers fixed with bolts sufficiently closely spaced.

2.2 Gaskets

2.2.1 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness.

2.2.2 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

2.2.3 For non-bolted hatch covers, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. They are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

3 Small hatches fitted on the exposed fore deck

3.1 Application

3.1.1 Small hatches designed for emergency escape need not comply with the requirements in [3.4.1], items a) and b), [3.4.3] and [3.5.1].

Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

3.2 Strength

3.2.1 The gross thickness of covers is to be not less than that of the adjacent plating based on the same spacing and the same steel.

3.2.2 For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Tab 1 and Fig 1.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [3.3.1] (see also Fig 1).

Primary stiffeners are to be continuous.

All stiffeners are to be welded to the inner edge stiffener (see Fig 2).

3.2.3 The upper edge of the hatch coamings is to be suitably reinforced by an horizontal section, generally not more than 170 to 190 mm from the upper edge of the coamings.

3.2.4 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with Ch 11, Sec 9, [5].

3.2.5 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

Table 1 : Gross scantlings for small steel hatch covers on the fore deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Ordinary stiffeners
		Flat bar (mm x mm) ; number	
630 x 630	8	–	–
630 x 830	8	100 x 8 ; 1	–
830 x 630	8	100 x 8 ; 1	–
830 x 830	8	100 x 10 ; 1	–
1030 x 1030	8	120 x 12 ; 1	80 x 8 ; 2
1330 x 1330	8	150 x 12 ; 2	100 x 10 ; 2

3.3 Weathertightness

3.3.1 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal-to-metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig 1 and of a sufficient capacity to withstand the bearing force.

3.4 Primary securing devices

3.4.1 Small hatches located on exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and made weathertight by means of a mechanism employing any one of the following methods:

a) butterfly nuts tightening onto forks (clamps)

b) quick acting cleats

c) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

3.4.2 The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

3.4.3 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use by means of curving the forks upwards, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Fig 2.

3.4.4 For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas is to cause the cover to close, which means that the hinges are normally to be located on the fore edge.

3.4.5 On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

3.5 Secondary securing devices

3.5.1 Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Figure 1 : Arrangement of stiffeners

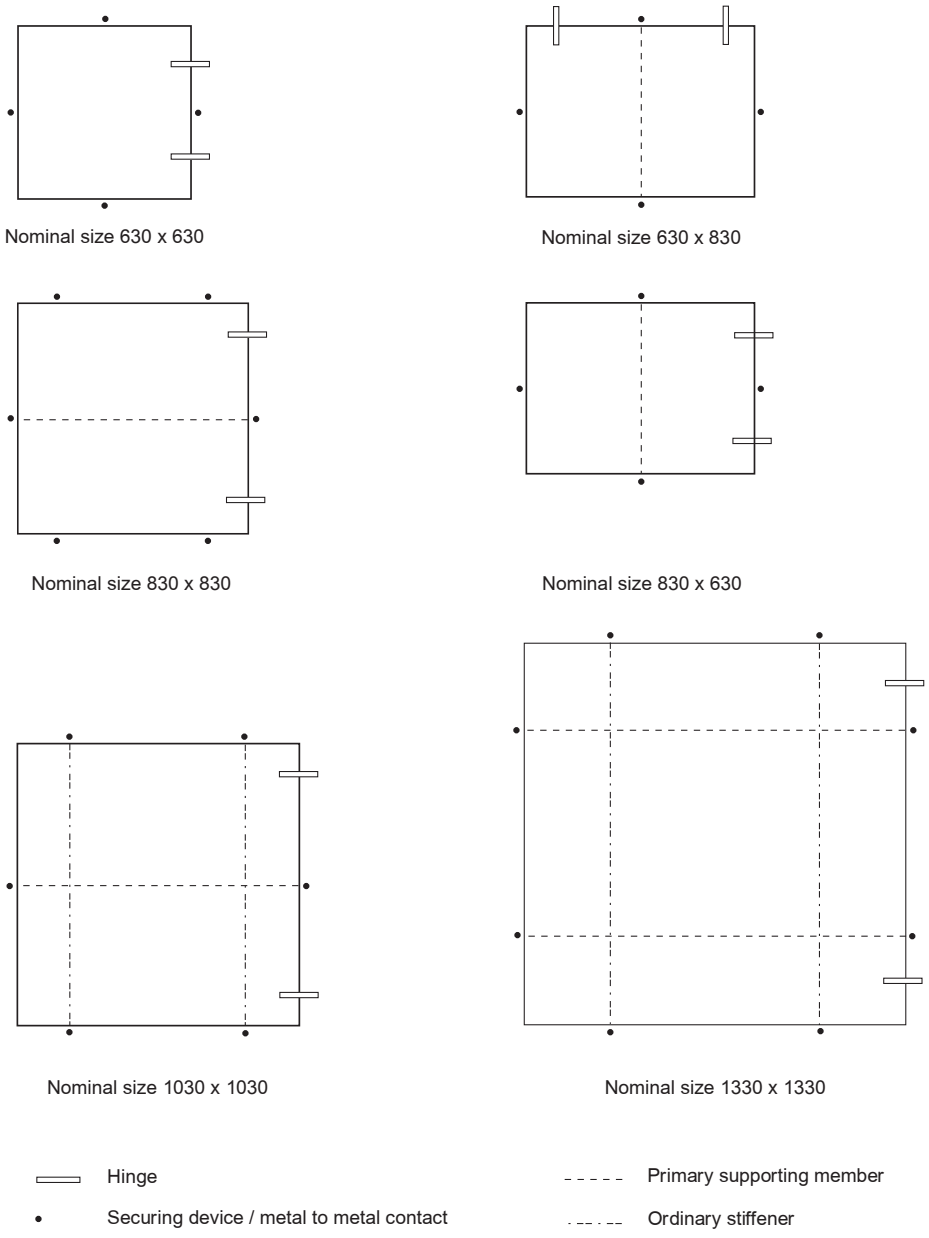
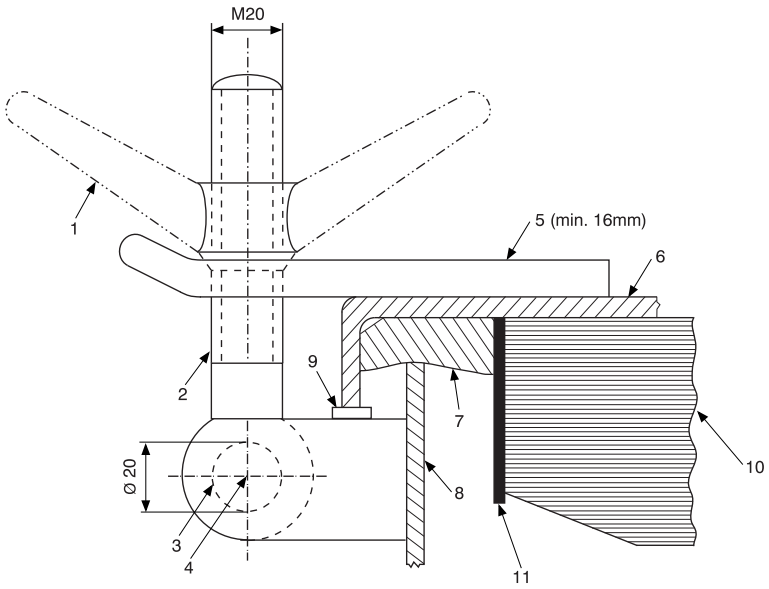


Figure 2 : Example of a primary securing method



1: Butterfly nut; 2: Bolt; 3: Pin; 4:Centre of pin; 5: Fork (clamp) plate; 6: Hatch cover; 7: Gasket; 8: Hatch coaming; 9: Bearing pad welded on the bracket of a toggle bolt for metal to metal contact; 10: Stiffener; 11: Inner edge stiffener.

4 Small hatch covers fitted on non-exposed decks

4.1 General

4.1.1 Hatch covers on non-exposed decks may not be weathertight.

4.1.2 Small hatch covers fitted on non-exposed decks are to have strength equivalent to that required for the adjacent deck (see Part B, Chapter 7).

4.1.3 Small hatch covers fitted on non-exposed decks are to have a level of tightness equivalent to that required for adjacent compartment(s).

4.1.4 If the hatch cover is weathertight or watertight and non-bolted, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. They are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

5 Testing

5.1 Initial test of watertight hatches

5.1.1 Watertight hatches are to be tested by water pressure to the maximum head of water they might sustain in a final or intermediate stage of flooding.

For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.

5.2 Prototype test

5.2.1 *Where testing of individual hatches is not carried out because of possible damage to insulation or outfitting items, testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the deck, the coaming and the hatch.*

Section 11 Movable Decks, Inner Ramps and External Ramps

1 Movable decks and inner ramps

1.1 Application

1.1.1 The requirements of this Section apply to movable decks and inner ramps when the additional class notation **ALP** is not granted and when no cargo gear register is issued.

1.1.2 On special request of the owner the movable inner ramps under load may be examined by the Society in the scope of application of additional class notation **ALP** (see Pt A, Ch 1, Sec 2, [6.12.1]).

1.2 Materials

1.2.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of NR216 Materials. Other materials of equivalent strength may be used, subject to a case by case examination by the Society.

1.3 Plating

1.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 4, [3.3], where nP_0 is not to be taken less than 5 kN.

1.4 Ordinary stiffeners

1.4.1 The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 5, [1.2].

1.5 Primary supporting members

1.5.1 General

The supporting structure of movable decks and inner ramps is to be verified through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.5.2 Loading cases

The scantlings of the supporting structure are to be verified for the design load sets DL-1 and DL-2, considering the following cases:

- loaded movable deck or inner ramp under loads according to the load distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m^2, equal to $P_1 + P_2$
- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m^2, equal to P_1

where:

$$P_1 = \frac{P_P}{A_P}$$

$$P_2 = n_V \frac{P_V}{A_P}$$

P_P : Mass of the movable deck, in kN

P_V : Mass of a vehicle, in kN

n_V : Maximum number of vehicles loaded on the movable deck

A_P : Effective area of the movable deck, in m^2.

1.5.3 Lateral pressure

The total pressure P, in kN/m^2, for both the static and the static + dynamic design load scenarios is to be derived for each dynamic load case and is to be taken as: $P = P_S + P_W$

where:

P_S, P_d : Still water and inertial pressures transmitted to the movable deck or inner ramp structures, obtained, in kN/m^2, from Tab 1.

1.5.4 Checking criteria

Combined stress σ_{VM} is to be checked in accordance with the criteria defined in Ch 7, Sec 6, [5.1.4].

1.5.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the loaded movable deck or loaded inner ramp does not exceed 5 mm/m.

1.6 Supports, suspensions and locking devices

1.6.1 Scantlings of wire suspensions are to be determined by direct calculation on the basis of the loads in [1.5.2] and [1.5.3], taking account of a safety factor at least equal to 5.

1.6.2 Combined stress σ_{VM} in rigid supports and locking devices is to be checked in accordance with the criteria defined in Ch 7, Sec 6, [5.1.4].

1.7 Tests and trials

1.7.1 Tests and trials defined in [1.7.2] to [1.7.4] are to be carried out in the presence of the Surveyor. Upon special request, these conditions of tests and trials may be modified to comply with any relevant national regulations in use.

1.7.2 The wire ropes are to be submitted to a tensile test on test-piece.

1.7.3 The loose gears used for the platform and ramp handling (chain, shackles, removable blocks, etc.) are to be indicated with a safe working load (SWL) compatible with the loads to be supported. The loose gears are to be individually tested before lifting onboard.

The test of these loose gears are to be in accordance with the applicable requirements of Rule Note NR 526, Rules for the classification of lifting appliances onboard ships and offshore units.

1.7.4 A trial to verify the correct operation of lowering and lifting devices of the platform is to be carried out before going into service.

This trial is made without overload unless special requirement of National Authorities.

2 External ramps

2.1 General

2.1.1 The external ramps are to be examined for their watertightness, if applicable.

2.1.2 The locking of external ramps in stowage position at sea is examined by the Society on a case by case basis.

2.1.3 The ship's structure under the reactions due to the ramp is examined by the Society on a case by case basis.

2.2 Plating

2.2.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 4, [3.3], where nP_0 is not to be taken less than 5 kN, and considering only the design load set DL-2 (harbour condition).

2.3 Ordinary stiffeners

2.3.1 The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 5, [1.2] considering only the design load set DL-2 (harbour condition).

2.4 Primary supporting members

2.4.1 The scantlings of ordinary stiffeners and primary supporting members are to be determined under vehicle loads in harbour condition at rest, as defined in Tab 1.

Table 1 : Still water pressure P_s and inertial pressure P_w for primary supporting members of movable decks and ramps

Ship condition	Item	Design load set	Acceptance criteria	P_S and P_W, in kN/m²
Seagoing conditions	• Movable decks • Inner ramps	DL-1	AC-2	$P_S = P_1 + P_2$ $P_{W,X} = \frac{a_X}{g}(P_1 + P_2)$ for x direction $P_{W,Y} = \frac{a_Y}{g}(P_1 + P_2)$ for y direction $P_{W,Z} = \frac{a_Z}{g}(P_1 + \alpha P_2)$ for z direction
Harbour condition during lifting **(1)**	• Movable decks • Inner ramps	DL-2	AC-1	$P_S = P_1$
Harbour condition at rest **(1)**	• Movable decks • Inner ramps • External ramps	DL-2	AC-1	$P_S = P_1 + P_2$

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account. In case the designer is proposing a heel angle of less than 5° based on specific operational conditions, the used angle is to be clearly specified on the loading manual.

Note 1:

P_1, P_2 : Pressures, in kN/m², to be calculated according to [1.5.2] for the condition considered.

α : Coefficient taken equal to 0,5

a_X : Longitudinal acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

a_Y : Transverse acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

a_Z : Vertical acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

Section 12 Arrangement of Hull and Superstructure Openings

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Ch 11, Sec 9 and Ch 11, Sec 10 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Ch 1, Sec 3, Tab 5.

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance equal to or less than 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0,04 B.

2 External openings

2.1 General

2.1.1 *All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.*

2.1.2 *External openings required to be watertight in accordance with [2.1.1]* are to be of sufficient strength and*, except for cargo hatch covers, are to be fitted with indicators on the bridge.*

2.1.3 No openings, be they permanent openings, recessed promenades or temporary openings such as shell doors, windows or ports, are allowed on the side shell between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition. Windows and sidescuttles of the non-opening type are allowed if complying with Pt C, Ch 4, Sec 5, [3.2.3], item c).

2.1.4 *Openings in the shell plating below the deck limiting the vertical extent of damage shall be fitted with a device that prevents unauthorized opening if they are accessible during the voyage.*

2.1.5 *Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.*

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1] to [3.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 are to be treated as windows.

3.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards*, and round or oval openings with an area exceeding 0,16 m²*.

3.1.4 Number of openings in the shell plating

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Sidescuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for sidescuttles below the freeboard deck.

3.1.6 Means of closing and opening

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of sidescuttles

All sidescuttles, the sills of which are below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

3.2 Opening arrangement

3.2.1 General

Sidescuttles are not to be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 0,025B or 0,5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

3.2.2 Sidescuttles below (1,4 + 0,025 B) m above the water

Where in 'tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side of passenger ships and the freeboard deck at side of cargo ships, and having its lowest point 1,4+0,025B m above the water when the voyage commences, all the sidescuttles in that 'tweendecks are to be closed watertight and locked before the voyage commences, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side of passenger ships and the freeboard deck at side of cargo ships, and having its lowest point 1,4+0,025B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible for the voyage to commence without them being closed and locked and to be opened during navigation on the responsibility of the master. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

3.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- *where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations*
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Ships with several decks

In ships having several decks above the bulkhead deck, such as passenger ships, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case by case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Automatic ventilating scuttles

Automatic ventilating sidescuttles are not to be fitted in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships without the special agreement of the Society.

3.2.8 Window arrangement

Windows may not be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

3.2.9 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.10 Gangway, cargo and fuelling ports

Cargo ports and other similar openings (e.g. gangway and fuelling ports) in the side of ships below the bulkhead deck of passenger ships and the freeboard deck of cargo ships are to be fitted with doors so designed as to ensure the same watertightness and structural integrity as the surrounding shell plating. Unless otherwise granted by the Society, these openings are to open outwards. The number of such openings is to be the minimum compatible with the design and proper working of the ship. In no case must these openings be so fitted as to have their lowest point below the summer load line.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

Direct metal to glass contact is to be avoided.

The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

Design loads are to be determined in accordance with the applicable requirements of Ch 5, Sec 5, [5].

In damaged ship conditions, where windows or sidescuttles are located below the deepest equilibrium waterline, the design pressure p, in kN/m², is to be taken equal to:

$p = p_S$

where:

p_S : Still water pressure, taken equal to:

$p_S = r\, g\, d_F$

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline.

The deepest equilibrium waterlines are the most critical waterlines for scantling during intermediate and final equilibrium stages, and are to be provided by the Designer under his own responsibility.

3.3.3 Scantling

The windows and sidescuttles assessment methodology defined in this Article is equivalent to Standard ISO 11336-1:2012.

The scantling of windows and sidescuttle defined in this sub-article are provided for the following types of window or sidescuttle:

- monolithic window or sidescuttle (see [3.3.4])
- laminated window or sidescuttle (see [3.3.5])
- double windows unit with gap (see [3.3.6]).

All the window and sidescuttle edges are considered as simply supported.

3.3.4 Thickness of monolithic window

The thicknesses, in mm, of monolithic windows and sidescuttles are to be obtained from the following formula:

- rectangular window or sidescuttle:

$$t = 31,6 s \alpha_{ec} \sqrt{\frac{\beta p S_f}{R_m}}$$

- circular window or sidescuttle:

$$t = 17,4 d \alpha_{ec} \sqrt{\frac{p S_f}{R_m}}$$

where:

α_{ec} : Coefficient to be taken equal to:

- for edges of glass considered as simply supported:

$\alpha_{ec} = 1,00$

- for edge of rectangular window or sidescuttle considered as clamped:
  $\alpha_{ec} = 0,81$
- for edge of circular window or sidescuttle considered as clamped:
  $\alpha_{ec} = 0,74$

s : Shorter side, in m, of rectangular window or sidescuttle
Where the window is supported only on 2 edges, s is to be taken as the unsupported side

ℓ : Longer side, in m, of rectangular window or sidescuttle

d : Diameter, in m, of circular window or sidescuttle

R_m : Guaranteed minimum flexural strength, in N/mm^2, of material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window is:

- for thermally or chemically toughened glass:
  $R_m = 120$ N/mm^2
- for polymethylmethacrilate (PMMA) glass:
  $R_m = 100$ N/mm^2
- for polycarbonate (PC) glass:
  $R_m = 90$ N/mm^2

S_f : Safety factor taken equal to:

- for thermally or chemically toughened glass:
  $S_f = 3,0$
- for polymethylmethacrilate (PMMA) or polycarbonate (PC) glass:
  $S_f = 3,5$ f

β : Aspect ratio coefficient of the rectangular window or sidescuttle, obtained in Tab 2
Where the window is supported only by 2 edges, β is to be taken equal to 1,0.

The thickness of windows or sidescuttles having other shapes may be obtained by considering rectangles or circles of equivalent dimensions s_{eq}, ℓ_{eq} or d_{eq} as defined in Tab 1.

Table 1 : Equivalent dimensions for windows having other shapes

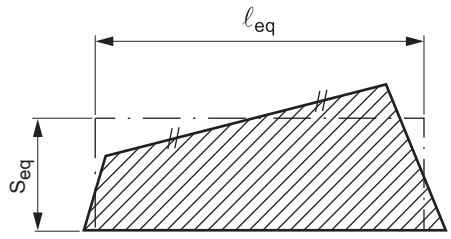
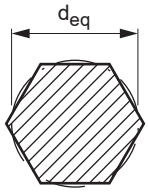
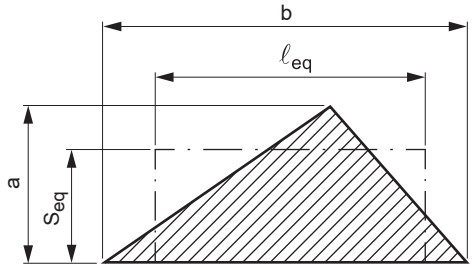
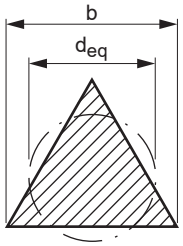
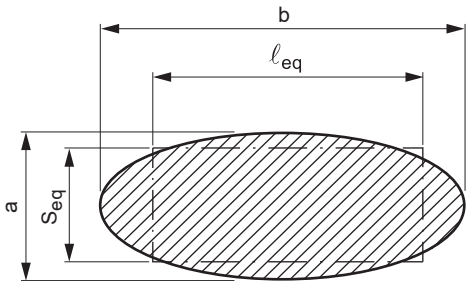
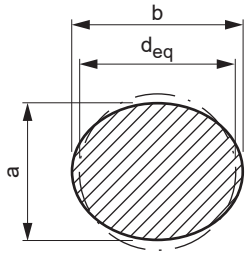
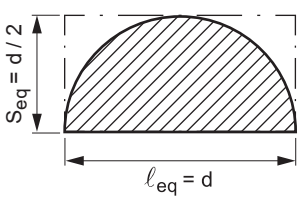
a) Quadrangle  The equivalent rectangle has the same area	b) Polygon  The equivalent circle has the same area	c) Triangle  $s_{eq} = 2a/3$ $l_{eq} = 3b/4$	
d) Equilateral triangle  $d_{eq} = 3b/4$	e) Flat ellipse  $s_{eq} = 0,87a$ $l_{eq} = 0,87b$	f) Round ellipse  $d_{eq} = \sqrt{ab}$	g) Semi circle  $s_{eq} = d/2$ $l_{eq} = d$

Table 2 : Coefficient β

ℓ/s	β
1,0	0,284
1,5	0,475
2,0	0,608
2,5	0,684
3,0	0,716
3,5	0,734
≥ 4,0	0,750

3.3.5 Laminated window

Laminated windows are windows realized by placing an interlayer of resin (polyvinyl butyral as a general rule) between plies of same or different materials.

For laminated windows made with plies of the same material:

- When the mechanical properties of the interlayer material (the laminating adhesive material) are not known, the plies of the laminated window are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.6].
- When the mechanical properties of the interlayer material are known in terms of shear modulus, G, in N/mm^2, the plies of the laminated window are considered as mechanically collaborating, and the equivalent thickness is to be calculated as defined in [3.3.7].

When the laminated window is made with plies of different materials, they are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.8].

3.3.6 Thickness of laminated window with independent plies

The equivalent thickness t_{eq}, in mm, of laminates made of n independent plies of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$, is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4].

3.3.7 Thickness of laminated window with collaborating plies

The equivalent thickness t_{eq}, in mm, of laminates made of two collaborating plies of the same material, and of thicknesses t_1 and t_2 separated by an interlayer of thickness t_l is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{1eq,s}, t_{2eq,s}]$$

$t_{1eq,s}$, $t_{2eq,s}$: Equivalent thickness for strength as obtained from the following formulae:

$$t_{1eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_1 + 2\Gamma t_{s2}}}$$

$$t_{2eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_2 + 2\Gamma t_{s1}}}$$

$t_{eq,d}$: Equivalent thickness for deflection as obtained from the following formula:

$$t_{1eq,d} = \sqrt[3]{t_1^3 + t_2^3 + 12\Gamma I_S}$$

Γ : Shear transfer coefficient as obtained from the following formula, without being taken less than 0 (independent plies behaviour) and more than 1,0 (monolithic behaviour):

$$\Gamma = \frac{1}{1 + 9,6\frac{E}{G}\frac{I_S}{hs^2}\frac{t_I}{s^2}\frac{1}{10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_S = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0,5(t_1 + t_2) + t_I$$

G : Shear modulus of the interlayer at 25 °C, in N/mm², generally taken equal to 1,6 N/mm² for polyvinyl butyral (PVB). For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer

E : Young's modulus of the plies, in N/mm²

s : Shorter side, in m, of rectangular window or sidescuttle.

In case of multiple (more than two plies) laminates the calculation is to be iterated. The iteration is to start from the outer ply (the one directly loaded by water pressure) and end with the inner ply.

3.3.8 Thickness of laminated window with plies of different materials

The equivalent thickness t_{eq}, in mm, of laminates made of n plies of different materials, of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$ and of Young's modulus $E_{p,1}$, $E_{p,2}$, ..., $E_{p,n}$ is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} E_{p,j} t_{p,j}^3}{E_{p,j} t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4] for the same material than the ply giving the minimum value of $t_{eq,j}$.

3.3.9 Thickness of double windows

Double windows are glass windows made of two plies of glass separated by an hermetically sealed spacebar.

The thickness of the ply exposed to the loads defined in [3.3.2] is to be calculated as per monolithic windows according to [3.3.4].

3.3.10 3.3.10 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.4 Deadlight arrangement

3.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- *spaces below the freeboard deck*
- *spaces within the first tier of enclosed superstructures*
- *first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.*

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

3.4.2 Watertight deadlights

Efficient hinged inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that, abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of (3,7+0,025B) m above the deepest subdivision

summer load line*, the deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the International Convention on Load Lines in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the sidescuttles they serve*.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1], are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4 Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-chute, rubbish-chute

The inboard opening of each ash-chute, rubbish-chute, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the chute in an easily accessible position above the deepest subdivision summer load line. When the chute is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5° heel, to port or starboard, at a draught corresponding to the assigned summer freeboard, but not less than 1000 mm above the summer load waterline.

Where the inboard end of the garbage chute exceeds 0,01L above the summer load waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the freeboard deck of a passenger ship, or the waterline corresponding to the deepest draught after damage in a cargo ship of more than 100 m in length, then:

- *the inboard end hinged cover/valve is to be watertight*
- *the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line*
- *the screw-down non-return valve is to be controlled from a position above the bulkhead deck and provided with open/shut indicators. The valve control is to be clearly marked: "Keep closed when not in use".*

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the freeboard deck. In addition, the lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper gate valve, as required in [4.2.3]*, may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap* which replaces the lower gate valve.

The cover and discharge *flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.*

4.2.5 Marking of valve and hinged cover

The gate valve controls and/or hinged cover are to be clearly marked: "Keep closed when not in use".

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from Tab 3.

Table 3 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7,0
$80 < d < 180$	7,0 + 0,03 (d – 80)
$180 \leq d \leq 220$	10,0 + 0,063 (d – 180)
$d > 220$	12,5

5 Transducers

5.1 General

5.1.1 Transducers are not to be fitted inside compartments intended for fuel and hydrocarbons. They may only be fitted in adjacent cofferdams.

If transducers are fitted in hazardous areas, they are to be fitted inside a watertight box. In this case, transducers are to be sealed and the connecting cables are to be specially protected.

5.2 Protection of transducers in ballast and main compartment

5.2.1 Transducers may be fitted in compartments intended for ballast (double bottoms, deep tank, peak). In such a case, the instrument and its power cable are to be mechanically protected and the watertightness of the protecting device is to be such that the material and its cable may be considered as protected against external agents.

5.2.2 Where transducers are not fitted inside a small box or a little separate compartment within a double bottom but directly within a main compartment, it is necessary to provide for inspection of materials of every part which ensures structural and watertight integrity and to test them at works after completion. Besides, the complete set is to be tested under a hydraulic pressure at least equal to 1,5 times the service pressure, the latter being considered as equal to the depth of the ship.

If a transducer is fitted inside a single bottom ship, the tank of the transducer itself is to be considered as ensuring the structural integrity. Special attention is to be paid to welding and testing of the transducer bell.

5.3 Fitting of hull boss and transducer receiver

5.3.1 The hull boss is to be made of steel with the same grade and yield stress as the bottom plates to which it is fitted. Full penetration welding is to be performed with suitable electrodes.

When the transducer receiver, owing to the fitting arrangement, slightly projects beyond the external surface of the shell plates, the precise position of the installation is to be supplied to the Owner to enable him to take the necessary precautions in case of docking.

5.4 Fitting of transducer in heavily stressed areas

5.4.1 Where the transducer is fitted in the midship region or in heavily stressed areas, the openings are to be either elliptical (ratio 2/1, the major axis being parallel to the longitudinal axis of the ship) or truncated ellipse shaped at least for large ships. Moreover, a possible compensation is to be provided on the location of the cut.

6 Freeing ports

6.1 General provisions

6.1.1 General

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

6.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the freeboard deck, on each side of the ship, are specified in Tab 4.

6.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

Where the exposed freeboard deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

Table 4 : Freeing port area in bulwark located on freeboard deck

Ship types or ship particulars	Area A of freeing ports, in m^2	Applicable requirement
Type A	$0,33\ \ell_B\ h_B$	[6.5.2]
Type B-100	$0,33\ \ell_B\ h_B$	[6.5.2]
Type B-60	$0,25\ \ell_B\ h_B$	[6.5.1]
Ships fitted with a trunk included in freeboard calculation and/ or breadth ≥ 0,6 B	$0,33\ \ell_B\ h_B$	[6.3.1]
Ships fitted with a trunk not included in freeboard calculation and/ or continuous or substantially continuous hatch coamings	A_2	[6.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[6.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[6.4.2] [6.4.3]
Other ships	A_1	[6.2.1]
Note 1: ℓ_B : Length, in m, of bulwark in a well at one side of the ship h_B : Mean height, in m, of bulwark in a well of length ℓ_B.		

6.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

6.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

In ships operating in areas where icing is likely to occur, no shutters are to be fitted in the feeing ports.

6.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks of tankers, in way of cargo manifolds and cargo piping, are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section.

6.2 Freeing port area in a well not adjacent to a trunk or hatchways

6.2.1 Freeing port area

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m², in Tab 5.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

Table 5 : Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m²	
	$\ell_B \leq 20$	$\ell_B > 20$
Freeboard deck and raised quarterdecks	$0,7 + 0,035\ \ell_B + A_C$	$0,07\ \ell_B + A_C$
Superstructure decks	$0,35 + 0,0175\ \ell_B + 0,5\ A_C$	$0,035\ \ell_B + 0,5\ A_C$

Note 1:

ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than $0,7\ L_{LL}$

A_C : Area, in m², to be taken, with its sign, equal to:

$$A_C = \frac{\ell_B}{25}(h_B - 1,2) \text{ for } h_B > 1,2$$

$$A_C = 0 \quad \text{for } 0,9 \leq h_B \leq 1,2$$

$$A_C = \frac{\ell_B}{25}(h_B - 0,9) \text{ for } h_B < 0,9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

6.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0,8 B and the width of the passageways along the side of the ship less than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 5, where ℓ_B is to be taken equal to the actual length of the well considered.

6.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [6.1.2].

6.3 Freeing port area in a well contiguous to a trunk or hatchways

6.3.1 Freeing port area for continuous trunk or continuous hatchway coaming

The freeing port area in the well contiguous to substantially continuous trunk/hatchway coaming is to be not less than:

- that obtained from Tab 6, where the trunk / hatchway coaming is not included in the freeboard calculation
- 33% of the bulwark area where the trunk / hatchway coaming meets the conditions of the International Convention on Load Lines in force and is included in the freeboard calculation.

Table 6 : Freeing port area in a well contiguous to a continuous trunk or hatchway

Breadth B_H, in m, of hatchway or trunk	Area A_2, in m², of freeing ports
$B_H \leq 0,4\ B$	$0,2\ \ell_B h_B \left(\frac{h_S}{2h_W}\right)$
$0,4\ B < B_H < 0,75\ B$	$\left[0,2 - 0,286\left(\frac{B_H}{B} - 0,4\right)\right] \ell_B h_B \left(\frac{h_S}{2h_W}\right)$
$B_H \geq 0,75\ B$	$0,1\ \ell_B h_B \left(\frac{h_S}{2h_W}\right)$

Note 1:

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B

h_S : Standard superstructure height, in m, defined in [1.2.1]

h_W : Distance, in m, of the well deck above the freeboard deck, to be taken not less than $0,5\ h_S$.

6.3.2 Freeing area for non-continuous trunk or hatchway coaming

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m^2, from Tab 7.

Table 7 : Freeing port area in a well contiguous to a non-continuous trunk or hatchway

Free flow area f_P, in m^2	Freeing port area A_3, in m^2
$f_p \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1

Note 1:

f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark

A_1 : Area of freeing ports, in m^2, to be obtained from Tab 5

A_2 : Area of freeing ports, in m^2, to be obtained from Tab 6.

6.4 Freeing port area in an open space within superstructures

6.4.1 General

In ships having superstructures on the freeboard or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

6.4.2 Freeing port area for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m^2, from the following formula:

$$A_S = A_1 c_{SH}\left[1 - \left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\,\ell_T h_W}\right)$$

where:

ℓ_T : Total well length, in m, to be taken equal to:

$\ell_T = \ell_W + \ell_S$

ℓ_W : Length, in m, of the open deck enclosed by bulwarks

ℓ_S : Length, in m, of the common space within the open superstructures

A_1 : Freeing port area, in m^2, required for an open well of length ℓ_T, in accordance with Tab 5, where A_C is to be taken equal to zero

c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:

$c_{SH} = 1,0$ in the case of standard sheer or sheer greater than standard sheer

$c_{SH} = 1,5$ in the case of no sheer

b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures

h_S, h_W : As defined in Tab 6.

6.4.3 Freeing port area for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m^2, from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2\,h_W}\right)$$

A_1 : Freeing port area, in m^2, required for an open well of length ℓ_W, in accordance with Tab 5

ℓ_W : Defined in [6.4.2].

The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

6.5 Freeing port area in bulwarks of the freeboard deck for ships of types A, B-100 and B-60

6.5.1 Freeing arrangement for type B-60

For type B-60 ships, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 25% of the total area of the bulwarks in the well considered.

The upper edge of the sheer strake is to be kept as low as possible.

6.5.2 Freeing arrangement for type A and type B-100 ships with trunks

For type A and type B-100 ships, open rails are to be fitted on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts.

Alternatively, if a continuous bulwark is fitted, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 33% of the total area of the bulwarks in the well considered.

7 Machinery space openings

7.1 Engine room skylights

7.1.1 Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

7.1.2 Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

7.2 Closing devices

7.2.1 Machinery casings

Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

7.2.2 Machinery casings on Type A ships

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength.

Machinery casings may, however, be exposed if there are no openings giving direct access from the freeboard deck to the machinery spaces.

However, a weathertight door is permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

7.2.3 Height of the sill of the door

The height of the sill of the door is to be not less than:

- *600 mm above the deck if in position 1*
- *380 mm above the deck if in position 2*
- 230 mm in all other cases.

7.2.4 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required for ships assigned freeboard less than that based on Table B of regulation 28 of the International Load Line Convention 1966, as amended. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

7.2.5 Fiddly openings

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

7.3 Coamings

7.3.1 *Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the freeboard deck or superstructure deck are to be as high above the deck as is reasonable and practicable.*

In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [9.1.2], but need not be fitted with weathertight closing appliances.

Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [9.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8 Companionway

8.1 General

8.1.1 Openings in freeboard deck

Openings in freeboard deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

8.1.2 Openings in superstructures

Openings in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck which give access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

8.1.3 Openings in superstructures having height less than standard height

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the standard height of a superstructure.

8.2 Scantlings

8.2.1 Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

8.3 Closing devices

8.3.1 Doors

Doorways in deckhouses or companionways leading to or giving access to spaces below the freeboard deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be watertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

8.3.2 Height of sills

The height above the deck of sills to the doorways in companionways is to be not less than:

- *600 mm in position 1*
- *380 mm in position 2.*

Where access is not provided from above, the height of the sills to doorways in a poop bridge or deckhouse on the freeboard deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck above as an alternative to access from the freeboard deck, the height of the sills into the bridge or poop is to be at least 380 mm. This also applies to deckhouses on the freeboard deck.

9 Ventilators

9.1 Closing appliances

9.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material, designed to offer equivalent strength compared to the adjacent bulkhead or coaming in which they are fitted.

9.1.2 Closing appliance exemption

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- *4,5 m above the deck in position 1*
- *2,3 m above the deck in position 2.*

9.1.3 Closing appliances for ships of not more than 100 m in length

In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

9.1.4 Closing appliances for ships of more than 100 m in length

Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

9.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [9.1.2], i.e. their openings are to be so located that they do not require closing appliances.

Note 1: See also Pt C, Ch 4, Sec 2, [2.1] regarding closing appliances for ventilation systems.

9.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [9.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [9.1.1], [9.1.3] and [9.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

9.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4,5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

9.2 Coamings

9.2.1 General

Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

9.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 8.

In exposed locations or for the purpose of compliance with buoyancy calculations, *the height of coamings may be required to be increased to the satisfaction of the Society.*

Table 8 : Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	h = 900 in position 1 h = 760 in position 2
Thickness of the coaming, in mm **(1)**	$t = 5,5 + 0,01\ d_V$ with $7,5 \leq t \leq 10,0$
Support	If h > 900 mm, the coaming is to be suitably stiffened or supported by stays
(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm. **Note 1:** d_V : Internal diameter of the ventilator, in mm.	

10 Tank cleaning openings

10.1 General

10.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

Section 13 Helicopter Decks and Platforms

Symbols

W_H : Maximum weight of the helicopter, in t.

1 Application

1.1 General

1.1.1 The requirements of this Section apply to areas equipped for the landing and take-off of helicopters with landing gears or landing skids, and located on a deck or on a platform permanently connected to the hull structure.

1.1.2 Helicopter deck or platform intended for the landing of helicopters having landing devices other than wheels or skids are to be examined by the Society on a case-by-case basis.

2 Definition

2.1 Landing gear

2.1.1 A landing gear may consist of a single wheel or a group of wheels.

3 General arrangement

3.1 Landing area and approach sector

3.1.1 The main dimensions of the landing area, its location on board, the approach sector for landing and take-off are to comply with the applicable requirements from National or other Authorities.

3.1.2 The landing area and the approach sector are to be free of obstructions above the level of the helicopter deck or platform.

Note 1: The following items may exceed the height of the landing area, but not more than 100 mm:

- guttering or slightly raised kerb
- lightning equipment
- outboard edge of the safety net
- foam monitors
- those handrails and other items associated with the landing area which are incapable of complete retraction or lowering for helicopter operations.

3.2 Sheathing of the landing area

3.2.1 Within the landing area, a non-skid deck covering is recommended.

Where the helicopter deck or platform is wood sheathed, special attention is to be paid to the fire protection.

3.3 Safety net

3.3.1 It is recommended to provide a safety net at the sides of the helicopter deck or platform.

3.4 Drainage system

3.4.1 Gutterways of adequate height and a drainage system are recommended on the periphery of the helicopter deck or platform.

4 Design principle

4.1 General

4.1.1 Local deck strengthening is to be fitted at the connection of diagonals and pillars supporting platform.

5 Design loads

5.1 Emergency landing load

5.1.1 The emergency landing force F_{EL} transmitted through one landing gear or one extremity of skid to the helicopter deck or platform is to be obtained for the static + dynamic design load scenario (design load set DL-1), in kN, from the following formula:

$F_{EL} = 1,25\ g\ W_H$

The point of application of the force F_{EL} is to be taken so as to produce the most severe stresses on the supporting structure.

5.2 Garage load

5.2.1 Where a garage zone is fitted in addition to the landing area, the static and dynamic forces $F_{W\text{-}S}$ and $F_{W\text{-}D}$ transmitted trough each landing gear or each landing skid to the helicopter deck or platform are to be obtained for both the static and the static + dynamic design load scenarios (design load sets DL-1 and DL-2), in kN, as specified in Ch 5, Sec 6, [7], where M is to be taken equal to:

- for helicopter with landing gears:

  M is the landing gear load, in t, to be specified by the Designer. If the landing gear load is not known, M is to be taken equal to:

  $$M = \frac{1,25}{n} W_H$$

  where n is the total number of landing gears
- for helicopter with landing skids: $M = 0,5\ W_H$

5.2.2 When helicopters are parked in an unprotected area, sea pressures on deck, as per Ch 5, Sec 5, [3], are to be considered independently of the loads defined in [5.2.1].

5.3 Specific loads for helicopter platforms

5.3.1 The total force F, in kN/m², for both the static and the static + dynamic design load scenarios (design load sets DL-1 and DL-2) is to be derived for each dynamic load case and is to be taken as:

- for static design load scenario: $F = F_S$
- for static + dynamic design load scenario: $F = F_S + F_W$

where:

F_S, F_W : Still water and inertial forces transmitted to the hull structure, obtained, in kN, from Tab 1.

Table 1 : Helicopter platforms - Still water and inertial forces

Ship condition	Design load set	Still water force F_S and inertial force F_W, in kN
Seagoing condition	DL-1	$F_S = (W_H + W_P)\ g$
		$F_{W,X} = (W_H + W_P)\ a_X + 1,2\ A_{HX}$ in x direction $F_{W,Y} = (W_H + W_P)\ a_Y + 1,2\ A_{HY}$ in y direction $F_{W,Z} = (W_H + W_P)\ a_Z$ in z direction
Harbour condition	DL-2	$F_S = (W_H + W_P)\ g$

Note 1:

W_p : Structural weight of the helicopter platform, in t, to be evenly distributed, and to be taken not less than the value obtained from the following formula:
$W_p = 0,2\ A_H$

A_H : Area, in m², of the entire landing area

a_X, a_Y, a_Z : Accelerations, in m/s², determined at the helicopter centre of gravity, and defined in Ch 5, Sec 3, [3]

A_{HX}, A_{HY} : Vertical areas, in m², of the helicopter platform in x and y directions respectively. Unless otherwise specified, A_{HX} and A_{HY} may be taken equal to $A_H/3$

6 Scantlings

6.1 General

6.1.1 The scantlings of the structure of an helicopter deck or platform are to be obtained according to [6.2], [6.3]and [6.4]. They are to be considered in addition to scantlings obtained from other applicable loads, in particular from sea pressures.

6.2 Plating

6.2.1 Load model

The following forces P_0, in kN, are to be considered independently:

- Emergency landing load: $P_0 = F_{EL}$
  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.1]
- Garage load:
  - for static design load scenario: $P_0 = F_{W\text{-}S}$
  - for static + dynamic design load scenario: $P_0 = F_{W\text{-}S} + F_{W\text{-}D}$

  where $F_{W\text{-}S}$ and $F_{W\text{-}D}$ are the forces corresponding to the garage load, as defined in [5.2].

6.2.2 Net thickness of plating

The net thickness of an helicopter deck or platform subjected to forces defined in [6.2.1] is not to be less than the value obtained according to Ch 7, Sec 4, [3.3], with:

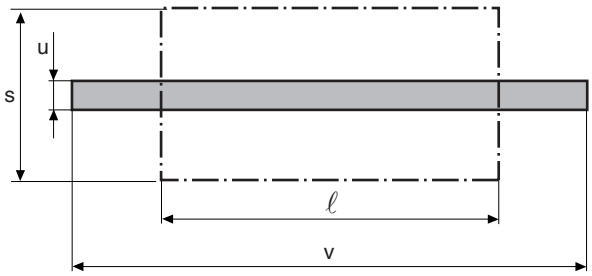
A_T : Tyre or skid print area, in m^2.
For helicopter with skids in emergency landing case, only the extremity of skid of 0,3 m x 0,01 m is to be considered.
For other cases, where the print area A_T is not specified by the Designer, the following values are to be taken into account:
- for one tyre: 0,3 m x 0,3 m
- for one skid: 1 m x 0,01 m.

C_a : Coefficient defined in Ch 7, Sec 4, [1.1.1] and taken equal to $C_{a\text{-}max}$ in the particular case of a platform.

6.2.3 Helicopter with skids

For helicopters with skids, in the particular case where $v > \ell$, v being equal to the skid length, the skid print outside of the plate panel is to be disregarded. The load and the print area to be considered are to be reduced accordingly. (see Fig 1).

Figure 1 : Skid print with v > ℓ



6.3 Ordinary stiffeners

6.3.1 Load model

The following forces P_0, in kN, are to be considered independently:

- Emergency landing load: $P_0 = F_{EL}$
  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.1]
- Garage load:
  - for static design load scenario: $P_0 = F_{W\text{-}S}$
  - for static + dynamic design load scenario: $P_0 = F_{W\text{-}S} + F_{W\text{-}D}$

  where $F_{W\text{-}S}$ and $F_{W\text{-}D}$ are the forces corresponding to the garage load, as defined in [5.2].
- Helicopter platform:
  - for static design load scenario: $F = F_S$
  - for static + dynamic design load scenario: $F = F_S + F_W$

  where F_S and F_W are the forces defined in [5.3].

6.3.2 Scantlings

Scantlings of stiffeners induced by loads defined in [6.3.1] are to be calculated according to Ch 7, Sec 5, [1.2] where:

$$w = \frac{\alpha_W K_S P_0 \ell_{bdg}}{6\chi C_s R_{eH}} 10^3$$

in case of helicopter with wheels, or

$$w = \frac{\alpha_w P_0 \ell_{bdg}}{10 \chi C_s R_{eH}} 10^3$$

in case of helicopter with landing skids.

6.4 Primary supporting members

6.4.1 Load model

The following loads are to be considered independently:

- emergency landing load, as defined in [5.1]
- garage load, as defined in [5.2], if applicable
- for an helicopter platform, specifics loads as defined in [5.3].

The most unfavourable case, i.e. where the maximum number of landing gears is located on the same primary supporting members, is to be considered.

6.4.2 Checking criteria

In both cases of helicopter with wheels and helicopter with landing skids, the calculated stress values are to comply with the requirements defined in Ch 7, Sec 6, [5.1.4].

In addition, the hull girder stresses are to be taken equal to 0 in the particular case of an helicopter platform.

CHAPTER 12
HULL OUTFITTING

Section 1 Rudders

Section 2 Bulwarks and Guard Rails

Section 3 Propeller shaft brackets

Section 4 Equipment

Appendix 1 Criteria for Direct Calculation of Rudder Loads

Appendix 2 Towing and Mooring Arrangement

Section 1 Rudders

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

V_{AV} : Maximum ahead service speed, in knots, with the ship on summer load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:

$$V_{MIN} = \frac{V_{AV} + 20}{3}$$

V_{AD} : Maximum astern speed the ship is estimated to attain at the designed maximum astern power at the deepest sea-going draught, in knots, to be taken not less than $0,5\ V_{AV}$

A : Total area of the rudder blade, in m^2, bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any

k_1 : Material factor, defined in [1.4.3]

k : Material factor, defined in Ch 4, Sec 1, [2.2] (see also [1.4.5])

C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.2]

M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.3] and [2.2.3]

M_B : Bending moment, in N.m, in the rudder stock, to be calculated according to Ch 12, App 1, [1.4], for each type of rudder listed in Tab 3.

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

1.1.2 High efficiency rudders

The requirements of this Section also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed different from 35° may be accepted. In these cases, the rudder forces are to be calculated by the Designer for the most severe combinations between orientation angle and ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in Article [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] are to be considered by the Society on a case-by-case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1.1.2], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

1.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.3.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 14.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the waterline at scantling draught (without trim), two separate watertight seals / stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in:

- NR216 Materials and Welding, Chapter 3 (steel plate)
- NR216 Materials and Welding, Chapter 5 (steel forgings)
- NR216 Materials and Welding, Chapter 6 (steel castings).

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a specified minimum yield stress not less than 200 N/mm^2.

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a specified minimum yield stress equal to 235 N/mm^2.

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a specified minimum yield stress different from 235 N/mm^2, the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^n$$

where:

R_{eH} : Specified minimum yield stress, in N/mm^2, of the specified steel, and not exceeding the lower of 0,7 R_m and 450 N/mm^2

R_m : Tensile strength, in N/mm^2, of the steel used

n : Coefficient to be taken equal to:

- for $R_{eH} > 235$ N/mm^2:
  n = 0,75
- for $R_{eH} \leq 235$ N/mm^2:
  n = 1,00

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with specified minimum yield stresses greater than 235 N/mm^2 may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations (refer to [4.2.1]).

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.2] is to be used.

1.5 Welding and non-destructive testing

1.5.1 Welded parts of rudders are to be assembled in compliance with the applicable requirements of Ch 13, Sec 2.

1.5.2 Non destructive testing of new construction welds are to be carried out in compliance with the applicable requirements of Ch 13, Sec 4.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula:

$$C_R = 132\, n_R\, A\, V^2\, r_1\, r_2\, r_3$$

where:

n_R : Navigation coefficient, defined in Tab 1

V : V_{AV} or V_{AD}, depending on the condition under consideration (for high lift profiles see [1.1.2])

r_1 : Shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

λ : Coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

and not greater than 2

h : Mean height, in m, of the rudder area to be taken equal to (see Fig 1):

$$h = \frac{z_3 + z_4 - z_2}{2}$$

A_T : Area, in m^2, to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h

r_2 : Coefficient to be obtained from Tab 2

r_3 : Coefficient to be taken equal to:

- for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases):

  $r_3 = 0,8$

- for rudders behind a fixed propeller nozzle:

  $r_3 = 1,15$

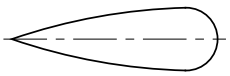
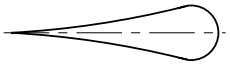
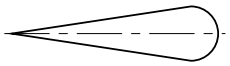
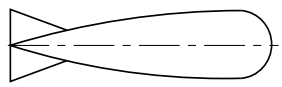
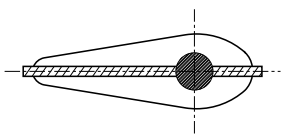
- in other cases:

  $r_3 = 1,0$

Table 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_R
unrestricted navigation	1,00
summer zone	0,95
tropical zone	0,85
coastal area	0,85
sheltered area	0,75

Table 2 : Values of coefficient r_2

Rudder profile type		Ahead condition	Astern condition
NACA 00 - Goettingen		$r_2 = 1,10$	$r_2 = 0,80$
Hollow		$r_2 = 1,35$	$r_2 = 0,90$
Flat side		$r_2 = 1,10$	$r_2 = 0,90$
High lift		$r_2 = 1,70$	$r_2 = 1,30$
Fish tail		$r_2 = 1,40$	$r_2 = 0,80$
Single plate		$r_2 = 1,00$	$r_2 = 1,00$
Mixed profiles (e.g. HSVA)		$r_2 = 1,21$	$r_2 = 0,90$

2.1.3 Rudder torque

The rudder torque M_{TR}, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = C_R\, r$

where:

r : Lever of the force C_R, in m, equal to:

$$r = b\left(\alpha - \frac{A_F}{A}\right)$$

and to be taken not less than 0,1 b for the ahead condition

b : Mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

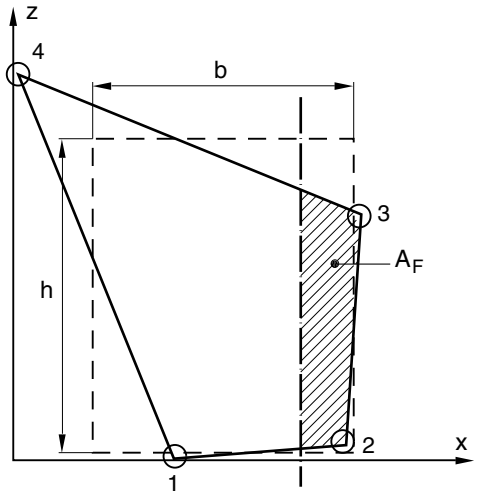
$$b = \frac{x_2 + x_3 - x_1}{2}$$

α : Coefficient to be taken equal to:

- for ahead condition:
  $\alpha = 0{,}33$
- or astern condition:
  $\alpha = 0{,}66\ f$

A_F : Area, in m^2, of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

Figure 1 : Geometry of rudder blade without cut-outs

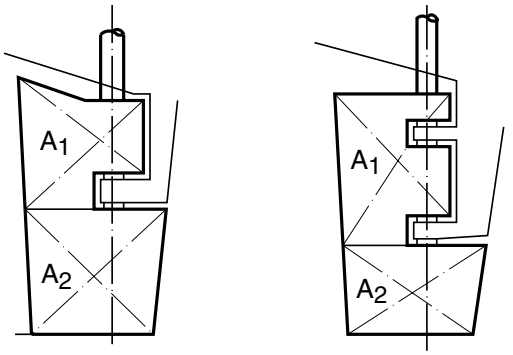


2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

Figure 2 : Rudder blades with cut-outs



Trapezoidal rudder blade
Semi-spade rudder with
rudder horn - 2 bearings

Trapezoidal rudder blade
Semi-spade rudder with
rudder horn - 3 bearings

2.2.2 Rudder force

The rudder force C_R, in N, acting on the blade is to be calculated in accordance with [2.1.2].

2.2.3 Rudder torque

The rudder torque M_{TR}, in N.m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2, defined in Fig 2, so that:

$A = A_1 + A_2$

The rudder forces C_{R1} and C_{R2}, acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2}, respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1\left(\alpha - \frac{A_{1F}}{A_1}\right)$$

$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

where:

b_1, b_2 : Mean breadths of the rudder blade parts having areas A_1 and A_2, respectively, to be determined according to [2.1.3]

A_{1F}, A_{2F} : Areas, in m^2, of the rudder blade parts, defined in Fig 3

α : Coefficient to be taken equal to:

- for ahead condition:
  $\alpha = 0,33$
- for astern condition:
  $\alpha = 0,66$

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- for ahead condition:
  $\alpha = 0,25$
- for astern condition:
  $\alpha = 0,55$

The torques M_{TR1} and M_{TR2}, relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$M_{TR1} = C_{R1}\, r_1$

$M_{TR2} = C_{R2}\, r_2$

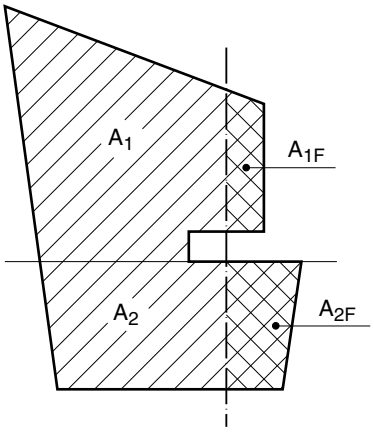
The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = M_{TR1} + M_{TR2}$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0,1 C_R \frac{A_1 b_1 + A_2 b_2}{A}$$

Figure 3 : Geometry of rudder blade with cut-outs



3 Rudder types and relevant loads acting on the rudder structure

3.1 General

3.1.1 Loads per rudder category - basic assumptions

Depending on the shape of the rudder blade and arrangement of the rudder, twelve types of rudders are considered. Tab 3 summarizes these rudder types.

The force and torque acting on the rudder, defined in [2], may induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock
- support forces at pintle and rudder stock bearings
- bending moment, shear force and torque in the rudder body
- bending moment, shear force and torque in rudder horns and solepieces.

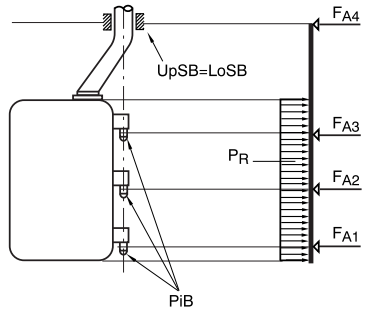
Support forces, bending moments and shear forces are to be obtained according to Ch 12, App 1, [1.4], depending on the rudder type.

3.1.2 Loads for the scantlings and assembling of rudder parts

The loads to be considered for the scantlings of rudder parts and some assembling parts are indicated in Tab 4.

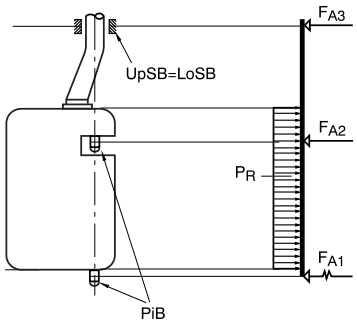
Table 3 : Types of rudders and load diagram

Type 1



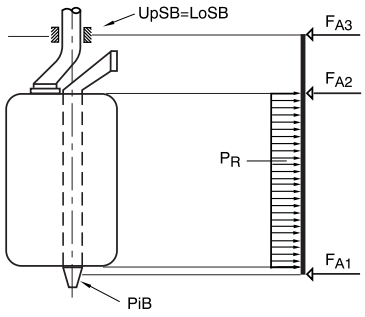
General description: 4-bearing rudder, including 3 pintle bearings and 1 rudder-stock bearing.
See Ch 12, App 1, [1.4.1].

Type 2



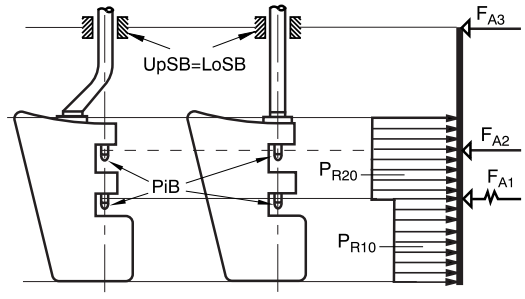
General description: 3-bearing rudder, including 2 pintle bearings and 1 rudder-stock bearing (the lower pintle bearing is represented by 1-elastic support).
See Ch 12, App 1, [1.4.2].

Type 3



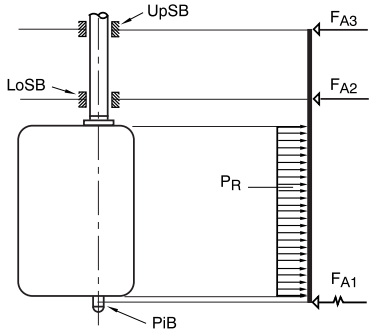
General description: 3-bearing rudder, including 2 bearings associated to the simplex rudder shaft and 1 rudder-stock bearing.
See Ch 12, App 1, [1.4.3].

Type 4



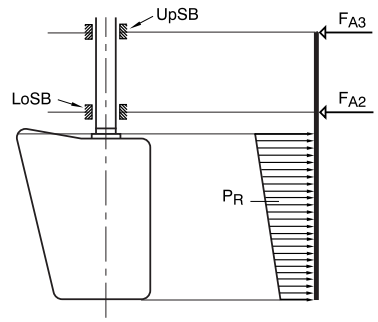
General description: 3-bearing semi-spade rudder, including 2 pintle bearings and 1 rudder-stock bearing (the lower pintle bearing is represented by 1-elastic support).
See Ch 12, App 1, [1.4.4].

Type 5



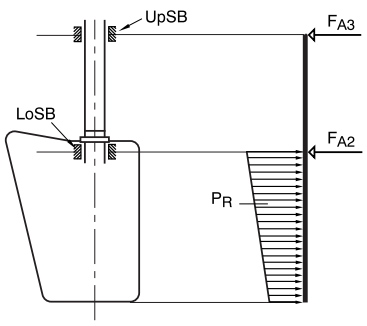
General description: 3-bearing rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings.
See Ch 12, App 1, [1.4.5].

Type 6a



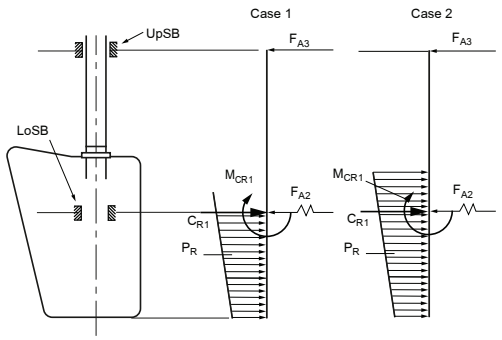
General description: 2-bearing spade rudder, including 2 rudder-stock bearings, both of them located out of the rudder blade area.
See Ch 12, App 1, [1.4.6].

Type 6b



General description: 2-bearing spade rudder, including 2 rudder-stock bearings, the lowest one located inside of the rudder blade area and close to its upper edge. See Ch 12, App 1, [1.4.7].

Type 6c

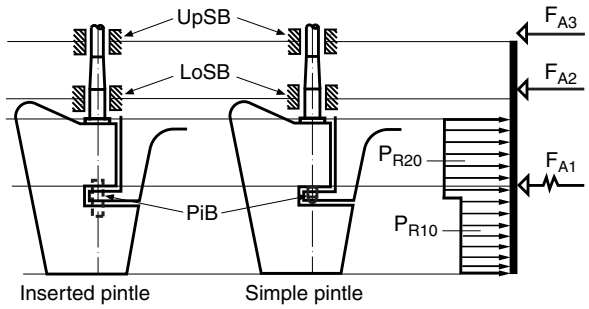


General description: 2-bearing spade rudder, including 2 rudder-stock bearings, the lowest one located inside of the rudder blade area.
Two load cases are to be checked:

- Case 1: pressure applied only on the rudder area below the middle of neck bearing
- Case 2: pressure applied on the entire rudder area

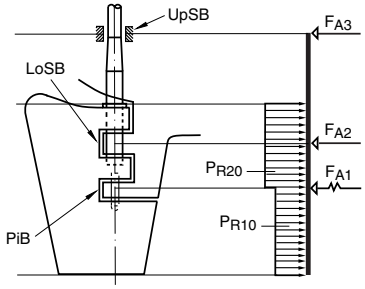
See Ch 12, App 1, [1.4.8].

Type 7



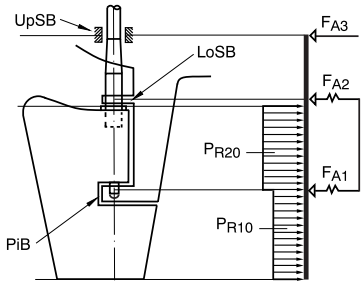
General description: 3-bearing semi-spade rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings.
See Ch 12, App 1, [1.4.9].

Type 8



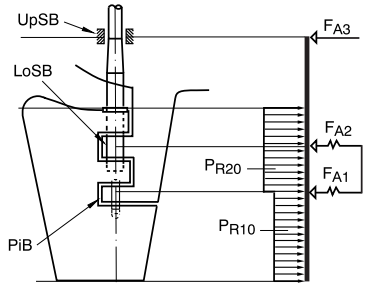
General description: 3-bearing semi-spade rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings (with 1 rudder-stock bearing inside of the rudder blade area).
See Ch 12, App 1, [1.4.10].

Type 9



General description: 3-bearing semi-spade rudder, including 1 pintle bearing and 2 rudder-stock bearings (lower pintle and stock bearings represented by 2-conjugate elastic supports).
See Ch 12, App 1, [1.4.11].

Type 10



General description: 3-bearing semi-spade rudder, including 1 pintle bearing and 2 rudder-stock bearings (lower pintle and stock bearings represented by 2-conjugate elastic supports, located inside of the rudder blade area).
See Ch 12, App 1, [1.4.12].

Note 1: Bending moment and shear forces need to be calculated at any generic horizontal section of the rudder blade, to make possible strength checks prescribed under [7.2].

Note 2:

UpSB : Upper rudder-stock bearing
LoSB : Lower rudder-stock bearing
PiB : Position of pintle bearing(s).

Note 3: Steering nozzle rudders are not included in this table (refer to [10] for more details).

Table 4 : Scantling of parts, rudder stock couplings and relevant loads

Item identification	Relevant loads	
Rudder stock scantlings	• either torque only, or • both, torque and bending moment	See [4]
Rudder stock couplings	• either torque only, or • both, torque and bending moment	See [5]
Rudder stock bearings	Horizontal reaction forces, F_{Ai},	See [6.2]
Pintle bearings	Horizontal reaction forces, F_{Ai},	See [6.3]
Scantling of pintles	Horizontal reaction forces, F_{Ai},	See [6.4]
Rudder blade scantlings	Bending moment and shear force	See [7]
Rudder horn scantlings	Bending moment, shear force and torque	See [8.1] and [8.2]
Solepiece scantlings	Bending moment and shear force	See [8.4]

4 Rudder stock scantlings

4.1 Rudder stock diameter

4.1.1 Basic formulation

The scantling of the rudder stock diameter is based on the Von Mises equivalent stress criterion, written for a state of stress induced by a combined torque, M_{TR}, and a bending moment, M_B, acting on the rudder stock. The Von Mises equivalent stress, σ_E, calculated for this state of stress, has to be in compliance with the following formula: $\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

σ_B : Bending stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_B = \frac{10{,}2\,M_B}{d_S^3} \cdot 10^3$$

τ_T : Torsional stress, in N/mm^2, to be obtained from the following formula:

$$\tau_T = \frac{5{,}1\,M_{TR}}{d_S^3} \cdot 10^3$$

d_S : Stock diameter, in mm

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to: $\sigma_{E,ALL} = 118 / k_1$

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_{TFi} = 4{,}2\,(M_{TR}\,k_1)^{1/3}\left[1 + \frac{4}{3}\left(\frac{M_{Bi}}{M_{TR}}\right)^2\right]^{1/6}$$

where M_{Bi} is to be obtained according to Ch 12, App 1, [1.1.1], for each type of rudder listed in Tab 3.

4.1.2 Rule rudder stock diameter

The rudder stock diameter, at the lower part, is to be not less than the value obtained, in mm, from the following formula:

$$d_{TF} = 4{,}2\,(M_{TR}\,k_1)^{1/3}\left[1 + \frac{4}{3}\left(\frac{M_B}{M_{TR}}\right)^2\right]^{1/6}$$

with:

M_B : Maximum absolute value of bending moment M_{Bi} over the rudder stock length, to be obtained according to Ch 12, App 1, [1.4], for each type of rudder listed in Tab 3.

If not otherwise specified, the notation d_1 used in this Section is equivalent to d_{TF}.

4.1.3 Rudder stock cross sections with null bending moment

The diameter, in mm, of a rudder stock cross section subjected to torque only is not to be less than the diameter d_T obtained from [4.1.2], taking M_B equal to zero:

$$d_T = 4{,}2\,(M_{TR}\,k_1)^{1/3}$$

This is equivalent to check that the torsional shear stress τ_T, in N/mm^2, induced by the torque only, is in compliance with the following formula:

$$\tau_T \leq \tau_{ALL}$$

where:

τ_{ALL} : Allowable torsional shear stress, in N/mm^2:

$\tau_{ALL} = 68 / k_1$

τ_T : Torsional stress, in N/mm^2, defined in [4.1.1].

4.1.4 Rule rudder stock diameter in way of the tiller

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the lower stock bearing so as to reach, from d_{TF} value, the value of d_T in way of the quadrant or the tiller.

4.2 Deformation criterion

4.2.1 Rudder stock slope in way of bearings

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

The Society may require an additional check of the rudder stock diameter to make sure that the rudder stock slopes in way of bearings are acceptable, by relating them to bearing lengths (see [6.2.3]) and bearing clearances (see [6.2.4]).

4.3 Service notations - Navigation in ice

4.3.1 Service notations

For specific service notations, increase in rudder stock diameter is required according to the relevant requirements in Part D or Part E.

4.3.2 Navigation in ice

For ships having an additional **ICE CLASS** notation, refer to applicable requirements in Pt F, Ch 8, Sec 2.

5 Rudder stock couplings

5.1 Horizontal flange couplings

5.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than 0,15 d_1, where d_1 is defined in [4.1.2].

5.1.2 Welding

Where the rudder stock diameter does not exceed 350 mm, the coupling flange may be welded onto the stock, provided that its thickness is increased by 10% and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis and a carbon equivalent CEQ not exceeding 0,41. The welding conditions (preparation before welding, choice of electrodes, pre- and post-heating, inspection after welding) are to be defined to the satisfaction of the Society. The throat weld at the top of the flange is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius:

- is to be not less than $0,15d_1$, where d_1 is defined in [4.1.2]
- may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld
- is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

The inspection is to include full non destructive tests at weld location (dye penetrant or magnetic particle test and ultrasonic test).

5.1.3 Bolts

Horizontal flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = 0,62 \sqrt{\frac{d_1^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

k_{1B} : Material factor k_1 for the steel used for the bolts

e_M : Mean distance, in mm, of the bolt axes from the centre of the bolt system

n_B : Total number of bolts, which is to be not less than 6.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of ($0,25d_T$ x $0,10d_T$) mm² and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

5.1.4 Coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formulae, whichever is the greater:

$$t_P = d_B \sqrt{\frac{k_{1F}}{k_{1B}}}$$

$$t_p = 0,9\ d_B$$

where:

d_B : Bolt diameter, in mm, calculated in accordance with [5.1.3], where the number of bolts n_B is to be taken not greater than 8

k_{1F} : Material factor k_1 for the steel used for the flange

k_{1B} : Material factor k_1 for the steel used for the bolts.

5.1.5 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.2 Couplings between rudder stocks and tillers

5.2.1 Application

The requirements of this sub-article apply in addition to those specified in Pt C, Ch 1, Sec 14.

The requirements specified in [5.2.3] and [5.2.4] apply to solid rudder stocks in steel and to tiller bosses, either in steel or in SG iron, with constant external diameter. Solid rudder stocks others than those above will be considered by the Society on a case-by-case basis, provided that the relevant calculations, to be based on the following criteria, are submitted to the Society:

- Young's modulus:
  - for steel:
    $E = 2,06.10^5$ N/mm²
  - for SG iron:
    $E = 1,67.10^5$ N/mm²
- Poisson's ratio:
  - for steel:
    $\nu = 0,30$
  - for SG iron:
    $\nu = 0,28$
- Frictional coefficient:
  - for contact steel/steel:
    $\mu = 0,15$
  - for contact steel/SG iron:
    $\mu = 0,13$
- Torque C_T transmissible through friction:
  $C_T \geq \eta\ M_{TR}$
  where η is defined in [5.2.3]
- Combined stress in the boss:
  $$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T} \leq (0,5 + 0,2\ \eta)R_{eH}$$
  where:
  σ_R, σ_T : Algebraic values of, respectively, the radial compression stress and the tangent tensile stress, in N/mm², induced by the grip pressure and calculated at the bore surface ($\sigma_R = p_F$, where p_F is the grip pressure in the considered horizontal cross-section of the boss)
- Where the rudder stock is hollow, the following strength criterion is to be complied with, at any point of the rudder stock cross-section:
  $$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T + 3\tau^2} \leq 0,7\ R_{eH}$$
  where:

σ_R, σ_T : Algebraic values of, respectively, the radial and the tangent compressive stresses, in N/mm^2, induced by the grip pressure

τ : Shear stress, in N/mm^2, induced by the torque M_{TR}.

5.2.2 General

The entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

The right fit of the tapered bearing is to be checked before final fit up, to ascertain that the actual bearing is evenly distributed and at least equal to 80% of the theoretical bearing area; push-up length is measured from the relative positioning of the two parts corresponding to this case.

The required push-up length is to be checked after releasing of hydraulic pressures applied in the hydraulic nut and in the assembly.

5.2.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E, in mm, of the rudder stock tapered part into the tiller boss is in compliance with the following formula:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

where:

$$\Delta_0 = 6,2 \frac{M_{TR} \eta \gamma}{c d_M t_i \mu_A \beta} 10^{-3}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{c} 10^{-6}$$

η : Coefficient to be taken equal to:

- for keyed connections:

  $\eta = 1$

- for keyless connections:

  $\eta = 2$

c : Taper of conical coupling measured on diameter, to be obtained from the following formula:

$c = (d_U - d_0) / \ell_c$

t_i, ℓ_c, d_U, d_0: Geometrical parameters of the coupling, in mm, defined in Fig 4

β : Coefficient to be taken equal to:

$$\beta = 1 - \left(\frac{d_M}{d_E}\right)^2$$

d_M : Mean diameter, in mm, of the conical bore, to be obtained from the following formula:

$d_M = d_U - 0,5\ c\ \ell_c$

d_E : External boss diameter, in mm

μ_A : Coefficient to be taken equal to:

$$\mu_A = \sqrt{\mu^2 - 0,25 c^2}$$

μ, γ : Coefficients to be taken equal to:

- for rudder stocks and bosses made of steel:

  $\mu = 0,15$

  $\gamma = 1$

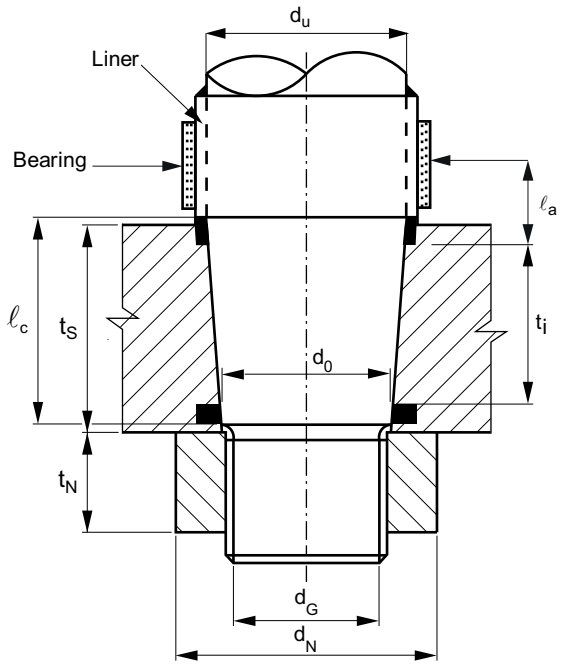
- for rudder stocks made of steel and bosses made of SG iron:

  $\mu = 0,13$

  $\gamma = 1,24 - 0,1\ \beta$

R_{eH} : Defined in [1.4.3].

Figure 4 : Geometry of cone coupling



5.2.4 Boss of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

The scantlings of the boss are to comply with the following formula:

$$\frac{1,8}{2\eta + 5} \cdot \frac{\Delta_E c}{\gamma d_0} 10^6 \leq R_{eH}$$

where:

Δ_E : Push-up length adopted, in mm

c, η, γ : As defined in [5.2.3]

d_0 : As defined in Fig 4, in mm

R_{eH} : As defined in [1.4.3].

5.2.5 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E, in mm, is in compliance with the following formula:

$$\delta_0 \leq \delta_E \leq \delta_1$$

where:

$$\delta_0 = 6,2 \cdot \frac{M_{TR}\eta\gamma}{d_U t_i \mu \beta_1} 10^{-3}$$

$$\delta_1 = \frac{2\eta + 5}{1,8} \cdot \gamma d_U R_{eH} 10^{-6}$$

η, μ, γ, c : As defined in [5.2.3]

d_U : As defined in Fig 4, in mm

β_1 : Coefficient to be taken equal to:

$$\beta_1 = 1 - \left(\frac{d_U}{d_E}\right)^2$$

R_{eH} : As defined in [1.4.3].

5.2.6 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by the Society on a case-by-case basis provided that the following conditions are complied with:

- evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) are to be submitted to the Society
- the torque transmissible by friction is to be not less than 2 M_{TR}
- design conditions and strength criteria are to comply with [5.2.1]
- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

5.3 Cone couplings between rudder stocks and rudder blades

5.3.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

- for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \leq \frac{d_U - d_0}{\ell_c} \leq \frac{1}{8}$$

- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \leq \frac{d_U - d_0}{\ell_c} \leq \frac{1}{12}$$

where:

d_U, ℓ_c, d_0 : Geometrical parameters of the coupling, in mm, defined in Fig 4.

5.3.2 Push-up pressure of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

The push-up pressure, in N/mm^2, is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_M^2 t_i \pi \mu_0} 10^3$$

$$p_{req2} = \frac{6M_{Bc}}{t_i^2 d_M} 10^3$$

where:

d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]

M_{Bc} : Bending moment in rudder stock at the top of the cone coupling, in N.m, to be deduced from the calculation of the bending moment in the rudder stock, M_B, as defined in Ch 12, App 1

Q_F : Design yield moment of rudder stock, in N.m, defined in [5.3.6]

t_i : Geometrical parameter of the coupling, in mm, defined in Fig 4

μ_0 : Frictional coefficient, taken equal to 0,15.

It has to be demonstrated by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure, in N/mm^2, is to be determined by the following formula:

$$p_{perm} = \frac{0,95 R_{eH}(1 - \alpha^2)}{\sqrt{3 + \alpha^4}} - p_b$$

where:

p_b : Pressure due to rudder bending, to be taken as follows:

$$p_b = \frac{3,5 M_{Bc}}{t_i^2 d_M} 10^3$$

R_{eH} : Minimum yield stress for the steel used for the gudgeon

$\alpha = d_M / d_E$

d_E : Minimum outer dimension (diameter or width) of the solid part in way of any horizontal cross section.

The outer diameter of the gudgeon is to be not less than 1,25 d_U, with d_U the rudder stock diameter, in mm, as defined in Fig 4.

5.3.3 Push-up length of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E, in mm, of the rudder stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

where:

$$\Delta_0 = \frac{p_{req} d_M}{E\left(\frac{1 - \alpha^2}{2}\right)c} + \frac{0,8 R_{tm}}{c}$$

$$\Delta_1 = \frac{p_{perm} d_M}{E\left(\frac{1 - \alpha^2}{2}\right)c} + \frac{0,8 R_{tm}}{c}$$

c : Taper on conical coupling defined in [5.2.3].

d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]

p_{perm} : Permissible surface pressure, in N/mm^2, calculated in [5.3.2]

p_{req} : Push-up pressure, in N/mm², as defined in [5.3.2]

R_{eH} : Minimum yield stress for the steel used for the gudgeon

R_{tm} : Mean roughness, in mm, taken equal to 0,01

α : Ratio defined in [5.3.2].

Note 1: In case of hydraulic pressure connections, the required push-up force P_e, in N, may be determined by the following formula:

$$P_e = p_{req} d_M \pi t_i \left(\frac{c}{2} + 0,02\right)$$

5.3.4 Lower rudder stock end

The lower rudder stock end is to be fitted with a threaded part having a core diameter, d_G, in mm, not less than (see Fig 4):

$$d_G = 0,65\ d_U$$

where:

d_U : Rudder stock diameter, in mm, as defined in Fig 4.

This threaded part is to be fitted with an adequate slogging nut efficiently locked in rotation.

The contact length t_i, in mm, of the rudder stock coupling cone inserted in the massive part (see Fig 4), deduction made of the chamfers and sealing ring grooves (oil grooves may be disregarded), is to be such that:

$$t_i \geq 1,5 d_U \sqrt{k_1}$$

where:

k_1 : Material factor of the massive part.

When the foreseen contact surface ratio between the rudder stock and the massive part is greater than 70%, a lower t_i/d_U ratio may be accepted, on a case-by-case basis, provided that the contact percentage is proportionally higher, without however being taken less than 1,2.

The dimensions of the slogging nut, in mm, are recommended to be as follows (see Fig 4):

- outer diameter:
  $d_N \geq$ Max (1,2 d_0 ; 1,5 d_G)
- thickness:
  $t_N \geq 0,60\ d_G$

where:

d_0 : As defined in Fig 4, in mm.

These dimensions and the core diameter d_G of the lower rudder stock end are given for guidance only, the determination of the adequate scantlings being left to the Designer.

5.3.5 Washer

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, a washer is to be fitted between the nut and the rudder gudgeon, having a thickness not less than 0,09 d_G and an outer diameter not less than 1,3 d_0 or 1,6 d_G, whichever is the greater.

The washer is not needed if the seat-surface of the nut is flat and, at least, identical to the contact surface calculated for a washer with the required diameter.

5.3.6 Couplings with key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted and keyways in both the tapered part and the rudder gudgeon.

The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

The key shear area a_S, in cm², is to be not less than:

$$a_S = \frac{17,55 Q_F}{d_k R_{eH1}}$$

where:

Q_F : Design yield moment of rudder stock, in N.m, obtained from the following formula:

$$Q_F = 0,02664 \frac{d_1^{\ 3}}{k_{1S}}$$

Where the actual stock diameter is greater than the calculated diameter d_1, the actual diameter is to be used, without being taken greater than 1,145 d_1.

d_1 : Rudder stock diameter, in mm, taken equal to d_T, as defined in [4.1.3]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

d_k : Mean diameter of the conical part of the rudder stock at the key, in mm

R_{eH1} : Specified minimum yield stress R_{eH} for the steel used for key.

The effective surface area a_k, in cm^2, of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5Q_F}{d_k R_{eH2}}$$

where:

R_{eH2} : Specified minimum yield stress R_{eH} of the key, stock or coupling material, whichever is less.

It is to be proved that 50% of the design yield moment Q_F is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure p_{req} and push-up length Δ_E according to [5.3.2] and [5.3.3] for a torsional moment Q'_F equal to 0,5 Q_F.

In the specific case where the key is considered to transmit the entire rudder torque to the couplings, the scantlings of the key, as well as the push-up force and push-up length, are to be at the discretion of the Society.

5.3.7 Instructions

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

5.4 Vertical flange couplings

5.4.1 Vertical flange couplings are to be connected by fitted bolts having a diameter, in mm, not less than the value obtained, in mm, from the following formula:

$$d_B = \frac{0{,}81\, d_1}{\sqrt{n_B}} \sqrt{\frac{k_{1B}}{k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

k_{1S}, k_{1B} : Material factors, defined in [5.1.3]

n_B : Total number of bolts, which is to be not less than 8.

5.4.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained, in cm^3, from the following formula:

$$M_S = 0{,}00043\ d_1^3$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2].

5.4.3 The thickness of the coupling flange, in mm, is to be not less than d_B, defined in [5.4.1].

5.4.4 The distance, in mm, from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B, where d_B is defined in [5.4.1].

5.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.5 Couplings by continuous rudder stock welded to the rudder blade

5.5.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than 0,20 d_1, where d_1 is defined in [4.1.2].

5.5.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic test.

The throat weld at the top of the rudder upper plate is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius:

- is to be not less than 0,15 d_1, where d_1 is defined in [4.1.2]
- may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld
- is to be checked with a template for accuracy. Four profiles, at least, are to be checked. A report is to be submitted to the Surveyor.

5.6 Rudder trunks

5.6.1 The requirements [5.6.2] to [5.6.8]apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

5.6.2 The bending and equivalent stresses in the rudder trunk, in N/mm^2, are to be in compliance with the following formulae:

$\sigma \leq 80 / k$

$\sigma_E \leq 0,35\ R_{eH}$

where k is not to be taken less than 0,7.

For the calculation of the bending and shear stresses, refer to Ch 12, App 1, [1.8].

5.6.3 The steel grade used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis or a carbon equivalent CEQ not exceeding 0,41.

5.6.4 The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

For rudder trunks extending below shell or skeg, the fillet shoulder radius r is to be as large as practicable and to comply with the following formulae: $r = 0,1\ d_1 / k$

where d_1 is defined in [4.1.2],

without being less than:

- when $\sigma \geq 40 / k$ N/mm^2:
  r = 60 mm
- when $\sigma < 40 / k$ N/mm^2:
  r = 30 mm

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld.

The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

5.6.5 In case of type 6c rudders, the trunk tube is to be made with a protrusion at connection with skeg bottom, and scallops in webs are to be avoided at connection between the bottom of the skeg and the trunk or the shell, as shown in Fig 5.

5.6.6 Before welding is started, a detailed welding procedure specification is to be submitted to the Society covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures. This welding procedure is to be supported by approval tests in accordance with the applicable requirements of NR216 Materials and Welding, Ch 12, Sec 3.

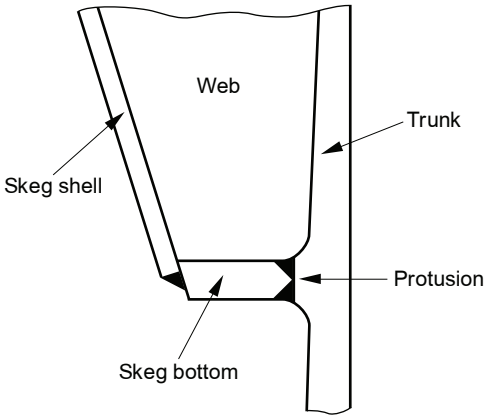
The manufacturer is to maintain records of welding, subsequent heat treatment and inspections traceable to the welds. These records are to be submitted to the Surveyor.

Non destructive tests are to be conducted at least 24 hours after completion of the welding. The welds are to be 100% magnetic particle tested and 100% ultrasonic tested. The welds are to be free from cracks, lack of fusion and incomplete penetration. The non destructive tests reports are to be handed over to the Surveyor.

5.6.7 Rudder trunks in materials other than steel are to be specially considered by the Society.

5.6.8 The thickness of the shell or of the bottom plate is to be compatible with the trunk thickness.

Figure 5 : Typical trunk/skeg connection on type 6c rudders



6 Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Support forces F_{Ai}, for i = 1, 2, 3, 4, as described in Tab 3, are to be obtained according to Ch 12, App 1, depending on the rudder type.

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the rudder stock bearings, in N/mm^2, equal to:

$$p_F = \frac{F_{Ai}}{d_m h_m}$$

F_{Ai} : Support force acting on the rudder stock bearing, in N

d_m : Actual inner diameter, in mm, of the rudder stock bearings (contact diameter)

h_m : Bearing length, in mm (see [6.2.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm^2, defined in Tab 5.

Values greater than those given in Tab 5 may be accepted by the Society on the basis of specific tests.

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

6.2.3 The length/diameter ratio of the bearing surface is not to be greater than 1,2.

Table 5 : Allowable bearing pressure

Bearing material	$p_{F,ALL}$, in N/mm^2
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness greater than 60 Shore D **(1)**	5,5 **(2)**
Steel, bronze and hot-pressed bronze-graphite materials **(3)**	7,0

(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by the Society

(2) Surface pressures exceeding 5,5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2

(3) Stainless and wear-resistant steel in combination with stock liner approved by the Society

6.2.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_m}{1000} + 1$$

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed. In any case, for non metallic supports, the clearance on support diameter is to be not less than 1,5 mm unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

6.2.5 Liners and bushes are to be fitted in way of the bearings. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. Their minimum thickness is to be equal to:

- 8 mm for metallic and synthetic materials
- 22 mm for lignum vitae material.

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula: $p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeons, in N/mm^2, equal to:

$$p_F = \frac{F_{Ai}}{d_{AC} h_L}$$

F_{Ai} : Support force acting on the pintle, in N

d_{AC} : Actual diameter, in mm, of the rudder pintles (contact diameter)

h_L : Bearing length, in mm (see [6.3.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm^2, defined in Tab 5.

Values greater than those given in Tab 5 may be accepted by the Society on the basis of specific tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The length/diameter ratio of the bearing surface is not to be less than 1 and not to be greater than 1,2.

6.3.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_{AC}}{1000} + 1$$

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed. In any case, for non-metallic supports, the clearance on support diameter is to be not less than 1,5 mm.

6.3.5 The thickness of any liner or bush, in mm, is to be not less than the greater of:

- $0,01\sqrt{F_{Ai}}$
- the minimum thickness defined in [6.2.5].

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \frac{0,38V_{AV}}{V_{AV} + 3}\sqrt{F_{Ai}k_1} + f_C$$

where:

d_A : corresponds to d_U value, in mm, shown in Fig 4

F_{Ai} : Force, in N, acting on the pintle, as specified in Tab 3

f_C : Coefficient depending on corrosion, whose value may generally be obtained from the following formula:

$$f_C = 30\sqrt{k_1}$$

The Society may accept lower values of f_C, considering the ship's dimensions and satisfactory service experience of corrosion control systems adopted.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with [5.3.1].

The conical coupling is to be secured by a nut. The dimensions of the massive part and slogging nut are to be in accordance with the following formulae:

$d_E \geq d_M + 0,6\ d_A$

$t_N \geq 0,60\ d_G$

$d_N \geq 1,2\ d_0$ and, in any case, $d_N \geq 1,5\ d_G$

where:

d_A : Pintle diameter defined in [6.4.1]

d_E : External diameter, in mm, of the massive part of Fig 4, having the thickness t_S

d_M : Mean diameter, in mm, of the conical bore, as defined in [5.2.3]

t_S, d_G, t_N, d_N, d_0 : Geometrical parameters of the coupling, in mm, defined in Fig 4.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

6.4.4 The length of the pintle housing in the gudgeon, which corresponds to t_i in Fig 4, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$h_L = 0,35\sqrt{F_{Ai}k_1}$$

$h_L = d_A$

where:

F_{Ai} : Force, in N, acting on the pintle, as specified in Tab 3.

The thickness of pintle housing in the gudgeon, in mm, is to be not less than $0,25\ d_A$, where d_A is defined in [6.4.1].

6.4.5 The required push-up pressure p_{req} for pintle bearings, in N/mm^2, is to be determined as follows:

- In case of dry fitting, p_{req} is to be taken equal to p_{req1}
- In case of oil injection fitting, p_{req} is to be taken as the maximum between p_{req1} and p_{req2}

where:

$$p_{req1} = 0,4\frac{F_{Ai}d_A}{d_M^2 t_i}$$

$$p_{req2} = \frac{6M_{Bp}}{t_i^2 d_M} 10^3$$

d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]

t_i : Geometrical parameter of the coupling, in mm, defined in Fig 4

M_{Bp} : Bending moment in the pintle cone coupling, in N.m, taken equal to:

$$M_{Bp} = F_{Ai} \ell_a$$

ℓ_a : Length between middle of pintle-bearing and top of contact surface between cone coupling and pintle, in m, defined in Fig 4

The required push-up length Δ_0 is to be calculated according to [5.3.3] using the required push-up pressure as defined above and pintle bearing properties.

7 Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in [7.1] to [7.6] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the dismantling of pintles or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.1.4 Connection of the rudder blade to the trailing edge for rudder blade area greater than 6 m^2

Where the rudder blade area is greater than 6 m^2, the connection of the rudder blade plating to the trailing edge is to be made by means of a forged or cast steel fashion piece, a flat or a round bar.

7.1.5 Rudder horn recess

Except in way of solid parts in cast steel, the corners of the recess intended for the passage of the rudder horn heel are to be designed with a radius at least equal to 5 times the plate thickness, but in no case smaller than 100 mm.

Welding in side plate is to be avoided in or at the end of these radii.

Edges of side plate and weld adjacent to radii are to be ground smooth.

7.2 Strength checks

7.2.1 Bending stresses

For the generic horizontal section of the rudder blade it is to be checked that the bending stress σ, in N/mm^2, induced by the loads defined in [3.1], is in compliance with the following formula:

$$\sigma \leq \sigma_{ALL}$$

where:

σ_{ALL} : Allowable bending stress, in N/mm^2, specified in Tab 6.

7.2.2 Shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the shear stress τ, in N/mm^2, induced by the loads defined in [3.1], is in compliance with the following formula:

$$\tau \leq \tau_{ALL}$$

where:

τ_{ALL} : Allowable shear stress, in N/mm^2, specified in Tab 6.

7.2.3 Combined bending and shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the equivalent stress σ_E is in compliance with the following formula:

$\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress induced by the loads defined in [3.1], to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2}$$

σ : Bending stress, in N/mm^2

τ : Shear stress, in N/mm^2

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, specified in Tab 6.

Table 6 : Allowable stresses for rudder blade scantlings

Type of rudder blade	Allowable bending stress σ_{ALL} in N/mm^2	Allowable shear stress τ_{ALL} in N/mm^2	Allowable equivalent stress $\sigma_{E,ALL}$ in N/mm^2
General	110 / k	50 / k	120 / k
In way of the recess for rudder horn pintle on semi-spade rudders **(1)**	75	50	100
(1) No benefit is given for high tensile steel in this case.			

7.3 Rudder blade plating

7.3.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained, in mm, from the following formula:

$$t_F = 5{,}5 s \beta \sqrt{k\left(T_{SC} + \frac{C_R 10^{-4}}{A}\right)} + 2{,}5$$

where:

β : Coefficient equal to:

$$\beta = \sqrt{1{,}1 - 0{,}5\left(\frac{s}{b_L}\right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2{,}5$

s : Length, in m, of the shorter side of the plate panel

b_L : Length, in m, of the longer side of the plate panel.

7.3.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be taken as the maximum of:

- the thickness t_F defined in [7.3.1], by considering the relevant values of s and b_L, for both the top and bottom plates
- 1,2 times the thicknesses obtained for the attached side platings around the top and bottom plates, respectively, calculated according to [7.3.1], by considering the relevant values of s and b_L

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder coupling flange is to be not less than 1,1 times the thickness calculated above.

7.3.3 Web thickness

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs. The thickness of each of these webs is to be uniform and not less than that of the web panel having the greatest thickness t_F, as calculated in [7.3.1]. In any case it is not required that the thickness is increased by more than 20% in respect of normal webs.

When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced, having thickness not less than that obtained from Tab 7. In rudders having area less than 6 m^2, one vertical web only may be accepted provided its thickness is at least twice that of normal webs.

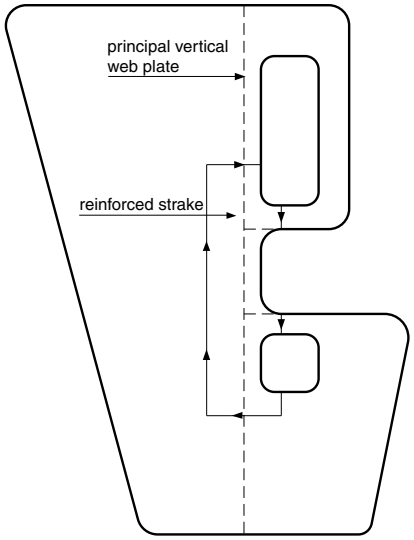
7.3.4 Thickness of side plating and vertical web plates welded to solid part or to rudder coupling flange

The thickness, in mm, of the vertical web plates welded to the solid part where the rudder stock is housed, or welded to the rudder coupling flange, as well as the thickness of the rudder side plating under this solid part, or under the rudder coupling flange, is to be not less than the value obtained, in mm, from Tab 7.

7.3.5 Reinforced strake of semi-spade rudders

A reinforced strake is to be provided in the lower pintle zone of semi-spade rudders. Its thickness is to be not less than 1,6 t_F, where t_F is defined in [7.3.1]. This strake is to be extended forward of the main vertical web plate (see Fig 6).

Figure 6 : Reinforced strake extension for semi-spade rudders



7.3.6 Main vertical webs of semi-spade rudders

The thickness of the main vertical web plate in the area between the rudder blade upper part and the pintle housing of semi-spade rudders is to be not less than 2,6 t_F, where t_F is defined in [7.3.1].

Under the pintle housing the thickness of this web is to be not less than the value obtained from Tab 7.

Where two main vertical webs are fitted, the thicknesses of these webs are to be not less than the values obtained from Tab 7 depending on whether the web is fitted in a rudder blade area without opening or if the web is along the recess cut in the rudder for the passage of the rudder horn heel.

Table 7 : Thickness of the vertical webs and rudder side plating welded to solid part or to rudder coupling flange

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Rudder types 1, 2, 3 and 4 (see Tab 3)	t_F	1,3 t_F	t_F	1,2 t_F
Rudder type 5 (see Tab 3)	1,2 t_F	1,6 t_F	1,2 t_F	1,4 t_F
Rudder types 6, 7, 8, 9 and 10 (see Tab 3)	1,4 t_F	2,0 t_F	1,3 t_F	1,6 t_F
Note 1: t_F as defined in [7.3.1].				

7.3.7 Welding

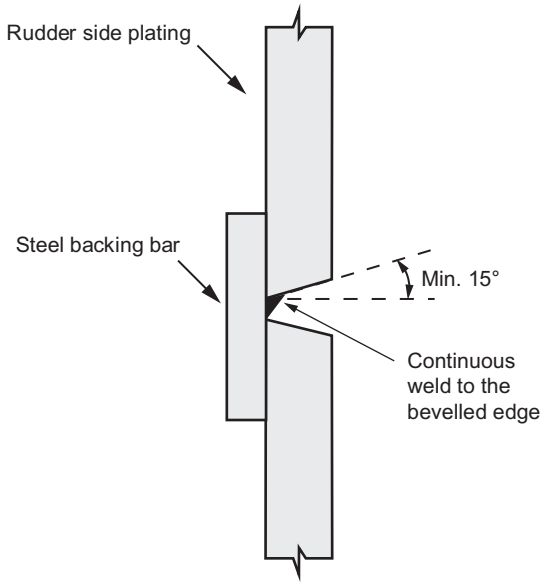
Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transverse to the slots or in way of cut-out areas of semi-spade rudders.

When slot welding is applied, the length of the slots is to be at least 75 mm with a breadth of 2 times the rudder plate thickness t_F, in mm. The distance between ends of slots is not to be greater than 125 mm. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be fitted with continuous weld on one side to the bevelled edge, see Fig 7. The bevel angle is to be at least 15° for one sided welding.

Figure 7 : Use of steel backing bar in way of full penetration welding of rudder side plating



7.3.8 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than:

- for $t_F < 22$ mm:

  $1{,}25\ t_F$ without exceeding 22 mm
- for $t_F \geq 22$ mm:

  t_F

where t_F is defined in [7.3.1].

The rudder nose plate thickness may be increased on a case by case basis to be considered by the Society.

7.4 Connections of rudder blade structure with solid parts in forged or cast steel

7.4.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

7.4.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm^3, from the following formula:

$$w_S = c_S d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:
- if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate:

  $c_S = 1{,}0$
- if there is an opening in the considered cross-section of the rudder:

  $c_S = 1{,}5$

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined in [1.4], for the rudder blade plating and the rudder stock, respectively.

7.4.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

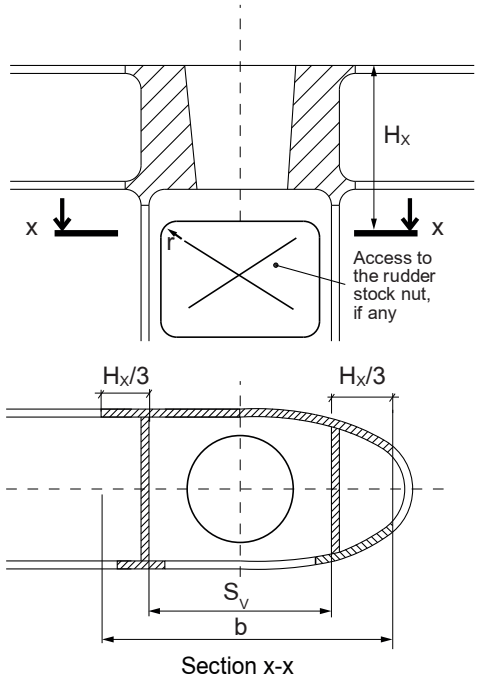
s_V : Spacing, in m, between the two vertical webs (see Fig 8)

H_X : Distance defined in [7.4.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to [7.1.3], they are to be deducted (see Fig 8).

Figure 8 : Cross-section of the connection between rudder blade structure and rudder stock housing



7.4.4 Thickness of horizontal web plates

The thickness of the horizontal web plates connected to the upper and lower ends of the solid part, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t_H = 1,2\ t_F$

$$t_H = 0,045\frac{d_S^2}{s_H}$$

where:

t_F : Defined in [7.3.1]

d_S : Diameter, in mm, to be taken equal to:

- d_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

d_A : Pintle diameter, in mm, defined in [6.4.1]

s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

7.4.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 7.

7.4.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.5.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained, in cm^3, from the following formula:

$$w_S = 1{,}3\ d_1^3\ 10^{-4}$$

where d_1 is the rudder stock diameter d_{TF}, in mm, to be calculated in compliance with [4.1.2], taking k_1 equal to 1.

7.5.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder coupling flange is to be considered.

Where the rudder plating is provided with an opening under the rudder coupling flange, the actual section modulus of the rudder blade is to be calculated in compliance with [7.4.3].

7.5.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100% inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder coupling flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder coupling flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.5.4 Thickness of side plating and vertical web plates welded to the rudder coupling flange

The thickness of the vertical web plates directly welded to the rudder coupling flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder coupling flange are to be not less than the values obtained, in mm, from Tab 7.

7.6 Single plate rudders

7.6.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [4.1.2] or [4.1.3].

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.6.2 Blade thickness

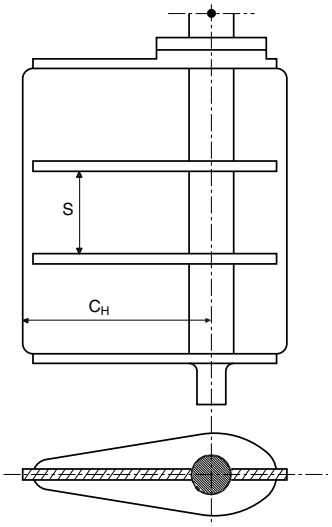
The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_B = 1{,}5 s V_{AV} \sqrt{k} + 2{,}5$$

where:

s : Spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 9).

Figure 9 : Single plate rudder



7.6.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained, in cm^3, from the following formula:

$Z_A = 0,5\ s\ C_H^2\ V_{AV}^2\ k$

where:

C_H : Horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock (see Fig 9)

s : Defined in [7.6.2].

8 Rudder horn and solepiece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the solepiece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the applicable requirements of Pt C, Ch 1, Sec 14.

8.2 Rudder horn

8.2.1 General

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

8.2.2 Loads

The following loads acting on the generic section of the rudder horn are to be considered:

- bending moment
- shear force
- torque.

Bending moment, shear forces and torque are to be calculated according to Ch 12, App 1, [1.6], or Ch 12, App 1, [1.7], depending on the relevant type of rudder.

8.2.3 Shear stress check

For the generic section of the rudder horn, it is to be checked that:

$\tau_S \leq \tau_{ALL}$

where:

τ_S : Shear stress, in N/mm^2, to be obtained according to, either Ch 12, App 1, [1.6] or Ch 12, App 1, [1.7]

τ_{ALL} : Allowable shear stress, in N/mm^2:

$\tau_{ALL} = 48 / k_1$

8.2.4 Combined stress strength check

For the generic section of the rudder horn, it is to be checked that:

$\sigma_E \leq \sigma_{E,ALL}$

$\sigma_B \leq \sigma_{B,ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3(\tau_S^2 + \tau_T^2)}$$

σ_B : Bending stress, in N/mm^2, to be obtained from, either Ch 12, App 1, [1.6] or Ch 12, App 1, [1.7], depending on the rudder type

τ_S, τ_T : Shear and torsional stresses, in N/mm^2, to be obtained according to, either Ch 12, App 1, [1.6] or Ch 12, App 1, [1.7]

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 120 / k_1$

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 67 / k_1$.

8.2.5 Rudder horn plating

The thickness, in mm, of the rudder horn side plating is not to be less than:

$$t = 2,4\sqrt{(Lk)}$$

where

L : Rule length as defined in Ch 1, Sec 2, [3.1]

k : Material factor as given in [1.4].

8.3 Connection of after peak structures with the rudder horn

8.3.1 General

The requirement in Ch 11, Sec 3, [3] apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

8.4 Solepieces

8.4.1 Strength checks

For the generic section of the solepiece, it is to be checked that:

$\sigma_B \leq \sigma_{B,ALL}$

$\tau \leq \tau_{ALL}$

where:

σ_B : Bending stress, in N/mm^2, to be obtained according to Ch 12, App 1, [1.5.2]

τ : Shear stress, in N/mm^2, to be obtained according to Ch 12, App 1, [1.5.2]

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 80 / k_1$

τ_{ALL} : Allowable shear stress, in N/mm^2, equal to:

$\tau_{ALL} = 48 / k_1$.

8.4.2 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Ch 12, App 1, Fig 12) is to be not less than the value obtained, in cm^3, from the following formula:

$W_Y = 0,5\ W_Z$

where:

W_Z : Section modulus, in cm^3, around the vertical axis Z (see Ch 12, App 1, Fig 12).

9 Simplex rudder shaft

9.1 Scantlings

9.1.1 Diameter of the rudder shaft

The rudder shaft diameter is to be not less than the value obtained, in mm, from the following formula:

$$d = 17{,}9\left(\frac{\alpha A(V_{AV}+2)^2}{\ell}\right)^{1/3}$$

where:

α : Coefficient equal to:

- if $a \le b$:

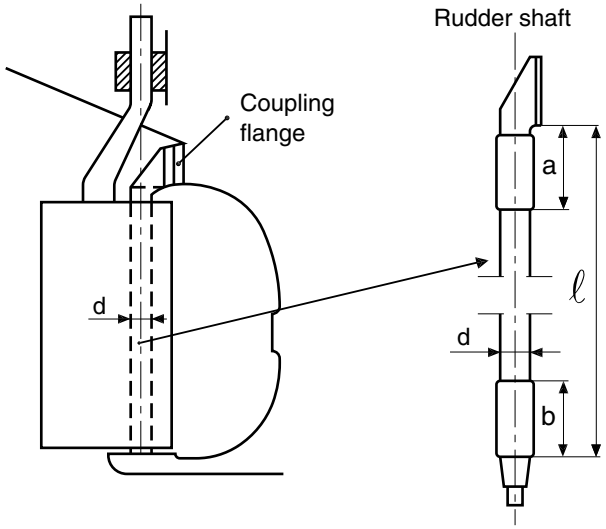
  $\alpha = b\,(\ell - b + a)$

- if $a > b$:

  $\alpha = a\,(\ell - a + b)$

a, b, ℓ : Geometrical parameters, in m, defined in Fig 10.

Figure 10 : Simplex rudder shaft geometry



9.1.2 Sectional area of rudder shaft

The overall sectional area of the rudder shaft is to be not less than the greater of the following values:

- 70% of the sectional area for the propeller post defined in Ch 11, Sec 3, [4.2]
- value of the sectional area of the pintle supporting half the rudder blade, whose diameter is to be calculated from the formula in [6.4.1].

If the latter value is the greater, it is to be applied only where the rudder bears on the rudder shaft; in such case, it is recommended that an overthickness or a bush is provided in way of the bearing areas.

9.1.3 Bearings

The bearing length of the rudder shaft is to be not less than 1,2 d, where d is the shaft diameter defined in [9.1.1].

The mean pressure acting on the bearings is not to exceed the relevant allowable values, defined in Tab 5.

9.1.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_A}{1000} + 1$$

where:

d_A : Actual inner diameter, in mm, of the rudder shaft bearing (contact diameter).

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, for non-metallic supports, the clearance on support diameter is to be not less than 1,5 mm.

9.2 Connections

9.2.1 Connection with the hull

The shaft is to be connected with the hull by means of a vertical coupling flange having thickness at least equal to d/4, where d is the shaft diameter, obtained from the formula in [9.1.1] (see Fig 10).

The coupling flange is to be secured by means of six fitted bolts. The shank diameter of the bolts is to be not less than the coupling flange thickness defined above.

The distance from the bolt centre lines to the coupling flange edge is to be not less than 1,17 times the bolt diameter defined above.

9.2.2 Connection with the solepiece

The rudder shaft is to be connected with the solepiece by means of a cone coupling, having a taper on the radius equal to about 1/10 and housing length not less than 1,1 d, where d is obtained from the formula in [9.1.1] (See Fig 10).

The mean pressure exerted by the rudder shaft on the bearing is to be not greater than the relevant allowable bearing pressure, defined in Tab 5 assuming a rudder with two pintles.

10 Nozzles

10.1 General

10.1.1 The requirements of this Article apply to the scantlings of steering and fixed nozzles for which the power transmitted to the propeller is less than the value obtained, in kW, from the following formula:

$$P = \frac{16900}{d_M}$$

where:

d_M : Inner diameter of the nozzle, in m.

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

10.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

One of the ring webs is to be fitted in way of the axis of rotation of the nozzle.

10.1.3

The section modulus W_N, in cm^3, of the nozzle double skin profile (half nozzle cross section) around its neutral axis parallel to the center line, is not to be less than:

$$W_N = n d^2 b V_{AV}^2$$

where:

d : Inner diameter of nozzle, in m

b : Length of nozzle, in m

n : Coefficient taken equal to:

- for steering nozzles:
  n = 1,0
- for fixed nozzles:
  n = 0,7

10.1.4 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

10.1.5 The internal part of the nozzle is to be adequately protected against corrosion.

10.2 Nozzle plating and internal diaphragms

10.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formulae:

$$t_F = (0{,}085\sqrt{Pd_M} + 9{,}65)\sqrt{k} \quad \text{for} \quad P \le \frac{6100}{d_M}$$

$$t_F = (0{,}085\sqrt{Pd_M} + 11{,}65)\sqrt{k} \quad \text{for} \quad P > \frac{6100}{d_M}$$

where:

P, d_M : Defined in [10.1.1].

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one fourth of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than $(t_F - 7)$ mm and, in any case, not less than 7 mm.

10.2.2 The thickness of the outer plating of the nozzle is to be not less than $(t_F - 9)$ mm, where t_F is defined in [10.2.1] and, in any case, not less than 7 mm.

10.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than $(t_F - 7)$ mm, where t_F is defined in [10.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F.

The Society may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

10.3 Nozzle stock

10.3.1 The diameter of the nozzle stock is to be not less than the value obtained, in mm, from the following formula:

$$d_{NTF} = 6,42\ (M_T\ k_1)^{1/3}$$

where:

M_T : Torque, to be taken as the greater of those obtained, in N.m, from the following formulae:

$M_{TAV} = 0,3\ S_{AV}\ a$

$M_{TAD} = S_{AD}\ b$

S_{AV} : Force, in N, equal to: $S_{AV} = 150\ V_{AV}^2\ A_N$

S_{AD} : Force, in N, equal to: $S_{AD} = 200\ V_{AD}^2\ A_N$

A_N : Area, in m^2, equal to: $A_N = 1,35\ A_{1N} + A_{2N}$

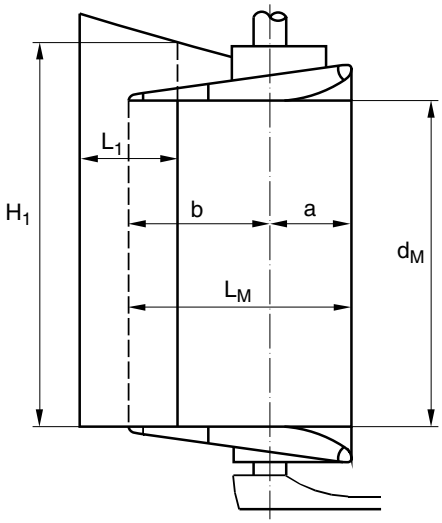
A_{1N} : Area, in m^2, equal to: $A_{1N} = L_M\ d_M$

A_{2N} : Area, in m^2, equal to: $A_{2N} = L_1\ H_1$

a, b, L_M, d_M, L_1, H_1 : Geometrical parameters of the nozzle, in m, defined in Fig 11.

The diameter of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach, in way of the tiller or quadrant, the value obtained, in mm, from the following formula: $d_{NT} = 0,75\ d_{NTF}$

Figure 11 : Geometrical parameters of the nozzle



10.4 Pintles

10.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{0,35 V_{AV}}{V_{AV} + 3}\sqrt{S_{AV}} + 30\right)\sqrt{k_1}$$

where:

S_{AV} : Defined in [10.3.1].

10.4.2 The length/diameter ratio of the pintle is not to be less than 1 and not to be greater than 1,2.

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeon, to be obtained in N/mm^2, from the following formula:

$$p_F = \frac{0,6S'}{d'_A h'_A}$$

S' : The greater of the values S_{AV} and S_{AD}, in N, defined in [10.3.1]

d'_A : Actual pintle diameter, in mm

h'_A : Actual bearing length of pintle, in mm

$p_{F,ALL}$: Allowable bearing pressure, in N/mm^2, defined in Tab 5.

10.5 Nozzle coupling

10.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained, in mm, from the following formula:

$$d_B = 0,62\sqrt{\frac{d_{NTF}^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]

k_{1S} : Material factor k_1 for the steel used for the stock

k_{1B} : Material factor k_1 for the steel used for the bolts

e_M : Mean distance, in mm, from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)

n_B : Total number of bolts, which is to be not less than:

- if $d_{NTF} \leq 75$ mm:

  $n_B = 4$

- if $d_{NTF} > 75$ mm:

  $n_B = 6$

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of ($0,25d_{NT}$ x $0,10d_{NT}$) mm^2, where d_{NT} is defined in [10.3.1], and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

10.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_B\sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_B : Diameter of the coupling bolts, in mm, defined in [10.5.1]

k_{1B}, : Material factor k_1 for the steel used for the bolts

k_{1F} : Material factor k_1 for the steel used for the coupling flange.

10.5.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula:

$\Delta_0 \leq \Delta_E \leq \Delta_1$

where:

Δ_0 : The greater of:

$$\Delta_0 = 6,2 \cdot \frac{M_{TR}\eta\gamma}{c d_M t_i \mu_A \beta}$$

$$\Delta_0 = 16 \cdot \frac{M_{TR}\eta\gamma}{c t_i^2 \beta} \cdot \sqrt{\frac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$$

$$\rho_1 = \frac{80\sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_i^2 \left[1 - \left(\frac{d_0}{d_E}\right)^2\right]}$$

d_{NTF}, d_{NT}: Nozzle stock diameters, in mm, to be obtained from [10.3.1], considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ:Defined in [5.2.3]

t_i, d_0 : Defined in Fig 4, in mm

R_{eH} : Defined in [1.4.3].

10.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

11 Azimuth propulsion system

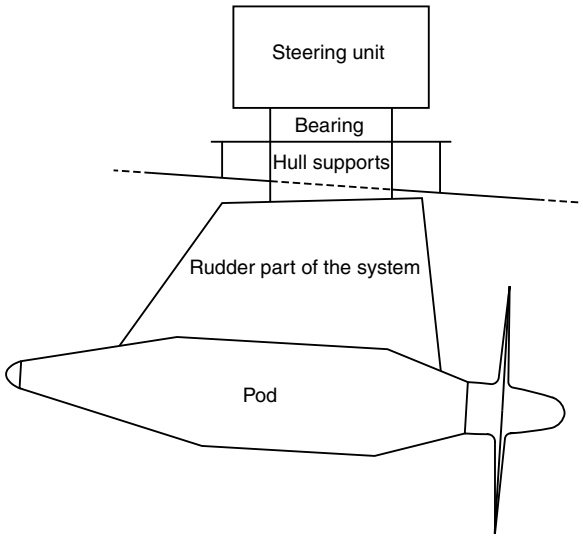
11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 12):

- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

Figure 12 : Azimuth propulsion system



11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the requirements in Pt C, Ch 1, Sec 14 and Pt C, Ch 1, Sec 15 respectively.

11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1 The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.

The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [7.3.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 7, Sec 4, where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [7.3.3], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 7, Sec 5, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in [11.6.2].

The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered by the Designer in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see [11.1.3])
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm^2, for the load cases defined in [11.6.2], is in compliance with the following criteria:

$\sigma_{VM} \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, to be taken equal to 0,55 R_{eH}

R_{eH} : Minimum yield stress, in N/mm^2, of the specified steel. R_{eH} is not to exceed the lower of 0,7 R_m and 450 N/mm^2

R_m : Minimum ultimate tensile strength, in N/mm^2, of the steel used.

When the loads are calculated for crash stop of the ship, the criteria given in [11.6.4] are to be complied with.

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{ALL} / R_{eH}.

11.6.4 Strength check for crash stop of the ship

When the loads are calculated for crash stop of the ship, the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm^2, is to be checked with the following criteria:

$\sigma_{VM} \leq \sigma_{CRASH}$

where:

$\sigma_{CRASH} = 1,25\ \sigma_{ALL}$

σ_{ALL} : Allowable stress as defined in [11.6.3].

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{CRASH} / R_{eH}.

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_{VM} in hull supports, in N/mm^2, calculated for the load cases defined in [11.6.2], is in compliance with the following criteria:

$\sigma_{VM} \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, equal to:

$\sigma_{ALL} = 65 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.2].

When the loads are calculated for crash stop of the ship, the criteria given in [11.7.4] is to be complied with.

Values of σ_{VM} greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localisation of σ_{VM} and on the type of direct calculation analysis.

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{ALL} / R_{eH}.

11.7.4 Strength check for crash stop of the ship

When the loads are calculated for crash stop of the ship, the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm^2, is to be checked with the following criteria:

$\sigma_{VM} \leq \sigma_{CRASH}$

where:

$\sigma_{CRASH} = 1,25\ \sigma_{ALL}$

σ_{ALL} : Allowable stress as defined in [11.7.3].

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{CRASH} / R_{eH}.

11.7.5 Buckling check

A local buckling check is to be carried out, for plate panels which constitute hull supports of the azimuth propulsion system, according to Ch 9, Sec 1 calculating the stresses in the plate panels according to [11.7.1] and [11.7.2].

Section 2 Bulwarks and Guard Rails

1 General

1.1 Application

1.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks.

1.2 General requirements

1.2.1 Minimum height

Bulwarks or guard rails, are to be of 1,0 m in height as a minimum, measured above sheathing, and are to be constructed as required in [2.2] and [3.2]. Where this height would interfere with the normal operation of the ship, a lesser height may be accepted by the Society on a case-by-case basis.

1.2.2 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

1.2.3 In type A and B-100 ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 11, Sec 12, [6.5.2] are to be fitted.

1.2.4 In ships with bulwarks and trunks of breadth not less than 0,6 B, which are included in the calculation of freeboard, open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 11, Sec 12, [6.3.1] are to be fitted.

1.2.5 The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 11, Sec 12, [6].

2 Bulwarks

2.1 Construction of bulwarks

2.1.1 Bulwark plating is to be stiffened at the upper edge by a suitable rail and supported either by stays or brackets spaced not more than 2,0 m apart.

The free edge of the stay or bracket is to be stiffened.

Bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.

As an alternative, the lower end of the stay may be supported by a longitudinal stiffener.

In type A, B-60 and B-100 ships, the spacing forward of 0,07 L from the fore end of brackets and stays is to be not greater than 1,2 m.

2.1.2 Bulwarks are to be arranged to ensure that they do not contribute to hull girder strength.

As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society on a case-by-case basis.

2.1.3 Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles used for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.1.4 Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.2.3].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

Cut-outs in bulwarks for gangways or other openings are to be kept clear of superstructures discontinuities.

Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.5 In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

2.2 Scantlings

2.2.1 Thickness

The thickness of bulwarks on the freeboard deck not exceeding 1100 mm in height is to be not less than:

- 5,5 mm for $L \leq 30$ m
- 6,0 mm for $30 \text{ m} < L \leq 120$ m
- 6,5 mm for $L > 120$ m.

Where the height of the bulwark is equal to or greater than 1800 mm, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark, as obtained from Ch 11, Sec 5, [2.1.1], without being taken less than the minimum thicknesses specified above.

For bulwarks between 1100 mm and 1800 mm in height, their thickness is to be calculated by linear interpolation.

2.2.2 Stays

The gross section modulus of stays in way of the lower part of the bulwark is to be not less than the value $Z_{stay\text{-}gr}$, in cm^3, obtained from the following formula:

$$Z_{stay\text{-}gr} = 40\, s_{stay}\, (1 + 0{,}01\, L)\, h_{blwk}^2$$

where:

s_{stay} : Spacing of the stays, in m

L : Length of ship, in m, to be assumed not greater than 100 m

h_{blwk} : Height of bulwark from the top of the deck plating to the top of the rail, in m.

The Society may accept scantlings determined by direct calculations as an alternative to the above value of $Z_{stay\text{-}gr}$.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required minimum section modulus is considered by the Society on a case-by-case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having width not exceeding 600 mm may also be included in the calculation of the actual section modulus of stays.

2.2.3 At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating; where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4 Bulwarks located in the bow flare area as defined in Ch 11, Sec 1, [3.3] are to be reinforced according to Ch 11, Sec 1, [3], considering the stays as cantilever primary supporting members.

3 Guard rails

3.1 General

3.1.1 Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2 Where superstructures are connected by trunks, open rails are to be fitted along the whole length of the exposed parts of the freeboard deck.

3.1.3 Guard rails fitted on superstructure and freeboard decks shall have at least three courses. In other locations, guard rails with at least two courses shall be fitted.

3.2 Construction of guard rails

3.2.1 Stanchions of guard rails are to comply with the following requirements:

a) fixed, removable or hinged stanchions are to be fitted approximately 1,5 m apart

b) at least every third stanchion is to be supported by a bracket or stay (other alternatives may be accepted under the requirements of [3.2.2])

c) removable or hinged stanchions are to be capable of being locked in the upright position

d) in the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck

e) in the case of ships with welded sheerstrake, the stanchions are not to be attached to the sheerstrake, an upstand or a continuous gutter bar.

3.2.2 In lieu of at least every third stanchion supported by a stay, three other alternatives may be accepted:

- at least every third stanchion is of increased breadth: $k\ b_s = 2,9\ b_s$
- at least every second stanchion is of increased breadth: $k\ b_s = 2,4\ b_s$
- every stanchion is of increased breadth: $k\ b_s = 1,9\ b_s$

where:

b_s : breadth of normal stanchion according to the design standard

Flat steel stanchions of increased breadth (see Fig 1) are to be aligned with member below deck. A minimum flat bar 100 x 12 is to be welded to deck by double continuous fillet welds with leg size of minimum 7 mm or as specified by the design standard.

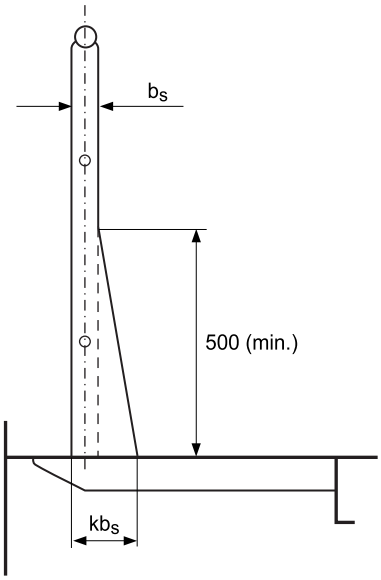
The stanchions with increased breadth need not be aligned with under deck structure for deck plating exceeding 20 mm. This minimum plate thickness may be achieved by doubling plates.

3.2.3 The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230 mm. The distance between other courses is not to be greater than 380 mm.

3.2.4 Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

3.2.5 Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks. If the opening is wide, the chains are to be fitted with vertical courses to prevent the horizontal courses from spreading apart.

Figure 1 : Guard rail stanchion of increased breadth



Section 3 Propeller Shaft Brackets

Symbols

F_C : Force, in kN, taken equal to:

$$F_C = \left(\frac{2\pi N}{60}\right)^2 R_P P$$

P : Mass of a propeller blade, in t

N : Number of revolutions per minute of the propeller

R_P : Distance, in m, of the centre of gravity of a blade in relation to the rotation axis of the propeller

σ_{ALL} : Allowable stress, in N/mm^2:

$$\sigma_{ALL} = 70 / k$$

k : Material factor, as defined in Ch 4, Sec 1, [2.2]

w_A : Section modulus, in cm^3, of the arm at the level of the connection to the hull with respect to a transversal axis

w_B : Section modulus, in cm^3, of the arm at the level of the connection to the hull with respect to a longitudinal axis

A : Sectional area, in cm^2, of the arm

A_S : Shear sectional area, in cm^2, of the arm

d_P : Propeller shaft diameter, in mm, measured inside the liner, if any.

1 Propeller shaft brackets

1.1 General

1.1.1 Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

1.2 Double arm propeller shaft brackets

1.2.1 General

This type of propeller shaft bracket consists of two arms arranged, as far as practicable, at right angles and converging in the propeller shaft bossing.

Exceptions to this will be considered by the Society on a case by case basis.

1.2.2 Scantlings of arms

The moment in the arm, in kN.m, is to be obtained from the following formula:

$$M = \frac{F_C}{\sin\alpha}\left(\frac{L}{\ell} d_1 \cos\beta + L - \ell\right)$$

where:

α : Angle between the two arms

β : Angle defined in Fig 1

d_1 : Distance, in m, defined in Fig 1

L, ℓ : Lengths, in m, defined in Fig 2.

It is to be checked that the bending stress σ_F, the compressive stress σ_N and the shear stress τ are in compliance with the following formula:

$$\sqrt{(\sigma_F + \sigma_N)^2 + 3\tau^2} \leq \sigma_{ALL}$$

where:

$$\sigma_F = \frac{M}{w_A} 10^3$$

$$\sigma_N = 10 F_C \frac{L \sin\beta}{A \ell \sin\alpha}$$

$$\tau = 10 F_C \frac{L \cos\beta}{A_S \ell \sin\alpha}$$

Figure 1 : Angle β and length d_1

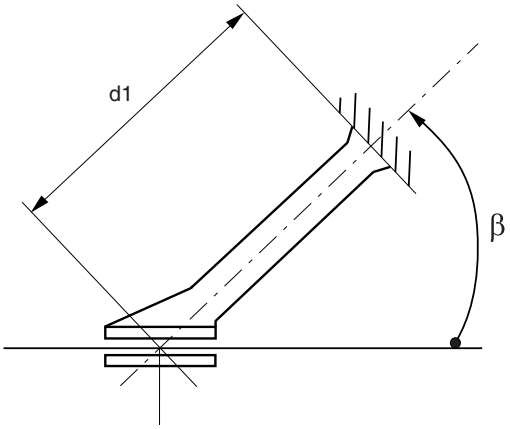
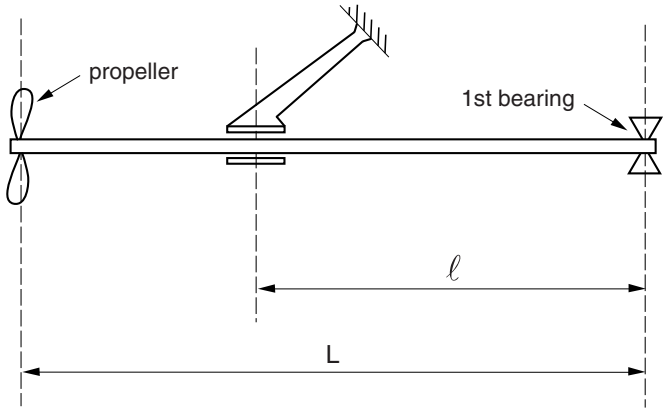


Figure 2 : Lengths L and ℓ



1.2.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the propeller shaft bossing is to be not less than $0,33\ d_P$.

1.2.4 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

The securing of the arms to the hull structure is to prevent any displacement of the brackets with respect to the hull.

1.3 Single arm propeller shaft brackets

1.3.1 General

This type of propeller shaft bracket consists of one arm and may be used only on ships less than 65 m in length.

1.3.2 Scantlings of arms

The moment in case of a single arm, in kN.m, is to be obtained from the following formula:

$$M = d_2 0,75 F_C \frac{L}{\ell}$$

where:

d_2 : Length of the arm, in m, measured between the propeller shaft axis and the hull

L, ℓ : Lengths, in m, defined in Fig 2.

It is to be checked that the bending stress σ_F and the shear stress τ are in compliance with the following formula:

$$\sqrt{\sigma_F^2 + 3\tau^2} \leq \sigma_{ALL}$$

where:

$$\sigma_F = \frac{M}{w_B} 10^3$$

$$\tau = 10 F_C \frac{L}{A_S \ell}$$

1.3.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the propeller shaft bossing is to be not less than $0,33\ d_p$.

1.3.4 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

The securing of the arm to the hull structure is to prevent any displacement of the bracket with respect to the hull.

1.4 Bossed propeller shaft brackets

1.4.1 General

Where bossed propeller shaft brackets are fitted, their scantlings are to be considered by the Society on a case by case basis.

1.4.2 Scantling of the boss

The length of the boss is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the boss, in mm, is to be not less than $0,33\ d_p$.

The aft end of the bossing is to be adequately supported.

1.4.3 Scantling of the end supports

The scantlings of end supports are to be specially considered. Supports are to be adequately designed to transmit the loads to the main structure.

End supports are to be connected to at least two deep floors of increased thickness or connected to each other within the ship.

1.4.4 Stiffening of the boss plating

Stiffening of the boss plating is to be specially considered. At the aft end, transverse diaphragms are to be fitted at every frame and connected to floors of increased scantlings.

At the fore end, web frames spaced not more than four frames apart are to be fitted.

Section 4 Equipment

Symbols

EN : Equipment Number defined in [1.2]

R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 1, Sec 3, Tab 2

R_m : Tensile strength, in N/mm², of the material, defined in Ch 1, Sec 3, Tab 2

σ_{ALL} : Allowable stress, in N/mm², used for the yielding check in [3.9.7], [3.10.7], [3.11.2] and [3.11.3], to be taken as the lesser of:

- $\sigma_{ALL} = 0,67\ R_{eH}$
- $\sigma_{ALL} = 0,40\ R_m$

1 General

1.1 Application

1.1.1 The requirements of the present Article and Article [2] apply to temporary anchoring of a ship within a harbour or sheltered area when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with these requirements:

- is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.
- is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is significantly reduced.

1.1.2 The required anchoring equipment in [1.2] is given considering the following environmental conditions:

- maximum current speed of 5 knots (2,5 m/s)
- maximum wind speed of 50 knots (25 m/s)
- no waves
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth.

1.1.3 As guidance for the limitations of the anchoring equipment used in semi-sheltered anchorages, the required anchoring equipment as defined in [1.2] can also be considered applicable for ships with the length L_E as defined in [1.2.2] greater than 135 m to the following environmental conditions including waves:

- maximum current speed of 3 knots (1,54 m/s)
- maximum wind speed of 21 knots (11 m/s)
- waves with maximum significant height of 2 m
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth.

1.1.4 For ships intended to anchor in deep and unsheltered water and assigned with the additional class notation **UNSHELTERED ANCHORING** refer to additional applicable requirements in Pt F, Ch 11, Sec 4.

1.1.5 It is assumed that under normal circumstances a ship uses only one bow anchor and chain cable at a time.

1.2 Equipment number

1.2.1 General

All ships are to be provided with equipment in anchors and chain cables, to be obtained from Tab 1, based on their Equipment Number EN.

For ships having the navigation notation **coastal area** or **sheltered area**, the equipment in anchors and chain cables may be reduced. The reduction consists of entering in Tab 1 one line higher for ships having the navigation notation **coastal area** and two lines higher for ships having the navigation notation **sheltered area**, based on their Equipment Number EN.

Table 1 : Equipment

Equipment number EN A ≤ EN < B		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				Q1	Q2	Q3
50	70	2	180	220,0	14,0	12,5	
70	90	2	240	220,0	16,0	14,0	
90	110	2	300	247,5	17,5	16,0	
110	130	2	360	247,5	19,0	17,5	
130	150	2	420	275,0	20,5	17,5	
150	175	2	480	275,0	22,0	19,0	
175	205	2	570	302,5	24,0	20,5	
205	240	2	660	302,5	26,0	22,0	20,5
240	280	2	780	330,0	28,0	24,0	22,0
280	320	2	900	357,5	30,0	26,0	24,0
320	360	2	1020	357,5	32,0	28,0	24,0
360	400	2	1140	385,0	34,0	30,0	26,0
400	450	2	1290	385,0	36,0	32,0	28,0
450	500	2	1440	412,5	38,0	34,0	30,0
500	550	2	1590	412,5	40,0	34,0	30,0
550	600	2	1740	440,0	42,0	36,0	32,0
600	660	2	1920	440,0	44,0	38,0	34,0
660	720	2	2100	440,0	46,0	40,0	36,0
720	780	2	2280	467,5	48,0	42,0	36,0
780	840	2	2460	467,5	50,0	44,0	38,0
840	910	2	2640	467,5	52,0	46,0	40,0
910	980	2	2850	495,0	54,0	48,0	42,0
980	1060	2	3060	495,0	56,0	50,0	44,0
1060	1140	2	3300	495,0	58,0	50,0	46,0
1140	1220	2	3540	522,5	60,0	52,0	46,0
1220	1300	2	3780	522,5	62,0	54,0	48,0
1300	1390	2	4050	522,5	64,0	56,0	50,0
1390	1480	2	4320	550,0	66,0	58,0	50,0
1480	1570	2	4590	550,0	68,0	60,0	52,0
1570	1670	2	4890	550,0	70,0	62,0	54,0
1670	1790	2	5250	577,5	73,0	64,0	56,0
1790	1930	2	5610	577,5	76,0	66,0	58,0
1930	2080	2	6000	577,5	78,0	68,0	60,0
2080	2230	2	6450	605,0	81,0	70,0	62,0
2230	2380	2	6900	605,0	84,0	73,0	64,0
2380	2530	2	7350	605,0	87,0	76,0	66,0
2530	2700	2	7800	632,5	90,0	78,0	68,0
2700	2870	2	8300	632,5	92,0	81,0	70,0
2870	3040	2	8700	632,5	95,0	84,0	73,0
3040	3210	2	9300	660,0	97,0	84,0	76,0
3210	3400	2	9900	660,0	100,0	87,0	78,0
3400	3600	2	10500	660,0	102,0	90,0	78,0
3600	3800	2	11100	687,5	105,0	92,0	81,0
3800	4000	2	11700	687,5	107,0	95,0	84,0

Equipment number EN A ≤ EN < B		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				Q1	Q2	Q3
4000	4200	2	12300	687,5	111,0	97,0	87,0
4200	4400	2	12900	715,0	114,0	100,0	87,0
4400	4600	2	13500	715,0	117,0	102,0	90,0
4600	4800	2	14100	715,0	120,0	105,0	92,0
4800	5000	2	14700	742,5	122,0	107,0	95,0
5000	5200	2	15400	742,5	124,0	111,0	97,0
5200	5500	2	16100	742,5	127,0	111,0	97,0
5500	5800	2	16900	742,5	130,0	114,0	100,0
5800	6100	2	17800	742,5	132,0	117,0	102,0
6100	6500	2	18800	742,5		120,0	107,0
6500	6900	2	20000	770,0		124,0	111,0
6900	7400	2	21500	770,0		127,0	114,0
7400	7900	2	23000	770,0		132,0	117,0
7900	8400	2	24500	770,0		137,0	122,0
8400	8900	2	26000	770,0		142,0	127,0
8900	9400	2	27500	770,0		147,0	132,0
9400	10000	2	29000	770,0		152,0	132,0
10000	10700	2	31000	770,0			137,0
10700	11500	2	33000	770,0			142,0
11500	12400	2	35500	770,0			147,0
12400	13400	2	38500	770,0			152,0
13400	14600	2	42000	770,0			157,0
14600	16000	2	46000	770,0			162,0

1.2.2 Equipment Number formulae

The Equipment Number EN is to be obtained from the following formula:

$$EN = \Delta^{2/3} + 2\,(h\,B + S_{fun}) + 0{,}1\,A$$

where:

A : Side projected area, in m^2, of the hull, superstructures houses and funnels above the summer load waterline which are within the length L_E and also have a breadth greater than B/4.

In case a single funnel is fitted on the ship, the side projected area is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F.

In case several funnels are fitted on the ship, the total side projected area of the funnels is to be considered in the side projected area A when A_{FS} is greater than zero.

In case of several funnels, the shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.

A_{FS} : In case a single funnel is fitted on the ship, front projected area of the funnel, in m^2, calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. A_{FS} is taken equal to zero if the funnel breadth is less than or equal to B/4 at all elevations along the funnel height.

In case several funnels are fitted on the ship, sum of the front projected area of each funnel, in m^2, calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective eight h_F. A_{FS} is to be taken equal to zero if the sum of each funnel breadth is less or equal to B/4 at all elevations along the funnels height.

a : Vertical distance at hull side, in m, from the Summer Load waterline amidships to the upper deck.

h : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$h = a + \Sigma h_n$

When calculating h, sheer and trim are to be disregarded.

h_F : In case a single funnel is fitted on the ship, effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, to the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches B/4.

In case several funnels are fitted on the ship, effective height of the funnel, in m, measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, to the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches B/4.

h_n : Height, in m, at the centreline of tier "n" of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored.

For the lowest tier, h_1 is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Fig 1.

L_E : Equipment length, in m, equal to L without being taken neither less than 96% nor greater than 97% of the total length of the summer load waterline.

S_{fun} : Effective front projected area of the funnel, in m^2, defined as:

$S_{fun} = A_{FS} - S_{shield}$

S_{shield} : The section of front projected area A_{FS}, in m^2, which is shielded by all deck houses having breadth greater than B/4.

If there are more than one shielded section, the individual shielded sections i.e $S_{shield1}$, $S_{shield2}$, etc., as shown in Fig 2 are to be added together.

To determine S_{shield}, the deckhouse breadth is assumed B for all deck houses having breadth greater than B/4 as shown for $S_{shield1}$, $S_{shield2}$ in Fig 2.

Δ : Moulded displacement of the ship, in t, to the summer load waterline.

Fixed screens, fixed picture windows or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 3 is to be included. In case of non butt-jointed picture windows, only the efficient closed areas are to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

1.2.3 Specific cases

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that in Tab 1 on a case-by-case basis.

The Society may accept ships high equipment number (EN ≥ 16000). The determination of the equipment will be considered on a case-by-case basis.

However, the design of such equipment is to comply with the present Section and the requirements in NR216 Materials and Welding, Chapter 10."

1.2.4 Ship fitted with wind propulsion systems

The force induced by wind applied on the rigging for the calculation of the equipment in chain and anchor for temporary anchoring is to be considered according to NR206 Sec 8, [5.3] taking into account the wind speed assumptions defined in [1.1].

Figure 1 : Effective height h

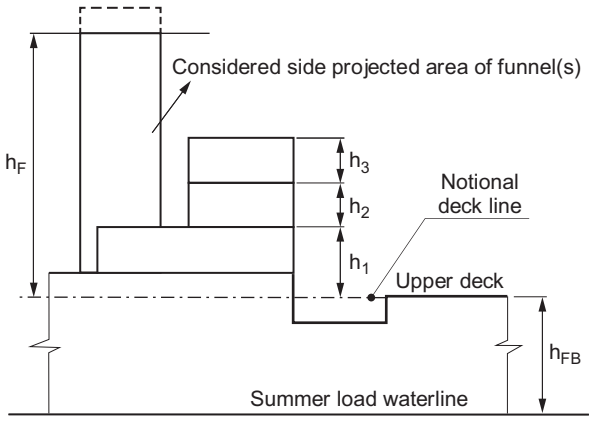


Figure 2 : Shielded sections

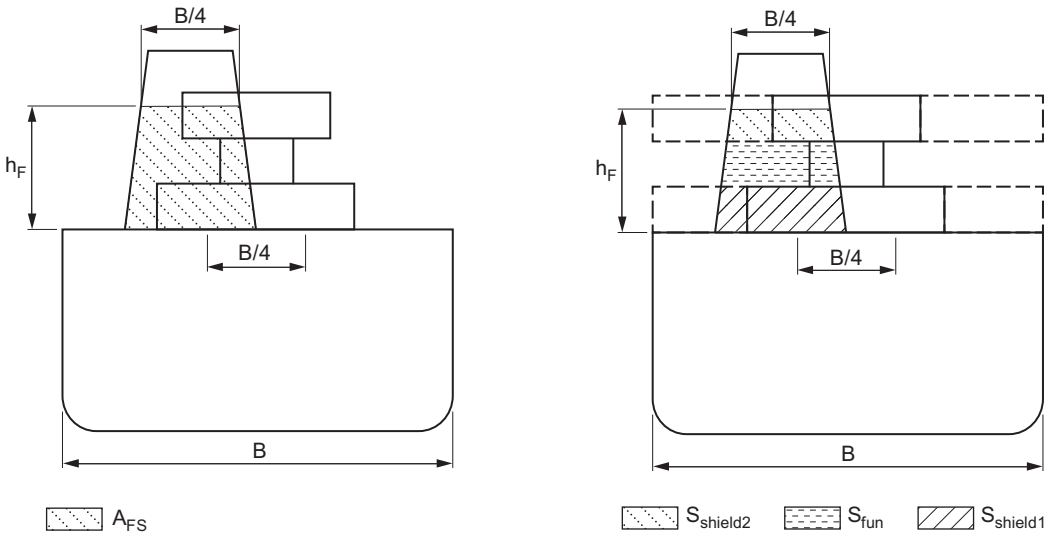
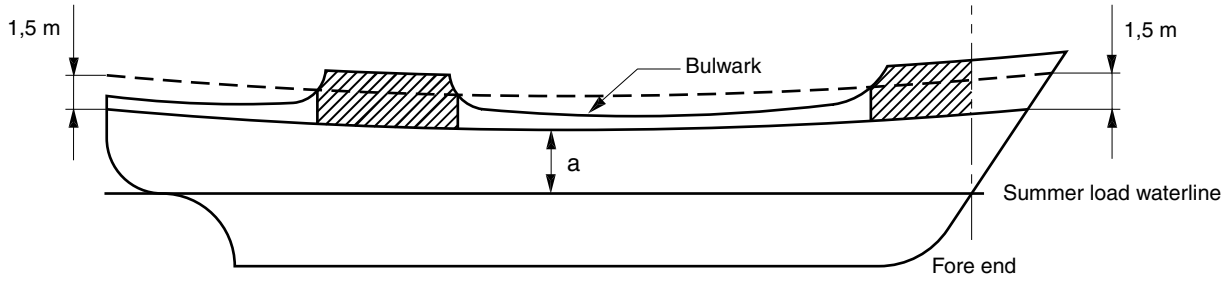


Figure 3 : Effective area of bulwarks or fixed screen to be included in the Equipment Number



2 Anchoring equipment

2.1 Anchors

2.1.1 General

The anchors are to be of an approved type and satisfy the testing conditions laid down in NR216 Rules for Materials and Welding.

The scantlings of anchors are to be in compliance with [2.1.2] to [2.1.8].

In general, stockless anchors are to be adopted.

Anchors are to be constructed and tested in compliance with approved plans.

2.1.2 Ordinary anchors

The required mass for each bower anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

2.1.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors are to be certified according to NR216 Materials and Welding, Ch 10, Sec 1. Their holding power is to be demonstrated through the tests described in [2.1.5] [2.1.6].

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless bower anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

2.1.4 High and very high holding power anchors do not require any particular adjustment or special placement when dropped to the sea bottom.

2.1.5 Installation of chain cables and anchors on board

The bower anchors are to be connected to their own chain cables and positioned on board ready for use.

To hold the anchor tight in against the hull or the anchor pocket, respectively, it is recommended to fit anchor lashings, e.g., a 'devil's claw'.

Anchor lashings should be designed to resist a load at least corresponding to twice the anchor mass plus 10 m of cable without exceeding 40% of the yield strength of the material.

2.1.6 Tests for high holding power anchors approval

For approval of a HHP anchor, comparative full scale tests are to be performed to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval as HHP anchors of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0,1 times the minimum size tested.

2.1.7 Tests for very high holding power anchors approval

For approval of a VHHP anchor, comparative full scale tests are to be performed to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass.

For approval as VHHP anchors of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested, indicative of the bottom, middle and top of the mass range.

2.1.8 Specification for tests on high holding power and very high holding power anchors

Full scale tests are to be performed on various types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material.

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by-case basis.

The holding power test load is to be less than or equal to the proof load of the anchor, specified in NR216 Materials and Welding, Ch 10, Sec 1.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis, without being less than 6.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

2.2 Chain cables for bower anchors

2.2.1 Material

The anchor chain cables are classified as grade Q1, Q2 or Q3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of:

- NR216 Materials and Welding, Ch 10, Sec 2
- NR216 Materials and Welding, Ch 10, Sec 3.

Chain cables made of grade Q1 may not be used with high holding power and very high holding power anchors.

2.2.2 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in NR216 Materials and Welding, Ch 10, Sec 2.

The diameter of stud link chain cables is to be not less than the value in Tab 1.

2.2.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in NR216 Materials and Welding, Ch 10, Sec 3, and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [2.2.1].

2.2.4 Wire ropes

Wire ropes may be used as an alternative to chain cables on the following ships:

- Ships with length L < 90 m which will need anchor for emergency purposes only. These ships, not intended to use their anchor in normal temporary anchoring operation, may typically include ships designed for the following types of operations:
  - fishing boats
  - small workboats
  - research vessels
  - dive boats
  - survey vessel
  - tugs intended for towing service only.
- Ships using their anchoring equipment for positioning with a minimum of 4 points anchoring, e.g., cable or pipe laying ships.

The use of wire cable is subject to the following conditions:

- the length of the wire rope is to be 1,5 times the required chain cable total length, and its strength is to be equal to that required for a chain cable of grade Q1
- the anchor weight is to be increased by 25% compared to anchor associated with chain cable according to Tab 1
- a short length of chain cable is to be fitted between the wire rope and anchor having a length of 12,5 m or the distance between anchor in stowed position and winch, whichever is less
- a minimum mass per unit length of 30% of the required grade Q2 chain cable
- all surfaces being in contact with the wire are to be rounded with a radius of not less than 10 times the wire rope diameter (including stem)
- steel wire is to be selected to be fit for purpose based on the manufacturer recommendation and is to be provided with guidance for maintenance and inspection.

2.2.5 Anchor chain cable arrangement

Anchor chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis.

2.3 Attachment pieces

2.3.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [2.3.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

2.3.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 2.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having diameter = 1,2 d
- increased stud link, having diameter = 1,1 d.

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 2 : Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1,4 d
Open end link	1,2 d
Increased stud link	1,1 d
Common stud link	d
Lugless shackle	d
Note 1: d : Diameter, in mm, of the common link.	

2.3.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Chapter 10.

2.4 Hawse pipes

2.4.1 Hawse pipes are to be of substantial construction. Their position and slope are to be arranged so as to facilitate housing and dropping of the anchors and avoid damage to the hull during these operations. The parts on which the chains bear are to be rounded to a suitable radius.

2.4.2 All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened, to the Surveyor's satisfaction.

2.5 Windlass

2.5.1 General

Windlasses used for handling anchors and suitable for the sizes of chain cables are to be fitted on board the ship.

Considering the windlass brake capacity defined in [2.5.2], the anchor windlass is to comply with the applicable requirements given in NR626 Anchor Windlass and Chain Stopper.

2.5.2 Brake capacity

Based on mooring line arrangements with brakes engaged and cable lifter disengaged, the capacity HL (Holding Load), in kN, of the windlass brake is to be sufficient to withstand the following design loads without any permanent deformation of the stressed parts and without brake slip:

- 0,8 times the breaking load BL of the chain, if not combined with a chain stopper
- 0,45 times the breaking load BL of the chain, if combined with a chain stopper.

2.6 Chain stopper

2.6.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. The chain stopper is to comply with applicable requirements given in the Rule Note NR626 Anchor Windlass.

The chain stopper is to comply with the applicable requirements given in NR626 Anchor Windlass and Chain Stopper.

2.6.2 Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

2.7 Chain locker

2.7.1 The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

2.7.2 Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

2.7.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

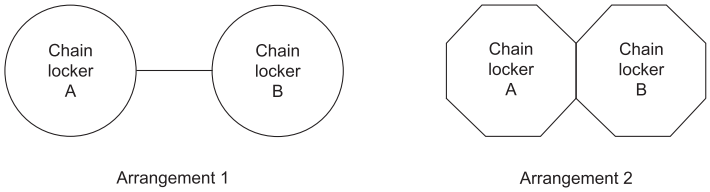
In an emergency, the attachments are to be easily released from outside the chain locker.

2.7.4 The chain locker boundaries and access openings are to be watertight. Provisions are to be made to minimise the probability of the chain locker being flooded in bad weather. Adequate drainage facilities for the chain locker are to be provided.

2.7.5 Spurling pipes and chain lockers are to be watertight up to the weather deck.

Bulkheads between separate chain lockers (see Fig 4, Arrangement 1) or which form a common boundary of chain lockers (see Fig 4, Arrangement 2), need not however be watertight.

Figure 4 : Chain locker arrangement



2.7.6 Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

2.7.7 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognized standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

2.7.8 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances, to minimize water ingress.

Examples of arrangements for permanently attached closing appliances are such as steel plates with cut-outs to accommodate chain links or canvas hoods with a lashing arrangement that maintains the cover in the secured position.

3 Emergency towing arrangement

3.1 Definitions

3.1.1 Deadweight

Deadweight is the difference, in t, between the displacement of a ship in water of a specific gravity of 1,025 t/m^3 at the summer load line *corresponding to the assigned summer freeboard and the lightweight of the ship.*

3.2 Application

3.2.1 The requirements of this Article apply to equipment arrangement for towing ships out of danger in emergencies such as complete mechanical breakdowns, loss of power or loss of steering capability.

The concerned ships are:

- the ships as defined in [3.2.2]
- all ships when the additional class notation **ETA** is assigned.

3.2.2 An emergency towing arrangement is to be fitted at both ends on board of ships of 20000 t deadweight and above with one of the following service notations:

- **combination carrier ESP**
- **oil tanker ESP**
- **FLS tanker**
- **chemical tanker ESP**
- **liquefied gas carrier**.

3.3 Documentation

3.3.1 Documentation for approval

In addition to the documents in Ch 1, Sec 4, the following documentation is to be submitted to the Society for approval:

- general layout of the bow and stern towing arrangements and associated equipment
- operation manual for the bow and stern towing arrangements
- construction drawings of the bow and stern strongpoints (towing brackets or chain cable stoppers) and fairleads (towing chocks), together with material specifications and relevant calculations
- drawings of the local ship structures supporting the loads applied by strongpoints, fairleads and roller pedestals.

3.3.2 Documentation for information

The following documentation is to be submitted to the Society for information (see Ch 1, Sec 4):

- specifications of chafing gears, towing pennants, pick-up gears and roller fairleads
- height, in m, of the lightest seagoing ballast freeboard measured at stern towing fairlead
- deadweight, in t, of the ship at summer load line.

3.4 General

3.4.1 Scope

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on the concerned ship, primarily to reduce the risk of pollution.

3.4.2 Main characteristics

The emergency towing arrangements are, at all times, to be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship.

To demonstrate such rapid and easy deployment, the emergency towing arrangements are to comply with the requirements in [3.12].

3.4.3 Typical layout

Fig 5 shows an emergency towing arrangement which may be used as reference.

3.4.4 List of major components

The major components of the towing arrangements, their position on board and the requirements of this Article which they are to comply with are defined in Tab 3.

3.4.5 Inspection and maintenance

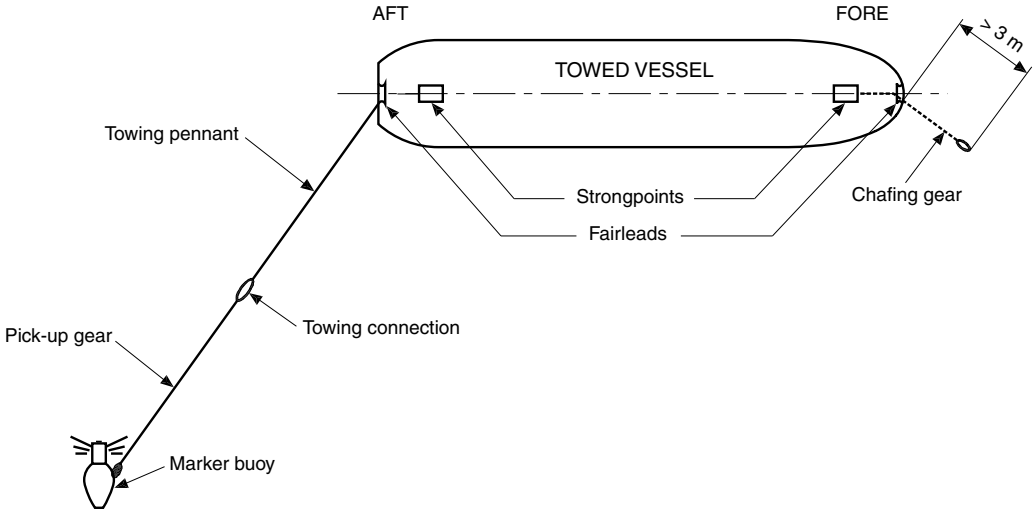
All the emergency towing arrangement components are to be inspected by ship personnel at regular intervals and maintained in good working order.

Table 3 : Major components of the emergency towing arrangement

Towing component	Non pre-rigged	Pre-rigged	Reference of applicable requirements
Towing pennant	Optional	Required	[3.7]
Fairlead	Required	Required	[3.9]
Strongpoint (inboard end fastening of the towing gear)	Required	Required	[3.10]
Pick-up gear	Optional	Required	No requirement
Pedestal roller fairlead	Required	Depending on design	No requirement

Towing component	Forward	Afterward	Reference of applicable requirements
Chafing gear	Required	Depending on design	[3.8]

Figure 5 : Typical emergency towing arrangement



3.5 Emergency towing arrangement approval

3.5.1 General

Emergency towing arrangements of ships are to comply with the following requirements:

- they are to comply with the requirements of this item
- they are to be type approved according to the requirements in [3.13]
- Certificates of inspection of materials and equipment are to be provided according to [3.13.2]
- fitting on board of the emergency towing arrangements is to be witnessed by a Surveyor of the Society and a relevant Certificate is to be issued
- demonstration of the rapid deployment according to the criteria in [3.12] is to be effected for each ship and this is to be reported in the above Certificate.

3.5.2 Alternative to testing the rapid deployment for each ship

At the request of the Owner, the testing of the rapid deployment for each ship according to [3.5.1] may be waived provided that:

- the design of emergency towing arrangements of the considered ship is identical to the type approved arrangements and this is confirmed by the on board inspection required in [3.5.1]
- the strongpoints (chain stoppers, towing brackets or equivalent fittings) are type approved (prototype tested).

In this case, an exemption certificate is to be issued.

In general, such dispensation may be granted to subsequent ships of a series of identical new buildings fitted with identical arrangements.

3.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strongpoints

3.6.1 Safe working load

The safe working load (defined as one half of the ultimate strength) of towing pennants, chafing gear, fairleads and strongpoints is to be not less than that obtained, in kN, from Tab 4.

The strength of towing pennants, chafing gear, fairleads and strongpoints is to be sufficient for all pulling angles of the towline, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards.

The safe working load of other components is to be sufficient to withstand the load to which such components may be subjected during the towing operation.

Table 4 : Safe working load

Ship deadweight DWT, in t	Safe working load, in kN
20000 ≤ DWT < 50000	1000
DWT ≥ 50000	2000

3.7 Towing pennant

3.7.1 Material

The towing pennant may be made of steel wire rope or synthetic fibre rope, which is to comply with the applicable requirements in NR216 Materials and Welding, Ch 10, Sec 5.

3.7.2 Length of towing pennant

The length ℓ_P of the towing pennant is to be not less than that obtained, in m, from the following formula:

$\ell_P = 2\,H + 50$

where:

H : *Lightest seagoing ballast freeboard measured, in m, at the fairlead.*

3.7.3 Minimum breaking strength of towing pennants when separate chafing gear is used

Where a separate chafing gear is used, the minimum breaking strength MBS_P of towing pennants, including their terminations, is to be not less than that obtained from the following formula:

$MBS_P = 2\,SWL$

where:

SWL : Safe working load of the towing pennants, defined in [2.6.1].

3.7.4 Minimum breaking strength of towing pennants when no separate chafing gear is used

Where no separate chafing gear is used (i.e. where the towing pennant may chafe against the fairlead during towing operation), the minimum breaking strength of the towing pennants MBS_{PC} is to be not less than that obtained, in kN, from the following formula:

$MBS_{PC} = \varphi\,MBS_P$

where:

MBS_P : Minimum breaking strength, in kN, defined in [3.7.3]

φ : Coefficient to be taken equal to:

$$\varphi = \frac{2\sqrt{\rho}}{2\sqrt{\rho} - 1}$$

φ may be taken equal to 1,0 if tests carried out under a test load equal to twice the safe working load defined in [3.6.1] demonstrate that the strength of the towing pennants is satisfactory

ρ : Bending ratio (ratio between the minimum bearing surface diameter of the fairlead and the towing pennant diameter), to be taken not less than 7.

3.7.5 Towing pennant termination

For towing connection, the towing pennant is to have a hard eye-formed termination allowing connection to a standard shackle.

Socketed or ferrule-secured eye terminations of the towing pennant are to be type tested in order to demonstrate that their minimum breaking strength is not less than twice the safe working load defined in [3.6.1].

3.8 Chafing gear

3.8.1 General

Different solutions for the design of chafing gear may be used.

If a chafing chain is to be used, it is to have the characteristics defined in the following requirements.

3.8.2 Type

Chafing chains are to be stud link chains.

3.8.3 Material

In general, grade Q3 chain cables and associated accessories complying with the applicable requirements in:

- NR216 Materials and Welding, Ch 10, Sec 2
- NR216 Materials and Welding, Ch 10, Sec 3

are to be used.

3.8.4 Chafing chain length

The chafing chain is to be long enough to ensure that the towing pennant, or the towline, remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3 m beyond the fairlead complies with this requirement.

3.8.5 Minimum breaking strength

The minimum breaking strength of the stud link chafing chain and the associated links is to be not less than twice the safe working load defined in [3.6.1].

3.8.6 Diameter of the common links

The diameter of the common links of stud link chain cables is to be not less than:

- 52 mm for a safe working load, defined in [3.6.1], equal to 1000 kN
- 76 mm for a safe working load, defined in [3.6.1], equal to 2000 kN.

3.8.7 Chafing chain ends

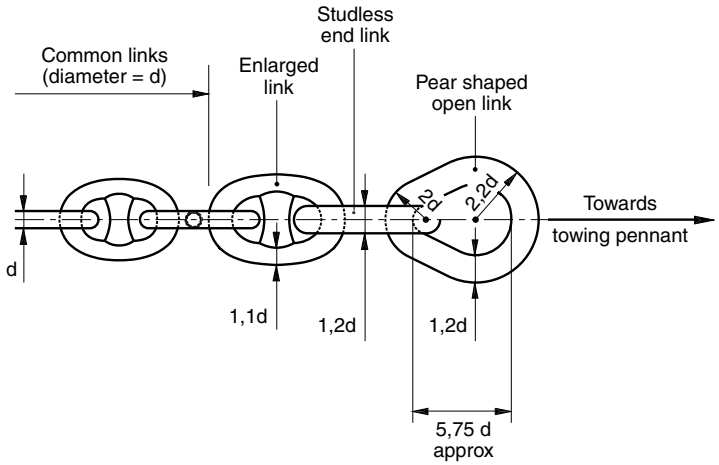
One end of the chafing chain is to be suitable for connection to the strongpoint. Where a chain stopper is used, the inboard end of the chafing chain is to be efficiently secured in order to prevent any inadvertent loss of the chafing chain when operating the stopping device. Where the chafing chain is connected to a towing bracket, the corresponding chain end may be constructed as shown in Fig 6, but the inner dimension of the pear link may be taken as 5,30 d (instead of 5,75 d).

The other end of the chafing chain is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle. A typical arrangement of this chain end is shown in Fig 6. Arrangements different than that shown in Fig 6 are considered by the Society on a case-by-case basis.

3.8.8 Storing

The chafing chain is to be stored and stowed in such a way that it can be rapidly connected to the strongpoint.

Figure 6 : Typical outboard chafing chain end



3.9 Fairleads

3.9.1 General

Fairleads are normally to be of a closed type (such as Panama chocks).

Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towline. The corners of the opening are to be suitably rounded.

Where the fairleads are designed to pass chafing chains, the openings are to be not less than 600mm in width and 450mm in height.

3.9.2 Material

Fairleads are to be made of fabricated steel plates or other ductile materials such as weldable forged or cast steel complying with the applicable requirements of:

- NR216 Materials and Welding, Chapter 3 (steel plate)
- NR216 Materials and Welding, Chapter 5 (steel forgings)
- NR216 Materials and Welding, Chapter 6 (steel castings).

3.9.3 Operating condition

The fairleads are to give adequate support for the towing pennant during towing operation, which means bending 90° to port and starboard side and 30° vertical downwards.

3.9.4 Positioning

The fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimise the stress on the towing system.

The fairleads are to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

Furthermore, the bow and stern fairleads are normally to be located on the ship's centreline. Where it is practically impossible to fit the towing fairleads exactly on the ship's centreline, it may be acceptable to have them slightly shifted from the centreline.

3.9.5 Bending ratio

The bending ratio(ratio between the towing pennant bearing surface diameter and the towing pennant diameter) is to be not less than 7.

3.9.6 Fairlead lips

The lips of the fairlead are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when deployed or during towing.

3.9.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the fairlead by a load equal to the safe working load defined in [3.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the fairleads are analysed through standard mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

3.9.8 Alternative to the yielding check

The above yielding check may be waived provided that fairleads are tested with a test load equal to twice the safe working load defined in [3.6.1] and this test is witnessed by a Surveyor of the Society. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

3.10 Strongpoint

3.10.1 General

The strongpoint (inboard end fastening of the towing gear) is to be a chain cable *stopper or a towing bracket or other fitting of equivalent strength* and ease of connection. *The strongpoint can be designed integral with the fairlead.*

The strongpoint is to be type approved according to [3.13] and is to be clearly marked with its SWL.

3.10.2 Materials

The strongpoint is to be made of fabricated steel or other ductile materials such as forged or cast steel complying with the applicable requirements of:

- NR216 Materials and Welding, Chapter 3 (steel plate)
- NR216 Materials and Welding, Chapter 5 (steel forgings)
- NR216 Materials and Welding, Chapter 6 (steel castings).

Use of spheroidal graphite cast iron (SG iron) may be accepted for the main framing of the strongpoint provided that:

- the part concerned is not intended to be a component part of a welded assembly
- the SG iron is of ferritic structure with an elongation not less than 12%
- the yield stress at 0,2% is measured and certified
- the internal structure of the component is inspected by suitable non-destructive means.

The material used for the stopping device (pawl or hinged bar) of chain stoppers and for the connecting pin of towing brackets is to have mechanical properties not less than those of grade Q3 chain cables, defined in NR216 Materials and Welding, Chapter 10.

3.10.3 Typical strongpoint arrangement

Typical arrangements of chain stoppers and towing brackets are shown in Fig 7, which may be used as reference.

Chain stoppers may be of the hinged bar type or pawl (tongue) type or of other equivalent design.

3.10.4 Position and operating condition

The operating conditions and the positions of the strongpoints are to comply with those defined in [3.9.3] and [3.9.4], respectively, for the fairleads.

3.10.5 Stopping device

The stopping device (chain engaging pawl or bar) is to be arranged, when in closed position, to prevent the chain stopper from working in the open position, in order to avoid chain cable release and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

3.10.6 Connecting pin of the towing bracket

The scantlings of the connecting pin of the towing bracket are to be not less than those of a pin of a grade Q3 end shackle, as shown in Fig 7, provided that clearance between the two side lugs of the bracket does not exceed 2,0d, where d is the chain diameter specified in [3.8.6] (see also Fig 6).

3.10.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the strongpoint by a load equal to the safe working load defined in [3.6.1], is to comply with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the strongpoints are analysed through standard mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

3.10.8 Alternative to the yielding check

The above yielding check may be waived provided that strongpoints are tested with a test load equal to twice the safe working load defined in [3.6.1] and this test is witnessed by a Surveyor. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

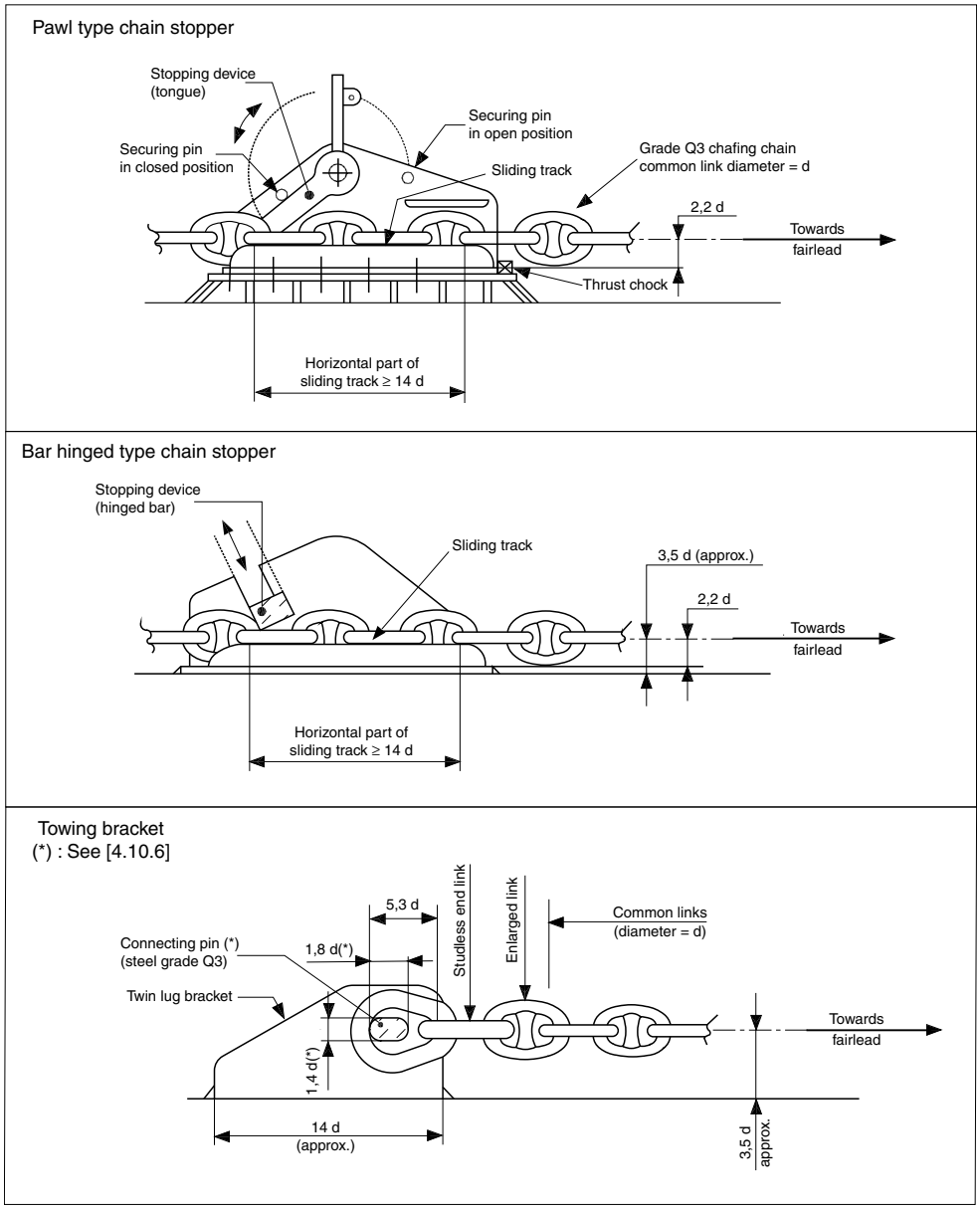
3.10.9 Bolted connection

Where a chain stopper or a towing bracket is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by means of efficient thrust chocks capable of withstanding a horizontal force equal to 1,3 times the safe working load defined in [3.6.1] within the allowable stress defined in [3.10.7].

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1.

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

Figure 7 : Typical strongpoint arrangement



3.11 Hull structures in way of fairleads or strongpoints

3.11.1 Materials and welding

The materials used for the reinforcement of the hull structure in way of the fairleads or the strongpoints are to comply with the applicable requirements of NR216 Materials and Welding.

Main welds of the strongpoints with the hull structure are to be 100% inspected by adequate non-destructive tests.

3.11.2 Yielding check of bulwark and stays

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the bulwark plating and stays in way of the fairleads by a load equal to the safe working load defined in [3.6.1], for the operating condition of the fairleads defined in [3.9.3], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

3.11.3 Yielding check of deck structures

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the deck structures in way of chain stoppers or towing brackets, including deck seatings and deck connections, by a horizontal load equal to 1,3 times the safe working load defined in [3.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

3.11.4 Minimum gross thickness of deck plating

The gross thickness of the deck is to be not less than:

- 12 mm for a safe working load, defined in [3.6.1], equal to 1000 kN
- 15 mm for a safe working load, defined in [3.6.1], equal to 2000 kN.

3.12 Rapid deployment of towing arrangement

3.12.1 General

To facilitate approval of towing arrangements and to ensure rapid deployment, emergency towing arrangements are to comply with the requirements of this item.

3.12.2 Marking

All components, including control devices, of the emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

3.12.3 Aft arrangement

The aft emergency towing arrangement is to be pre-rigged and be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions that may prevail during such emergency towing operations.

The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

3.12.4 Forward

The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 hour.

The forward emergency towing arrangement is to be designed at least with a means of securing a tow line to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

Forward emergency towing arrangements which comply with the requirements for aft emergency towing arrangements may be accepted.

3.13 Type approval

3.13.1 Type approval procedure

Emergency towing arrangements are to be type approved according to the following procedure:

- the arrangement design is to comply with the requirements of this Section
- each component of the towing arrangement is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [3.13.2]
- prototype tests are to be carried out in compliance with [3.13.3].

3.13.2 Inspection and certification

The materials and equipment are to be inspected and certified as specified in Tab 5.

3.13.3 Prototype tests

Prototype tests are to be witnessed by a Surveyor and are to include the following:

- demonstration of the rapid deployment according to the criteria in [3.12]
- load test of the strongpoints (chain stoppers, towing brackets or equivalent fittings) under a proof load equal to 1,3 times the safe working load defined in [3.6.1].

A comprehensive test report duly endorsed by the Surveyor is to be submitted to the Society for review.

Table 5 : Material and equipment certification status

Component	Material		Equipment	
	Certificate	Reference of applicable requirements	Certificate	Reference of applicable requirements
Towing pennant	Not applicable	[3.7.1]	COI **(1)**	[3.7]
Chafing chain and associated accessories	COI **(2)**	[3.8.3]	COI **(1)**	[3.8]
Fairleads	CW	[3.9.2]	COI	[3.9]
Strongpoint:			COI **(3)**	[3.10]
• main framing	COI **(2)**	[3.10.2]		
• stopping device	COI **(2)**	[3.10.2]		
Pick-up gear:				No requirement
• rope	Not applicable	–	CW	
• buoy	Not applicable	–	Not required **(4)**	
• line-throwing appliance	Not applicable	–	Not required **(4)**	
Pedestal roller fairlead	CW	–	Not required **(4)**	No requirement

(1) According to NR216 Materials and Welding, Ch 10, Sec 2
(2) According to NR216 Materials and Welding, Ch 1, Sec 1, [4.2].
(3) To be type approved.
(4) May be type approved.
Note 1:
COI : Certificate of inspection,
CW : Works' certificate 3.1.B according to EN 10204.

4 Towing and mooring arrangement

4.1 General

4.1.1 Condition of classification

The towing and mooring arrangement as defined in Ch 12, App 2, [1] and the towing and mooring lines as defined in Ch 12, App 2, [2] are given as a guidance but are not required as a condition of classification.

4.2 Shipboard fittings and supporting hull structures associated with towing and mooring

4.2.1 Definitions

- "Normal towing" means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.
- "Escort towing" means towing operations required in specific estuaries, in particular, for laden oil tankers or LNG carriers. Its main purpose is to control the ship in case of failures of the propulsion or steering system.
- "Other towing" means towing operations necessary for towing the ship by another ship or a tug, e.g. such as to assist the ship in case of emergency, for ships not assigned with the additional class notation **ETA**.
- "Emergency towing" means towing operations to assist the ship in case of emergency, for ships assigned with the additional class notation **ETA**.
- "Canal transit towing" means towing operations for ships transiting canals, e.g. the Panama Canal.
- "Shipboard fittings" means the components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for mooring and similar components used for normal, escort and other towing operations. Other components such as capstans, winches, etc. are not covered by the present sub-article. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an recognised standard subject to that standard.
- "Supporting hull structure" means the part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structure of capstans, winches, etc. used for mooring and for normal, escort and other towing operations is also subject to the present sub-article.
- The "nominal capacity condition" is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For ships carrying containers, the nominal capacity condition

represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

- "Ship Design Minimum Breaking Load" (MBL_{SD}) means the minimum breaking load of new, dry mooring lines or tow line for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.
- "Line Design Break Force" (LDBF) means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

  LDBF is to be neither less than 100% nor greater than 105% of the MBL_{SD}.

4.2.2 Application

Requirements under the present sub-article apply to:

- conventional ships, i.e. displacement-type ships of 500 GT and above, excluding special purpose ships as defined in the IMO resolution MSC.266(84)
- shipboard fittings used for mooring and for normal, escort and other towing operations
- supporting hull structure under shipboard fittings used for mooring and for normal, escort and other towing operations
- supporting hull structure under winches and capstans used for mooring operations.

Requirements under the present sub-article do not apply for following towing operations:

- emergency towing: refer to Article [3]
- canal transit towing: reference is to be made to local canal transit requirements.

4.2.3 Arrangement

The strength of shipboard fittings used for mooring and for normal, escort and other towing operations at bow, sides and stern, and of their supporting hull structures are to comply with the present sub-article.

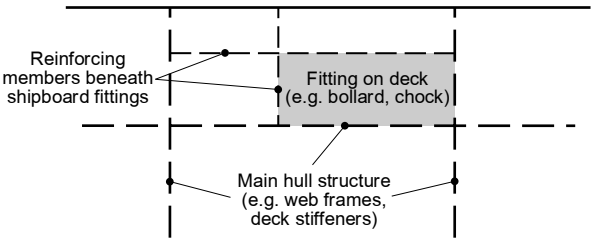
The strength of supporting hull structures of winches and capstans used for mooring are to comply with the present sub-article as well.

Shipboard fittings, winches and capstans are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing and mooring loads.

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the mooring and towing forces acting upon the shipboard fittings, see Fig 8 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

Figure 8 : Reinforced members beneath shipboard fittings



4.2.4 Selection of shipboard fittings

Shipboard fittings may be selected from a recognised standard accepted by the Society (ISO standard for example) and at least based on the following loads:

a) Normal towing operations: the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan

b) Escort or other towing operations: the MBL_{SD} of the tow line according to Ch 12, App 2

c) For fittings intended to be used for, both, normal and escort or other towing operations, the greater of the loads according to a) and b)

d) Mooring operations: the MBL_{SD} of the mooring line according to Ch 12, App 2.

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the recognised standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment, see Fig 9.

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the recognised standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment, see Fig 10.

When the shipboard fitting is not selected from an accepted standard:

- The design load used to assess its strength and its attachment to the ship is to be in accordance with [4.2.5].
- Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice
- Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion.
- At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

Note 1: With the line attached to a mooring bitt in the usual way (figure-of-eight fashion), either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line.

Figure 9 : Attachment point of the towing line on bollard and bitts

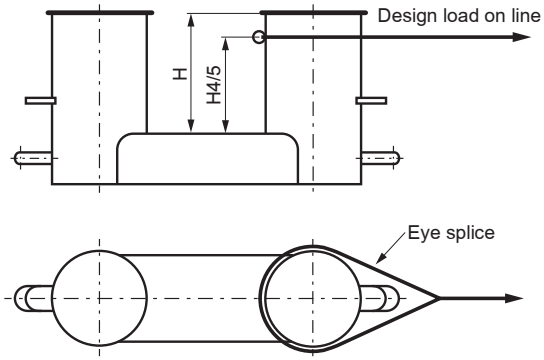
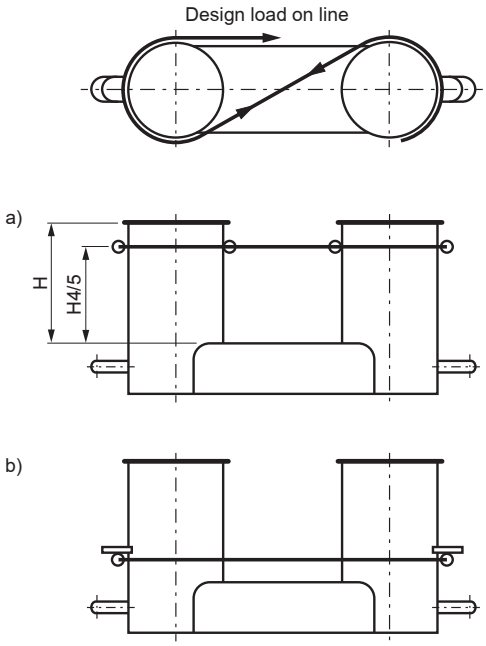


Figure 10 : Attachment point of the mooring line on bollard and bitts



4.2.5 Design load

The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the mooring and towing arrangements plan. Where the mooring or towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, see Fig 11.

However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

The acting point of the force on shipboard fittings is to be taken at the attachment point of the mooring or towing line or at a change in its direction. For bollards and bitts the attachment point of the line is to be taken not less than 4/5 of the tube height above the base, see Fig 9 and Fig 10.

However, if fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see b) in Fig 10.

The design load to be applied to supporting hull structures and to shipboard fittings not selected from a recognised standard, in kN, is to be taken equal to:

a) Normal towing operations:

1,25 times the greater of the intended maximum towing load (e.g. static bollard pull) and the safe towing load TOW requested by the applicant, see [4.2.8]

b) Escort or other towing operations:

the greater of the ship design minimum breaking load according to Ch 12, App 2 and 1,25 times the safe towing load TOW requested by the applicant, see [4.2.8]

c) For fittings intended to be used for, both, normal and escort or other towing operations:

the greater of the design loads according to a) and b).

d) Mooring operations:

1,15 times the greater of the MBL_{SD} of the mooring line according to Ch 12, App 2 and the SWL of the shipboard fitting requested by the applicant, see [4.2.9].

The design load to be applied to supporting hull structure of winches and capstans used for mooring operations, in kN, is to be taken equal to:

- Supporting hull structure of winches:

  1,25 times the intended maximum brake holding load, see notes below.

- Supporting hull structure of capstans:

  1,25 times the maximum hauling-in force.

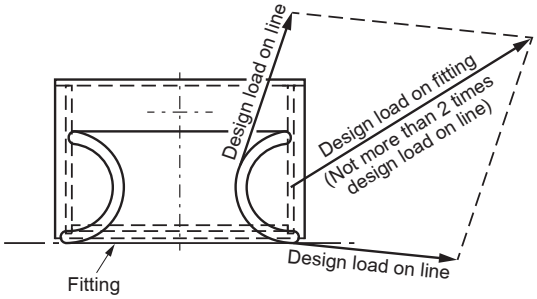
Note 1: The maximum brake holding load of winches used for mooring operations is to be assumed neither less than 80% nor greater than 100% of the MBL_{SD} of the mooring line according to Ch 12, App 2, [2].

Note 2: The MBLSD of tow and mooring lines taken in Ch 12, App 2, Tab 1 are to be based on an Equipment Number calculated according to Ch 12, App 2, [2.1.1].

Note 3: The increase of the LDBF of tow and mooring lines for synthetic ropes as required in Ch 12, App 2, [2.5] needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

Note 4: For fittings intended to be used for both towing and mooring operations, the corresponding design loads are to be considered independently.

Figure 11 : Design load on fitting



4.2.6 Allowable stresses

Allowable stresses under the design load conditions as specified in [4.2.5] are as follows:

a) For strength assessment by means of beam theory or grillage analysis:

- normal stress: 1,0 R_{eH}
- shear stress: 0,6 R_{eH}

b) For strength assessment by means of finite element analysis:

- Von Mises stress: 1,0 R_{eH}

Note 1: Normal stress is to be considered as the sum of bending stress and axial stress, with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.

Note 2: For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs is not to exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

4.2.7 Corrosion additions

The scantlings obtained by applying the allowable stresses as specified in [4.2.6] are net scantlings excluding any addition for corrosion.

The total corrosion addition t_c is not to be less than the following values:

- for the supporting hull structure, according to Ch 4, Sec 3 for the surrounding structure (e.g. deck structures, bulwark structures).

- for pedestals and foundations on deck which are not part of a fitting according to a recognised standard, 2.0 mm.
- for shipboard fittings not selected from a recognised standard, 2.0 mm.

Note 1: In addition to the corrosion addition t_c given above, a wear allowance t_w not less than 1.0 mm is to be included for shipboard fittings not selected from an recognised standard. This wear allowance is to be added to surfaces which are intended to regularly contact the line.

4.2.8 Safe Towing Load (TOW)

The safe towing load (TOW) is the safe load limit of shipboard fittings used for towing purpose.

Unless a greater TOW is requested by the applicant, the TOW is not to exceed:

a) Normal towing operations: the intended maximum towing load (e.g. static bollard pull)

b) Escort or other towing operations: 80% of the MBL_{SD} according to Ch 12, App 2

c) For fittings intended to be used for, both, normal and escort or other towing operations: the greater of the design loads according to a) and b).

TOW, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing.

For fittings intended to be used for, both, towing and mooring, SWL, in t, according to [4.2.9] is to be marked in addition to TOW.

Note 1: The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.

4.2.9 Safe Working Load (SWL)

The safe working load (SWL) is the safe load limit of shipboard fittings used for mooring purpose.

Unless a greater SWL is requested by the applicant, the SWL is not to exceed the MBL_{SD} as given in Ch 12, App 2, Tab 1.

SWL, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring.

For fittings intended to be used for, both, mooring and towing, TOW, in t, according to [4.2.8] is to be marked in addition to SWL.

Note 1: The above requirements on SWL apply for the use with no more than one mooring line.

4.2.10 Towing and mooring arrangements plan

A plan showing the towing and mooring arrangement is to be submitted to the Society for information. This plan is to define the method of using the towing and mooring lines and is to include the following information for each shipboard fitting:

a) Location on the ship

b) Fitting type

c) SWL/TOW

d) Purpose (mooring, harbour towing, escort towing, other towing)

e) Manner of applying towing and mooring lines including limiting fleet angle i.e. angle of change in direction of a line at the fitting.

Item c) with respect to items d) and e), is subject to approval by the Society.

Furthermore, following information is to be clearly indicated on the plan:

- the arrangement of mooring lines showing the number of lines
- the MBL_{SD} of each mooring line
- the length of each mooring line
- restrictions or limitations on the type (including material and construction), stiffness and diameter of mooring lines which are compatible with the mooring equipments and fittings
- the acceptable environmental conditions as given in Ch 12, App 2, [2.7.3] for the MBL_{SD} of mooring lines for ships with Equipment Number EN > 2000:
  - 30 second mean wind speed from any direction (v_w or v_w^* according to Ch 12, App 2, [2.7.3])
  - maximum current speed acting on bow or stern (±10°)
- maximum brake holding load of each mooring winch.

Note 1: The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bitts it is to be noted that TOW is the load limit for a towing line attached with eye-splice.

Note 2: The information as listed above is to be incorporated into the pilot card in order to provide the pilot proper information on harbour, escort and other towing operations.

Appendix 1 Criteria for Direct Calculation of Rudder Loads

Symbols

ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} : Lengths, in m, of the individual girders of the rudder system

ℓ_{50} : Length, in m, of the solepiece

ℓ_{TRU} : Length, in m, of the trunk

J_{10}, J_{20}, J_{30}, J_{40} : Moments of inertia about the x axis, in cm^4, of the individual girders of the rudder system having lengths ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40}.

For rudders supported by a solepiece only, J_{20} indicates the moment of inertia of the pintle in the sole piece

J_{50} : Moment of inertia about the z axis, in cm^4, of the solepiece

J_{TRU} : Moment of inertia about the x axis, in cm^4, of the trunk

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 12, Sec 1, [2.1.1]

C_{R1}, C_{R2} : Rudder forces, in N, defined in Ch 12, Sec 1, [2.2.3]

E : Young's modulus, in N/m^2: $E = 2,06 \cdot 10^{11}$ N/m^2

G : Shear elasticity modulus, in N/m^2: $G = 7,85 \cdot 10^{10}$ N/m^2.

1 Criteria for direct calculation of the loads acting on the rudder structure

1.1 General

1.1.1 Application

The requirements of this Appendix apply to all types of rudders listed under Ch 12, Sec 1, Tab 3.

The requirements of this Appendix provide the criteria for calculating the following forces and moments:

- bending moment M_{Bi} in the rudder stock (defined as the maximum of absolute values of bending moment M_{Bi} over the rudder stock length)
- support forces F_{Ai}
- bending moment M_R and shear force Q_R in the rudder body.

1.1.2 Calculation of forces and moments

The forces and moments in [1.1.1] are to be calculated according to [1.4], for each type of rudder.

They are to be used for the stress analysis required in:

- Ch 12, Sec 1, [4], for the rudder stock
- Ch 12, Sec 1, [6], for the rudder stock and the pintle bearings
- Ch 12, Sec 1, [7] for the rudder blade
- Ch 12, Sec 1, [8] for the rudder horn and the solepiece.

1.2 Required data

1.2.1 Forces per unit length

The forces per unit length are to be calculated, in N/m, for each type of rudder, according to requirements given under [1.4].

1.2.2 Support stiffness properties

Three general cases are considered:

a) all supports are completely rigid. This is assumed for the rudder types 1 and 3.

b) Combination of one elastic support with several rigid supports.

The elastic support is represented by a spring, with its constant calculated in N/m, according to [1.3.1] and [1.3.2]:

- Z_C for rudders with solepiece (rudder type 2 as in Fig 1, and rudder type 5 as in Fig 3)
- Z_P for semi-spade rudders with one elastic support provided by a rudder horn (rudder type 4 as in Fig 2, rudder type 7 as in Fig 8, and rudder type 8 as in Fig 9)
- Z_{TRU} for spade rudders with rudder trunk (rudder type 6c, as shown in Fig 6 and Fig 7).

c) Combination of 2-conjugate elastic supports and one rigid support (rudder type 9 as in Fig 10, and rudder type 10 as in Fig 11).

The 2-conjugate elastic supports are defined by using two additional equations, according to [1.3.3].

1.3 Calculation of support stiffness properties

1.3.1 Sole piece

The spring constant Z_C for the support in the solepiece (see Fig 12) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{3EJ_{50}}{\ell_{50}^3} \cdot 10^{-8}$$

1.3.2 Rudder horn with 1-elastic support

The spring constant Z_P for the support in the rudder horn (see Fig 13 and Fig 14) is to be obtained, in N/m, from the following formula:

$$Z_P = \frac{1}{f_B + f_T}$$

where:

f_B : Unit displacement of rudder horn due to a unit force of 1 N acting in the centroid of the rudder horn, to be obtained, in m/N, from the following formula:

$$f_B = 1{,}3\frac{d^3}{3EJ_N} \cdot 10^8$$

f_T : Unit displacement due to torsion, in m/N, to be obtained, in case of a rudder horn with a hollow cross section, from the following formula:

$$f_T = \frac{de^2}{4GF_T^2}\sum_i \frac{u_i}{t_i}$$

with:

d : Height, in m, of the rudder horn as defined in Fig 13 and Fig 14. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

J_N : Moment of inertia of rudder horn about the x axis, in cm^4

e : Rudder-horn torsion lever, in m, as defined in Fig 13 and Fig 14(value taken at z = d/2)

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness of the individual plates mentioned above, in mm.

1.3.3 Rudder horn with 2-conjugate elastic supports

The 2-conjugate elastic supports are defined by the following equations:

- at the lower rudder horn bearing:
  $y_1 = -K_{12} F_{A2} - K_{22} F_{A1}$
- at the upper rudder horn bearing:
  $y_2 = -K_{11} F_{A2} - K_{12} F_{A1}$

where:

y_1, y_2 : Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively

F_{A1}, F_{A2} : Horizontal support forces, in N, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12}: Rudder horn compliance constants obtained, in m/N, from the following formulae:

$$K_{11} = 1,3 \cdot \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{12} = 1,3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d-\lambda)}{2EJ_{1h}}\right] + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{22} = 1,3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d-\lambda)}{EJ_{1h}} + \frac{\lambda \cdot (d-\lambda)^2}{EJ_{1h}} + \frac{(d-\lambda)^3}{3EJ_{2h}}\right] + \frac{e^2 \cdot d}{GJ_{th}}$$

where:

d : Height of the rudder horn, in m, defined in Fig 15 and Fig 16. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length, in m, as defined in Fig 15 and Fig 16. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those given in [1.3.2], in case of a rudder horn with a hollow cross-section

e : Rudder-horn torsion lever, in m, as defined in Fig 15 and Fig 16 (value taken at z = d/2)

J_{1h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Fig 16)

J_{2h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see Fig 16)

J_{th} : Torsional stiffness factor of the rudder horn, in m^4.

For any thin wall closed section:

$$J_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness, in mm, of the individual plates mentioned above

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

1.3.4 Rudder trunk

The spring constant Z_{TRU} for the support in the trunk (lower rudder stock bearing as shown in Fig 17) is to be obtained, in N/m, from the following formula:

$$Z_{TRU} = \frac{3EJ_{TRU}}{\ell_{TRU}^3} \cdot 10^{-8}$$

1.4 Calculation of the main structure of the rudder system

1.4.1 Rudder type 1

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

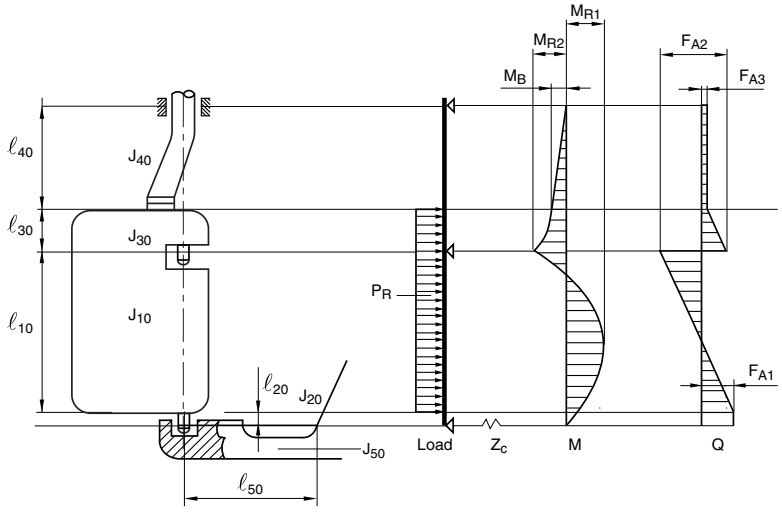
The rudder structure is to be calculated according to approximate formulae given here below:

- maximum bending moment in the rudder stock, in N·m:
  $M_B = 0$
- support forces, in N:
  $F_{A1} = F_{A2} = F_{A3} = C_R / 3$
  $F_{A4} = 0$
- bending moment in the rudder blade of streamlined rudders, in N·m:
  $M_R = C_R \ell / 24$

1.4.2 Rudder type 2

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 1.

Figure 1 : Rudder type 2



The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m, as follows:

$\ell = \ell_{10} + \ell_{30}$

The spring constant Z_c is to be calculated according to [1.3.1].

1.4.3 Rudder type 3

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

The rudder structure is to be calculated according to approximate formulae given here below:

- maximum bending moment in the rudder stock, in N·m: $M_B = 0$
- support forces, in N:

  $F_{A1} = F_{A2} = C_R/2$

  $F_{A3} = 0$

1.4.4 Rudder type 4

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 2.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

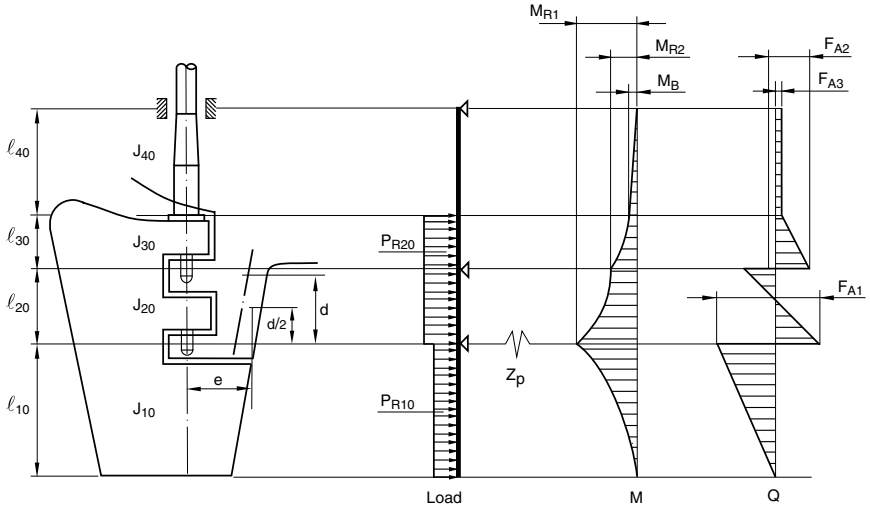
$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20} + \ell_{30}$

The spring constant Z_P is to be calculated according to [1.3.2].

Figure 2 : Rudder type 4



1.4.5 Rudder type 5

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 3.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

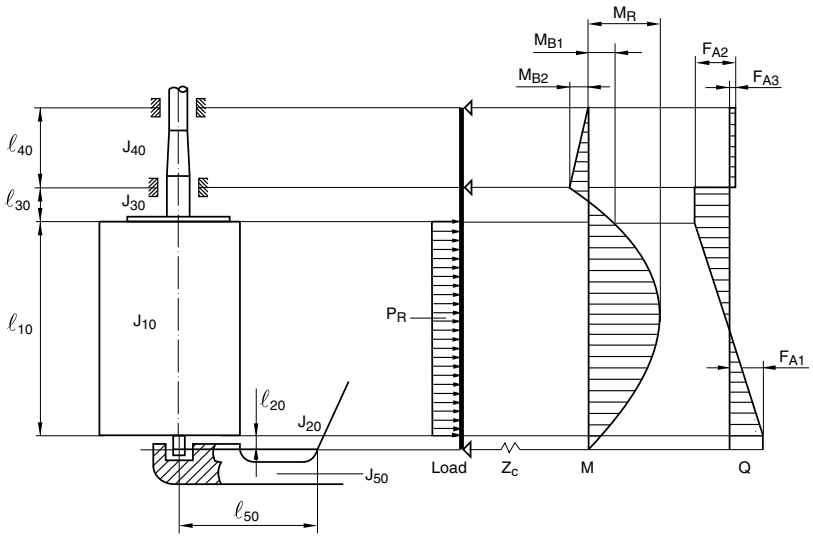
$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

The spring constant Z_c is to be calculated according to [1.3.1].

Figure 3 : Rudder type 5



1.4.6 Rudder type 6a

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 4.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}}\right) \cdot z$$

where:

z : Position of rudder blade section, in m, taken over ℓ_{10} length

p_{Rz} : Force per unit length, in N/m, obtained at the z position

p_{R10} : Force per unit length, in N/m, obtained for z equal to zero

p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10}.

For this type of rudder, the results of calculations performed according to diagrams shown in Fig 4 may also be obtained from the following formulae:

- maximum bending moment in the rudder stock, in N·m:

  $$M_B = C_R\left(\ell_{20} + \frac{\ell_{10}(2C_1 + C_2)}{3(C_1 + C_2)}\right)$$

  where C_1 and C_2 are the lengths, in m, defined in Fig 4

- support forces, in N:

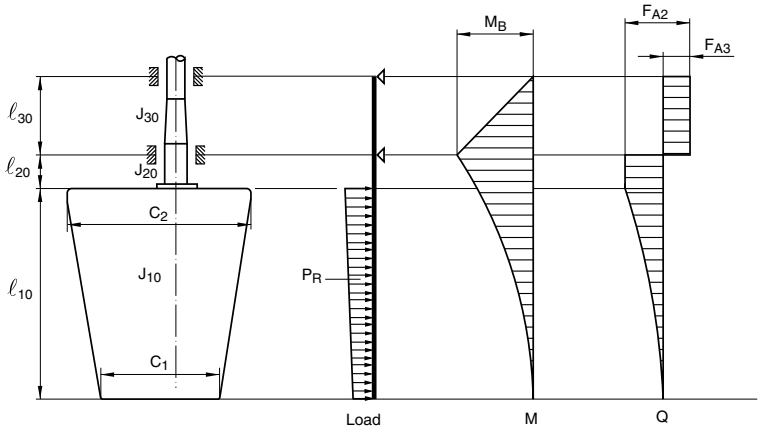
  $$F_{A3} = \frac{M_B}{\ell_{30}}$$

  $F_{A2} = C_R + F_{A3}$

- maximum shear force in the rudder body, in N:

  $Q_R = C_R$.

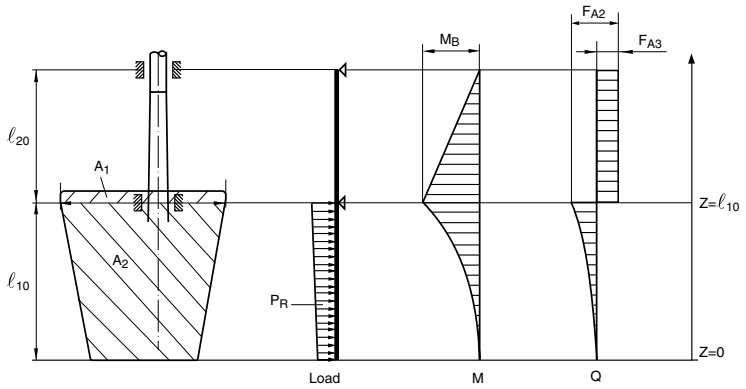
Figure 4 : Rudder type 6a



1.4.7 Rudder type 6b

This type of rudder is regarding spade rudders with rudder trunks continued into the rudder blade, through a quite short length, in such way the centre of gravity of the rudder blade is located below the lower rudder stock bearing. The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 5.

Figure 5 : Rudder type 6b



The force per unit length p_R acting on the lower part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}}\right) \cdot z$$

where:

z : Position of rudder blade section, in m, taken over ℓ_{10} length

p_{Rz} : Force per unit length, in N/m, obtained at the z position

p_{R10} : Force per unit length, in N/m, obtained for z equal to zero

p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10}.

The values of p_{R10} and p_{R20} are obtained from the following two equations:

$$p_{R10} = \frac{2C_R(2\ell_{10} - 3\ell_{CG})}{\ell_{10}^2}$$

$$p_{R20} = \frac{2C_R(3\ell_{CG} - \ell_{10})}{\ell_{10}^2}$$

where:

C_R : Force, in N, acting on the total rudder blade area A, to be calculated in accordance with Ch 12, Sec 1, [2.1.2]

A : Total rudder blade area, in m^2

ℓ_{CG} : Vertical position, in m, of the centre of gravity of the total rudder blade area A, to be taken from the bottom of the rudder blade.

The bending moments M_R and M_B, in N·m, for the scantling of both the rudder blade and the lower rudder stock diameter, respectively, are identical and shall be taken as follows:

$$M_R = M_B = C_R \cdot (\ell_{10} - \ell_{CG})$$

The reaction forces F_{A2} and F_{A3}, in N, may be determined as follows:

$$F_{A3} = M_B / \ell_{20}$$

$$F_{A2} = -(C_R + F_{A3})$$

1.4.8 Rudder type 6c

This type of rudder provides a more general solution for the scantling of spade rudders with rudder trunks continued into the rudder blade. There is no limitation on the location of the centre of gravity of the total rudder blade area, which may be located either below the lower rudder stock bearing or slightly above it. The rudder structure is to be calculated according to load, shear force and bending moment diagrams corresponding to the two following load cases:

- Case 1: pressure applied only on the rudder area below the middle of neck bearing, as shown in Fig 6
- Case 2: pressure applied on the entire rudder area, as shown in Fig 7

Figure 6 : Rudder type 6c - pressure applied only on lower area A_2

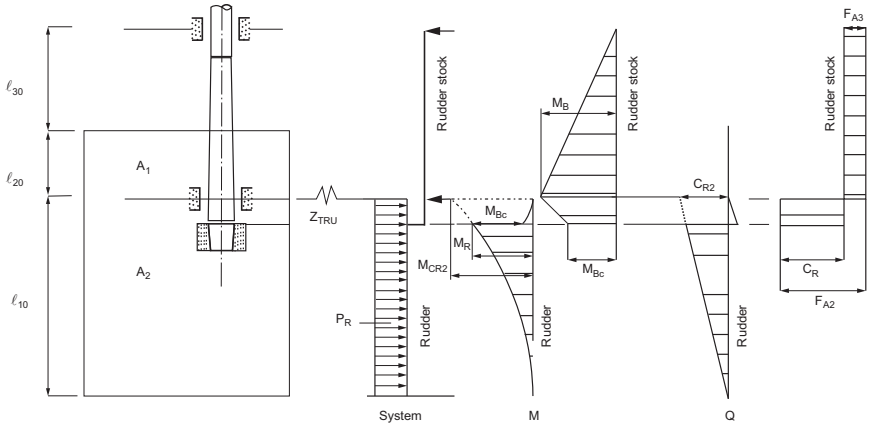
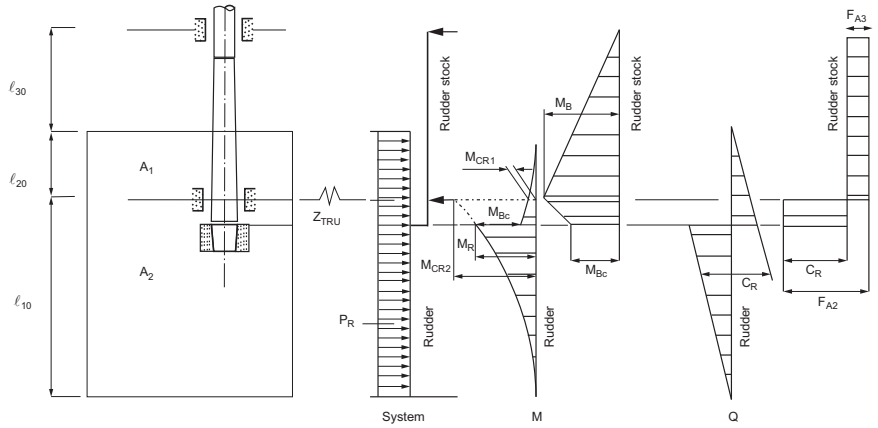


Figure 7 : Rudder type 6c - pressure applied on the entire rudder area



The force per unit length p_{RzL} acting on the lower part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{RzL} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}}\right) \cdot z$$

The force per unit length p_{RzU} acting on the upper part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{RzU} = p_{R20} + \left(\frac{p_{R30} - p_{R20}}{\ell_{20}}\right) \cdot (z - \ell_{10})$$

where:

z : Position of rudder blade section, in m

p_{R10} : Force per unit length, in N/m, obtained for z equal to zero

p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10}.

p_{R30} : Force per unit length, in N/m, obtained for z equal to $\ell_{10} + \ell_{20}$.

The values of p_{R10}, p_{R20} and p_{R30} are obtained from the following equations:

$$p_{R10} = \frac{2C_{R2}(2\ell_{10} - 3\ell_{CG2})}{\ell_{10}^2}$$

$$p_{R20} = \frac{2C_{R2}(3\ell_{CG2} - \ell_{10})}{\ell_{10}^2}$$

$$p_{R30} = \frac{2C_{R1}(\ell_{CG1} - \ell_{10})}{\ell_{20}^2}$$

where:

C_{R2} : Force, in N, acting on the rudder blade area A_2, to be calculated in accordance with Ch 12, Sec 1, [2.2.3]

A_2 : Rudder blade area, in m^2, located below the lower rudder stock bearing

ℓ_{CG2} : Vertical position, in m, of the centre of gravity of the rudder blade area A_2, to be taken from the bottom of the rudder blade.

The bending moment M_B, in N·m, for the scantling of the lower rudder stock diameter, is given by the algebraic sum of M_C_{R2} and M_C_{R1}, as follows: $M_B = M_C_{R2} + M_C_{R1}$

where:

M_C_{R2} : Bending moment, in N·m, induced by the rudder force C_{R2} (M_C_{R2} is assumed to be of a negative sign), taken equal to:

$$M_C_{R2} = C_{R2} \cdot (\ell_{10} - \ell_{CG2})$$

M_C_{R1} : Bending moment, in N·m, induced by the rudder force C_{R1} (M_C_{R1} is assumed to be of a positive sign), taken equal to:

$$M_C_{R1} = C_{R1} \cdot (\ell_{CG1} - \ell_{10})$$

C_{R1} : Force, in N, acting on the rudder blade area A_1, to be calculated in accordance with Ch 12, Sec 1, [2.2.3]

A_1 : Rudder blade area, in m^2, located above the lower rudder stock bearing

ℓ_{CG1} : Vertical position, in m, of the centre of gravity of the rudder blade area A_1, to be taken from the bottom of the rudder blade.

The reaction forces F_{A2} and F_{A3}, in N, may be determined as follows:

$$F_{A3} = M_B / (\ell_{20} + \ell_{30})$$

$$F_{A2} = -(C_{R1} + C_{R2} + F_{A3})$$

1.4.9 Rudder type 7

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 8.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

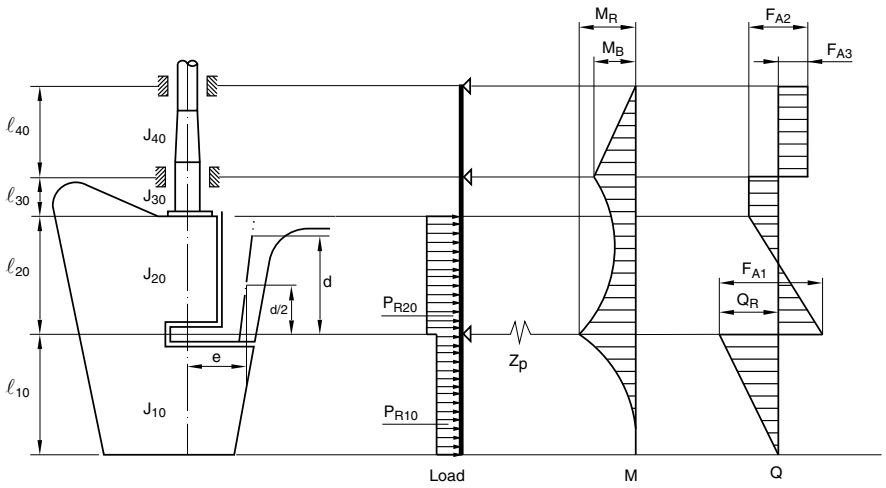
$$p_{R20} = \frac{C_{R1}}{\ell}$$

where:

ℓ : Value equal to: $\ell = \ell_{20}$

The spring constant Z_p is to be calculated according to [1.3.2].

Figure 8 : Rudder type 7



1.4.10 Rudder type 8

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 9.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

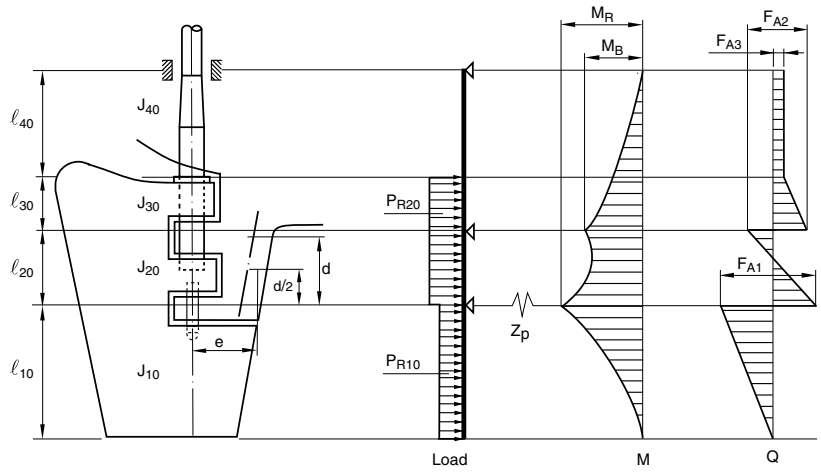
$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$$\ell = \ell_{20} + \ell_{30}$$

The spring constant Z_p is to be calculated according to [1.3.2].

Figure 9 : Rudder type 8



1.4.11 Rudder type 9

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 10.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

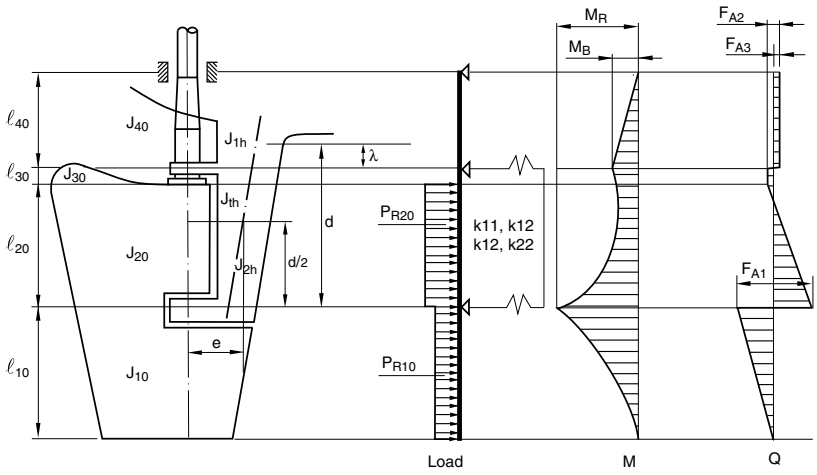
$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20}$

The stiffness properties of the 2-conjugate elastic supports are to be calculated according to [1.3.3].

Figure 10 : Rudder type 9



1.4.12 Rudder type 10

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 11.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

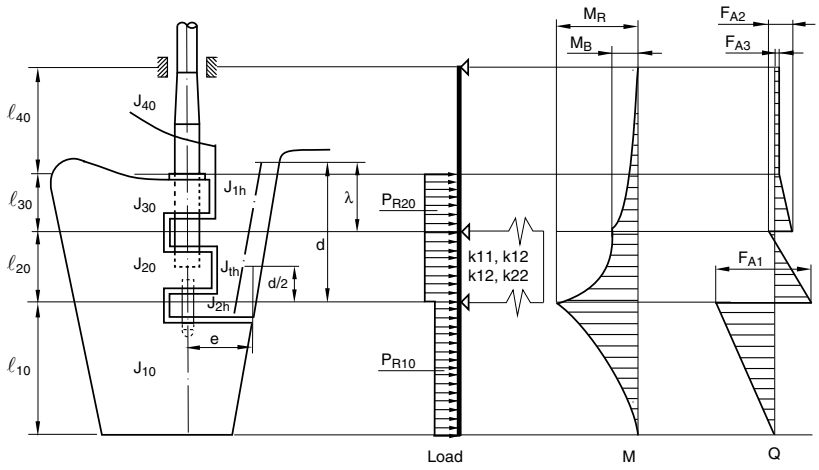
$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20} + \ell_{30}$

The stiffness properties of the 2-conjugate elastic supports are to be calculated according to [1.3.3].

Figure 11 : Rudder type 10



1.5 Calculation of the solepiece

1.5.1 Bending moment

The bending moment acting on the generic section of the solepiece is to be obtained, in N·m, from the following formula:

$M_S = F_{A1}\ x$

where:

F_{A1} : Supporting force, in N, in the pintle bearing, to be determined according to [1.4], for the relevant type of rudder

x : Distance, in m, defined in Fig 12.

1.5.2 Stress calculations

For the generic section of the solepiece within the length ℓ_{50}, defined in Fig 12, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = \frac{M_S}{W_Z}$$

τ : Shear stress to be obtained, in N/mm^2, from the following formula:

$$\tau = \frac{F_{A1}}{A_S}$$

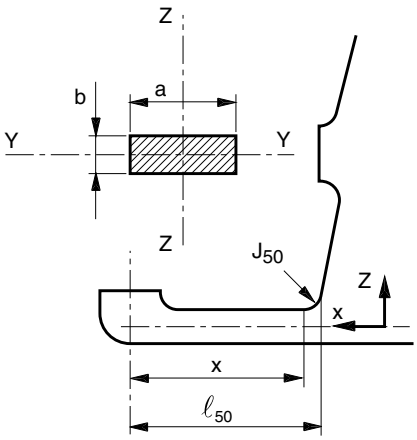
M_S : Bending moment, in N·m, at the section considered, as defined in [1.5.1]

F_{A1} : Force, in N, defined in [1.5.1]

W_Z : Section modulus, in cm^3, around the vertical axis Z (see Fig 12)

A_S : Shear sectional area, in mm^2, in a plane perpendicular to the X axis of the solepiece.

Figure 12 : Solepiece geometry



1.6 Rudder horn calculation (case of 1-elastic support)

1.6.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$M_H = F_{A1}\, z$

where:

F_{A1} : Support force at the rudder horn lower-pintle, in N, to be obtained according to [1.4], for the relevant type of rudder

z : Distance, in m, defined in Fig 14, to be taken less than the distance d, in m, defined in the same figure.

1.6.2 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formula:

$Q_H = F_{A1}$

where:

F_{A1} : Force, in N, defined in [1.6.1].

1.6.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$M_T = F_{A1}\, e_{(z)}$

where:

F_{A1} : Force, in N, defined in [1.6.1]

$e_{(z)}$: Torsion lever, in m, defined in Fig 14.

1.6.4 Stress calculations

For the generic section of the rudder horn within the length d, defined in Fig 14, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [1.6.1]

W_X : Section modulus, in cm^3, around the horizontal axis X (see Fig 14)

τ_S : Shear stress to be obtained, in N/mm^2, from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

F_{A1} : Force, in N, defined in [1.6.1]

A_H : Effective shear sectional area of the rudder horn, in mm^2, in y-direction

τ_T : Torsional stress to be obtained for hollow rudder horn, in N/mm^2, from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

M_T : Torque, in N·m, defined in [1.6.3]

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T, is obtained at the minimum value of t_H.

Figure 13 : Rudder and rudder horn geometries (1-elastic support)

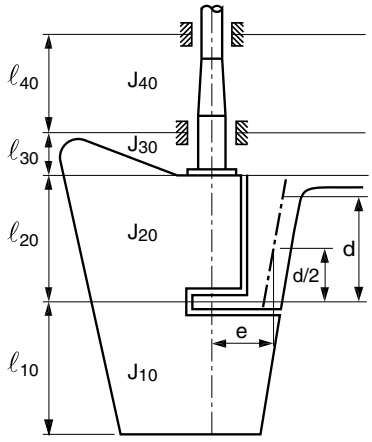
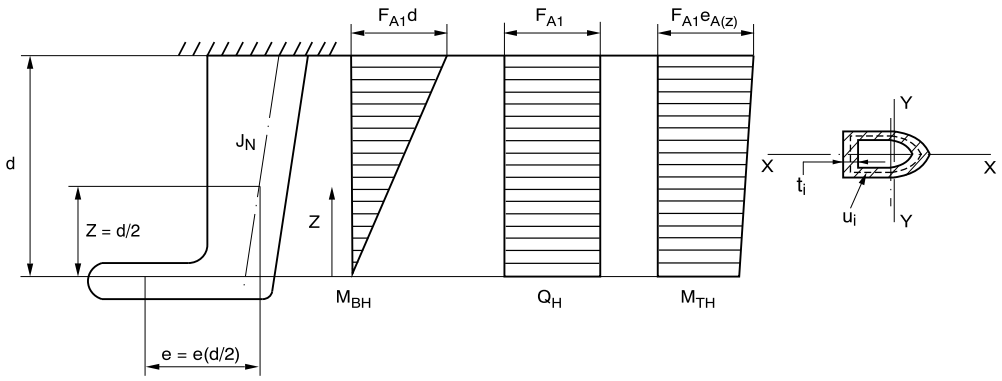


Figure 14 : Rudder horn geometry (1-elastic support)



1.7 Rudder horn calculation (case of 2-conjugate elastic supports)

1.7.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

- between the lower and upper supports provided by the rudder horn:
  $M_H = F_{A1}\, z$
- above the rudder horn upper-support:
  $M_H = F_{A1}\, z + F_{A2}\, (z - d_{lu})$

where:

F_{A1} : Support force at the rudder horn lower-support, in N, to be obtained according to [1.4], for the relevant type of rudder

F_{A2} : Support force at the rudder horn upper-support, in N, to be obtained according to [1.4], for the relevant type of rudder

z : Distance, in m, defined in Fig 16, to be taken less than the distance d, in m, defined in the same figure

d_{lu} : Distance, in m, between the rudder-horn lower and upper bearings (according to Fig 15, $d_{lu} = d - \lambda$).

1.7.2 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

- between the lower and upper rudder horn bearings:
  $Q_H = F_{A1}$
- above the rudder horn upper-bearing:
  $Q_H = F_{A1} + F_{A2}$

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1].

1.7.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

- between the lower and upper rudder horn bearings:
  $M_T = F_{A1}\, e_{(z)}$
- above the rudder horn upper-bearing:
  $M_T = F_{A1}\, e_{(z)} + F_{A2}\, e_{(z)}$

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1]

$e_{(z)}$: Torsion lever, in m, defined in Fig 16.

1.7.4 Shear stress calculation

a) For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

b) For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1]

A_H : Effective shear sectional area of the rudder horn, in mm^2, in y-direction

M_T : Torque, in N·m, defined in [1.7.3]

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T, is obtained at the minimum value of t_H.

1.7.5 Bending stress calculation

For the generic section of the rudder horn within the length d, defined in Fig 16, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [1.7.1]

W_X : Section modulus, in cm^3, around the horizontal axis X (see Fig 16).

Figure 15 : Rudder and rudder horn geometries (2-conjugate elastic supports)

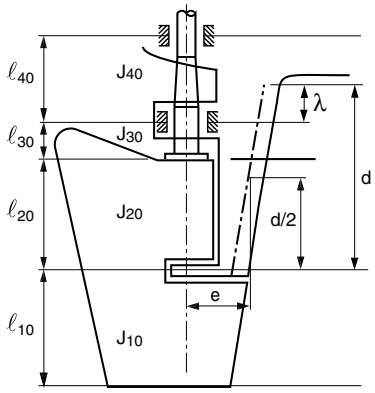
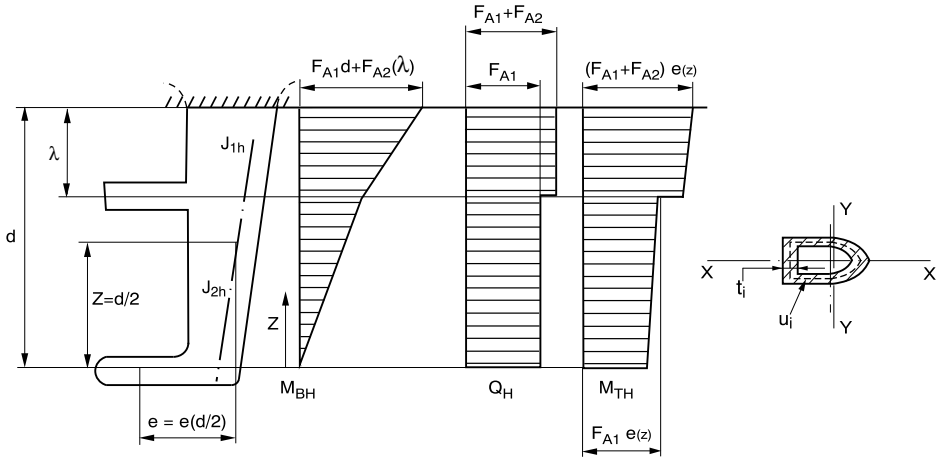


Figure 16 : Rudder horn geometry (2-conjugate elastic supports)



1.8 Calculation of the rudder trunk

1.8.1 Bending moment

The bending moment acting on the generic section of the trunk is to be obtained, in N·m, from the following formula:

$M_{TRU} = F_{A2}\, z$

where:

F_{A2} : Support force, in N, at the lower rudder stock bearing, as defined in [1.4]

z : Distance, in m, defined in Fig 17.

1.8.2 Stress calculations

For the generic section of the trunk within the length ℓ_{TRU}, defined in Fig 17, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = \frac{M_{TRU}}{W_{TRU}}$$

τ : Shear stress to be obtained, in N/mm^2, from the following formula:

$$\tau = \frac{F_{A2}}{A_{TRU}}$$

M_{TRU} : Bending moment, in N·m, at the section considered, as defined in [1.8.1]

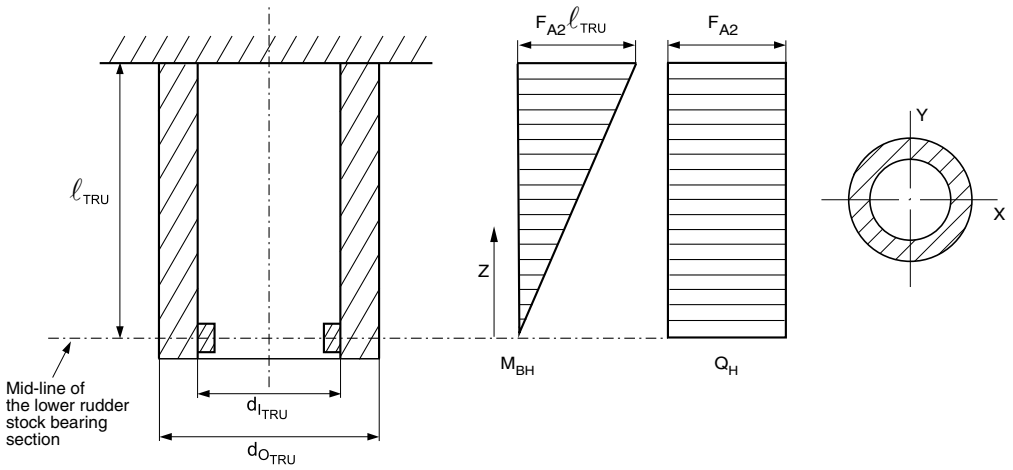
F_{A2} : Support force, in N, at the lower rudder stock bearing, as defined in [1.4]

W_{TRU} : Section modulus, in cm^3, around the horizontal axis X (see Fig 17)

A_{TRU} : Shear sectional area, in mm^2, in a plane perpendicular to the Z axis of the trunk.

The length ℓ_{TRU} is the distance in m, taken between the mid-line of the lower rudder stock bearing and the "top line" of the trunk. This "top line" is defined either where the trunk is clamped into the shell or at the bottom of the skeg, as shown in the diagram Fig 17.

Figure 17 : Rudder trunk geometry



Appendix 2 Towing and Mooring Arrangement

1 General

1.1 Application

1.1.1 The towing and mooring arrangement as defined in the present article and the towing and mooring lines as defined in Article [2] are given as a guidance but are not required as a condition of classification.

1.2 Definition

1.2.1 For symbols and definitions not defined in this Section, refer to Ch 12, Sec 4.

1.3 Mooring arrangement

1.3.1 Attention is to be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and towing lines as far as practicable. It is beneficial to provide dedicated towing arrangements separate from the mooring equipment.

1.3.2 Mooring lines in the same service (e.g. breast lines as defined in [2.7.1]) are to be of the same characteristic in terms of strength and elasticity.

1.3.3 As far as possible, sufficient number of mooring winches are to be fitted to allow for all mooring lines to be belayed on winches. This allows for an efficient distribution of the load to all mooring lines in the same service and for the mooring lines to shed load before they break. If the mooring arrangement is designed such that mooring lines are partly to be belayed on bitts or bollards, it should be considered that these lines may not be as effective as the mooring lines belayed on winches.

1.3.4 Mooring lines are to have as straight a lead as is practicable from the mooring drum to the fairlead.

1.3.5 At points of change in direction sufficiently large radii of the contact surface of a rope on a fitting are to be provided to minimize the wear experienced by mooring lines and as recommended by the rope manufacturer for the rope type intended to be used.

1.4 Towing arrangement

1.4.1 As far as possible, towing lines is to be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads is to be avoided.

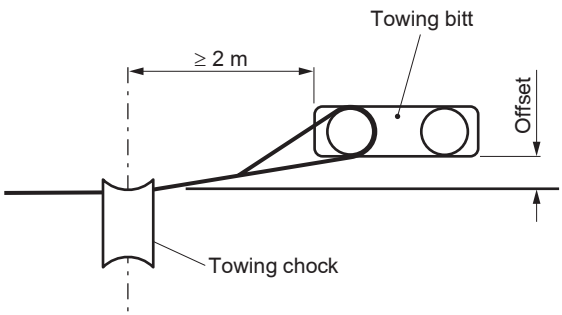
1.4.2 For towing purpose it is recommended to provide at least one chock close to centreline of the ship forward and aft. It is also beneficial to provide additional chocks on port and starboard side at the transom and at the bow.

1.4.3 Towing lines are to have a straight lead from the towing bitt or bollard to the chock.

1.4.4 For the purpose of towing, bitts or bollards serving a chock are to be located slightly offset and in a distance of at least 2 m away from the chock, see Fig 1.

1.4.5 Warping drums are to be preferably positioned not more than 20 m away from the chock, measured along the path of the line.

Figure 1 : Bitts or bollards serving a chock for towing purpose



2 Tow lines and mooring lines

2.1 General

2.1.1 The equipment in tow line and mooring lines (length, MBL_{SD} and number of lines) is obtained from Tab 1 and Tab 2 based on an Equipment Number EN calculated according to Ch 12, Sec 4, [1.2.2] with a side projected area A including deck cargoes at ship nominal capacity, as defined in Ch 12, Sec 4, [4.2.1].

For ship fitted with wind propulsion system, the force induced by wind applied on the rigging for the calculation of the equipment for towing and mooring is to be considered according to NR206 Sec 8, [5.3] taking into account the wind speed assumptions defined in Ch 12, Sec 4, [1.1].

2.1.2 For mooring lines for ships with EN > 2000, length, breaking load and number of lines are defined in [2.7].

2.1.3 The breaking load given in Tab 1, Tab 2 or in [2.7.4] is used to determine the maximum design load applied to shipboard fittings as defined in Ch 12, Sec 4, [4.2.5].

2.1.4 The tow lines having the characteristics defined in Tab 1, Tab 2 and [2.7] are intended as those belonging to the ship to be towed by a tug or another ship under normal towing conditions (calm water / harbour).

2.1.5 The Designer is to verify the adequacy of towing lines based on assessments carried out for the individual towing arrangement.

2.1.6 The designer is to verify the adequacy of mooring lines based on assessments carried out for the individual mooring arrangement, expected shore-side mooring facilities and design environmental conditions for the berth.

2.2 Materials

2.2.1 Tow lines and mooring lines may be of wire or synthetic fibre or a mixture of wire and fibre.

2.2.2 The breaking loads defined in Tab 1, Tab 2 and [2.7.4] refer to steel wires.

2.2.3 As a guidance, all requirements about manufacturing, sampling and testing for steel wires and fibre ropes are available in NR216 Materials and Welding, Ch 10, Sec 5.

Table 1 : Tow line and mooring lines for EN ≤ 2000

Equipment number EN A < EN ≤ B		Tow line		Mooring lines		
A	B	Minimum length, in m	MBL_{SD}, in kN **(1)**	N **(2)**	Length of each line, in m	MBL_{SD}, in kN **(1)**
50	70	180	98	3	80	37
70	90	180	98	3	100	40
90	110	180	98	3	110	42
110	130	180	98	3	110	48
130	150	180	98	3	120	53
150	175	180	98	3	120	59
175	205	180	112	3	120	64
205	240	180	129	4	120	69
240	280	180	150	4	120	75
280	320	180	174	4	140	80
320	360	180	207	4	140	85
360	400	180	224	4	140	96
400	450	180	250	4	140	107
450	500	180	277	4	140	117
500	550	190	306	4	160	134
550	600	190	338	4	160	143
600	660	190	370	4	160	160
660	720	190	406	4	160	171
720	780	190	441	4	170	187
780	840	190	479	4	170	202
840	910	190	518	4	170	218
910	980	190	559	4	170	235

(1) Refer to Ch 12, Sec 4, [4.2.1]

(2) Refer to [2.6].

Equipment number EN A < EN ≤ B		Tow line		Mooring lines		
A	B	Minimum length, in m	MBL_{SD}, in kN **(1)**	N **(2)**	Length of each line, in m	MBL_{SD}, in kN **(1)**
980	1060	200	603	4	180	250
1060	1140	200	647	4	180	272
1140	1220	200	691	4	180	293
1220	1300	200	738	4	180	309
1300	1390	200	786	4	180	336
1390	1480	200	836	4	180	352
1480	1570	220	888	5	190	352
1570	1670	220	941	5	190	362
1670	1790	220	1024	5	190	384
1790	1930	220	1109	5	190	411
1930	2000	220	1168	5	190	437

(1) Refer to Ch 12, Sec 4, [4.2.1]

(2) Refer to [2.6].

Table 2 : Tow line for EN > 2000

Equipment number EN A < EN ≤ B		Tow line	
A	B	Minimum length, in m	MBL_{SD}, in kN **(1)**
2000	2080	220	1168
2080	2230	240	1259
2230	2380	240	1356
2380	2530	240	1453
2530	2700	260	1471
2700	2870	260	1471
2870	3040	260	1471
3040	3210	280	1471
3210	3400	280	1471
3400	3600	280	1471
3600	3800	300	1471
3800	4000	300	1471
4000	4200	300	1471
4200	4400	300	1471
4400	4600	300	1471
4600	4800	300	1471
4800	5000	300	1471
5000	5200	300	1471
5200	5500	300	1471
5500	5800	300	1471
5800	6100	300	1471
6100	6500	300	1471
6500	6900	300	1471
6900	7400	300	1471
7400	7900	300	1471
7900	8400	300	1471
8400	8900	300	1471
8900	9400	300	1471
9400	10000	300	1471
10000	10700	300	1471
10700	11500	300	1471
11500	12400	300	1471

(1) Refer to Ch 12, Sec 4, [4.2.1]

Equipment number EN A < EN ≤ B		Tow line	
A	B	Minimum length, in m	MBL_{SD}, in kN **(1)**
12400	13400	300	1471
13400	14600	300	1471
14600	16000	300	1471
(1) Refer to Ch 12, Sec 4, [4.2.1]			

2.3 Steel wires

2.3.1 Steel wires are to be made of flexible galvanised steel and are to be of types defined in Tab 3.

2.3.2 Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have not less than 186 threads in addition to the metallic core.

Table 3 : Steel wire composition

Breaking load B_L , in kN	Steel wire components		
	Number of threads	Range of ultimate tensile strength of threads, in N/mm^2	Composition of wire
$B_L < 216$	72	1420 – 1570	6 strands with 7-fibre core
$216 < B_L < 490$	144	1570 – 1770	6 strands with 7-fibre core
$B_L > 490$	216 or 222	1770 – 1960	6 strands with 1-fibre core

2.4 Length of mooring lines

2.4.1 The length of individual mooring lines may be reduced by up to 7% of the length defined in Tab 1 and [2.7.5] provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Tab 1 and [2.7.5].

2.4.2 For ships with the service notation **supply**, the length of mooring lines may be reduced. The reduced length ℓ is to be not less than that obtained, in m, from the following formula:

$\ell = L + 20$

2.5 Synthetic fibre ropes

2.5.1 Where synthetic fibre ropes are adopted, their size is to be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes.

2.5.2 It is recommended to use lines with reduced risk of recoil (snap-back) to mitigate the risk of injuries or fatalities in the case of breaking mooring lines.

2.5.3 Fibre rope diameters are to be not less than 20 mm.

2.5.4 For mooring lines made of nylon, the LDBF is to be verified under wet and spliced conditions when breaking tests are performed according to NR216, Ch 10, Sec 6, [1.3.4].

2.6 Additional mooring lines

2.6.1 For ships having the ration A/EN > 0,9, additional mooring lines are defined in Tab 4, in addition to the number of mooring lines defined in Tab 1.

Table 4 : Additional mooring lines

A / EN	Number of additional mooring lines
0,9 < A / EN ≤ 1,1	1
1,1 < A / EN ≤ 1,2	2
1,2 < A / EN	3
Note 1: A and EN are defined in Ch 12, Sec 4, [1.2.2].	

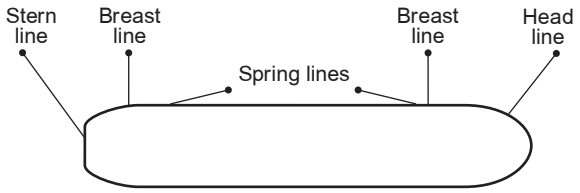
2.7 Mooring lines for ships with EN > 2000

2.7.1 Definitions

The following is defined with respect to the purpose of mooring lines, see also Fig 2:

- breast line: mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.
- spring line: mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.
- head/Stern line: mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.

Figure 2 : Breast, spring and head/stern mooring lines



2.7.2 Side projected area A_1

The strength of mooring lines and the number of head, stern, and breast lines for ships with an Equipment Number EN > 2000 are based on the side-projected area A_1.

Side projected area A_1 is to be calculated similar to the side-projected area A according to Ch 12, Sec 4, [1.2.2] but considering the following conditions:

- the ballast draft is to be considered for the calculation of the side projected area A_1. For ship types having small variation in the draft, like e.g. passenger and RO/RO ships, the side projected area A_1 may be calculated using the summer load waterline.
- deck cargoes at ship nominal capacity condition as defined in Ch 12, Sec 4, [4.2.1] are to be included for the determination of side-projected area A_1. For the condition with cargo on deck, the summer load waterline may be considered.

Note 1: Wind shielding of the pier can be considered for the calculation of the side-projected area A_1 unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m over waterline may be assumed, i.e. the lower part of the side-projected area with a height of 3 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A_1.

Note 2: Deck cargoes may not need to be considered if ballast draft condition generates a larger side-projected area A_1 than the full load condition with cargoes on deck. The larger of both side-projected areas is to be chosen as side-projected area A_1.

2.7.3 Environmental conditions

The mooring lines are based on a maximum current speed of 2 knots (1,0 m/s) and the following maximum wind speed v_w, in m/s:

- for ships with one of the service notations **passenger ship**, **ro-ro passenger ship** or **ro-ro cargo ship**:
  - with 2000 m^2 < A_1 ≤ 4000 m^2:

    $v_w = 25,0 - 0,002\ (A_1 - 2000)$
  - with A_1 > 4000 m^2:

    $v_w = 21,0$
- for other ships:

  $v_w = 25,0$

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern (±10°) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current.

Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it should be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

2.7.4 Ship design minimum breaking load

The ship design minimum breaking load MBL_{SD}, in kN, of the mooring lines is to be taken as:

$MBL_{SD} = 0,1\ A_1 + 350$

The ship design minimum breaking load MBL_{SD} may be limited to 1275 kN (130 t).

However, in this case the moorings are to be considered as not sufficient for environmental conditions given in [2.7.3].

For these ships, the acceptable wind speed v_w^*, in m/s, can be estimated as follows:

$$v_w^* = v_w \sqrt{\frac{MBL_{SD}^*}{MBL_{SD}}}$$

where v_w as defined in [2.7.3], MBL_{SD} as defined above and MBL_{SD}^* the ship design minimum breaking load of the mooring lines intended to be supplied.

However, the ship design minimum breaking load is not to be taken less than corresponding to an acceptable wind speed of 21 m/s:

$$MBL_{SD}^* \geq \left(\frac{21}{v_w}\right)^2 MBL_{SD}$$

If lines are intended to be supplied for an acceptable wind speed v_w^* higher than v_w as defined in [2.7.3], the ship design minimum breaking load MBL_{SD}^* is to be taken as:

$$MLB_{SD}^* = \left(\frac{v_w^*}{v_w}\right)^2 MBL_{SD}$$

2.7.5 Length of mooring lines

For ships with EN > 2000, the length of mooring lines may be taken as 200 m.

2.7.6 Head, stern and breast lines

The total number of head, stern and breast lines is to be taken as:

- for ships with one of the service notations **oil tanker**, **oil tanker ESP**, **chemical tanker ESP**, **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**:

  $n = 8{,}3\ 10^{-4}\ A_1 + 4$

- for other ships:

  $n = 8{,}3\ 10^{-4}\ A_1 + 6$

This number n is to be rounded to the nearest whole number and may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted ship design minimum breaking load MBL_{SD}^{**}, should be taken as:

- for increased number of lines:

  $$MBL_{SD}^{**} = 1{,}2 \cdot MBL_{SD} \cdot \frac{n}{n^{**}} \leq MBL_{SD}$$

- for reduced number of lines:

  $$MBL_{SD}^{**} = MBL_{SD} \cdot \frac{n}{n^{**}}$$

where MBL_{SD} is MBL_{SD} or MBL_{SD}^* specified in [2.7.4], n^{**} is the increased or decreased total number of head, stern and breast lines and n the number of lines for the considered ship type as calculated by the above formulas without rounding.

Vice versa, the ship design minimum breaking load of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the number of lines.

2.7.7 Spring lines

The total number of spring lines is to be taken not less than:

- for ship with EN < 5000: two lines
- for ships with EN ≥ 5000: four lines.

The ship design minimum breaking load of spring lines is to be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking load of the lines, the number of spring lines should be taken as follows, but rounded up to the nearest even number:

$$n_S^* = \frac{MBL_{SD}}{MBL_{SD}^{**}} \cdot n_S$$

where MBL_{SD} is MBL_{SD} or MBL_{SD}^* specified in [2.7.4], n_S is the number of spring lines as given above and n_S^* is the increased number of spring lines.

CHAPTER 13
CONSTRUCTION AND TESTING

Section 1 Construction and Fabrication
Section 2 Fabrication by Welding
Section 3 Design of Weld Joints
Section 4 Non-Destructive Testing
Section 5 Special Structural Details
Section 6 Testing
Appendix 1 Welding Details
Appendix 2 Reference Sheets for Special Structural Details

Section 1 Construction and Fabrication

1 General

1.1 Workmanship

1.1.1 All workmanship is to be of standard marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of Ch 13, Sec 2. Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or any other composition.

1.2 Fabrication standard

1.2.1 Structural fabrication is to be carried out in accordance with IACS Recommendation No. 47 or with a recognised fabrication standard which has been accepted by the Society prior to the commencement of fabrication/construction.

1.2.2 The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Society prior to the commencement of the fabrication/construction.

1.2.3 The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

a) Cut edges:
The slope of the cut edge and the roughness of the cut edges.

b) Flanged stiffeners and brackets and built-up sections:
The breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate.

c) Pillars:
The straightness between decks and cylindrical structure diameter.

d) Brackets and flat bar stiffeners:
The distortion at the free edge line of tripping brackets and flat bar stiffeners.

e) Sub-assembly stiffeners:
Details of sniped end of face plates and webs.

f) Plate assembly:
For flat and curved blocks, the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate.

g) Cubic assembly:
In addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks.

h) Special assembly:
The distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, breadth and length of top plate of main engine bed. Where boring out of the propeller boss and stern frame, skeg or solepiece are to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft alignment is to be carried out using a method and sequence submitted to and recognised by the Society. The fit-up and alignment of the rudder, pintles and axles are to be carried out after completing the major parts of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

i) Butt joints in plating:
Alignment of butt joint in plating.

j) Cruciform joints:
Alignment measured on the median line and measured on the heel line of cruciform joints.

k) Alignment of interior members:
Alignments of flange of T profiles, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut-outs for continuous stiffeners in assembly and in erection joints.

l) Keel and bottom sighting:
Deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships.

m) Dimensions:

Length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine.

n) Fairness of plating between frames:

Deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deckhouse deck and wall plating.

o) Fairness of plating in way of frames:

Deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames.

2 Cut-outs, plate edges

2.1 General

2.1.1 The free edges (cut surfaces) of cut-outs, hatch corners, etc are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as specified above. This also applies to cutting drag lines, etc, in particular to the upper edge of sheer strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.1.2 Corners in hatch opening are to be machine cut.

3 Cold forming

3.1 Special structural members

3.1.1 For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in Ch 4, Sec 1, Tab 3, such as radius gunwales (bent sheer plates) and bilge strakes), the inside bending radius, in cold formed plating, is not to be less than 10 times the as-built plate thickness for carbon-manganese steels (see Ch 4, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.2 Corrugated bulkheads and hopper knuckles

3.2.1 For corrugated bulkheads and hopper knuckles, the inside bending radius R, as defined in Ch 4, Sec 5, Fig 27, in cold formed plating, is not to be less than 4.5 times the as-built plate thickness for carbon-manganese steels (see Ch 4, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.3 Low bending radius

3.3.1 When the inside bending radius is reduced below the limits defined [3.1], supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:

a) For all bent plates:

- 100% visual inspection of the bent area is to be carried out
- random checks by magnetic particle testing are to be carried out.

b) In addition to item a), for bent plates at boundaries to tanks or ballast holds:

- the steel is to be of grade D/DH or higher
- the material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as\text{-}built} / (2r_{bdg} + t_{as\text{-}built})$, where $t_{as\text{-}built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

4 Hot forming

4.1 Temperature requirements

4.1.1 Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 30°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with [4.2.1], these mechanical tests are not required.

4.1.2 After further heating, other than specified in [4.1.1], of thermo-mechanically controlled steels (TMCP plates) for forming and stress relieving, it is to be demonstrated that the mechanical properties meet the requirements specified by a procedure test using representative material.

4.2 Line or spot heating

4.2.1 Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature on the surface is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

5 Modifications and repairs during construction

5.1 General

5.1.1 Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with the Society on a case by case basis.

5.2 Gap and weld deformations

5.2.1 Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by the Society upon special examination.

5.3 Defects

5.3.1 Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of the Society.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case by case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

5.4 Repairs on structures already welded

5.4.1 In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with the Society on a case by case basis.

Section 2 Fabrication by Welding

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the criteria given in Ch 13, App 1, to which reference is made. These criteria being given as recommendations, minor departures may be accepted by the Society, on a case by case basis.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in NR216 Materials and Welding, Chapter 12.

1.1.2 Weld connections are to be executed according to the approved plans. A detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the approved plans.

1.1.4 The quality standard adopted by the shipyard is to be submitted to the Society and applies to all constructions unless otherwise specified on a case by case basis.

1.2 Base material

1.2.1 The requirements of this Section apply for the welding of hull structural steels or aluminium alloys of the types considered in NR216 Materials and Welding or other types accepted as equivalent by the Society.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Documentation to be submitted

1.3.1 The structural plans to be submitted for approval, according to Ch 1, Sec 4, are to contain the necessary data relevant to the fabrication by welding of the structures and items represented as far as class is concerned.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

Plans relevant to the special details specified in Ch 13, Sec 5 are to be submitted.

1.3.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.4 Personnel and equipment

1.4.1 Welders and welding operators

Welders for manual welding and for semi-automatic welding processes are to be properly trained and are to be certified by the Society, as required in the individual applications, unless otherwise agreed.

Welders are to be certified according to the procedures given in Rule Note NR476 Approval Testing of Welders.

The certification is to be in due course of validity.

1.4.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.4.3 Organisation

The internal organisation of the shipyard is to be such as to ensure compliance with the requirements in [1.4.1] and [1.4.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.4.4 Non-destructive testing operators

Requirements for NDT personnel are given in Ch 13, Sec 4, [3].

1.4.5 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensure their preservation in proper condition. Especially, where consumables with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer's instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-backing, ...) hydrogen-controlled grade.

2 Welding

2.1 General

2.1.1 All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables, in compliance with NR216 Materials and welding.

2.2 Welding consumables and procedures

2.2.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by the Society.

The requirements for the approval of welding consumables are given in NR216 Materials and Welding, Chapter 11.

The requirements for the approval of welding procedures are given in NR216 Materials and Welding, Chapter 12.

2.2.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted, as defined in NR216 Materials and welding, are specified in Tab 1 depending on the steel grade.

Consumables used for manual or semi-automatic welding (covered electrodes, flux-cored and flux-coated wires) of higher strength hull structural steels are to be at least of hydrogen-controlled grade H15 (H). Where the carbon equivalent Ceq is not more than 0,41% and the thickness is below 30 mm, any type of approved higher strength consumables may be used at the discretion of the Society.

Especially, welding consumables with hydrogen-controlled grade H15 (H) and H10 (HH) shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than R_{eH_weld} specified in Ch 13, Sec 3 and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

Table 1 : Consumable grades

Steel grade	Consumable minimum grade	
	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 - DH32 - DH36	2Y	2Y
EH32 - EH36 - EH36CAS	3Y	
FH32 - FH36 - FH36CAS	4Y	
AH40	2Y40	2Y40
DH40 - EH40 - EH40CAS	3Y40	
FH40 - FH40CAS	4Y40	
EH47 - EH47CAS	3Y47	3Y47
Note 1: Welding consumables approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumables approved in grade Y40 may be used in lieu of those approved in grade Y having the same or a lower grade. **Note 2:** In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumables appropriate to one or the other steel are to be adopted.		

2.3 Welding operations

2.3.1 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

2.3.2 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

2.3.3 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by the Society.

Shop primers are to be approved by the Society for a specific type and thickness according to NR216 Materials and Welding, Ch 13, Sec 1.

2.3.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

Completed welded joints are to be to the satisfaction of the attending Surveyor. Edge preparations and root gaps are to be in accordance with the approved welding procedure. The gap between the members being joined should not exceed the maximum values given in IACS Recommendation No. 47 or as specified in recognised fabrication standard approved by the Society. Where the gap between members being joined exceeds the specified values, corrective measures are to be taken in accordance with an approved welding procedure specification.

2.3.5 Gap in fillet weld tee connections

In fillet weld tee connections, a gap g, as shown in Fig 1, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to Ch 13, Sec 3, [3.2.7] or Ch 4, Sec 5, [5.2.8], as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased accordingly as specified in Ch 13, Sec 5 for some special connections of various ship types.

In any event, the gap g may not exceed 4 mm.

2.3.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 2, between plates with the same as-built thickness $t_{as\text{-}built}$ is to be less than 0,15 $t_{as\text{-}built}$, without being greater than 3 mm.

2.3.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 3, is to be less than:

- $t_{as\text{-}built}/2$, in general, where $t_{as\text{-}built}$ is the thickness of the thinner abutting plate
- the values specified in Ch 13, Sec 5 for some special connections of various ship types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 1 : Gap in fillet weld tee connections

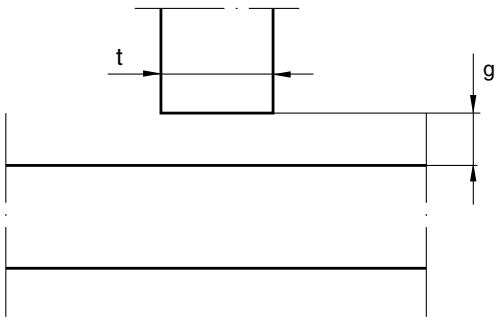


Figure 2 : Plate misalignment in butt connections

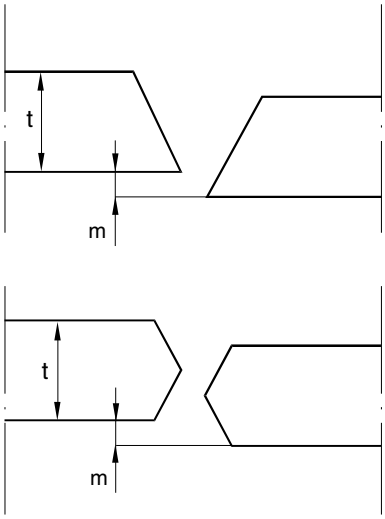
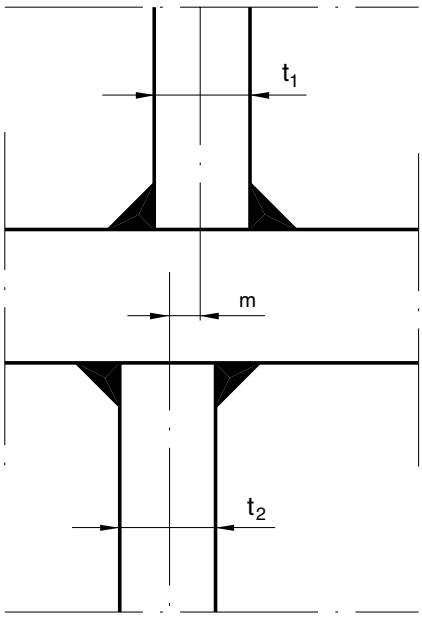


Figure 3 : Misalignment in cruciform connections



2.3.8 Assembling of aluminium alloy parts

When welding aluminium alloy parts, particular care is to be taken so as to:

- reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose
- keep possible deformations within the allowable limits.

2.3.9 Preheating and interpass temperatures

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case by case basis.

2.3.10 Welding sequences

Consideration is to be given to the assembly sequence and the effect of the overall shrinkage of plate panels, assemblies, etc, resulting from the welding processes employed. Welding is to proceed systematically, with each welded joint being completed in correct sequence, without undue interruption. When practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

Welding sequences and direction of welding are to be determined so as to minimise deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case by case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

Moreover, during the welding operation afloat, loading conditions are to be adjusted in order to have an acceptable level of longitudinal stress.

Note 1: As a general guidance, the level of longitudinal stress during the welding operation is to be below 50 MPa in the concerned area; however, lower limits may be requested by the surveyor depending on the specificities of the ship and/or welding.

In general, butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

2.3.11 Interpass cleaning

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

2.3.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range 550°C ÷ 620°C, as appropriate for the type of steel.

2.3.13 Arrangements at junctions of welds

Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions can not be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of the size, and in a position, that a satisfactory return weld can be made.

2.4 Crossing of structural elements

2.4.1 In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

2.5 Hatch coaming

2.5.1 Application

This sub-article applies to welding of plates having a minimum specified yield stress R_{eH} equal to 460 N/mm^2 and a thickness equal to or greater than 50 mm but not greater than 100 mm, used for longitudinal structural members in the upper deck region (such as hatch side coaming, hatch coaming top and attached longitudinal stiffeners).

Specific procedures are to be submitted to the Society for plates having a thickness greater than 100 mm.

Special care is to be paid to the final welding so that harmful defects do not remain.

2.5.2 Short bead

Short bead length for tack and repairs of welds by welding is not to be less than 50 mm. In the case where the cold cracking susceptibility index P_{cm}, as defined in NR216 Materials and Welding, is less than or equal to 0,19, short bead length of 25 mm may be considered by the Society on a case-by-case basis.

2.5.3 Preheating

Preheating is to be at least 50°C when air temperature is 5°C and under. In the case where the cold cracking susceptibility index P_{cm}, as defined in NR216 Materials and Welding, is less than or equal to 0,19, air temperature of 0°C and under may be considered by the Society on a case-by-case basis.

3 Inspections and checks

3.1 General

3.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipbuilder suitable to check compliance with the applicable requirements, approved plans and standards.

3.1.2 The Shipbuilder is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Shipbuilder's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective valid qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

3.1.3 The Shipbuilder is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

3.1.4 The Shipbuilder is responsible for ensuring that non-destructive testing are planned, carried out and reported in accordance with Ch 13, Sec 4.

3.2 Hatch coaming

3.2.1 Application

This sub-article applies to ships with hatch side coaming plate thickness t such that:

- 85 mm ≤ t ≤ 100 mm for steel with R_{eH} = 355 N/mm^2
- 50 mm ≤ t ≤ 100 mm for steel with R_{eH} = 390 N/mm^2 or R_{eH} = 460 N/mm^2.

Special consideration is to be given to hatch side coaming plate thickness greater than 100 mm.

3.2.2 Ultrasonic testing

Ultrasonic testing is to be performed on all block-to-block butt welds of upper longitudinal members along central part over their full lengths.

Upper longitudinal members are defined as follows:

- uppermost strakes of inner hull and longitudinal bulkheads
- sheerstrake
- main deck
- coaming side plate
- coaming top plate

and all their attached longitudinal stiffeners.

Section 3 Design of Weld Joints

Symbols

A_{weld} : Effective fillet weld area, in cm², weld throat multiplied by weld length

d : Length of the welded connection in mm

f : Root face, in mm

f_{yd} : Coefficient not to be taken less than:

$$f_{yd} = \left(\frac{1}{k}\right)^{0,50} \left(\frac{235}{R_{eH_weld}}\right)^{0,75}$$

nor less than 0,71

k : Material factor of the abutting member

ℓ_{dep} : Total length of deposit of weld metal, in mm

ℓ_{leg} : Leg length of continuous, lapped or intermittent fillet weld, in mm

p : Distance between successive fillet welds, in mm

R_{eH_weld} : Minimum yield stress of weld deposit, in N/mm²

R_{eH_weld} : Specified minimum yield stress for the weld deposit, in N/mm², not to be less than:

- 305 N/mm² for welding of normal strength steel with R_{eH} = 235 N/mm²
- 375 N/mm² for welding of higher strength steel with R_{eH} from 265 to 355 N/mm²
- 400 N/mm² for welding of higher strength steel with R_{eH} = 390N/mm²
- 460 N/mm² for welding of higher strength steel with R_{eH} = 460N/mm².

t_{throat} : Throat thickness of fillet weld in mm, as defined in [3.2.7]

t_{gap} : Allowance for fillet weld gap, is to be taken equal to 2,0 mm

$t_{as\text{-}built}$: As-built thickness of the plating abutting on another plating, in mm

w_F : Weld factor

1 General

1.1 Application

1.1.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognised standards and past experience are to apply as agreed by the Society.

1.1.2 Weld type, size and materials

The requirements of this Section apply to the design of welded connections in hull structures and are based on the following considerations:

- joint type
- criticality of the joint
- magnitude, type and direction of the stress in the joint
- material properties of the parent and weld material
- weld gap size.

1.1.3 The requirements given in this Section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

1.1.4 Plans and/or specifications showing weld sizes and weld details are to be submitted for approval.

1.1.5 Minimum leg length

Whether the welds are continuous or intermittent, the leg length thickness of the fillet welds is not to be less than the value indicated in Tab 1.

Table 1 : Minimum leg length

Structural element		Minimum leg length (mm)
Superstructures not contributing to hull girder strength		3,5
Other	$t_{as_built} < 6$ mm	4,0
	$t_{as_built} \geq 6$ mm	4,5

1.2 Arrangement

1.2.1 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case-by-case basis; tests as deemed necessary (for example, transverse impact tests) may be required by the Society.

1.2.2 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

1.2.3 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.2.4 Distance between welds

In general, the distance between two adjacent butts in the same strake of shell or deck plating is to be greater than two frame spaces.

2 Butt joint

2.1 General

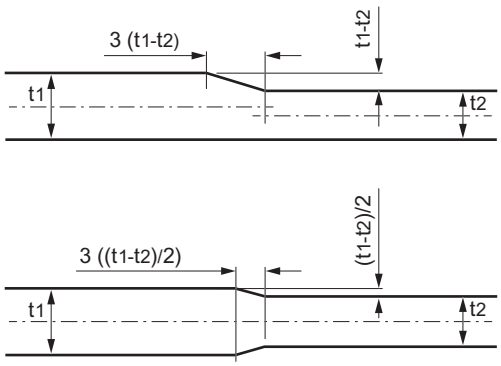
2.1.1 In general, butt connections of plating are to be full penetration, welded on both sides except where special procedures or specific techniques, considered equivalent by the Society, are adopted.

Connections different from the above may be accepted by the Society on a case by case basis; in such cases, the relevant detail and workmanship specifications are to be approved.

2.1.2 Welding of plates with different thicknesses

In the case of welding of plates with difference in as-built thickness greater than 4 mm on one side, the thicker plate is normally to be tapered. The taper length is to be not less than 3 times the difference in as-built thickness on the considered side (see Fig 1).

Figure 1 : Taper length



2.1.3 Edge preparation, root gap

Typical edge preparations and gaps are indicated in Ch 13, App 1, [1.2].

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.1.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by the Society.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.1.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by the Society on a case by case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by the Society.

Welding of bulbs without a doubler is to be performed by welders specifically certified by the Society for such type of welding.

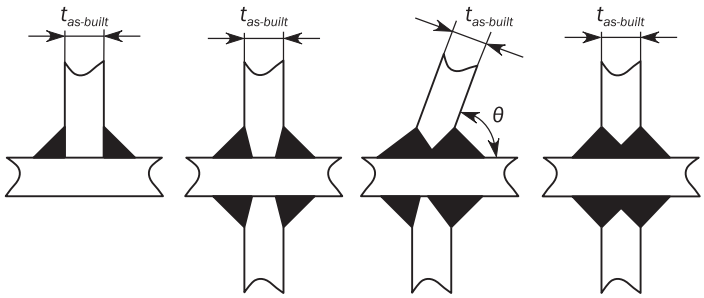
3 Tee or cross joint

3.1 Application

3.1.1 The connection of primary supporting members, stiffener webs to plating as well as the plating abutting on another plating, are to be made by fillet or penetration welding, as shown in Fig 2.

3.1.2 Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate.

Figure 2 : Tee or cross joints



$t_{as\text{-}built}$: As-built thickness of the member being attached, in mm

θ : Connecting angle, in deg.

3.2 Fillet welding

3.2.1 General

Ordinary fillet welding may be adopted for tee connections of the various simple and composite structural elements, where they are subjected to low tensile stress or where they are not critical for fatigue.

Where this is not the case, partial or full tee penetration welding according to [3.3] is to be adopted.

3.2.2 The required weld sizes are to be rounded to the nearest half millimetre.

3.2.3 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see [3.2.4])
- intermittent fillet welding, which may be subdivided (see [3.2.5]) into:
  - chain welding
  - scallop welding
  - staggered welding.

3.2.4 Continuous fillet welding

Continuous fillet welding is to be adopted in general:

- for watertight connections
- for connections of brackets, lugs and scallops
- at the ends of connections for a length of at least 75mm
- where intermittent welding is not allowed, according to [3.2.5]
- for connections of stiffeners subject to wheeled loads.

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p, calculated according to [3.2.5], is low.

3.2.5 Intermittent welding

Where continuous welding is not required, intermittent welding may be applied.

Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds (double continuous welds having the length of an intermittent fillet weld) on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

Where intermittent welding or one side continuous welding is permitted, double continuous welds are to be applied for one-tenth of their shear span at each end, in accordance with [3.2.6] and [3.2.7].

One side continuous welding may be accepted instead of chain and staggered intermittent welding for connections of stiffeners in the dry spaces of deckhouses and superstructures, where not affected by sea pressure, tank pressure or concentrated loads.

The size for one side continuous weld is to be of fillet required by [3.2.6] for intermittent welding, where f_3 factor is to be taken as 2,0.

The spacing p and the length d, in mm, of an intermittent weld, shown in:

- Fig 3, for chain welding
- Fig 4, for scallop welding
- Fig 5, for staggered welding

are to be such that:

$$\frac{p}{d} \leq \varphi$$

where the coefficient φ is defined in Tab 2 and Tab 4 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

In addition, the following limitations are to be complied with:

- chain welding (see Fig 3):
  $d \geq 75$ mm
  $p - d \leq 200$ mm
- scallop welding (see Fig 4):
  $d \geq 75$ mm
  $p - d \leq 150$ mm
  $v \leq 0,25\ b$ without being greater than 75 mm
- staggered welding (see Fig 5):
  $d \geq 75$ mm
  $p - 2d \leq 300$ mm
  $p \leq 2d$ for connections subjected to high alternate stresses.

Figure 3 : Intermittent chain welding

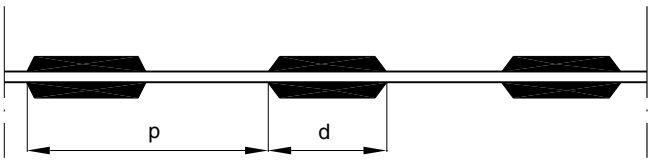


Figure 4 : Intermittent scallop welding

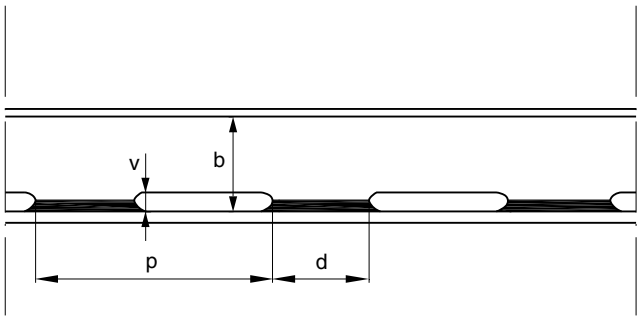
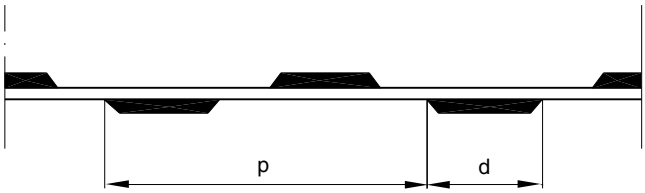


Figure 5 : Intermittent staggered welding



3.2.6 Leg length

The leg length ℓ_{leg} , in mm, of continuous, lapped or intermittent fillet welds is not to be taken less than the greater of the following values:

$\ell_{leg} = f_1 \, f_2 \, t_{as\text{-}built}$

$\ell_{leg} = f_{yd} \, w_F \, f_2 \, f_3 \, t_{as\text{-}built} + t_{gap}$

nor less than the minimum values given in [1.1.5],

where:

f_1 : Coefficient depending on the welding type:

- for double continuous welding:
  $f_1 = 0,30$
- for intermittent welding:
  $f_1 = 0,38$

f_2 : Coefficient depending on the edge preparation:

- for welds without bevelling:
  $f_2 = 1,0$
- for welds with one/both side bevelling and $f = t_{as\text{-}built} / 3$ (see Ch 13, App 1):
  $f_2 = 0,7$

w_F : Weld factor, defined in Tab 2 for various hull structural connections and Tab 3; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 2 or Tab 3, w_F is defined in Tab 4; for some connections of specific ship types, the values of w_F specified in Part D or Part E for these ship types are to be used in lieu of the corresponding values in Tab 2, Tab 3 or Tab 4

f_3 : Correction factor for the type of weld:

- for double continuous weld:
  $f_3 = 1,0$
- for intermittent welding:
  $f_3 = p / d$

Leg length for intermittent welding is not to exceed the greater of 6,5 mm or 0,62 $t_{as\text{-}built}$.

3.2.7 Throat size

The throat size, in mm, as shown in Fig 6, is not to be less than:

$$t_{throat} = \frac{\ell_{leg}}{\sqrt{2}}$$

In the case of automatic or semi-automatic deep penetration weld, the throat thickness (the minimum values included) may be reduced according to [3.2.13].

The throat thickness may be required by the Society to be increased, depending on the results of structural analyses.

Figure 6 : Weld scantlings definitions

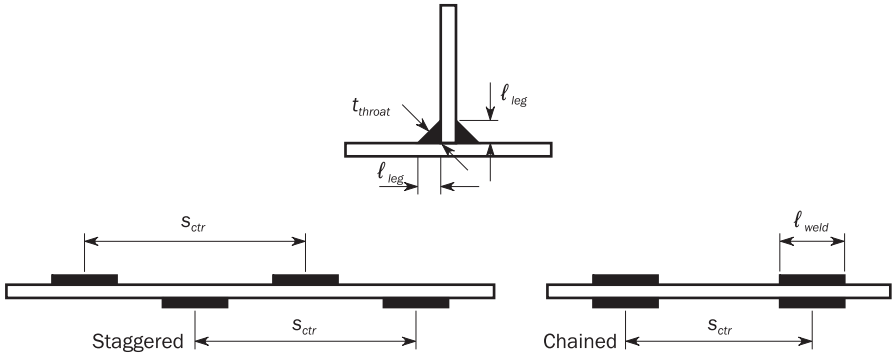


Table 2 : Weld factors w_F and coefficient φ for the various hull structural connections

Hull area	Connection			w_F **(1)**	φ **(2) (3)**			p_1, in mm (see [3.2.9]) **(3)**
	of	to			CH	SC	ST	
General, unless otherwise specified in the table	watertight plates	boundaries		0,48				
	oil-tight plates	boundaries		0,51				
	brackets at ends of members			0,48				
	ordinary stiffener and collar plates	deep tank bulkheads		0,24				
		web of primary supporting members and collar plates		see Ch 4, Sec 5, [5.2.8]				
	webs of ordinary stiffeners	plating (except deep tank bulkhead)	at ends **(4)**	0,20				
			elsewhere	0,20	3,5	3,0	4,6	ST 260
		face plate of fabricated stiffeners	at ends (15% span) **(4)**	0,38				
			elsewhere	0,20	3,5	3,0	4,6	ST 260
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating		0,24	3,5	3,0	4,6	ST 260
	centre girder	shell plating		0,38	1,8	1,8		CH/SC 130
		inner bottom plating		0,38	2,2	2,2		CH/SC 160
	side girders	bottom and inner bottom plating		0,24	3,5	3,0	4,6	ST 260
		floors (interrupted girders)		0,28	2,2			CH 160
	floors	bottom and inner bottom plating	in general	0,18	3,5	3,0	4,6	ST 260
			at ends (20% of span) for longitudinally framed double bottom	0,38	1,8			CH 130
		inner bottom plating in way of brackets of primary supporting members		0,35	1,8			CH 130
		girders (interrupted floors)		0,28	2,2			CH 160
		centre girder and side girders in way of hopper tanks		0,38				
	partial side girders	floors		0,35	1,8			CH 130
	bracket on centre girder	Centre girder, inner bottom, floors and shell plates		0,38				
	web stiffeners	floor and girder webs		0,20	3,5	3,0	4,6	ST 260
Side and inner side	ordinary stiffeners	side and inner side plating		0,18	3,5	3,0	4,6	ST 260
	girders and web frames in double side skin ships	side plating		0,30				
		inner side plating and web of primary supporting members	in way of deck transverse and end connections	0,43				
			in way of cross tie	0,36				
			elsewhere	0,30				
Deck	strength deck $t_{as\text{-}built} \geq 15$ mm	side plating within 0,6 L amidships		Partial penetration welding				
		elsewhere		0,48				
	strength deck $t_{as\text{-}built} < 15$ mm	side plating		0,48				
	non-watertight decks	side plating		0,38	2,2			CH 160
	ordinary stiffeners and intercostal girders	deck plating		0,20	3,5	3,0	4,6	ST 260
	hatch coamings	deck plating	in general	0,38				
			at ends of hatch coamings (over a length equal to 15% of the hatch coaming height)	Full penetration welding **(7)**				
	web stiffeners	coaming webs		0,20 **(8)**	3,5	3,0	4,6	ST 260

Hull area	Connection			w_F **(1)**	φ **(2) (3)**			p_1, in mm (see [3.2.9]) **(3)**
	of	to			CH	SC	ST	
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,63				
			vertical corrugations (corrugated bulkheads)	Full penetration welding, in general				
		boundaries other than tank bottom		0,50				
	watertight bulkhead structures	boundaries		0,50				
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,24	2,2	2,2		CH/SC 160
			others	0,18	3,5	3,0	4,6	ST 260
	ordinary stiffeners	bulkhead plating	in general	0,18	3,5	3,0	4,6	ST 260
			at ends (25% of span), where no end brackets are fitted	0,48				
Structures located forward of 0,75 L from the AE **(5)**	bottom longitudinal ordinary stiffeners	bottom plating		0,28	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,35	1,8			CH 130
	side frames in panting area	side plating		0,28	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	$A < 65$ cm^2 **(6)**	0,35	1,8	1,8		CH/SC 130
			$A \geq 65$ cm^2 **(6)**	See Tab 4				
After peak **(5)**	internal structures	boundaries and each other: below waterline		0,38				
		above waterline		0,20				
	side ordinary stiffeners	side plating		0,28				
	floors	bottom and inner bottom plating		0,28				
Machinery space **(5)**	centre girder	keel and inner bottom plating	in way of main engine foundations	0,63				
			in way of seating of auxiliary machinery and boilers	0,50				
			elsewhere	0,48	1,8	1,8		CH/SC 130
	side girders	inner bottom plating	in way of main engine foundations	Partial penetration welding				
			in way of seating of auxiliary machinery and boilers	0,50				
			elsewhere	0,38	2,2	2,2		CH/SC 160
		bottom plating		0,38	2,2	2,2		CH/SC 160
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,50				
			elsewhere	0,38	2,2	2,2		CH/SC 160
	floors in way of main engine foundations	bottom plating		0,50				
		foundation plates		0,63				
	floors	centre girder	single bottom	0,63				
			double bottom	0,48	1,8	1,8		CH/SC 130
Superstructures and deckhouses	external bulkheads	deck	in general	0,48				
			engine and boiler casings at corners of openings (15% of opening length)	0,63				
	internal bulkheads	deck		0,20	3,5	3,0	4,6	ST 260
	ordinary stiffeners	external and internal bulkhead plating		0,18	3,5	3,0	4,6	ST 260
Hatch covers	ordinary stiffener	plating		0,24	3,5	3,0	4,6	ST 260

Hull area	Connection			w_F **(1)**	φ **(2) (3)**			p_1, in mm (see [3.2.9]) **(3)**
	of	to			CH	SC	ST	
Pillars	elements composing the pillar section	each other (fabricated pillars)		0,18				
	pillars	deck	pillars in compression	0,50				
			pillars in tension	See [5.2]				
Rudders	horizontal and vertical webs directly connected to solid parts	solid parts or rudder stock		According to Ch 12, Sec 1, [7.4] or Ch 12, Sec 1, [7.5]				
		elsewhere	for shear force greater than or equal to 45% of the maximum rudder body value	0,63				
			for shear force lower than 45% of the maximum rudder body value	0,28				
	other webs	each other		0,28		2,2		SC 160
		plating	in general	0,28		2,2		SC 160
			top and bottom plates of rudder plating	0,50				

(1) In connections for which $w_F \geq 0,50$, continuous fillet welding is to be adopted

(2) For coefficient φ, see [3.2.5]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted

(3) CH = chain welding, SC = scallop welding, ST = staggered welding

(4) The web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance d at least equal to the depth h of the girder or stiffeners, with 300 mm ≥ d ≥ 75 mm. Where end brackets are fitted, ends means the area extended in way of brackets and at least 50 mm beyond the bracket toes

(5) For connections not mentioned, the requirements for the central part apply

(6) A is the face plate sectional area of the side girders, in cm^2

(7) $w_F = 0,43$ for hatch coaming other than in cargo holds

(8) Continuous welding

Table 3 : Weld factors w_F for miscellaneous fittings and equipment

Item		Connection to	w_F
Hatch cover	Primary supporting members	at ends (10% of span) of PSM	0,48
		elswhere	0,24
	Stiffeners	at ends	0,38
		elsewhere	0,20
Mast, derrick post, crane pedestal, etc.		deck / underdeck reinforced structure	0,43
Deck machinery seat		deck	0,24
Mooring equipment seat		deck	0,43
Ring for access hole type cover		anywhere	0,43
Stiffening of side shell doors and weathertight doors		anywhere	0,24
Frames of shell and weathertight doors		anywhere	0,43
Coaming of ventilator and air pipe		deck	0,43
Ventilators, etc., fittings		anywhere	0,24
Scupper and discharge		deck	0,55
Bulwark stay		deck	0,24
Bulwark plating		deck	0,43
Guard rail, stanchion		deck	0,43
Cleats and fittings		hatch coaming and hatch cover	0,24 **(1)**

(1) Minimum value of the weld factor. Where $t_{as\text{-}built} > 11,5$mm, ℓ_{leg} need not exceed $0,62\ t_{as\text{-}built}$. Penetration welding may be required depending on the design.

Table 4 : Welding factors w_F and coefficient φ for connections of primary supporting members

Primary supporting member	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	φ **(2) (3)** SC	φ **(2) (3)** ST	p_1, in mm (see [3.2.9]) **(3)**
General **(4)**	web, where A < 65 cm²	plating	at ends	0,48				
			elsewhere	0,38	3,0	3,0		CH/SC 210
		face plate	at ends	0,28				
			elsewhere	0,24	3,0	3,0		CH/SC 210
	web, where A ≥ 65 cm²	plating	at ends	0,48				
			elsewhere	0,38				
		face plate	at ends	0,50				
			elsewhere	0,38	1,8	1,8		CH/SC 130
	end brackets	face plate		0,38				
In tanks, where A < 65 cm² **(5)**	web	plating	at ends	0,48				
			elsewhere	0,38	2,2	2,2		CH/SC 160
		face plate	at ends	0,28				
			elsewhere	0,24	3,0	3,0		CH/SC 210
	end brackets	face plate		0,48				
In tanks, where A ≥ 65 cm²	web	plating	at ends	0,48				
			elsewhere	0,38				
		face plate		0,38				
	end brackets	face plate		0,48				

(1) In connections for which $w_F \geq 0,50$ continuous fillet welding is to be adopted.

(2) For coefficient φ, see [3.2.5]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted.

(3) CH = chain welding, SC = scallop welding, ST = staggered welding.

(4) For cantilever deck beams, continuous welding is to be adopted.

(5) For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.

Note 1: A is the face plate sectional area of the primary supporting member, in cm².

Note 2: Ends of primary supporting members means the area extended 15% of the shear span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.

3.2.8 Longitudinal stiffeners

Welding of longitudinal stiffeners to plating is to be double continuous at the ends of the longitudinal stiffeners over 15% of their shear span as defined in Ch 4, Sec 6, [1.1.3].

In way of primary supporting members, the length of the double continuous weld is to be equal to the depth of the longitudinal or the end bracket, whichever is greater.

Where the as-built web thickness of the abutting longitudinal stiffener is greater than 15 mm and exceeds the thickness of the attached plating, the welding is to be double continuous and the leg length of the weld is not to be less than the greatest of the following values:

a) $0,30\ t_{as\text{-}built}$, where $t_{as\text{-}built}$ is the as-built thickness of the attached plating without being taken greater than 30 mm

b) $0,27\ t_{as\text{-}built} + 1$, where $t_{as\text{-}built}$ is the as-built thickness of the abutting member. The leg size resulting of this formula need not be taken greater than 8,0 mm

c) the minimum leg length given in [1.1.5].

3.2.9 Weld dimensions in a specific case

Where intermittent fillet welding is adopted with:

- length d = 75 mm
- throat thickness t_{throat} specified in Tab 5 depending on the thickness $t_{as\text{-}built}$,

the weld spacing may be taken equal to the value p_1 defined in Tab 2. The values of p_1 in Tab 2 may be used when:

$8 \leq t_{as\text{-}built} \leq 16$ mm.

For thickness $t_{as\text{-}built}$ less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding,

without exceeding the limits in [3.2.5].

For thickness $t_{as\text{-}built}$ greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding.

Table 5 : Required throat thickness

$t_{as\text{-}built}$, in mm	t_{throat}, in mm	$t_{as\text{-}built}$, in mm	t_{throat}, in mm
6	3,0	17	7,0
8	3,5	18	7,0
9	4,0	19	7,5
10	4,5	20	7,5
11	5,0	21	8,5
12	5,5	22	8,5
13	6,0	23	9,0
14	6,0	24	9,0
15	6,5	25	10,0
16	6,5	26	10,0

3.2.10 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{TC} = t_{throat}\frac{\varepsilon}{\lambda}$$

where:

t_{throat} : Throat thickness defined in [3.2.7]

ε, λ : Dimensions, in mm, to be taken as shown in:

- Fig 7 for continuous welding
- Fig 8 for intermittent scallop welding.

Figure 7 : Continuous fillet welding between cut-outs

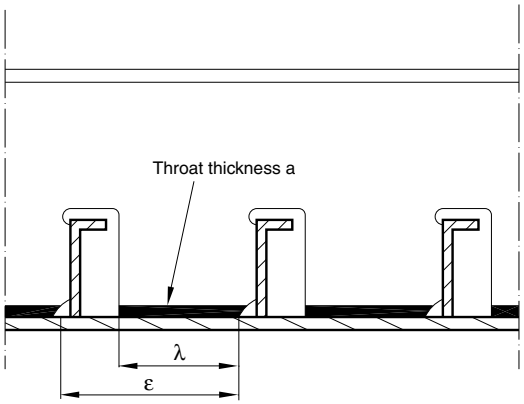
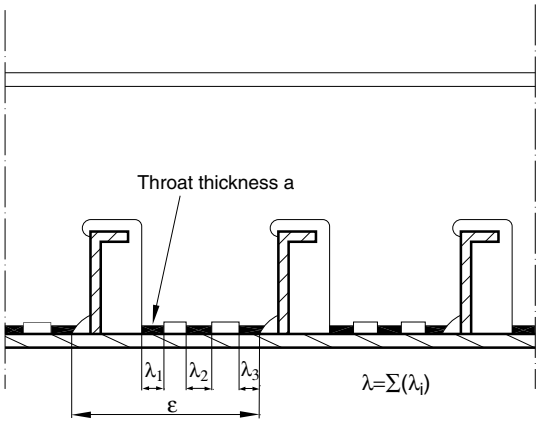


Figure 8 : Intermittent scallop fillet welding between cut-outs



3.2.11 Shear area of primary supporting member end connections

Welding of the end connections of primary supporting members is to be such that the weld area is to be equivalent to the gross cross-sectional area of the member. The weld leg length ℓ_{leg}, in mm, is to be taken as:

$$\ell_{leg} = 1,41\ f_{yd}\ \frac{h_w\ t_{gr-req}}{\ell_{dep}}$$

where:

h_w : Web height of primary supporting members, in mm

t_{gr_req} : Required gross thickness, in mm, of the web in way of the end connection, including 10% of shear span, based on the highest average usage factor for yield from cargo hold FE analysis or the shear area requirement for PSM outside central part

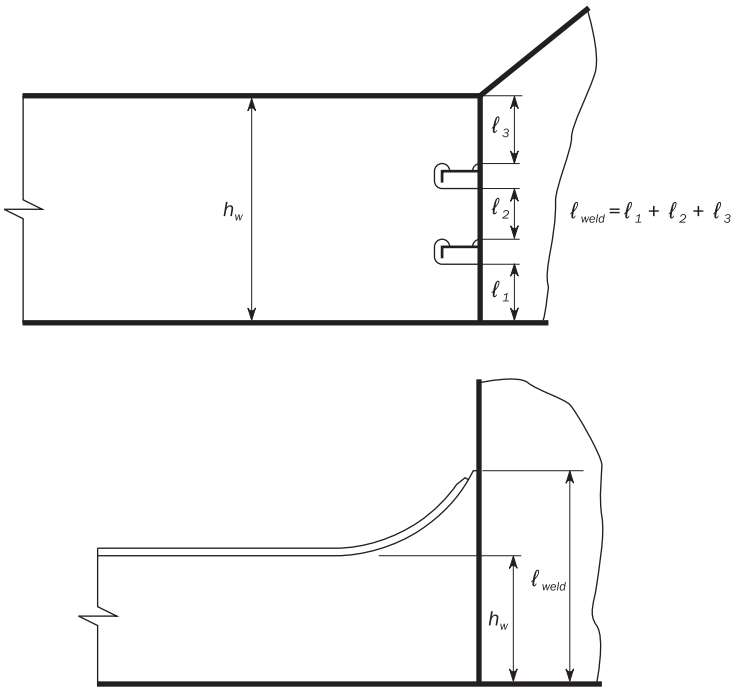
ℓ_{dep} : Total length of deposit of weld metal, in mm, taken as (see Fig 9):

$$\ell_{dep} = 2\ \ell_{weld}$$

ℓ_{weld} : Length of the welded connection in mm, as shown in Fig 9

The size of weld is not to be less than the value calculated in accordance with [3.2.6] considering a welding factor W_F equal to 0,25.

Figure 9 : Shear area of primary supporting member



Note: The length ℓ_{weld} is the length of the welded connection. The total length of the weld deposit ℓ_{dep} if welded with double continuous fillet welds is twice the length of the welded connection ℓ_{weld}.

3.2.12 Longitudinal continuity provided by brackets

Where the longitudinal continuity of a member contributing to the longitudinal strength of the ship is provided by brackets, the weld area A_{weld} is not to be less than the gross cross-sectional area of the member. The weld area A_{weld}, in cm^2, is to be determined by the following formula:

$$A_{weld} = \frac{f_{yd}\ t_{throat}\ \ell_{dep}}{100}$$

3.2.13 Reduced weld size of deep penetration fillet welding

Where an approved automatic deep penetration procedure is used and where the gap between the assembled members can be controlled to be not more than 1 mm, the weld factors given in Tab 3 may be reduced by 15%, without leading to leg size reduction of more than 1,5 mm. Reductions of up to 20%, without leading to leg size reduction of more than 1,5 mm, will be accepted provided that the shipyard is able to demonstrate that the following requirements are consistently met:

a) The welding is performed in accordance with welding procedure tests covering both minimum and maximum root gaps.

b) The weld penetration at the root is at least equivalent to the granted leg size reduction.

c) An established quality control system is in place.

The same reduction applies also for semi-automatic procedures where the welding is carried out in the downhand position.

3.2.14 Reduced weld size justification

Where any of the methods for reduction of the weld size are adopted, the specific requirements allowing the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld length and the required weld leg length given by [3.2.6] without the leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

3.3 Partial or full penetration welds

3.3.1 Partial or full penetration welding

In areas with high tensile stresses or areas considered critical and where indicated for the connections specified in Ch 13, App 2, in Part D or in Part E depending on the ship type, full or partial penetration welds are to be used.

Partial or full tee penetration welding is required, in any event, where indicated for the connections specified in Part D or Part E depending on the ship type. Further requirements are specified in Ch 13, Sec 5.

Examples of partial or full penetration welds with typical edge preparation are given in Ch 13, App 1.

3.3.2 One side partial penetration weld

For partial penetration welds with one side bevelling the fillet weld at the opposite side of the bevel is to satisfy the requirements given in [3.2].

3.3.3 Extent of full or partial penetration welding

The extent of full or partial penetration welding in each particular location is to be approved by the Society. However, the minimum extent of full/partial penetration welding from the reference point (i.e. intersection point of structural members, end of bracket toe, etc.) is not to be taken less than 300 mm, unless otherwise specially stated.

3.3.4 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing tee connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

3.3.5 Fine mesh finite element analysis

High stress area means an area where fine mesh finite element analysis is to be carried out and the fine mesh yield utilisation factor in elements adjacent to the weld is more than 90% of the fine mesh permissible utilisation factor, as defined in Ch 8, App 2, [4.1.3]

In high stress area, at least partial penetration welds as defined in [3.3.1] are to be used. The minimum extent of full or partial penetration welding in that case is to be the greater of the following:

- 150 mm in either direction from the element with the highest yield utilisation factor
- the extent covering all elements that exceed the above mentioned yield utilisation factor criteria.

4 Other types of joints

4.1 Lapped joints

4.1.1 General

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the following:

- peripheral connections of doubler plates
- internal structural elements subject to very low stress.

Elsewhere, lap-joint welding may be allowed by the Society on a case by case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

4.1.2 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case by case basis. Typical details are given in Ch 13, App 1, [1.4].

4.1.3 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

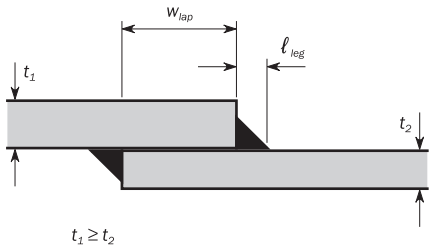
4.1.4 Overlaps for lugs

The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug and not be greater than 50 mm.

4.1.5 Lapped end connections

Lapped end connections are to have continuous welds on each edge with leg length ℓ_{leg}, in mm, as shown on Fig 10 such that the sum of the two leg lengths is not less than 1,5 times the as-built thickness of the thinner plate.

Figure 10 : Fillet weld in lapped joint



4.1.6 Overlapped seams

Overlapped seams are to have continuous welds on both edges, of the sizes required by [3.2.6] for the boundaries of tank/hold or watertight bulkheads. Seams for plates with as-built thickness of 12,5 mm or less, which are clear of tanks/holds, may have one edge with intermittent welds in accordance with [3.2.6] for watertight bulkhead boundaries.

4.2 Slot welds

4.2.1 General

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0,6 L amidships.

4.2.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in Ch 13, App 1, [1.4].

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case by case basis taking into account:

- the transverse spacing between adjacent slot weld lines
- the stresses acting in the connected plates
- the structural arrangement below the connected plates.

4.2.3 Closing plates

For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot welds to face plates fitted to the webs.

Slots are to be well-rounded and have a minimum slot length ℓ of 90 mm and a minimum width G of twice the as-built plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance L not greater than 140 mm. Slots are not to be filled with welding.

4.3 Stud and lifting lug welds

4.3.1 Where permanent or temporary studs or lifting lugs are to be attached by welding to main structural parts in areas subject to high stress, the proposed locations are to be submitted for approval.

4.4 Plug welding

4.4.1 Plug welding may be adopted only when accepted by the Society on a case by case basis, according to specifically defined criteria. Typical details are given in Ch 13, App 1, [1.4].

5 Specific weld connections

5.1 Bilge keels

5.1.1 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Tab 6.

5.1.2 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Fig 11. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

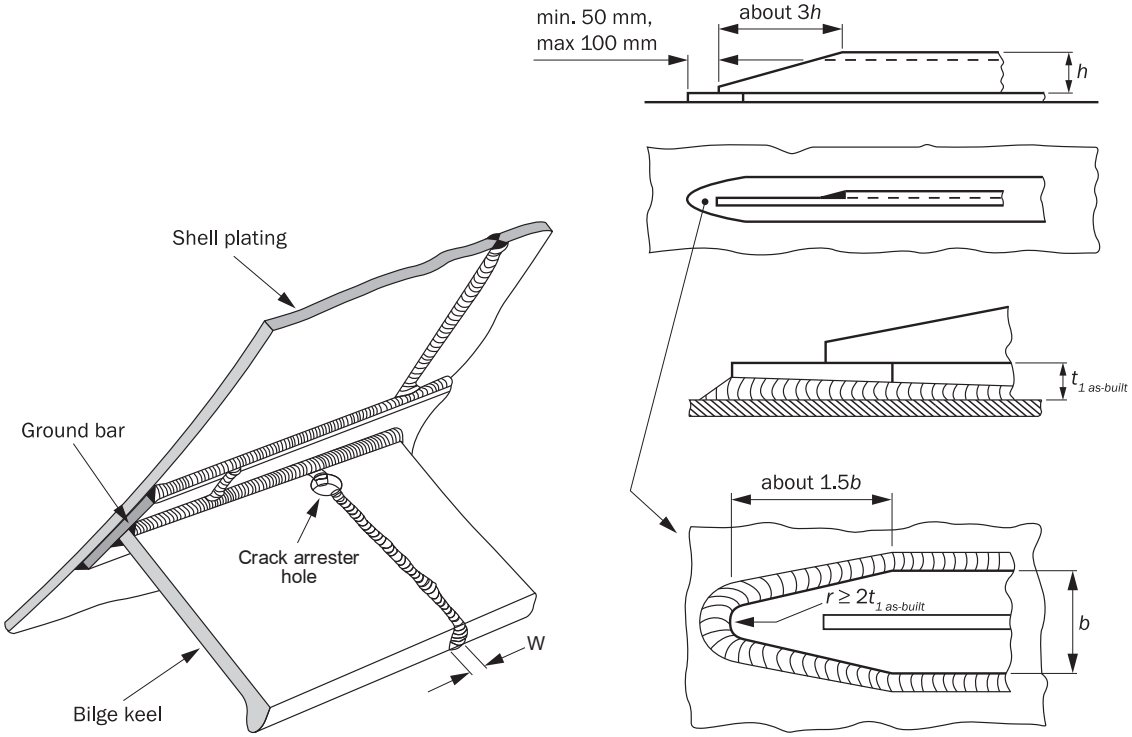
5.1.3 At the ends of the ground bar, the leg length is to be increased as given in Tab 6, without exceeding the as-built thickness of the ground bar as shown in Fig 11. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45° or less.

5.1.4 In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Table 6 : Connections of bilge keels

Structural items being joined	Leg length of weld, in mm	
	At ends **(1)**	Elsewhere
Ground bar to the shell	0,62 $t_{1as\text{-}built}$	0,48 $t_{1as\text{-}built}$
Bilge keel web to ground bar	0,48 $t_{2as\text{-}built}$	0,30 $t_{2as\text{-}built}$
$t_{1as\text{-}built}$: As-built thickness of ground bar, in mm $t_{2as\text{-}built}$: As-built thickness of web of bilge keel, in mm. **(1)** Zone "b" in Ch 4, Sec 5, Fig 25 and Ch 4, Sec 5, Fig 26 for definition of "ends"		

Figure 11 : Bilge keel



5.2 End connections of pillars

5.2.1 The end connections of pillars and any structural member acting as pillar are to have an effective fillet weld area, in mm^2, (weld throat multiplied by weld length) not less than:

$$A_{weld} = f_3 \left(\frac{235}{R_{eH_weld}} \right)^{0,75} F$$

where:

F : Design load, for the structure under consideration, in kN

f_3 : Coefficient equal to:

- 5 when pillar is in compression only
- 14 when pillar is in tension.

When A_{weld} cannot practically be achieved by fillet welding for pillars in tension, full penetration welding is to be adopted.

5.3 Abutting plates with small angles

5.3.1 Where angle θ between the abutting plate and the connected plate is less than 75° as shown in Fig 12, the size of fillet welds ℓ_θ, in mm, for the side of larger angle is to be increased in accordance with:

$$\ell_\theta = \frac{\ell_{leg}}{\sqrt{2}\sin\frac{\theta}{2}}$$

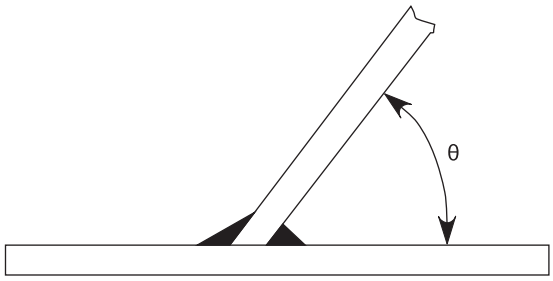
where:

ℓ_{leg} : Leg length of fillet weld, in mm, as defined in [3.2.6]

θ : Connecting angle, in deg, as shown in Fig 12.

5.3.2 Connections of main strength members where θ is less than 45°, see Fig 12, may be applied only in dry spaces and voids.

Figure 12 : Connecting angle



5.4 Struts connecting ordinary stiffeners

5.4.1 In case of a strut connected by lap joint to the ordinary stiffener, the throat thickness of the weld is to be obtained, in mm, from the following formula:

$$t_{throat} = \frac{\eta F}{n\ell_W\tau}10^3$$

where:

F : Maximum force transmitted by the strut, in kN

η : Safety factor, to be taken equal to 2

n : Number of welds in way of the strut axis

ℓ_W : Length of the weld in way of the strut axis, in mm

τ : Permissible shear stress, to be taken equal to 100 N/mm^2.

5.5 Connection between propeller post and propeller shaft bossing

5.5.1 Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

5.6 Bar stem connections

5.6.1 The bar stem is to be welded to the bar keel generally with butt welding.
The shell plating is also to be welded directly to the bar stem with butt welding.

5.7 Deck subjected to wheeled loads

5.7.1 Double continuous fillet welding is to be adopted for the connections of ordinary stiffeners with deck plating.

Section 4 Non-Destructive Testing

1 General

1.1 Scope

1.1.1 This Section gives requirements on the methods and quality levels that are to be adopted for the non-destructive testing (NDT) of ship hull structure steel welds and associated items during new building.

1.1.2 For the purpose of this Section, the hull structure is defined as follows:

a) hull envelope including all internal and external structures

b) superstructures, deckhouses and casings

c) welded foundations, e.g. main engine seatings

d) hatch coamings, bulwarks

e) all penetrations fitted and welded into bulkheads, decks and shell

f) the fittings of all connections to decks, bulkheads and shell, such as air pipes and ship side valves – all ILLC 1966, as amended, items

g) welded attachments to shell, decks and primary members, e.g. crane

h) pedestals, bitts and bollards, but only as regards their interaction on the hull structure.

1.1.3 For the purpose of this Section, the hull structure associated items are defined as follows:

- Welding of components that are integrated into the ship structure
- Rudders of welded construction

1.1.4 This Section covers conventional NDT methods. As far as advanced non-destructive testing (ANDT) methods are concerned, reference is made to NR216 Materials and Welding, Chapter 14. ANDT methods are typically phased array ultrasonic testing (PAUT), time of flight diffraction (TOFD), digital radiography (RT-D), radioscopic testing (RT-S), and computed radiography (RT-CR).

1.2 General requirements

1.2.1 The NDT is normally to be performed by the Shipbuilder or its subcontractors in accordance with the requirements of this Section. The Surveyor may require witnessing of the testing.

1.2.2 It is the Shipbuilder's responsibility to assure that testing specifications and procedures are adhered to during the construction and the reports are made available to the Society on the findings made by the NDT.

1.2.3 The quality levels given in this Section refer to production quality and not to fitness for-purpose of the welds examined.

1.3 Requirements for the entity carrying out NDT

1.3.1 In case of non-destructive testing carried out by an independent company from the manufacturer or shipyard, such company has to comply with the requirements for the independent NDT service supplier as set out in NR669 "Requirements for non-destructive testing suppliers".

1.3.2 In case of non-destructive testing carried out directly by the shipyard or manufacturer, the requirements for the internal NDT department as set out in NR669 "Requirements for non-destructive testing suppliers" are to be complied with.

1.4 Terms and definitions

1.4.1 The following terms and definitions apply:

NDT : Non-Destructive Testing: the development and application of technical methods to examine materials or components in ways that do not impair their future usefulness and serviceability, in order to measure geometrical characteristics and to detect, locate, measure and evaluate flaws. NDT is also known as non-destructive examination (NDE), non-destructive inspection (NDI) and non-destructive evaluation (NDE).

RT : Radiographic Testing

UT : Ultrasonic Testing

MT : Magnetic Particle Testing

PT : Dye or Liquid Penetrant Testing

PWHT : Post Weld Heat Treatment

VT : Visual Testing.

2 Application

2.1 Base metals

2.1.1 This Section applies to fusion welds made in normal and higher strength hull structural steels, extra high strength steels for welded structure, connection welds with hull steel forgings and castings in accordance with NR216 Materials and Welding. Base metal other than the above may be considered by the Society.

2.2 Welding processes

2.2.1 This Section applies to fusion welds made using manual metal arc welding (shielded metal arc welding, 111), gas-shielded metal arc welding (gas metal arc welding, including flux cored arc welding, 13x), gas-shielded arc welding with non-consumable tungsten electrode (gas tungsten arc welding, 14x), submerged arc welding (12x), electro-slag welding (72x) and electro-gas welding processes (73).

Note 1: Terms and numbers according to ISO 4063:2009 ("x" indicates that relevant subgroups are included).

This Section may also be applied to welding processes other than the above at the discretion of the Society.

2.3 Weld joints

2.3.1 This Section applies to butt welds with full penetration, tee, corner and cruciform joints with or without full penetration, and fillet welds.

2.4 Timing of NDT

2.4.1 NDT is to be conducted after welds have cooled to ambient temperature and after post weld heat treatment where applicable.

2.4.2 For high strength steels for welded structure with specified minimum yield stress in the range of 420 N/mm^2 to 690 N/mm^2, NDT is not to be carried out before 48 hours after completion of welding. For steel with specified minimum yield greater than 690 N/mm^2, NDT is not to be carried out before 72 hours after completion of welding. Regardless of yield strength, consideration is to be given to requiring a delayed inspection where evidence of delayed cracking has been observed in production welds.

At the discretion of the Surveyor, a longer interval and/or additional random inspection at a later period may be required, (for example in case of high thickness welds).

At the discretion of the Surveyor, the 72 hour interval may be reduced to 48 hours for RT or UT inspection, provided there is no indication of delayed cracking, and a complete visual and random MT or PT inspection to the satisfaction of the Surveyor is conducted 72 hours after welds have been completed and cooled to ambient temperature.

Where PWHT is carried out the requirement for testing after a delay period may be relaxed, at the discretion of the Surveyor.

2.5 Applicable methods for testing of weld joints

2.5.1 The methods mentioned in this Section for detection of surface imperfections are VT, PT and MT. The methods mentioned for detection of internal imperfections are UT and RT.

2.5.2 Applicable methods for testing of the different types of weld joints are given in Tab 1.

Table 1 : Applicable methods for testing of weld joints

Weld joints	Parent material thickness	Applicable test methods
Butt welds with full penetration	thickness < 8mm **(1)**	VT, PT, MT, RT
	thickness ≥ 8mm	VT, PT, MT, UT, RT
Tee joints, corner joints and cruciform joints with full penetration	thickness < 8mm **(1)**	VT, PT, MT, RT **(3)**
	thickness ≥ 8mm	VT, PT, MT, UT, RT **(3)**
Tee joints, corner joints and cruciform joints without full penetration and fillet welds	All	VT, PT, MT, UT **(2)**, RT **(3)**

(1) In cases of thickness below 8mm the Society may consider application of an appropriate advanced UT method

(2) UT may be used to check the extent of penetration in tee, corner and cruciform joints. This requirement is to be agreed with the Society

(3) RT may be applied however there will be limitations

3 Qualification of personnel involved in NDT

3.1 Requirements

3.1.1 Reference is made to NR669 “Requirements for non-destructive testing suppliers”.

4 Surface condition

4.1 General

4.1.1 Areas to be examined are to be free from scale, slag, loose rust, weld spatter, oil, grease, dirt or paint that might affect the sensitivity of the testing method.

Preparation and cleaning of welds for subsequent NDT are to be in accordance with the accepted NDT procedures, and are to be to the satisfaction of the Surveyor. Surface conditions that prevent proper interpretation may be cause for rejection of the weld area of interest.

5 General plan of testing

5.1 Extent of testing and selection of NDT method

5.1.1 The extent of testing, the number of checkpoints and the associated quality levels are to be planned by the Shipbuilder according to the ship design, ship type and welding processes used.

As far as criticality of structures is concerned, reference is made to Ch 4, Sec 1, Tab 3, Ch 4, Sec 1, Tab 8, Ch 4, Sec 1, Tab 10 and, as applicable, NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

For new construction survey, reference is to be made to the NDT requirements of Pt A, Ch 3, Sec 7 and applicable parts of NR540 Kick-Off Meeting Templates for Newbuilding.

5.1.2 For each construction, the Shipbuilder is to submit a plan for review by the Society, specifying the areas to be examined, the extent of testing and the quality levels, with reference to the NDT procedures to be used. Particular attention is to be paid to inspecting welds in highly stressed areas and welds in primary and special category structural members indicated in Ch 4, Sec 1. The NDT procedure(s) are to meet the requirement stated in Article [6]. The plan is only to be released to the personnel in charge of the NDT and its supervision.

5.1.3 In selecting checkpoints, emphasis is to be given to the following inspection locations:

- welds in high stressed areas
- fatigue sensitive areas
- other important structural elements
- welds which are inaccessible or very difficult to inspect in service
- field erected welds
- suspected problem areas.

Block construction welds performed in the yards, or at subcontracted yards/facilities, are to be considered in selecting checkpoints.

If an unacceptable level of indications is found the NDT extent is to be increased.

5.1.4 The NDT requirements given in Ch 13, Sec 6 are to be taken into consideration in the NDT plan.

5.1.5 The identification system is to identify the exact locations of the lengths of weld examined.

5.1.6 All welds over their full length are to be subject to VT by personnel designated by the Shipbuilder, who may be exempted from the qualification requirements defined in [3].

5.1.7 As far as practicable, PT or MT are to be used when investigating the outer surface of welds, checking the intermediate weld passes and back-gouged joints prior to subsequent passes deposition. MT is to be performed in ferromagnetic materials welds unless otherwise agreed with the Society. Surface inspection of important tee or corner joints, using an approved MT or PT method, is to be conducted to the satisfaction of the Surveyor.

5.1.8 Welded connections of large cast or forged components (e.g. stern frame, stern boss, rudder parts, shaft brackets...) are to be tested over their full length using MT (MT is the preferred method) or PT, (PT is to be applied for non-ferrous metals) and at agreed locations using RT or UT.

5.1.9 As given in Tab 1, UT or RT or a combination of UT and RT may be used for testing of butt welds with full penetration of 8 mm or greater. Methods to be used are to be agreed with the Society. The method used is to be suited for the detection of particular types and orientations of discontinuities. RT and UT are used for detection of internal discontinuities, and in essence they supplement and complement each other. RT is generally most effective in detecting volumetric discontinuities (e.g. porosity and slag) whilst UT is more effective for detecting planar discontinuities (e.g. laminations, lack of fusion and cracks).

5.1.10 In general start/stop points in welds made using automatic or fully mechanized welding processes are to be examined using RT or UT, except for internal members where the extent of testing is to be agreed with the attending Surveyor. Panel butt welds made using automatic or fully mechanized welding at pre-manufacturing stage are to be tested at random by RT or UT.

5.1.11 Where the Surveyor becomes aware that an NDT location has been repaired without a record of the original defect, the shipyard is to carry out additional examinations on adjacent areas to the repaired area to the satisfaction of the attending Surveyor.

6 Testing

6.1 General

6.1.1 The testing method, equipment and conditions are to comply with recognized National or International standards, or other documents to the satisfaction of the Society.

6.1.2 Sufficient details are to be given in a written procedure for each NDT technique submitted to the Society for acceptance.

6.1.3 The testing volume is to be the zone which include the weld and parent material for at least 10mm each side of the weld, or the width of the heat affected zone (HAZ), whichever is greater. In all cases inspection is to cover the whole testing volume.

6.1.4 Provision is to be made for the Surveyor to verify the inspection, reports and records (e.g. radiographs) on request.

6.2 Visual testing (VT)

6.2.1 The personnel in charge of VT is to confirm that the surface condition is acceptable prior to carrying out the inspection. VT is to be carried out in accordance with standards agreed between the Shipbuilder and the Society.

6.3 Liquid penetrant testing (PT)

6.3.1 PT is to be carried out in accordance to ISO 3452-1:2013 or a recognized standard accepted by the Society.

6.3.2 The extent of PT is to be in accordance to the plans agreed with the attending Surveyor and to the satisfaction of the Surveyor.

6.3.3 The surface to be examined is to be clean and free from scale, oil, grease, dirt or paint so there are not contaminants and entrapped material that may impede penetration of the inspection media.

6.3.4 The temperature of parts examined is to be typically between 5°C and 50°C. Outside this temperature range special low/high temperature penetrant and reference comparator blocks are to be used.

6.4 Magnetic particle testing (MT)

6.4.1 MT is to be carried out in accordance to ISO 17638:2016 or a recognized standard accepted by the Society.

6.4.2 The extent of MT is to be in accordance to the plans agreed with the attending Surveyor and to the satisfaction of the Surveyor.

6.4.3 The surface to be examined is to be free from scale, weld spatter, oil, grease, dirt or paint and is to be clean and dry. In general, the inside and outside of the welds to be inspected need to be sufficiently free from irregularities that may mask or interfere with interpretation.

6.5 Radiographic testing (RT)

6.5.1 RT is to be carried out in accordance to ISO 17636-1:2013 or a recognized standard accepted by the Society.

6.5.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see [5.1.2]).

For hull welds the minimum length inspected by RT is typically 300 mm.

The extent of RT is to be in accordance to the approved plans and the requirements of this paragraph, to the satisfaction of the Surveyor.

The number of checkpoints is to be increased if the proportion of non-conforming indications is abnormally high.

6.5.3 The inside and outside surfaces of the welds to be radiographed are to be sufficiently free from irregularities that may mask or interfere with interpretation. Surface conditions that prevent proper interpretation of radiographs may be cause for rejection of the weld area of interest.

6.5.4 RT is to be carried out on the welded butts of shell plating, strength deck plating as well as of members contributing to the longitudinal strength.

RT may also be required for the joints of members subject to heavy stresses.

6.5.5 The requirements given in [6.5.6] and Article [6] are to be considered as general rules. Reduction of the number of RT checkpoints may be accepted by the Society when consistent satisfactory quality is justified by the Shipbuilder. In such case, the extent of NDT is to remain equivalent to that given in [6.5.6] and Article [6].

6.5.6 In the midship area, RT checkpoints are to be selected at the joining of panels.

Each RT checkpoint is to be located at a crossing of butt joints.

In a given ship cross-section bounded by the panels, one RT checkpoint is to be selected for each butt of sheerstrake, stringer, bilge and keel plate. In addition, the following RT checkpoints are to be selected:

- bottom plating: two RT checkpoints
- deck plating: two RT checkpoints
- side shell plating: two RT checkpoints at each side.

For ships where B + D ≤ 15 m, only one RT checkpoint is to be selected for each of the above items.

This requirement remains applicable where panel butts are shifted or where some strakes are built independently from the panels. It is recommended to select most of these RT checkpoints at the crossing of butt and panel seams.

Still in the midship area, RT checkpoints are to be selected, at random, for the following main structural members:

- butts of continuous longitudinal bulkheads
- butts of longitudinal stiffeners, deck and bottom girders contributing to the overall strength
- assembly joints of insert plates at the corners of the openings.

Additionally, RT checkpoints are to be selected, at random, for the butt welds of the bilge keel and of intermediate flat.

6.5.7 Apart from the midship area, RT checkpoints are to be selected at random by the Shipbuilder in agreement with the Surveyor for the major location points. It is further recommended:

- to select a number of RT checkpoints for the very thick parts and those comprising restrained joint, such as sternframes, shaft brackets, stabiliser recesses, masts
- to check the full length or to increase the number of RT checkpoints for the first joint of a series of identical joints. This recommendation is applicable not only to the assembly joints of prefabricated members completed on the slip, but also to joints completed in the workshop to prepare such prefabricated members.

6.5.8 Consideration may be given for reduction of inspection frequency for automatic or fully mechanized welds where quality assurance techniques indicate consistent satisfactory quality.

6.6 Ultrasonic testing (UT)

6.6.1 UT is to be carried out according to procedure based on ISO 17640:2018 (testing procedure), ISO 23279:2017 (characterization) and ISO 11666:2018 (acceptance levels) or recognized standards accepted by the Society.

6.6.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see [5.1.2]).

The extent of UT is to be in accordance to the approved plans and to the satisfaction of the Surveyor.

A checkpoint is to consist of the entire weld length or a length agreed with the Society.

7 Acceptance Levels (criteria)

7.1 General

7.1.1 This Article details the acceptance levels (criteria) followed for the assessment of the NDT results. Techniques include but are not limited to: VT, MT, PT, RT and UT.

7.1.2 As far as necessary, testing techniques are to be combined to facilitate the assessment of indications against the acceptance criteria.

7.1.3 The assessment of indications not covered by this Article is to be made in accordance with a standard agreed with the Society. Alternative acceptance criteria can be agreed with the Society, provided equivalency is established.

The general accepted methods for testing of welds are provided in Tab 2 and Tab 3 for surface and embedded discontinuities respectively (Refer to ISO 17635:2016).

Table 2 : Method for detection of surface discontinuities (All type of welds including fillet welds)

Materials	Testing method
Ferritic steel	VT
	VT, MT
	VT, PT

Table 3 : NDT for detection of embedded discontinuities (for butt and T joints with full penetration)

Materials and type of joint	Nominal thickness (t) of the parent material to be welded (mm)		
	t < 8	8 ≤ t ≤ 40	t > 40
Ferritic butt-joints	RT or UT **(1)**	RT or UT	UT or RT **(2)**
Ferritic T-joints	UT **(1)** or RT **(2)**	UT or RT **(2)**	UT or RT **(2)**
(1) Below 8mm the Society may consider application of an appropriate advanced UT method. **(2)** RT may be applied however there will be limitations.			

7.2 Quality Levels

7.2.1 Testing requirements follow the designation of a particular quality level of imperfections in fusion-welded joints in accordance with ISO 5817:2014. Three quality levels (B, C and D) are specified.

In general Quality level C is to be applied for hull structure.

Quality level B corresponds to the highest requirement on the finished weld, and may be applied on critical welds.

This standard applies to steel materials with thickness above 0,5 mm.

Note 1: ISO 5817:2014 Table 1 provides the requirements on the limits of imperfections for each quality level. ISO 5817:2014 Annex A also provides examples for the determination of percentage of imperfections (number of pores in surface percent).

All levels (B, C and D) refer to production quality and not to the fitness for purpose (ability of product, process or service to serve a defined purpose under specific conditions). The correlation between the quality levels defined in ISO 5817:2014, testing levels/ techniques and acceptance levels (for each NDT technique) will serve to define the purpose under specific conditions. The acceptance level required for examination shall be agreed with the Society. This will determine the quality level required in accordance with the non-destructive technique selected. Refer to Tab 4 to Tab 9.

7.3 Testing Levels

7.3.1 The testing coverage and thus the probability of detection increases from testing level A to testing level C. The testing level is to be agreed with the Society. Testing level D is intended for special applications, this can only be used when defined by the Shipbuilder specification.

Note 1: ISO 17640:2018 Annex A tables A.1 to A.7 provide guidance on the selection of testing levels for all type of joints in relation to the thickness of parent material and inspection requirements.

7.3.2 The testing technique used for the assessment of indications is also to be specified.

7.4 Acceptance Levels

7.4.1 The acceptance levels are specified for each testing technique used for performing the inspection. The criteria applied is to comply with each standard identified in Tab 4 to Tab 9 (or any recognized acceptable standard agreed with the Society.

7.4.2 Probability of detection (POD) indicates the probability that a testing technique will detect a given flaw.

7.5 Visual testing (VT)

7.5.1 The acceptance levels and required quality levels for VT are provided in IACS Recommendation 47, "Shipbuilding and Repair Quality Standard" and Tab 4.

7.6 Penetrant testing (PT)

7.6.1 The acceptance levels and required quality levels for PT are provided in Tab 5.

7.7 Magnetic Particle testing (MT)

7.7.1 The acceptance levels and required quality levels for MT is provided in Tab 6.

Table 4 : Visual testing

Quality levels (ISO 5817:2014 applies) **(1)**	Testing techniques/ levels (ISO 17637:2016 applies) **(1)**	Acceptance levels **(2)**
B	Level not specified	B
C		C
D		D
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable **(2)** The acceptance levels for VT are the same to the quality levels requirements of ISO 5817:2014		

Table 5 : Penetrant testing

Quality levels (ISO 5817:2014 applies) **(1)**	Testing techniques/ levels (ISO 3452-1:2013 applies) **(1)**	Acceptance levels (ISO 23277:2015 applies) **(1)**
B	Level not specified	2X
C		2X
D		3X
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable		

Table 6 : Magnetic Particle Testing

Quality levels (ISO 5817:2014 applies) **(1)**	Testing techniques/ levels (ISO 17638:2016 applies) **(1)**	Acceptance levels (ISO 23278:2015 applies) **(1)**
B	Level not specified	2X
C		2X
D		3X
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable		

7.8 Radiographic testing (RT)

7.8.1 The acceptance levels and required quality levels for RT are provided in Tab 7.

Reference radiographs for the assessment of weld imperfections are to be provided in accordance to ISO 5817:2014 or acceptable recognized standard agreed with the Society.

Table 7 : Radiographic Testing

Quality levels (ISO 5817:2014 applies) **(1)**	Testing techniques/ levels (ISO 17636-1:2013 applies) **(1)**	Acceptance levels (ISO 10675-1:2016 applies) **(1)**
B	B (class)	1
C	B **(2)** (class)	2
D	at least A (class)	3
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable **(2)** For circumferential weld testing, the minimum number of exposures may correspond to the requirements of ISO 17636-1:2013, class A		

7.9 Ultrasonic testing (UT)

7.9.1 The acceptance levels and required quality levels for UT are provided in Tab 8 and Tab 9.

7.9.2 UT Acceptance Levels apply to the examination of full penetration ferritic steel welds, with thickness from 8 mm to 100 mm. The nominal frequency of probes used is to be between 2MHz and 5MHz. Examination procedures for other type of welds, material, thicknesses above 100 mm and examination conditions are to be submitted to the consideration of the Society.

7.9.3 The acceptance levels for UT of welds are to be defined in accordance to ISO 11666:2018 requirements or any recognized acceptable standard agreed with the Society. The standard specifies acceptance level 2 and 3 for full penetration welded joints in ferritic steels, corresponding to quality levels B and C (Refer to table 8).

Table 8 : Ultrasonic Testing

Quality levels (ISO 5817:2014 applies) **(1) (2)**	Testing techniques/ levels (ISO 17640:2018 applies) **(1) (2)**	Acceptance levels (ISO 11666:2018 applies) **(1) (2)**
B	at least B	2
C	at least A	3
D	at least A	3 **(3)**

(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable
(2) When characterization of indications is required, ISO 23279:2017 is to be applied
(3) UT is not recommended but can be defined in a specification with same requirement as Quality Level C

Table 9 : Recommended Testing and Quality Levels (ISO 17640)

Testing level **(1) (2) (3)** (ISO 17640:2018 applies)	Quality level (ISO 5817:2014 applies)
A	C, D
B	B
C	By agreement
D	Special application

(1) POD increases from testing level A to C as testing coverage increases
(2) Testing Level D for special application is to be agreed with the Society
(3) Specific requirements for testing levels A to C, are provided for various types of joints in ISO 17460:2018 Annex A

7.9.4 Sensitivity settings and levels. The sensitivity levels are set by the following techniques:

- Technique 1: based on 3 mm diameter side-drilled holes
- Technique 2: based on distance gain size (DGS) curves for flat bottom holes (diskshaped reflectors)
- Technique 3: using a distance-amplitude-corrected (DAC) curve of a rectangular notch of 1 mm depth and 1 mm width
- Technique 4: using the tandem technique with reference to a 6 mm diameter flatbottom hole (disk shaped reflector)

The evaluation levels (reference, evaluative, recording and acceptance) are specified in ISO 11666:2018 Annex A.

8 Reporting

8.1 General

8.1.1 Reports of NDT required are to be prepared by the Shipbuilder and are to be made available to the Society.

8.1.2 Reports of NDT are to include the following generic items:

- date of testing
- hull number, location and length of weld inspected
- names, qualification level and signature of personnel that have performed the testing
- identification of the component examined
- identification of the welds examined
- steel grade, type of joint, thickness of parent material, welding process
- acceptance criteria
- testing standards used
- testing equipment and arrangement used
- any test limitations, viewing conditions and temperature
- results of testing with reference to acceptance criteria, location and size of reportable indications
- statement of acceptance / non-acceptance, evaluation date, name and signature of evaluator
- number of repairs if specific area repaired more than twice.

8.1.3 In addition to generic items, reports of PT are to include the following specific items:

- type of penetrant, cleaner and developer used
- penetration time and development time.

8.1.4 In addition to generic items, reports of MT are to include the following specific items:

- type of magnetization
- magnetic field strength
- detection media
- viewing conditions
- demagnetization, if required.

8.1.5 In addition to generic items, reports of RT are to include the following specific items:

- type and size of radiation source (width of radiation source), X-ray voltage
- type of film/designation and number of film in each film holder/cassette
- number of radiographs (exposures)
- type of intensifying screens
- exposure technique, time of exposure and source-to-film distance as per below:
- distance from radiation source to weld
- distance from source side of the weld to radiographic film
- angle of radiation beam through the weld (from normal)
- sensitivity, type and position of IQI (source side or film side)
- density
- geometric un-sharpness
- specific acceptance class criteria for RT.

Examinations used for acceptance or rejection of welds are to be recorded in an acceptable medium. A written record providing following information: identification and description of welds, procedures and equipment used, location within recorded medium and results are to be included. The control of documentation unprocessed original images and digitally processes images is to be to the satisfaction of the Surveyor.

8.1.6 In addition to generic items, reports of UT are to include the following specific items:

- type and identification of ultrasonic equipment used (instrument maker, model, series number), probes (instrument maker, serial number), transducer type (angle, serial number and frequency) and type of couplant (brand)
- sensitivity levels calibrated and applied for each probe
- transfer loss correction applied Type of reference blocks
- signal response used for defect detection
- reflections interpreted as failing to meet acceptance criteria.

The method for review and evaluation of UT reports is required for adequate quality control and is to be to the satisfaction of the Surveyor.

8.1.7 The shipyard is to keep the inspection records specified in [8.1.2] to [8.1.6] for at least for 5 years.

9 Unacceptable indications and repairs

9.1 General

9.1.1 Unacceptable indications are to be eliminated and repaired where necessary. The repair welds are to be examined on their full length using appropriate NDT method at the discretion of the Surveyor.

9.1.2 When unacceptable indications are found, additional areas of the same weld length are to be examined unless it is agreed with the Surveyor and fabricator that the indication is isolated without any doubt. In case of automatic or fully mechanized welded joints, additional NDT are to be extended to all areas of the same weld length.

All radiographs exhibiting non-conforming indications are to be brought to the attention of the Surveyor. Such welds are to be repaired and inspected as required by the Surveyor. When non-conforming indications are observed at the end of a radiograph, additional RT is generally required to determine their extent. As an alternative, the extent of non-conforming welds may be ascertained by excavation, when approved by the Surveyor.

9.1.3 The extent of testing may be extended at the Surveyor's discretion when repeated non-acceptable discontinuities are found, specially for butts of sheerstrake, stringer plate, bilge strake or keel plate.

9.1.4 The inspection records specified in Article [8] are to include the records of repaired welds.

9.1.5 The Shipbuilder is to take appropriate actions to monitor and improve the quality of welds to the required level. The repair rate is to be recorded by the shipyard and any necessary corrective actions are to be identified in the builder's Quality Assurance system.

Section 5 Special Structural Details

1 General

1.1 Application

1.1.1 Special structural details are those characterised by complex geometry, possibly associated with high or alternate stresses.

1.1.2 For special structural details, specific requirements are to be fulfilled during:

- design
- construction
- selection of materials
- welding
- survey.

The purpose of these requirements is specified in [1.2] to [1.6].

1.1.3 Special structural details are those listed in Article [2] together with the specific requirements which are to be fulfilled.

Other structural details may be considered by the Society as special details, when deemed necessary on the basis of the criteria in [1.1.1]. The criteria to be fulfilled in such cases are defined by the Society on a case by case basis.

1.1.4 As regards matters not explicitly specified in Article [2], the Rule requirements are to be complied with in any event; in particular:

- Part B, Chapter 4 for design principles and structural arrangements
- Part B, Chapter 7, for structural scantling
- Part B, Chapter 13 for construction and welding requirements
- the applicable requirements of Part D, Part E and Part F.

1.2 Design requirements

1.2.1 General requirements

Design requirements specify:

- the local geometry, dimensions and scantlings of the structural elements which constitute the detail
- any local strengthening
- the cases where a fatigue check is to be carried out according to Part B, Chapter 10.

1.2.2 Fatigue check requirements

Where a fatigue check is to be carried out, the design requirements specify (see Ch 10, Sec 1, [2]):

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the ship operation and overall safety.

In addition, these requirements specify where material inspections are to be carried out.

1.5 Welding requirements

1.5.1 Welding requirements specify where partial or full T penetration welding (see Ch 13, Sec 3, [3.3]) or any particular welding type or sequence is to be adopted. In addition, these requirements specify when welding procedures are to be approved.

Since weld shape and undercuts are influencing factors on fatigue behaviour, fillet welds are to be elongated in the direction of the highest stresses and care is to be taken to avoid undercuts, in particular at the hot spots.

1.6 Survey requirements

1.6.1 Survey requirements specify where non-destructive examinations of welds are to be carried out and, where this is the case, which type is to be adopted.

2 List and characteristics of special structural details

2.1 General

2.1.1 This Article specifies the requirements which are to be fulfilled for the different ship types and related special structural details:

- a description of the hull areas where the details are located (see Tab 1)
- the structural detail description
- the requirements for the fine mesh yielding analysis
- the requirements for the fatigue check
- a reference to a table in Ch 13, App 2 where a sketch of the detail is shown together with the specific requirements which are to be fulfilled.

2.2 All types of ships with longitudinally framed sides

2.2.1 The special structural details relevant to all types of longitudinally framed ships, including those mentioned in [2.3] to [2.7], are listed and described in Tab 2.

2.3 Ships carrying liquid cargo in bulk, except liquefied gas carriers

2.3.1 The special structural details for various hull areas relevant to ships with the service notation **oil tanker ESP**, **chemical tanker ESP**, **FLS tanker**, **asphalt carrier** or **tanker** are listed and described in Tab 3.

When the structural arrangement in a certain area is such that the details considered in Tab 3 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.4 Liquefied gas carriers

2.4.1 The special structural details for various hull areas relevant to ships with the service notation **liquefied gas carrier** are listed and described in:

- Tab 4 for structural details common to all liquefied gas carriers
- Tab 5 for additional structural details for type A gas carriers and type B gas carriers fitted with independent tanks, primarily constructed of plane surfaces
- Tab 6 for additional structural details for type B gas carriers fitted with independent tanks, primarily constructed of bodies of revolution
- Tab 7 and Pt D, Ch 9, Sec 4, [11.7.7] for additional structural details for membrane type gas carriers.

When the structural arrangement in a certain area is such that the details considered in the above specified tables can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.5 Container ships

2.5.1 The special structural details for various hull areas relevant to ships with the service notation **container ship** are listed and described in Tab 8.

When the structural arrangement in a certain area is such that the details considered in Tab 8 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.6 Bulk, ore and combination carriers

2.6.1 The special structural details for various hull areas relevant to ships with the service notation **bulk carrier** or **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier ESP** are listed and described in Tab 9.

When the structural arrangement in a certain area is such that the details considered in Tab 9 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.7 Ro-ro ships

2.7.1 The special structural details for various hull areas relevant to ships with the service notation **ro-ro cargo ship**, **ro-ro passenger ship** or **PCTC** are listed and described in Tab 10.

When the structural arrangement in a certain area is such that the details considered in Tab 10 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.8 Passenger ships

2.8.1 The special structural details for various hull areas relevant to ships with the service notation **passenger ship** are listed and described in Tab 11.

When the structural arrangement in a certain area is such that the details considered in Tab 11 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

Table 1 : List of special structural detail areas

Area ref. No.	Area description	Ship type						
		All ships **(1)**	Ships carrying liquid cargo in bulk **(2)**	Liquefied gas carriers	Container ships	Bulk, ore and combination carriers	Ro-ro ships	Passenger ships
		see [2.2]	see [2.3]	see [2.4]	see [2.5]	see [2.6]	see [2.7]	see [2.7]
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between $0,7T_{BAL}$ and $1,15T_{SC}$ from the baseline	X	**(3)**					
2	Part of inner side and longitudinal bulkheads in the cargo area extended vertically above half tank height, where the tank breadth exceeds 0,55B		X					
3	Double bottom in way of longitudinal and / or transverse bulkheads		X	X	X	X		
4	Double bottom in way of hopper tanks		X	X		X		
5	Lower part of transverse bulkheads with lower stools		X			X		
6	Lower part of inner side		X	X		X		
7	Side frames			X		X		
8	Topside tanks			X		X		
9	Upper deck			X	X	X	X	X
10	Primary supporting members		X					X
11	Upper part of inner side		X	X	X	X		
12	Longitudinal and transverse bulkheads						X	X
13	Racking frames						X	
14	Side and stern doors				X		X	X
15	Supports and keys			X				
16	Foundation deck			X				
17	Double side in way of transverse bulkheads			X				
18	Engine room				X			X
19	Deep fuel tanks				X			
20	Miscellaneous							X

(1) All types of ships with longitudinally framed sides
(2) Except liquefied gas carriers
(3) See [2.2].

Table 2 : Ships with longitudinally framed sides - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between $0,7T_{BAL}$ and $1,15T_{SC}$ from the baseline **(1)**	End connections of side longitudinal stiffeners to transverse bulkheads or web frames				Ch 13, App 2, Tab 1 to Ch 13, App 2, Tab 6
		End connections of side longitudinal stiffeners to stiffeners of transverse bulkheads or web frames		X		Ch 13, App 2, Tab 7 to Ch 13, App 2, Tab 13

(1) where T_{BAL} is the ship's draft in light ballast condition and T_{SC} is the scantling draught, as defined in Ch 1, Sec 3, Tab 1

Table 3 : Ships carrying liquid cargo in bulk, except liquefied gas carriers - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
2	Part of inner side and longitudinal bulkheads in the cargo area extended vertically above half tank height, where the tank breadth exceeds 0,55B	Connection of bulkhead longitudinal stiffeners with transverse primary supporting members				Ch 13, App 2, Tab 14 to Ch 13, App 2, Tab 19
		Connection of bulkhead longitudinal stiffeners with stiffeners of transverse primary supporting members		X		Ch 13, App 2, Tab 20 to Ch 13, App 2, Tab 26
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connection of bottom and inner bottom longitudinal stiffeners with floors		X **(1)**		Ch 13, App 2, Tab 27 to Ch 13, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools			X **(2)**	Ch 13, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates			X	Ch 13, App 2, Tab 32 to Ch 13, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads			X	Ch 13, App 2, Tab 39 to Ch 13, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads			X **(3)**	Ch 13, App 2, Tab 46 to Ch 13, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side			X	Ch 13, App 2, Tab 54 to Ch 13, App 2, Tab 60
10	Primary supporting members	Transverse web frame bracket toe			X	–
		Horizontal stringer toe			X	–
11	Upper part of inner side	Intersection of upper hopper sloping plates with inner side			X **(5)**	–
15	Support and keys **(6)**	Vertical support of cargo **(7)**			X	–
		anti-rolling keys **(8)**			X	–
		anti-pitching keys **(9)**			X	–

(1) Only where longitudinal stiffeners are connected to floors vertical web stiffeners

(2) In way of double bottom girders

(3) Not for Ch 13, App 2, Tab 49 and Ch 13, App 2, Tab 53

(4) For which their geometry is required to be represented in the cargo hold model in accordance with Ch 8, App 1

(5) Where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location.

(6) For ships fitted with independent cargo tank.

(7) For the fatigue calculation of this detail, longitudinal and transverse forces due to friction are to be considered in addition to vertical reaction forces.

(8) For the fatigue calculation of this detail, longitudinal forces due to friction are to be considered in addition to transverse forces. Initial construction gap is also to be taken into account.

(9) For the fatigue calculation of this detail, transverse forces due to friction are to be considered in addition to longitudinal forces. Initial construction gap is also to be taken into account.

Table 4 : Liquefied gas carriers (All types) - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connection of bottom and inner bottom longitudinal stiffeners with floors		X **(1)**		Ch 13, App 2, Tab 27 to Ch 13, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools in way of double bottom girders **(2)**			X	Ch 13, App 2, Tab 31
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank slopping plates			X	Ch 13, App 2, Tab 36 to Ch 13, App 2, Tab 38
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side **(3)**			X	Ch 13, App 2, Tab 61 to Ch 13, App 2, Tab 62
8	Topside tanks	Intersection of upper hopper sloping plates with tween'deck			X	–
11	Upper part of inner side	Intersection of upper hopper sloping plates with inner side			X	–
17	Double side in way of transverse bulkheads	Connection between cofferdam bulkheads and side stringers			X	–

(1) Only where longitudinal stiffeners are connected to floors vertical web stiffeners

(2) Including swash bulkheads

(3) Where there is no prolonging bracket in way of knuckle joints, the connection of transverse webs to the inner hull and longitudinal girder plating is to be made with partial penetration welds over a length not less than 300 mm

Table 5 : Liquefied gas carriers (Type A and Type B) with independent tanks, primarily constructed of plane surfaces - Additional special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
7	Side frames	Connection of side frames with hopper and topside tanks			X	–
9	Upper deck	Liquid dome opening			X	–
15	Support and keys	Vertical supports of cargo **(1)**			X	–
		Anti-rolling keys **(2)**			X	–
		Anti-pitching keys **(3)**			X	–

(1) For the fatigue calculation of this detail, longitudinal and transverse forces due to friction are to be considered in addition to vertical reaction forces

(2) For the fatigue calculation of this detail, longitudinal forces due to friction are to be considered in addition to transverse forces. Initial construction gap is also to be taken into account

(3) For the fatigue calculation of this detail, transverse forces due to friction are to be considered in addition to longitudinal forces. Initial construction gap is also to be taken into account.

Table 6 : Liquefied gas carriers (Type B) fitted with independent tanks, primarily constructed of bodies of revolution - Additional special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
9	Upper deck	Connection between tank cover and main deck **(1)**			X	–
16	Foundation deck	Connection between inner side bulkhead and foundation deck **(2)**			X	–
		Connection between skirt and foundation deck **(3)**			X	–

(1) Hot spots to be checked are located in inner bottom plating, transverse bulkhead plating and girders plating. If an additional longitudinal bracket is fitted above inner bottom in line with girder in way of connection, hot spots in this bracket are also to be checked

(2) Hot spots to be checked are located in inner side plating, scarfing bracket and transverse web frames both below and above foundation deck. If an additional transverse bracket is fitted above foundation deck in way of connection, hot spots in this bracket are also to be checked

(3) Hot spots to be checked are located in skirt plating, in scarfing brackets and in transverse web frame below foundation deck on both sides of connection.

Table 7 : Liquefied gas carriers (Membrane type) - Additional special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
9	Upper deck	Connection between fore end of trunk deck and main deck			X	–
		Connection between aft end of trunk deck and superstructures			X	–
9	Upper deck	Liquid dome opening			X	–

Table 8 : Container ships - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connections of inner bottom girders with deep fuel tank longitudinal and transverse bulkheads			X	–
		Connection of bottom and inner bottom longitudinal stiffeners with floors		X		–
9	Upper deck	Ends of hatch coamings, if any in this region			X	Ch 13, App 2, Tab 67 Ch 13, App 2, Tab 68
		Connection of superstructures with strength deck			X	–
		Representative hatch corners in way of cargo holds **(1)**, in particular in way of: -connection between engine room area and cargo hold areas -connections between fuel tanks and adjacent cargo holds -watertight bulkheads -support bulkheads -any area with significant scantling discontinuities.			X	Ch 13, App 2, Tab 66
		Transverse stays in way of hatch coaming knuckles **(3)**			X	
11	Upper part of inner side	Large openings in the upper part of inner hull			X	–
14	Side and stern doors	Large openings in the upper part of the side shell (e.g. pilot doors, accommodation ladder)			X	–
18	Engine room	Openings in way of engine room platforms **(2)**			X **(3)**	–
19	Deep Fuel tanks	Openings in way of deep fuel tank platforms, when deep fuel tanks are located in the cargo hold area **(2)**			X **(3)**	–

(1) From the second deck to the top of hatch coaming, where second deck means the first complete deck below the main deck
(2) From the second deck to the upper deck
(3) Applicable for ships of length L greater than 230 m.

Table 9 : Bulk, ore and combination carriers - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connection of bottom and inner bottom longitudinal stiffeners with floors		X **(2)**		Ch 13, App 2, Tab 27 to Ch 13, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools			X **(2) (3)**	Ch 13, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates			X **(3)**	Ch 13, App 2, Tab 32 to Ch 13, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads			X	Ch 13, App 2, Tab 39 to Ch 13, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads			X **(5)**	Ch 13, App 2, Tab 46 to Ch 13, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side			X	Ch 13, App 2, Tab 54 to Ch 13, App 2, Tab 60
7	Side frames	Connection of side frames with hopper and topside tanks			X **(6)**	Ch 13, App 2, Tab 63 Ch 13, App 2, Tab 64
8	Topside tanks	Connection of transverse corrugated bulkheads with topside tanks				Ch 13, App 2, Tab 65
9	Upper deck	Deck plating in way of hatch corners			X	Ch 13, App 2, Tab 66
		Ends of longitudinal hatch coamings			X	Ch 13, App 2, Tab 67 Ch 13, App 2, Tab 68
11	Upper part of inner side	Intersection of upper hopper sloping plates with inner side			X **(7)**	–

(1) Only where longitudinal stiffeners are connected to floors vertical web stiffeners
(2) In way of double bottom girders
(3) Full or empty hold in alternate condition not assigned as a ballast hold (cargo hold closest to the midship)
(4) For single side skin ships
(5) Not for Ch 13, App 2, Tab 49 and Ch 13, App 2, Tab 53
(6) Full or empty hold in alternate condition and ballast hold of single skin ships (cargo hold closest to the midship)
(7) Where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location.

Table 10 : Ro-Ro cargo and Ro-Ro passenger ships - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
9	Upper deck	Connection with funnel			X	–
		Corners of ramp openings			X	–
12	Longitudinal and transverse bulkheads	Corners of doors openings			X	–
13	Racking frames	Connection to transverse bulkhead or bottom structure			X **(1)**	–
		Corners of openings			X	–
14	Side and stern doors	Corners of openings			X **(1)**	–

(1) Very fine mesh fatigue assessment is mandatory for these details only for Ro-Ro cargo ships.

Table 11 : Passenger ships - Special structural details

Area	Area description	Structural detail description	Yielding check / Fine mesh	Fatigue check		Reference tables in Ch 13, App 2
				Simplified rule based approach	Very fine mesh	
9	Upper deck	Large openings in upper decks	X			–
		Ends of the side decks strips of the uppermost continuous deck	X			–
10	Primary supporting members	Openings in webs of longitudinal girders and in webs of transverse deck beams and girders	X			–
12	Longitudinal and transverse bulkheads	Corners of doors openings	X			–
		Large openings in longitudinal bulkheads	X			–
		Openings in transverse bulkheads	X			–
14	Side and stern doors	Corners of shell doors openings	X			–
18	Engine room	Engine room casing	X			–
20	Miscellaneous	Atrium	X			–
		Corners of window openings	X			–

Section 6 Testing

1 Testing procedures of watertight compartments

1.1 Application

1.1.1 These test procedures are to confirm the watertightness of tanks, watertight boundaries and the structural adequacy of tanks forming a part of the watertight subdivisions of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting.

The tightness of all tanks and watertight boundaries of ships during new construction and ships relevant to major conversions or major repairs is to be confirmed by these test procedures prior to the delivery of the ships.

Note 1: Watertight subdivision means the transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

Note 2: Major repair means a repair affecting structural integrity.

1.1.2 Testing procedures of watertight compartments for SOLAS Ships are to be carried out in accordance with requirements [1.4.1] to [1.9.1], unless:

a) the shipyard provides documentary evidence of the shipowner's agreement to a request to the Flag Administration for an exemption from the application of SOLAS Chapter II-1, Regulation 11, or for an equivalency agreeing that the content of [1.10] is equivalent to SOLAS Chapter II-1, Regulation 11; and

b) the above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

1.1.3 All gravity tanks and other boundaries required to be watertight or weathertight are to be tested in accordance with these procedures and proven tight and structurally adequate as follows:

- gravity tanks for their tightness and structural adequacy
- watertight boundaries other than tank boundaries for their watertightness
- weathertight boundaries for their weathertightness.

Note 1: Gravity tank means a tank that is subject to vapour pressure not greater than 70 kPa.

1.1.4 Testing of structures not listed in Tab 2 or Tab 3 is to be specially considered by the Society.

1.2 General

1.2.1 Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to the completion of work, with all the hatches, doors, windows, etc., installed and all the penetrations including pipe connections fitted, and before any ceiling and cement work is applied over the joints. Specific test requirements are given in [1.6] and Tab 2. For the timing of the application of coating and the provision of safe access to joints, see [1.7], [1.8] and Tab 4.

1.3 Definitions

1.3.1 Structural test

A structural test is a test to verify the structural adequacy of tank construction. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

Each type of structural test is defined in Tab 1.

1.3.2 Leak test

A leak test is a test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/ hydropneumatic test or an air test. A hose test may be considered to be an acceptable form of leak test for certain boundaries, as indicated by footnote **(3)** of Tab 2.

Each type of leak test is defined in Tab 1.

1.3.3 Top of overflow

Top of any overflow system which is used to prevent overfilling of a tank. Such system can be an overflow pipe, airpipe, intermediate tank. For gravity tanks (i.e. sewage, grey water and similar tanks, not filled with pumps) the top of the overflow is to be taken as the highest point of the filling line.

Where a tank is fitted with multiple means of preventing overfilling, the decision on which overflow system is to be used to determine the test head is to be based on the highest point to which the liquid may rise in service.

Note 1: Gauging devices are not considered equivalent to an overflow system with the exception of fuel oil overflow tanks not intended to hold fuel which have been fitted with a level alarm.

1.4 Structural test procedures

1.4.1 Type and time of test

Where a structural test is specified in Tab 1 and Tab 3, a hydrostatic test in accordance with [1.6.1] is acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with [1.6.2] may be accepted instead.

A hydrostatic or hydropneumatic test for the confirmation of structural adequacy may be carried out while the ship is afloat, provided the results of a leak test are confirmed to be satisfactory before the ship is set afloat.

Alternative equivalent tank testing procedures may be considered for tanks which are constructed from composite materials such as glass reinforced plastic (GRP) and fibre reinforced plastic (FRP) based on the recommendations of the composite manufacturer.

Table 1 : Types of test

Test types	Procedure
Hydrostatic test (leak and structural)	The space to be tested is filled with a liquid to a specified head
Hydropneumatic test (leak and structural)	Combination of a hydrostatic test and an air test, the space to be tested being partially filled with liquid and pressurized with air
Hose test (leak)	Tightness check of the joint to be tested by means of a jet of water, the joint being visible from the opposite side
Air test (leak)	Tightness check by means of an air pressure differential and a leak-indicating solution. It includes tank air tests and joint air tests, such as compressed air fillet weld tests and vacuum box tests
Compressed air fillet weld test (leak)	Air test of fillet welded tee joints, by means of a leak indicating solution applied on fillet welds
Vacuum box test (leak)	A box over a joint with a leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks
Ultrasonic test (leak)	Tightness check of the sealing of closing devices such as hatch covers, by means of ultrasonic detection techniques
Penetration test (leak)	Check, by means of low surface tension liquids (i.e. dye penetrant test), that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment

1.4.2 Testing schedule for new construction and major structural conversion or repair

a) tanks which are intended to hold liquids, and which form part of the watertight subdivision of the ship, shall be tested for tightness and structural strength as indicated in Tab 2 and Tab 3

b) tank boundaries are to be tested from at least one side. The tanks for the structural test are to be selected so that all the representative structural members are tested for the expected tension and compression

c) watertight boundaries of spaces other than tanks may be exempted from the structural test, provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections. The tank structural test is to be carried out and the requirements from item a) to item b) are to be applied for ballast holds, chain lockers, and for a representative cargo hold in case of cargo holds intended for in-port ballasting

d) tanks which do not form part of the watertight subdivision of the ship, may be exempted from structural testing provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections.

1.5 Leak test procedures

1.5.1 For the leak tests specified in Tab 2, tank air tests, compressed air fillet weld tests and vacuum box tests, in accordance respectively with [1.6.3], [1.6.5] and [1.6.6], or their combinations, are acceptable. Hydrostatic or hydropneumatic tests may be also accepted as leak tests, provided [1.7], [1.8] and [1.9] are complied with. Hose tests, in accordance with [1.6.3], are also acceptable for items 14 to 17 referred to in Tab 2, taking footnote **(3)** into account.

1.5.2 Air tests of joints may be carried out at the block stage, provided that all work on the block that may affect the tightness of a joint is completed before the test. The application of the leak test for each type of welded joint is specified in Tab 4. See also [1.7.1] for the application of final coatings, [1.8] for the safe access to joints, and Tab 4 for the summary.

Table 2 : Test requirements for tanks and boundaries

No.	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
1	Double bottom tanks **(4)**	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)** • bulkhead deck	
2	Double bottom voids **(5)**	leak	See [1.6.4] to [1.6.6], as applicable	Including pump room double bottom and bunker tank protection double hull required by MARPOL Annex I
3	Double side tanks	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)** • bulkhead deck	
4	Double side voids	leak	See [1.6.4] to [1.6.6], as applicable	
5	Deep tanks other than those listed elsewhere in this Table	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)**	
6	Cargo oil tanks	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)** • top of tank plus the design vapour pressure **(2)**	
7	Ballast holds of bulk carriers	leak and structural **(1)**	The greater of: • top of the overflow • top of cargo hatch coaming	
8	Peak tanks	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)**	After peak to be tested after installation of stern tube
9	a) Fore peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	b) Fore peak voids	leak	See [1.6.3] to [1.6.6], as applicable	
	c) Aft peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	d) Aft peak voids	leak	See [1.6.4] to [1.6.6], as applicable	After peak to be tested after installation of stern tube
10	Cofferdams	leak	See [1.6.4] to [1.6.6], as applicable	
11	a) Watertight bulkheads	leak **(8)**	See [1.6.3] to [1.6.6], as applicable **(7)**	
	b) Superstructure end bulkheads	leak	See [1.6.3] to [1.6.6], as applicable	
12	Watertight doors below freeboard or bulkhead deck	leak **(6) (7)**	See [1.6.3] to [1.6.6], as applicable	
13	Double plate rudder blades	leak	See [1.6.4] to [1.6.6], as applicable	
14	Shaft tunnels clear of deep tanks	leak **(3)**	See [1.6.3] to [1.6.6], as applicable	
15	Shell doors	leak **(3)**	See [1.6.3] to [1.6.6], as applicable	
16	Weathertight hatch covers and closing appliances	leak **(3) (7)**	See [1.6.3] to [1.6.6], as applicable	Hatch covers closed by tarpaulins and battens excluded
17	Watertight hatch covers and closing appliances	leak and structural	Damage equilibrium waterline **(10) (11)**	
18	Dual purpose tank/dry cargo hatch covers	leak **(3) (7)**	See [1.6.3] to [1.6.6], as applicable	In addition to the structural test in item 6 or item 7
19	Chain lockers	leak and structural	Head of water up to top of chain pipe	
20	L.O. sump tanks and other similar tanks/spaces under main engines	leak **(12)**	See [1.6.3] to [1.6.6], as applicable	
21	Ballast ducts	leak and structural **(1)**	The greater of: • ballast pump maximum pressure • setting of any pressure relief valve	

No.	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
22	Fuel oil tanks	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)** • top of tank plus the design vapour pressure **(2)** • bulkhead deck	
23	Fuel oil overflow tanks not intended to hold fuel	leak and structural **(1)**	The greater of: • top of the overflow **(9)** • 2,4 m above top of tank **(2)** • bulkhead deck	

(1) See [1.4.2]

(2) The top of a tank is the deck forming the top of the tank, excluding any hatchways.

(3) Hose test may be also considered as a medium of the leak test. See [1.3.2].

(4) Including the tanks arranged in accordance with the provisions of Ch 2, Sec 2, [3.1.4].

(5) Including the duct keels and dry compartments arranged in accordance with the provisions of SOLAS, Regulations II-1/11.2 and II-1/9.4 respectively, and/or the oil fuel tank protection and pump room bottom protection arranged in accordance with the provisions of MARPOL Annex I, Chapter 3, Part A, Regulation 12A and Chapter 4, Part A, Regulation 22, respectively.

(6) Where watertightness of watertight doors has not been confirmed by a prototype test, a hydrostatic test (filling of the watertight spaces with water) is to be carried out. See SOLAS Regulation II-1/16.2 and MSC.1/Circ.1572/Rev.1.

(7) As an alternative to the hose test, other testing methods listed in [1.6.7] to [1.6.9] may be acceptable, subject to adequacy of such testing methods being verified. See SOLAS Regulation II-1/11.1. For watertight bulkheads (item 11 a)), alternatives to the hose test may be used only where the hose test is not practicable.

(8) A structural test (see [1.4.2]) is also to be carried out for a representative cargo hold in case of cargo holds intended for in-port ballasting. The filling level required for the structural test of such cargo holds is to be the maximum loading that will occur in-port, as indicated in the loading manual.

(9) See [1.3.3]

(10) For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck. (see SOLAS II-1 Part B-2 Reg 16)

(11) A prototype pressure test of each type and size of hatch may be carried out instead of individual hatches tests.

(12) Where L.O. sump tanks and other similar spaces under main engines intended to hold liquid form part of the watertight subdivision of the ship, they are to be tested as per the requirements of Item 5, Deep tanks other than those listed elsewhere in this table.

Table 3 : Additional test requirements for special service ships/tanks

Item	Type of ship/tank	Structure to be tested	Type of test	Test head or pressure	Remarks
1	Liquefied gas carriers	Integral tanks	leak and structural	See Pt D, Ch 9, Sec 4	
		Hull structure supporting membrane or semi-membrane tanks	See Pt D, Ch 9, Sec 4	See Pt D, Ch 9, Sec 4	
		Independent tanks type A	See Pt D, Ch 9, Sec 4	See Pt D, Ch 9, Sec 4	
		Independent tanks type B			
		Independent tanks type C			
2	Edible liquid tanks	Independent tanks	leak and structural **(1)**	The greater of: • top of the overflow **(2)** • 0,9 m above top of tank **(3)**	
3	Chemical carriers	Integral or independent cargo tanks	leak and structural **(1)**	The greater of: • 2,4 m above top of tank **(3)** • top of tank plus the design vapour pressure **(3)**	Where a cargo tank is designed for the carriage of cargoes with specific gravities greater than 1,0 (see [1.6.1])
4	Chemical fuel tanks **(4)**	Integral or independent tanks	leak and structural **(1)**	The greater of: • 2,4 m above top of tank **(3)** • top of tank plus the design vapour pressure **(3)** • bulkhead deck	Where a cargo tank is designed for the carriage of cargoes with specific gravities greater than 1,0 (see [1.6.1])

(1) See [1.4.2]

(2) See [1.3.3]

(3) Top of tank is deck forming the top of the tank excluding any hatchways

(4) Including independent or integral methanol fuel tanks of ships with additional service feature **methanolfuel**.

Table 4 : Application of leak test, coating, and provision of safe access for the different types of welded joints

Type of welded joints		Leak test	Coating **(1)**		Safe access **(2)**	
			Before leak test	After leak test but before structural test	Leak test	Structural test
Butt	Automatic	not required	allowed **(3)**	not applicable	not required	not required
	Manual or semi-automatic **(4)**	required	not allowed	allowed	required	not required
Fillet	Boundary including penetrations	required	not allowed	allowed	required	not required

(1) Coating refers to internal (tank/hold) coating, where applied, and external (shell/deck) painting. It does not refer to shop primer.
(2) Temporary means of access for verification of the leak test.
(3) The condition applies provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.
(4) Flux Core Arc Welding (FCAW) semi-automatic butt welds need not be tested, provided careful visual inspections show continuous and uniform weld profile shape, free from repairs, and the results of NDT show no significant defects.

1.6 Test methods

1.6.1 Hydrostatic test

Unless another liquid is approved, hydrostatic tests are to consist in filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in Tab 2 or Tab 3. See also [1.9].

In case where a tank is intended for cargoes having a density higher than the density of the liquid used for the test, the testing pressure height is to be adjusted to simulate the actual loading as far as practicable. The test pressure is not to exceed the maximum design internal pressure at the top of tank.

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.2 Hydropneumatic test

Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, simulates the actual loading as far as practicable. The requirements and recommendations in [1.6.4] for tank air tests apply also to hydropneumatic tests. See also [1.9].

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.3 Hose test

Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at $2 \cdot 10^5$ Pa during the test. The nozzle is to have a minimum inside diameter of 12 mm and to be at a perpendicular distance from the joint not exceeding 1,5 m. The water jet is to impinge upon the weld.

Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation, or outfitting items, it may be replaced by a careful visual examination of the welded connections, supported where necessary by means such as a dye penetrant test or an ultrasonic leak test, or equivalent.

1.6.4 Tank air test

All boundary welds, erection joints and penetrations including pipe connections are to be examined in accordance with approved procedures and under a stabilized pressure differential above atmospheric pressure not less than $0{,}15 \cdot 10^5$ Pa, with a leak-indicating solution (such as soapy water/detergent or a proprietary solution) applied.

A U-tube having a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross-sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank. Arrangements involving the use of two calibrated pressure gauges to verify the required test pressure may be accepted taking into account the provisions in F5.1 and F7.4 of IACS Recommendation 140, “Recommendation for Safe Precautions during Survey and Testing of Pressurized Systems”.

A double inspection of the tested welds is to be carried out. The first inspection is to be made immediately upon application of the leak indication solution; the second one is to be made approximately four or five minutes after, in order to detect those smaller leaks which may take time to appear.

1.6.5 Compressed air fillet weld test

In this air test, compressed air is injected from one end of a fillet welded joint, and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure of at least $0{,}15 \cdot 10^5$ Pa can be verified at each end of any passage within the portion being tested.

Note 1: Where a leak test is required for fabrication involving partial penetration welds, a compressed air test is also to be carried out in the same manner as to fillet weld where the root face is large, i.e. 6-8 mm.

1.6.6 Vacuum box test

A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak-indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of $0,20 \cdot 10^5$ to $0,26 \cdot 10^5$ Pa inside the box.

1.6.7 Ultrasonic test

An ultrasonic echo transmitter is to be arranged on the inside of a compartment, and a receiver on the outside. The watertight/ weathertight boundaries of the compartment are scanned with the receiver, in order to detect an ultrasonic leak indication. Any leakage in the sealing of the compartment is indicated at a location where sound is detectable by the receiver.

1.6.8 Penetration test

For the test of butt welds or other weld joints, a low surface tension liquid is applied on one side of a compartment boundary or a structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

1.6.9 Other test

Other methods of testing may be considered by the Society upon submission of full particulars prior to the commencement of the tests.

1.7 Application of coating

1.7.1 Final coating

For butt joints welded by means of an automatic process, the final coating may be applied at any time before completion of a leak test of the spaces bounded by the joints, provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.

The Surveyors reserve the right to require a leak test prior to the application of a final coating over automatic erection butt welds.

For all the other joints, the final coating is to be applied after the completion of the joint leak test. See also Tab 4.

1.7.2 Temporary coating

Any temporary coating which may conceal defects or leaks is to be applied at the same time as for a final coating (see [1.7.1]). This requirement does not apply to shop primers.

1.8 Safe access to joints

1.8.1 For leak tests, a safe access to all joints under examination is to be provided. See also Tab 4.

1.9 Hydrostatic or hydropneumatic tightness test

1.9.1 In cases where the hydrostatic or hydropneumatic tests are applied instead of a specific leak test, the examined boundaries are to be dew-free, otherwise small leaks are not visible.

1.10 SOLAS Exempt / Equivalent Ships

1.10.1 Testing procedures are to be carried out in accordance with the requirements [1.4.1] to [1.9.1] in association with the following alternative procedures for [1.4.2]

1.10.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

1.10.3 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

1.10.4 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

1.10.5 For tanks which are less than 2 m^3 in volume, structural testing may be replaced by leak testing.

1.10.6 Where the structural adequacy of the tanks and spaces of a vessel were verified by the structural testing required by either requirements [1.4] to [1.9] or [1.10.3], subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

a) water-tightness of boundaries of all tanks and spaces is verified by leak tests and thorough inspections are carried out.

b) structural testing is carried out for at least one tank or space of each type among all tanks/spaces of each sister vessel.

c) additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

1.10.7 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with [1.10.6] at the discretion of the Society, provided that:

a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Society); and

b) an NDT plan is implemented and evaluated by the Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey of the Society.

1.11 Non-SOLAS Ships

1.11.1 Testing procedures are to be carried out in accordance with the requirements [1.4.1] to [1.9.1] in association with the following alternative procedures for [1.4.2].

1.11.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

1.11.3 The requirements given in Tab 2 to structurally test tanks to 2,4 metres above the top of the tank do not apply. Instead, the minimum test pressure for structural testing is to be taken as 0,3D + 0,76 metres above the top of the tank where the top of the tank is the deck forming the top of the tank, excluding any hatchways and D is the depth of the ship. The minimum test pressure need not be taken greater than 2,4 metres above the top of the tank.

1.11.4 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

1.11.5 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

1.11.6 For tanks which are less than 2 m^3 in volume, structural testing may be replaced by leak testing.

1.11.7 Where the structural adequacy of the tanks of a vessel were verified by the structural testing required by either Tab 2 or [1.11.4], subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

a) water-tightness of boundaries of all tanks and spaces are verified by leak tests and thorough inspections are carried out.

b) structural testing is carried out for at least one tank or space among all tanks/spaces of each sister vessel.

c) additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

1.11.8 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with [1.11.7] at the discretion of the Society, provided that:

a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Society); and

b) an NDT plan is implemented and evaluated by the Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey of the Society.

2 Miscellaneous

2.1 Watertight decks, trunks, etc.

2.1.1 *After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.*

2.2 Steering nozzles

2.2.1 Upon completion of manufacture, the nozzle is to be subjected to a leak test.

Appendix 1 Welding Details

Symbols

f : Root face, in mm.

1 Contents

1.1 General

1.1.1 Types and edge plate preparation of the manual welds carried out on the various parts of the hull are dealt with in this Appendix.

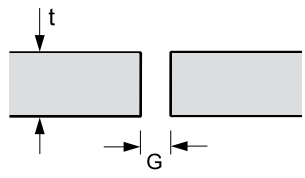
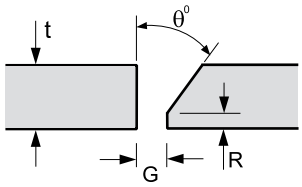
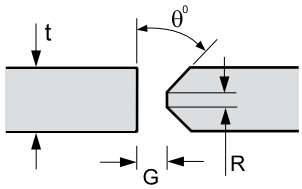
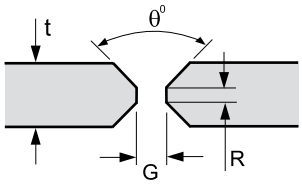
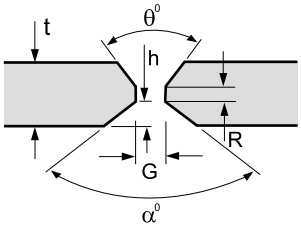
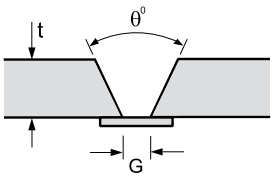
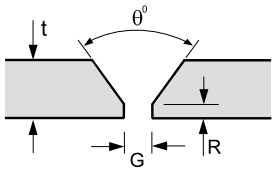
Other types and tolerances may be used after special examination of the Society.

1.1.2 The method used to prepare the parts to be welded is left to the discretion of each shipyard, according to its own technology and experience. It is approved at the same time as the approval of the welding procedures referred to in Ch 13, Sec 2, [2.2.1].

1.2 Butt welding edge preparation

1.2.1 Typical butt weld plate edge preparation for manual welding is specified in Tab 1.

Table 1 : Typical butt weld plate edge preparation (manual welding) - See Note 1

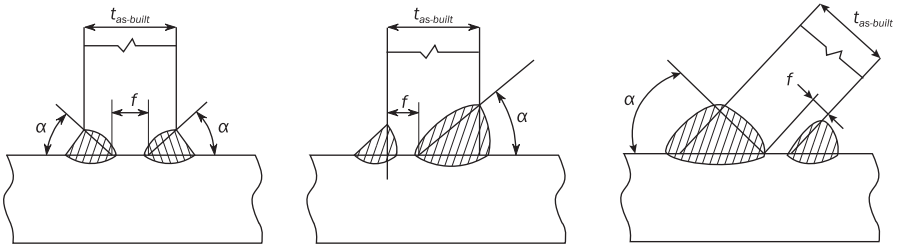
Square butt  t ≤ 5 mm G = 3 mm	**Single bevel butt**  t > 5 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°	**Double bevel butt**  t > 19 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°	
Double vee butt, uniform bevels  G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°	**Double vee butt, non-uniform bevels**  G ≤ 3 mm R ≤ 3 mm 6 ≤ h ≤ t/3 mm θ = 50° α = 90°	**Single vee butt, one side welding with backing strip (temporary or permanent)**  3 ≤ G ≤ 9 mm 30° ≤ θ ≤ 45°	**Single vee butt**  G ≤ 3 mm 50° ≤ θ ≤ 70° R ≤ 3 mm
Note 1: Different plate edge preparation may be accepted by the Society on the basis of an appropriate welding procedure specification.			

1.3 Partial of full penetration edge preparation

1.3.1 Typical edge preparations for partial or full penetration welding are indicated in:

- for partial penetration welds: Fig 1, in which f, in mm, is to be taken between 3 mm and $t_{as\text{-}built}/3$, and α between 40° and 60°

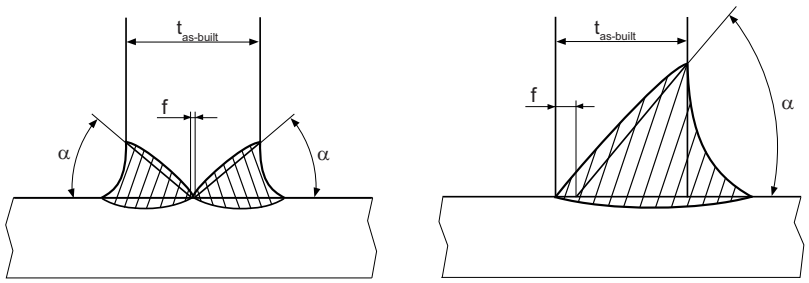
Figure 1 : Partial penetration weld



- for full penetration welds: Fig 2, in which f, in mm, is to be taken between 0 and 3 mm, and α between 40° and 60°
  Back gouging is generally required for full penetration welds.

In case of full penetration welding, the root face is to be removed, e.g. by gouging before welding of the back side.

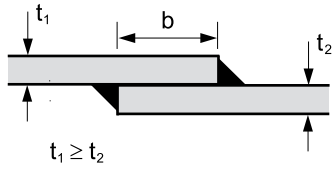
Figure 2 : Full penetration weld

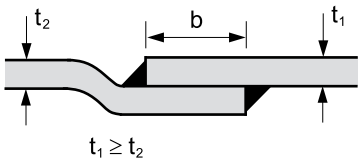


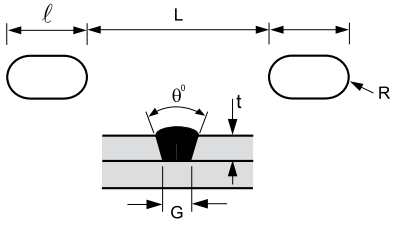
1.4 Lap-joint, slot and plug welding

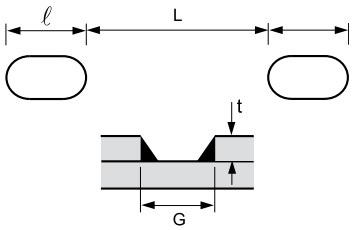
1.4.1 Welding details of lap-joint, slot and plug welds are specified in Tab 2.

Table 2 : Typical lap joint, plug and slot welding (manual welding)

<table>
<tr>
<td>Fillet weld in lap joint
 

b = 2 t2 + 25 mm
Remark: location of lap joint to be approved by the Society</td>
<td>Fillet weld in joggled lap joint
 

b ≥ 2 t2 + 25 mm
Remark: location of lap joint to be approved by the Society</td>
</tr>
<tr>
<td>Plug welding
 

• t ≤ 12 mm
ℓ = 60 mm
R = 6 mm
40° ≤ θ ≤ 50°
G = 12 mm
L > 2 ℓ
• 12 mm < t ≤ 25 mm
ℓ = 80 mm
R = 0,5 t mm
θ = 30°
G = t mm
L > 2 ℓ</td>
<td>Slot welding
 

• $t_{as\text{-}built}$ ≤ 12 mm
G = 20 mm
ℓ = 80 mm
2 ℓ ≤ L ≤ 3 ℓ, max 250 mm
• t > 12 mm
G = 2 t
ℓ = 100 mm
2 ℓ ≤ L ≤ 3 ℓ, max 250 mm</td>
</tr>
</table>

Appendix 2 Reference Sheets for Special Structural Details

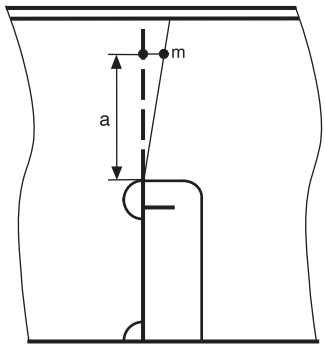
1 Contents

1.1 General

1.1.1 This Appendix includes the reference sheets for special structural details, as referred to in Ch 13, Sec 5.

Table 1 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_{BAL} and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate**	**Sheet 1.1**

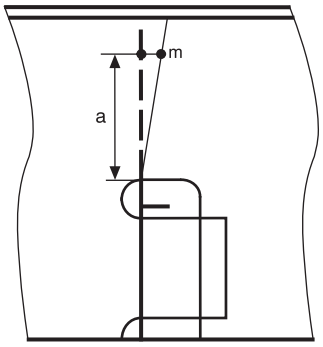


t_W = web thickness of transverse primary supporting member

SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal to be not greater than 4 mm.	Visual examination 100%.
WELDING AND MATERIALS:	
Welding requirements: - continuous fillet welding along the connection of web with side longitudinal, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm, - weld around the cuts in the web at the connection with the longitudinal and the side shell, - avoid burned notches on web.	

Table 2 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 1.2



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

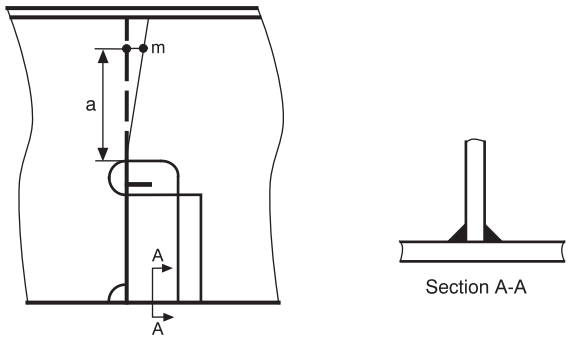
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 3 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate	Sheet 1.3



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

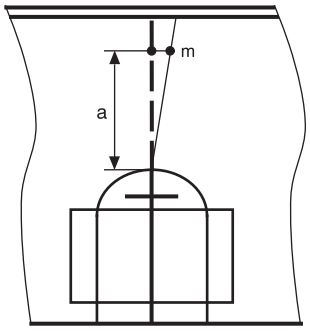
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - T joint connection of collar plate with side shell: see section A-A,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 4 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 1.4



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

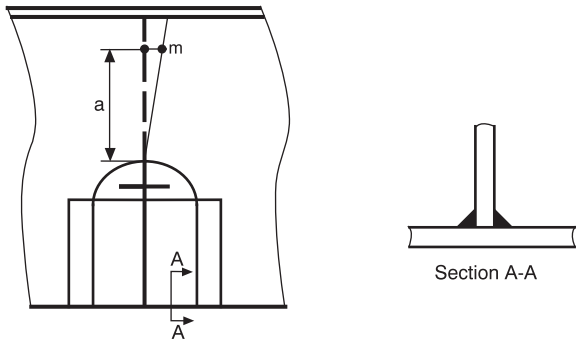
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 5 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates	Sheet 1.5



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

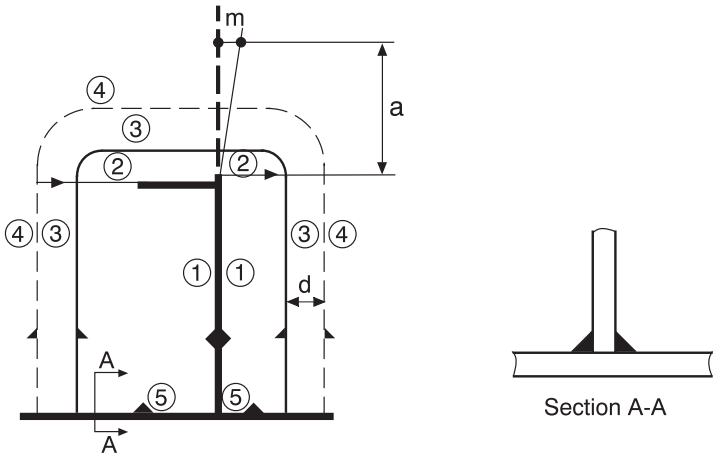
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - T joint connection of collar plates with side shell: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 6 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Watertight connection of side longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs	Sheet 1.6



t_W = transverse bulkhead web thickness

t_L = lug thickness

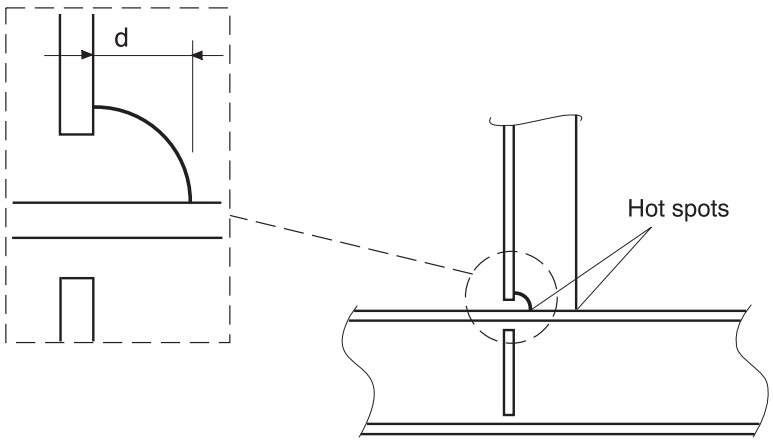
SCANTLINGS:	FATIGUE:
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between lugs across the side longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding along the connection of lugs with the side longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- T joint connection of collar plates with side shell: see section A-A,
- welding sequence: 1 to 5 (see sketch).

Table 7 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket**	**Sheet 1.7**



t = minimum thickness between those of:
- web of side longitudinal,
- stiffener of transverse primary supporting member.

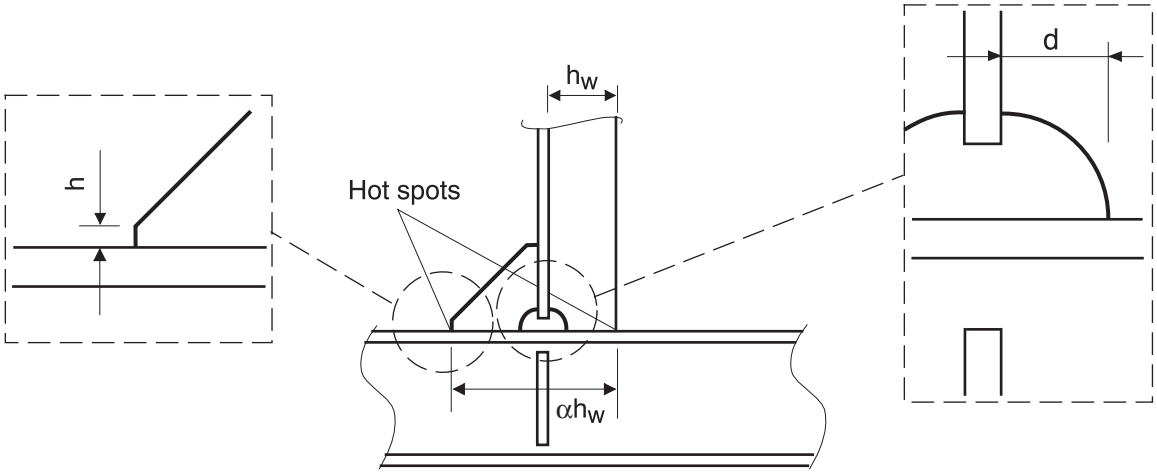
SCANTLINGS:	**FATIGUE:**
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 8 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.8



t = minimum thickness among those of the connected elements

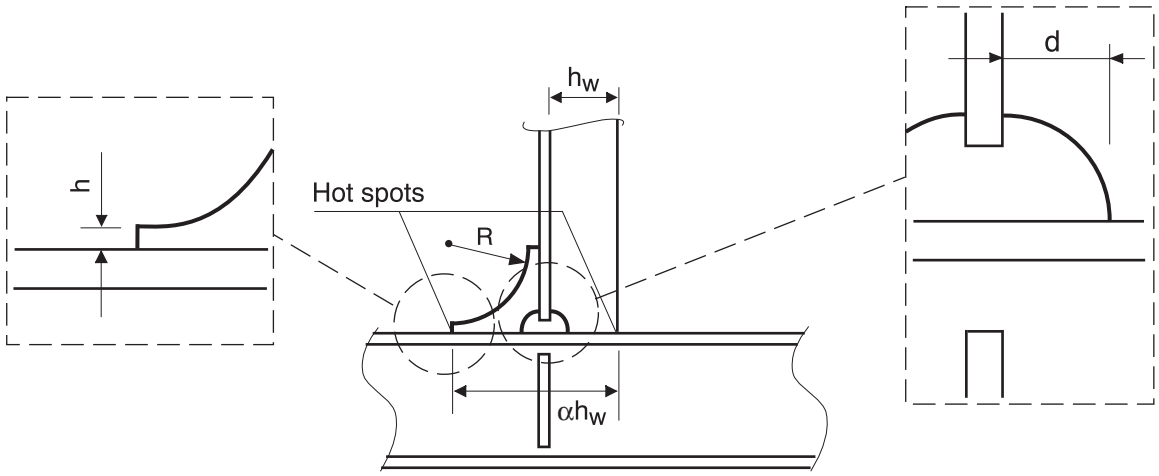
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 9 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.9



t = minimum thickness among those of the connected elements

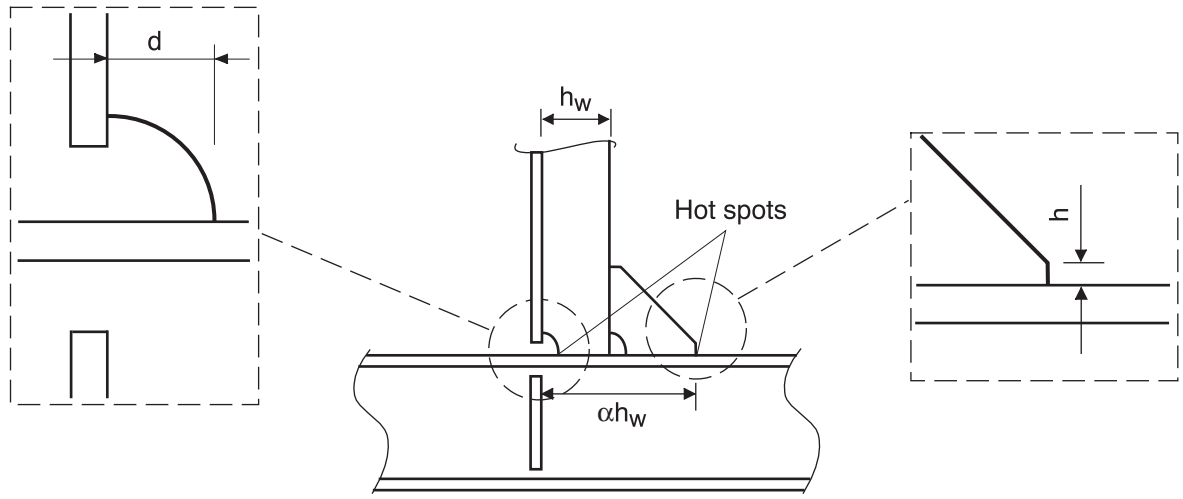
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 10 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.10



t = minimum thickness among those of the connected elements

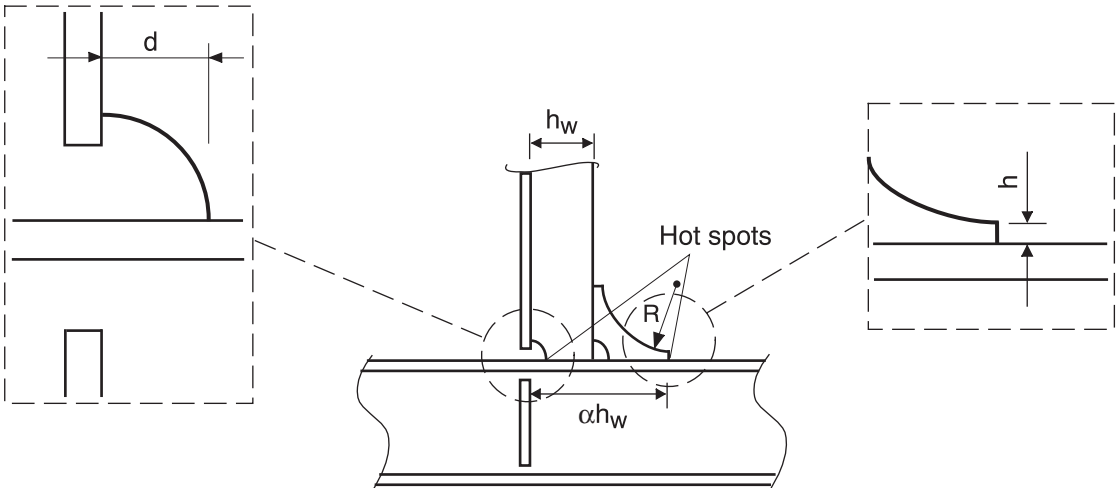
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 11 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.11



t = minimum thickness among those of the connected elements

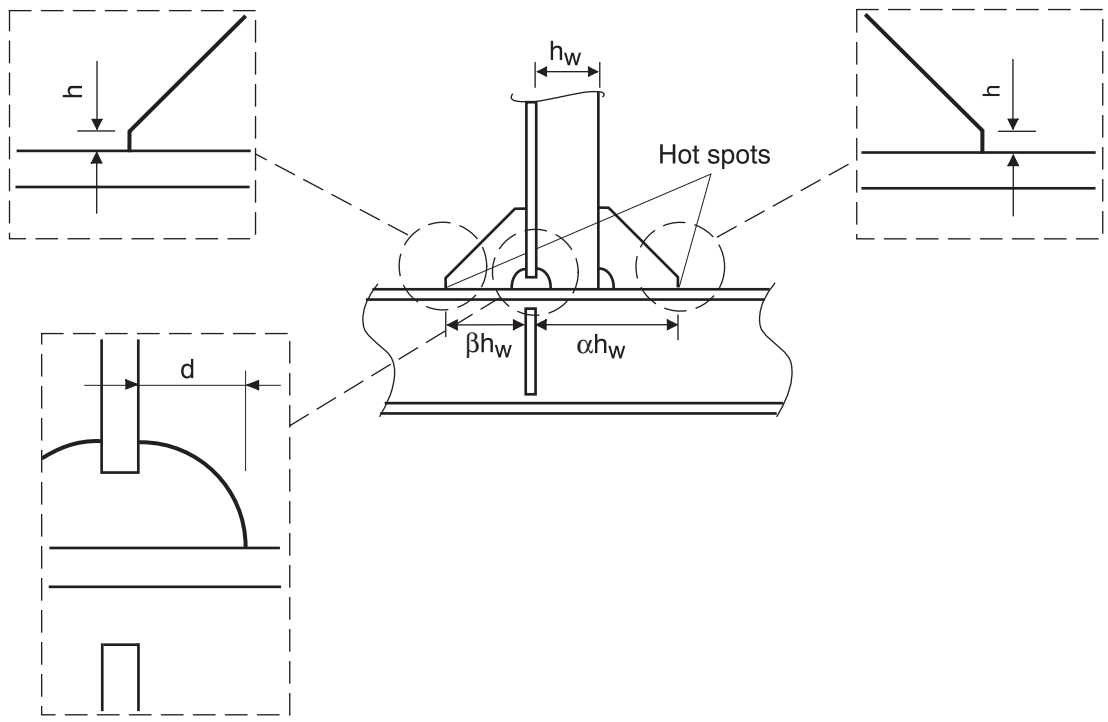
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 12 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 1.12



t = minimum thickness among those of the connected elements

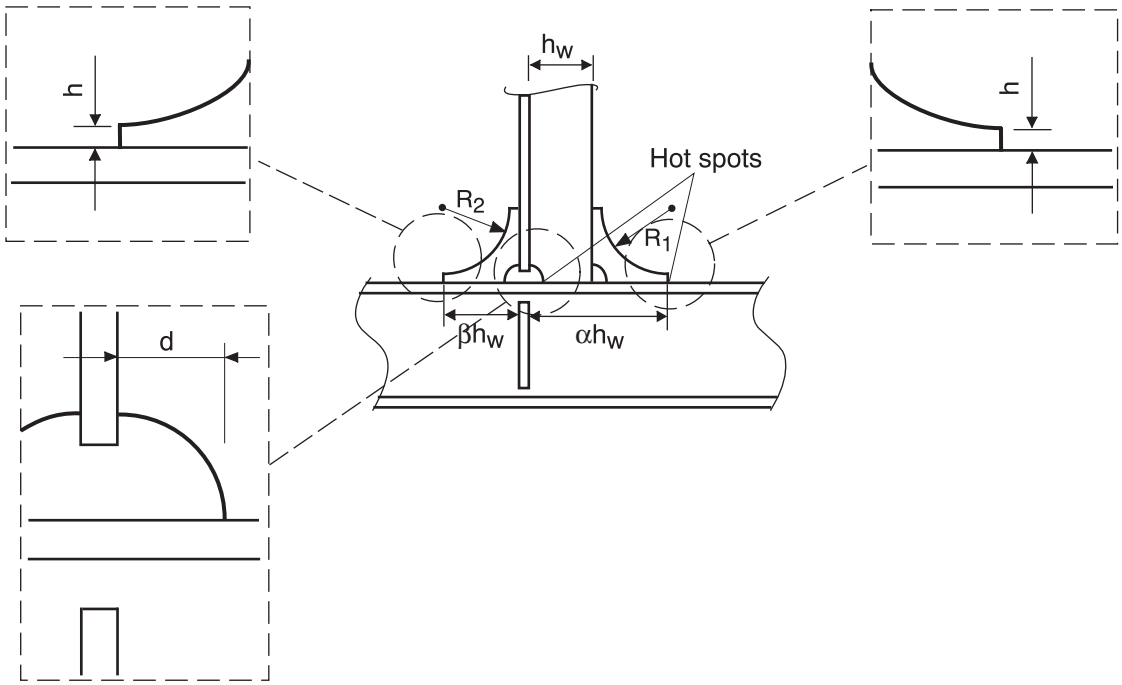
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 13 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_{BAL}$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 1.13



t = minimum thickness among those of the connected elements

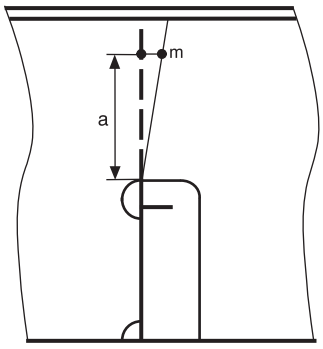
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1,5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t /3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 14 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate	Sheet 2.1



t_W = web thickness of transverse primary supporting member

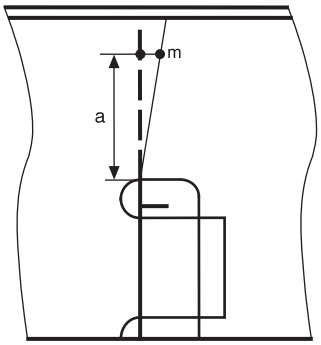
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding along the connection of web with longitudinal,
- throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- weld around the cuts in the web at the connection with the longitudinal and the plating,
- avoid burned notches on web.

Table 15 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 2.2



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

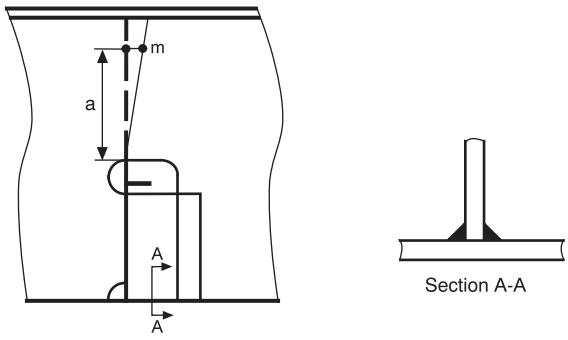
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the plating,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 16 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate	Sheet 2.3



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

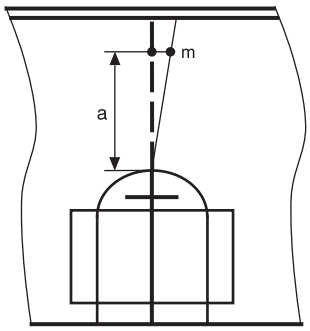
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - T joint connection of collar plate with the plating: see section A-A,
  - weld around the cuts in the web at the connection with the longitudinal and the plating,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 17 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 2.4



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

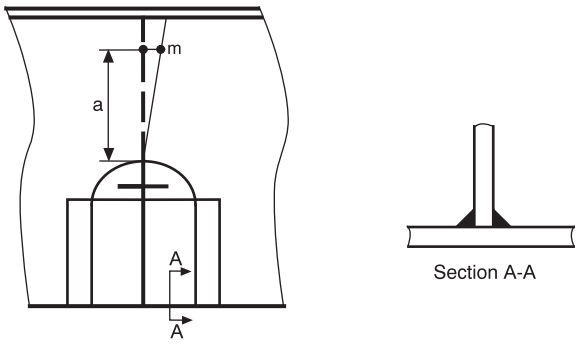
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between collar plates across the longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 18 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates	Sheet 2.5



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

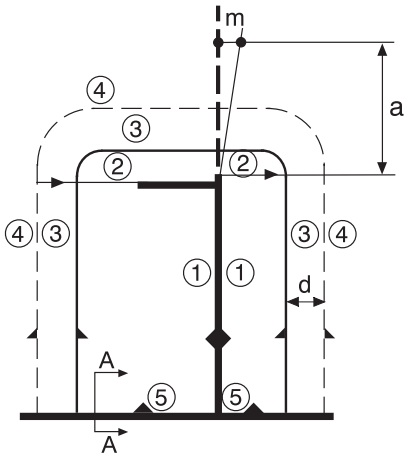
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between collar plates across the longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - T joint connection of collar plates with the plating: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 19 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Watertight connection of inner side or bulkhead longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs	Sheet 2.6



t_W = transverse bulkhead web thickness

t_L = lug thickness

SCANTLINGS:	FATIGUE:
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between lugs across the longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

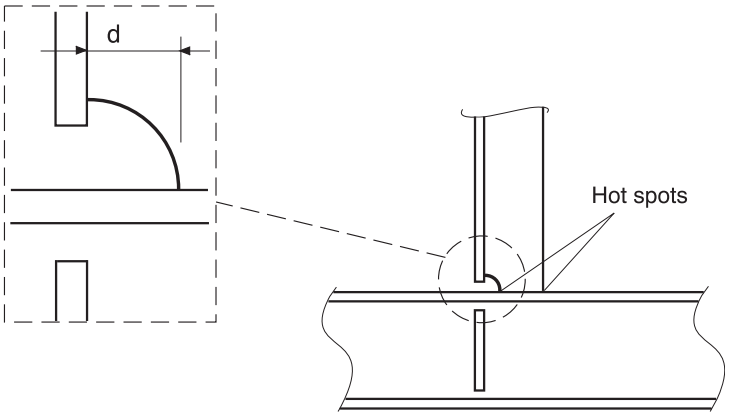
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding along the connection of lugs with the longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- T joint connection of collar plates with the plating: see section A-A,
- welding sequence: 1 to 5 (see sketch).

Table 20 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 2.7



t = minimum thickness between those of:
- web of longitudinal,
- stiffener of transverse primary supporting member.

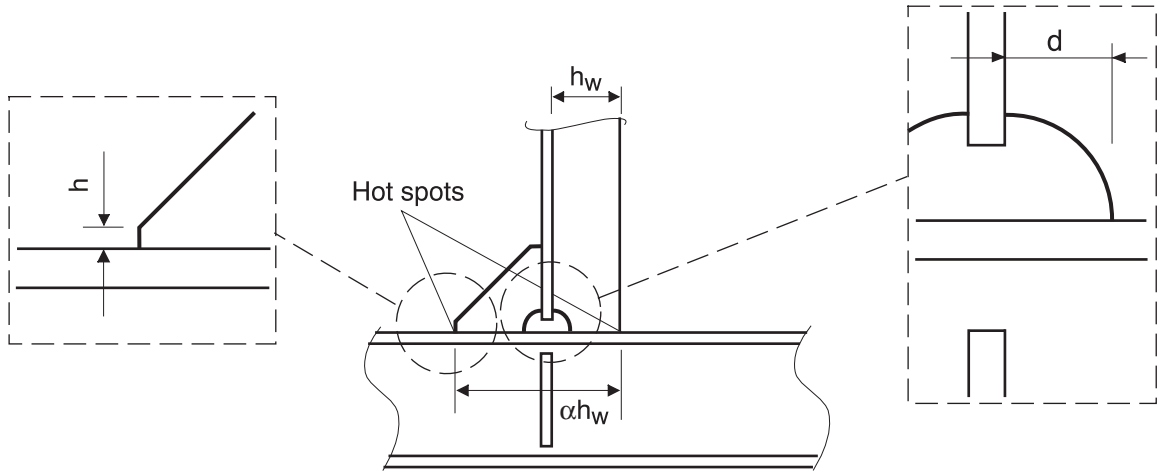
SCANTLINGS:	FATIGUE:
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 21 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.8



t = minimum thickness among those of the connected elements

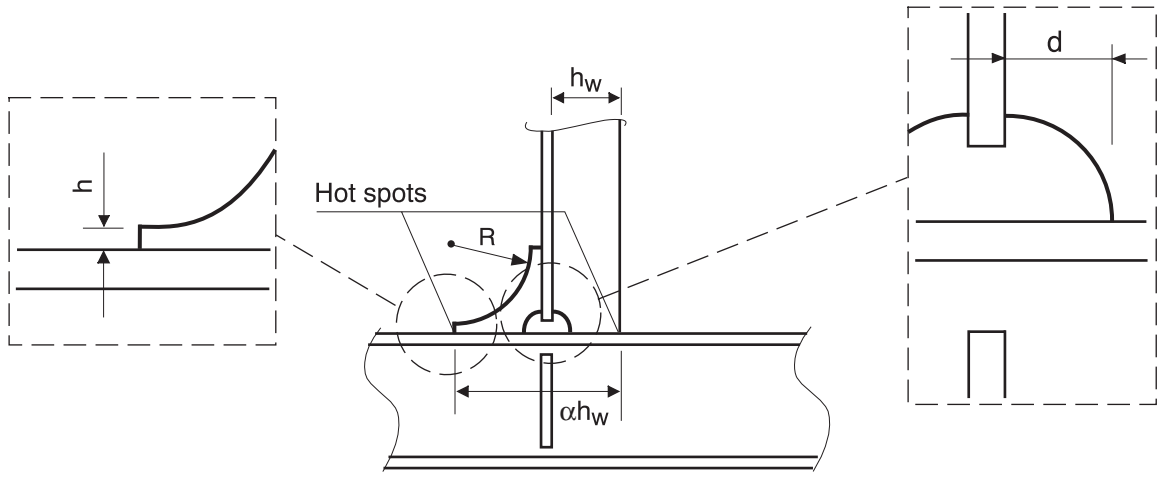
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 22 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 2.9



t = minimum thickness among those of the connected elements

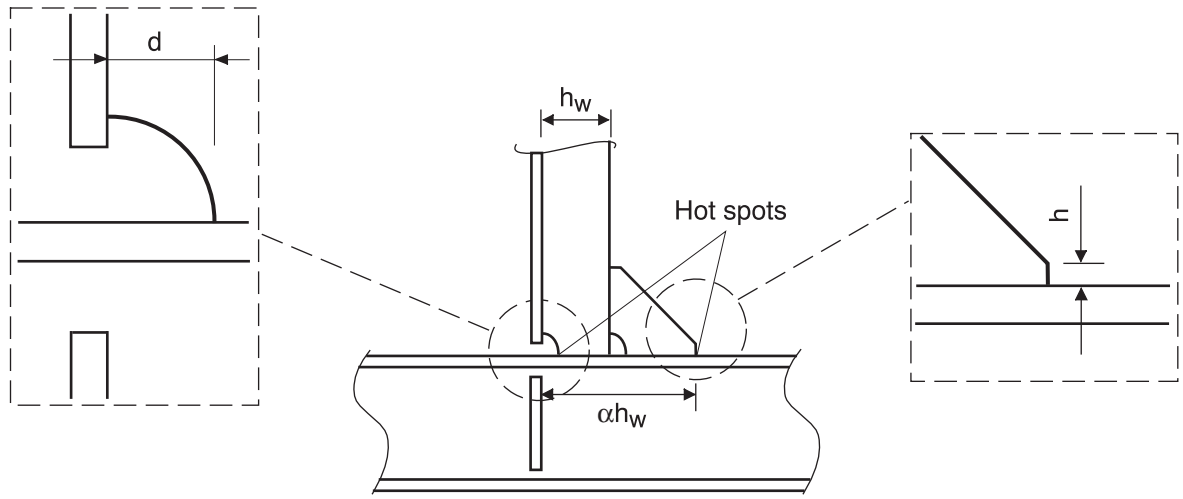
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 23 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.10



t = minimum thickness among those of the connected elements

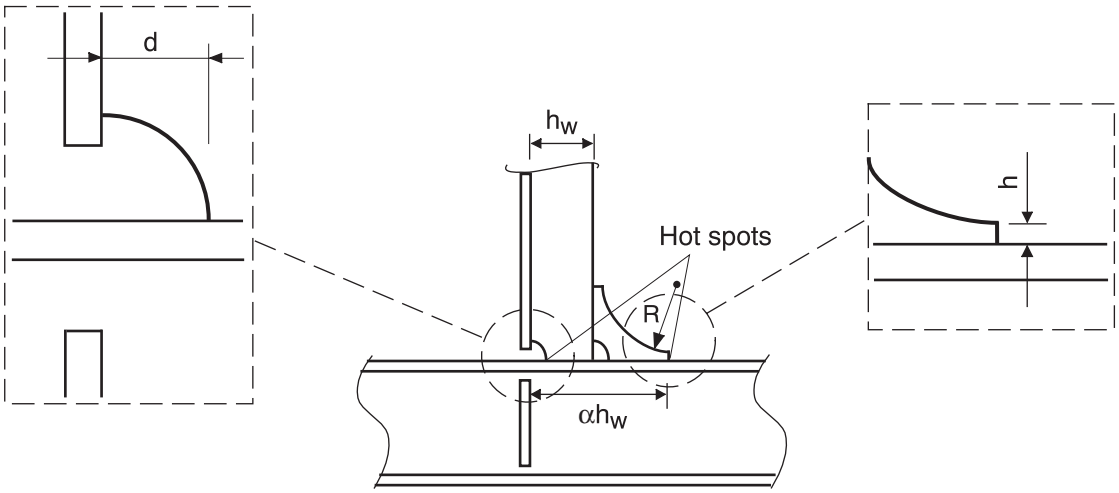
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 24 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 2.11

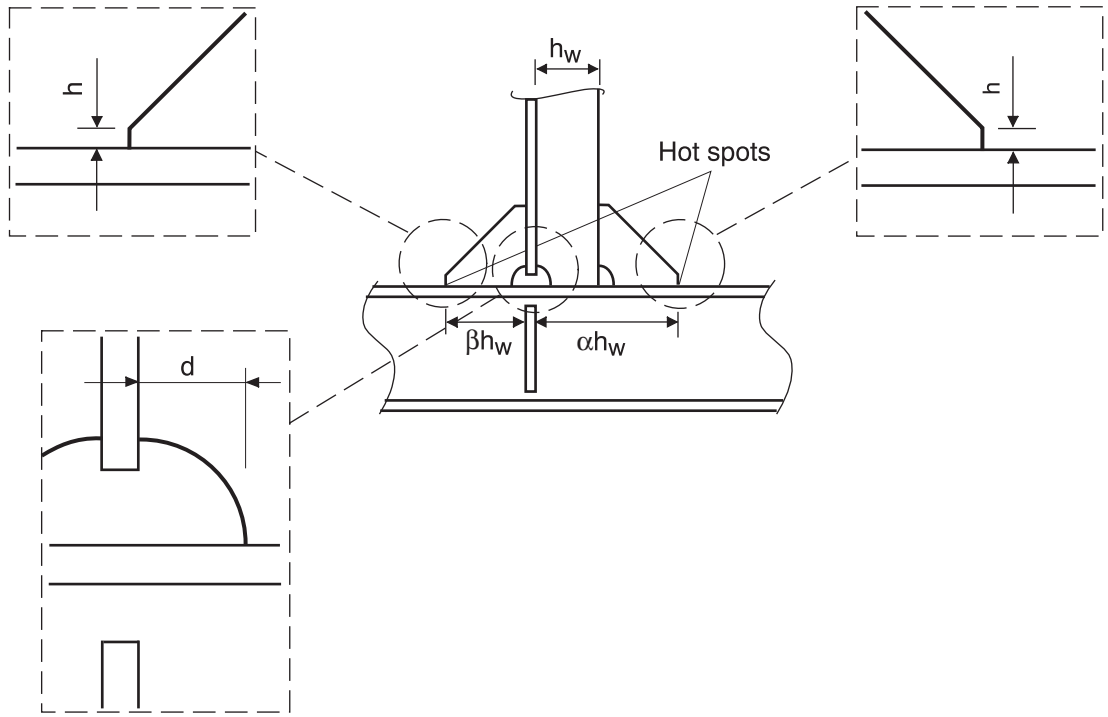


t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.
WELDING AND MATERIALS:	
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.	

Table 25 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 2.12



t = minimum thickness among those of the connected elements

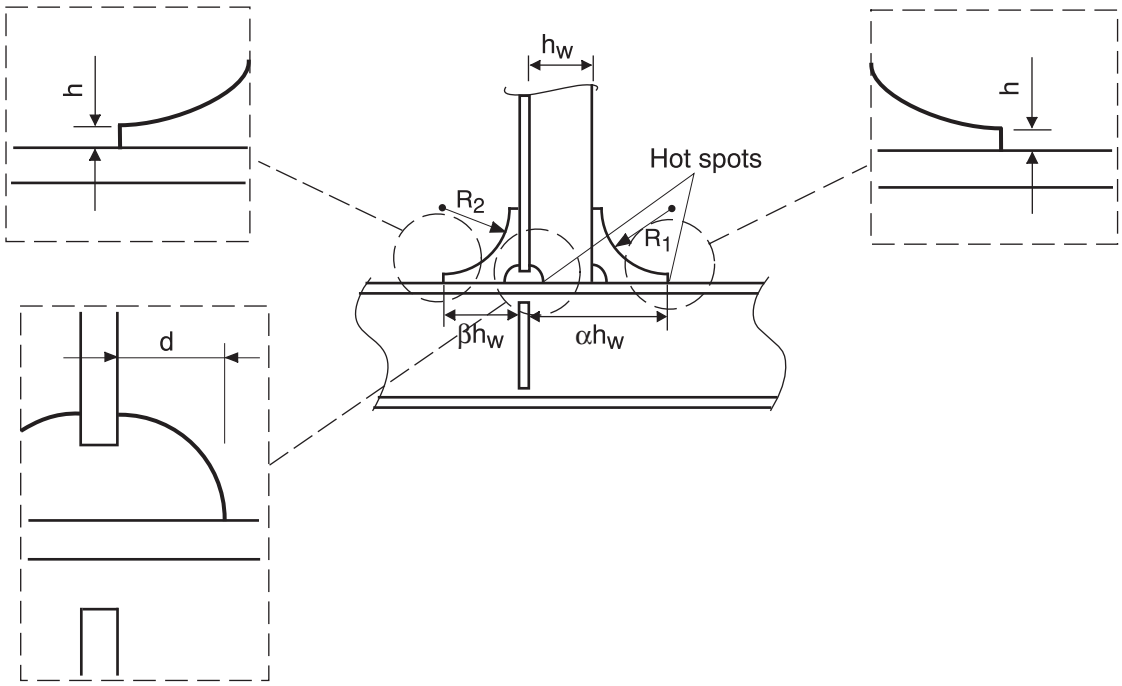
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 26 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 2.13



t = minimum thickness among those of the connected elements

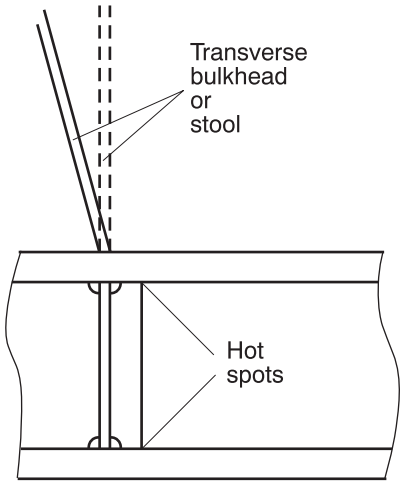
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1,5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 27 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket	Sheet 3.1



t = minimum thickness between those of:
- web of bottom or inner bottom longitudinal,
- floor stiffener.

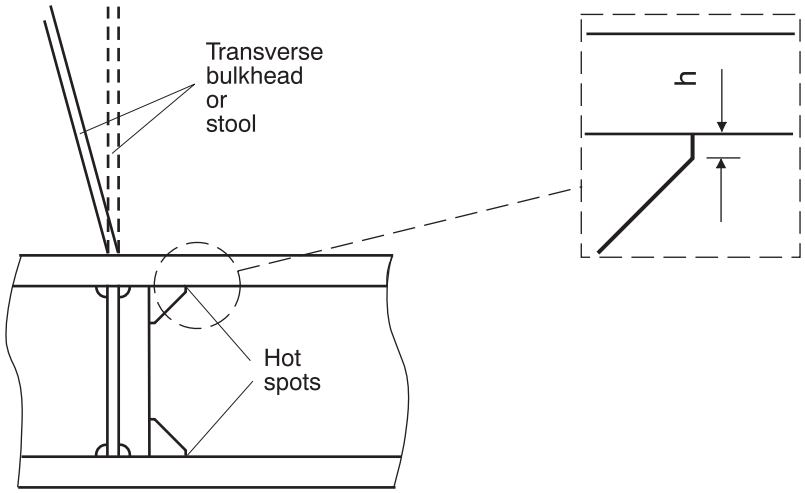
SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- weld all around the stiffeners,
- fair shape of fillet at toes in longitudinal direction.

Table 28 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets	Sheet 3.2



t = minimum thickness among those of the connected elements

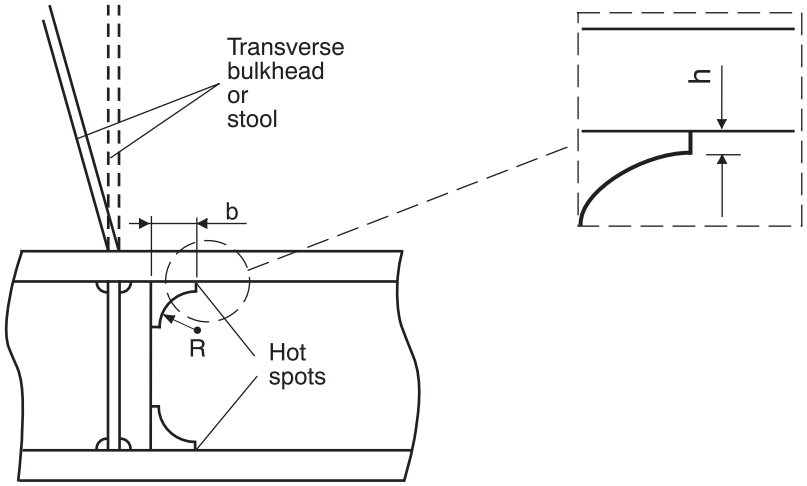
SCANTLINGS:	FATIGUE:
h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

Table 29 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Radiused brackets	Sheet 3.3



t = minimum thickness among those of the connected elements

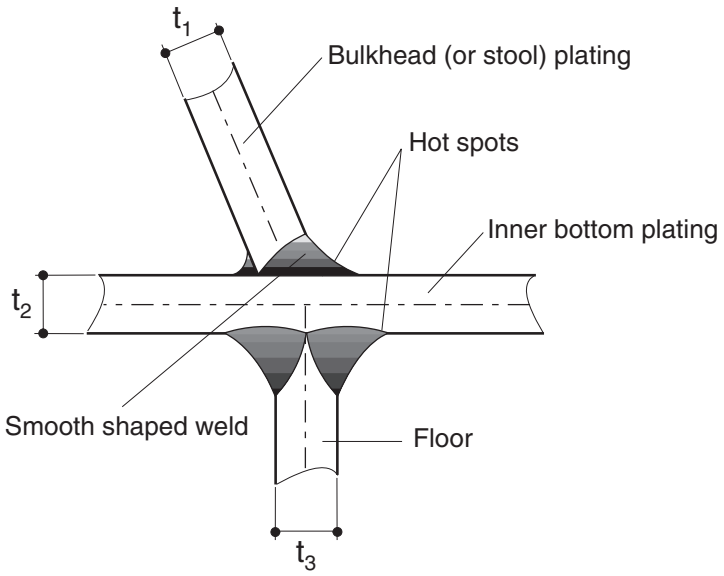
SCANTLINGS:	FATIGUE:
• Brackets to be symmetric. • R ≥ 1,5 b • h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

Table 30 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse bulkheads or lower stools	Sheet 3.4



$t = \min (t_1 , t_2 , t_3)$

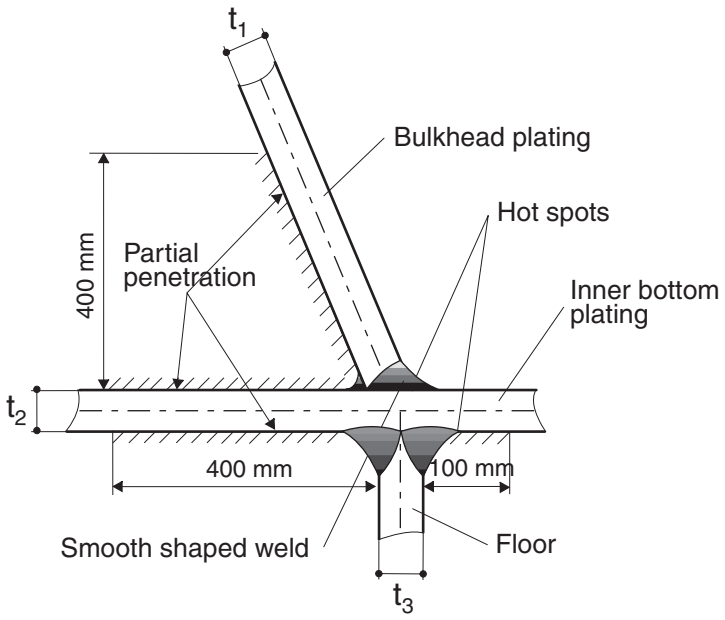
SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and bulkhead (or stool) plating ≤ t / 3. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates welded to the inner bottom.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead (or stool) plating and supporting floors generally to be connected with full penetration welding to inner bottom plating (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.

Table 31 : LIQUEFIED GAS CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse cofferdam bulkheads	Sheet 3.5



$t = \min (t_1 , t_2 , t_3)$

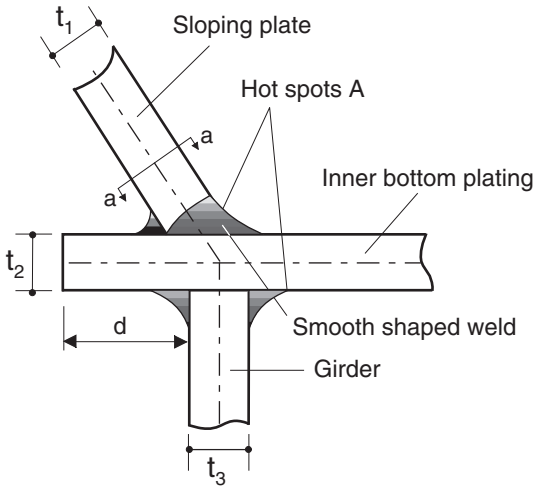
SCANTLINGS:	**FATIGUE:**
	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and bulkhead plating ≤ t / 3, max 6 mm. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates, welded to the inner bottom.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

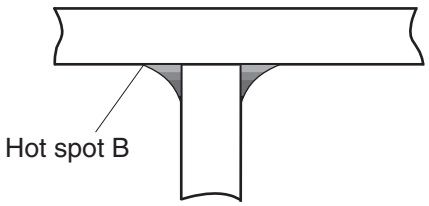
WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead plating and supporting floors to be connected with full penetration welding to inner bottom plating,
  - bulkhead vertical girders and bottom girders are to be connected with partial penetration to inner bottom plating for the extension shown in the sketch,
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is to be of be of Z grade steel. In particular cases, grade E/EH steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review.

Table 32 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	Sheet 4.1





Section a - a

t_A = min (t_1 , t_2 , t_3),

t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- t_3.

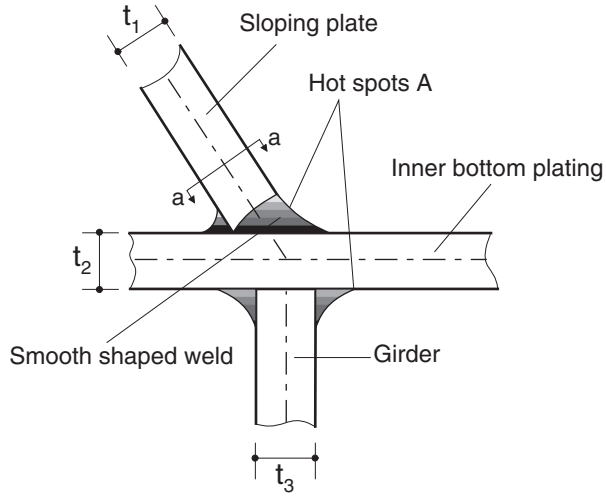
SCANTLINGS:	FATIGUE:
d ≥ 50 mm.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

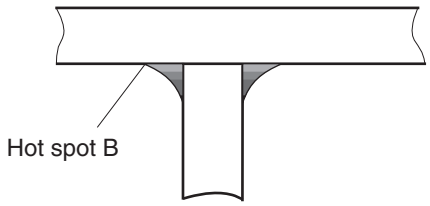
WELDING AND MATERIALS:

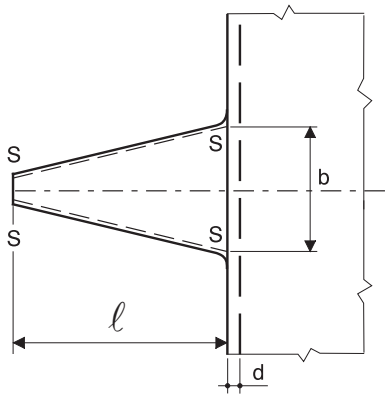
- Welding requirements:
  - sloping plate to be connected with partial penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.

Table 33 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Prolonging brackets	Sheet 4.2







t_A = min (t_1 , t_2 , t_3),

t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- t_3.

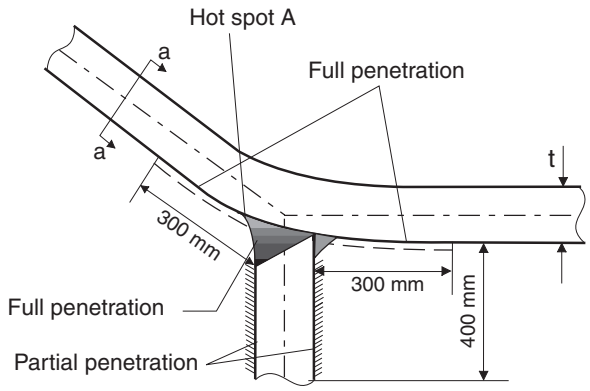
SCANTLINGS:	FATIGUE:
• Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • d ≥ 50 mm. • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 6: - thickness of the above brackets ≥ t_2, - b ≥ 0,4 times the floor spacing, - ℓ ≥ 1,5 b.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

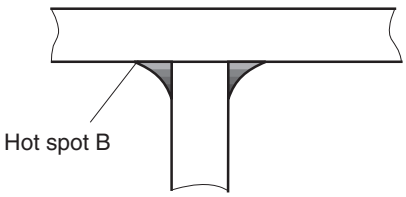
WELDING AND MATERIALS:

- Welding requirement:
  - sloping plate to be connected with partial penetration welding to inner bottom plating,
  - brackets to be connected with full penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirement:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of prolonging brackets to be not less than those of the inner bottom plating.

Table 34 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.3





Section a - a

t_A = minimum thickness between those of the girder and sloping plate,

t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- girder thickness.

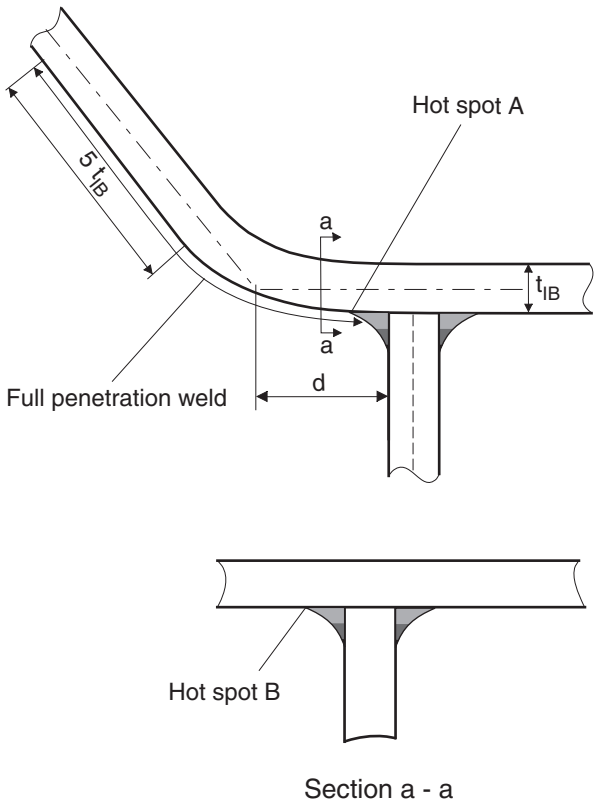
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm ≥ 9 + 0,03 L_1 $k^{1/2}$.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected (see sketches):
    - with full penetration welding to the inner bottom for a length ≥ 300 mm,
    - with partial penetration welding to the girder for a length ≥ 300 mm,
    - with continuous fillet welding in the remaining areas,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding,
  - weld finishing of butt welds well faired to the inner bottom plating on ballast tank,
  - fair shape of fillet at hot spots.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

Table 35 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.4



t = minimum among:
- floor thickness,
- hopper transverse web thickness,
- girder thickness,

t_{IB} = inner bottom plating.

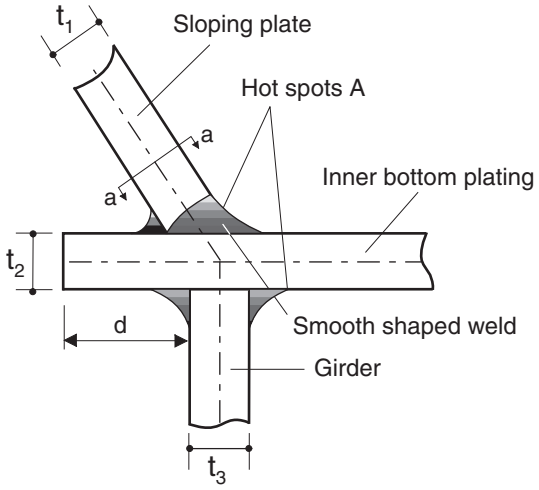
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • d ≤ 40 mm. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm ≥ 9 + 0,03 L_1 $k^{1/2}$.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and hopper transverse web ≤ t / 3. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.	Visual examination 100%.

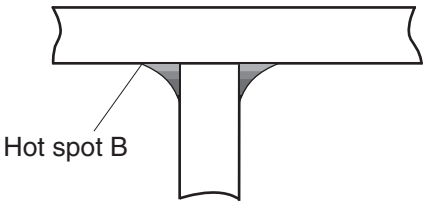
WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected with full penetration welding to the inner bottom plating for a length ≥ 5 t_{IB} ,
  - where girder is welded within the bent area, welding procedures to be submitted to the Society for review.
- Material requirements:
  - where girder is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

Table 36 : LIQUEFIED GAS CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	Sheet 4.5





Section a - a

t_A = min (t_1 , t_2 , t_3),

t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- t_3.

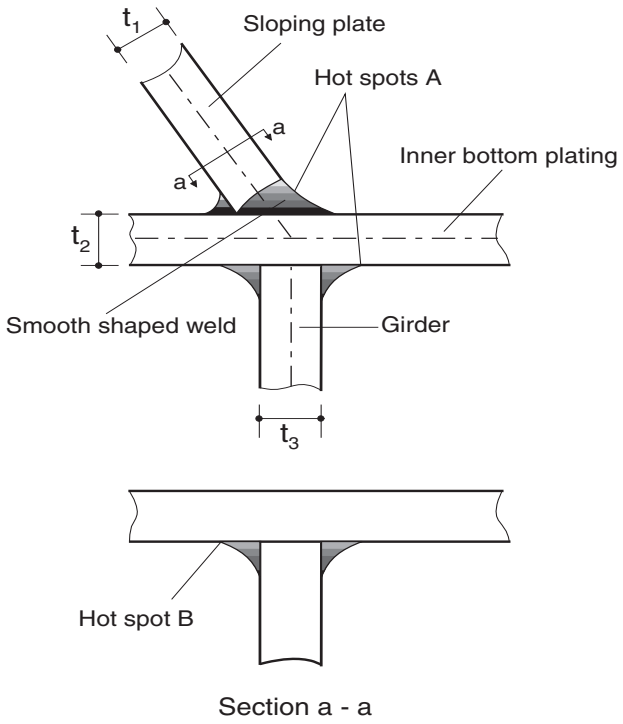
SCANTLINGS:	FATIGUE:
d ≥ 50 mm.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3, max 6 mm. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3, max 6 mm.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

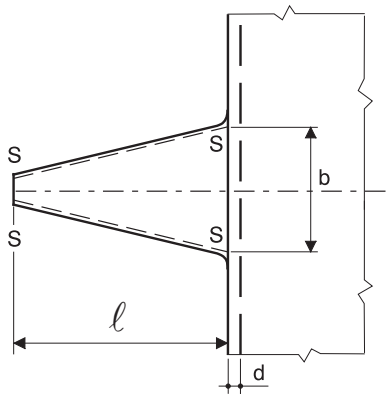
WELDING AND MATERIALS:

- Welding requirements:
  - sloping plate to be connected with full penetration welding to inner bottom plating, except in way of void spaces where partial penetration may be accepted,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review.

Table 37 : LIQUEFIED GAS CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Prolonging brackets	Sheet 4.6





t_A = min (t_1 , t_2 , t_3),

t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- t_3.

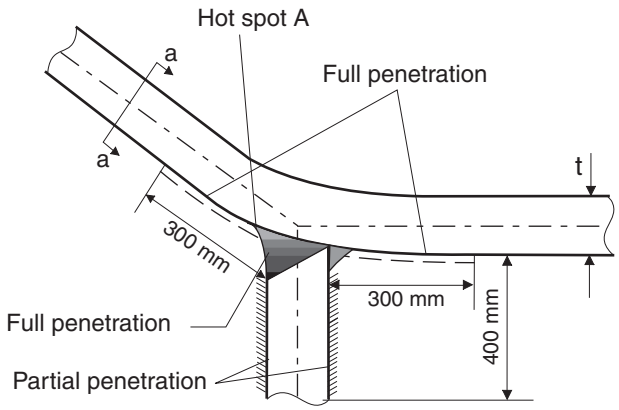
SCANTLINGS:	FATIGUE:
• Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • d ≥ 50 mm. • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 6: - thickness of the above brackets ≥ t_2 , - b ≥ 0,4 times the floor spacing, - ℓ ≥ 1,5 b.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3, max 6 mm. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3, max 6 mm.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

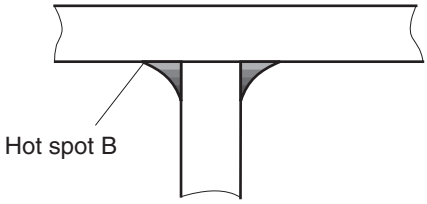
WELDING AND MATERIALS:

- Welding requirements:
  - sloping plate to be connected with full penetration welding to inner bottom plating, except in way of void spaces where partial penetration may be accepted,
  - prolonging brackets to be connected with full penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review,
  - material properties of prolonging brackets to be not less than those of the inner bottom plating.

Table 38 : LIQUEFIED GAS CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.7





Section a - a

t_A = minimum thickness between those of the girder and sloping plate,

t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- girder thickness.

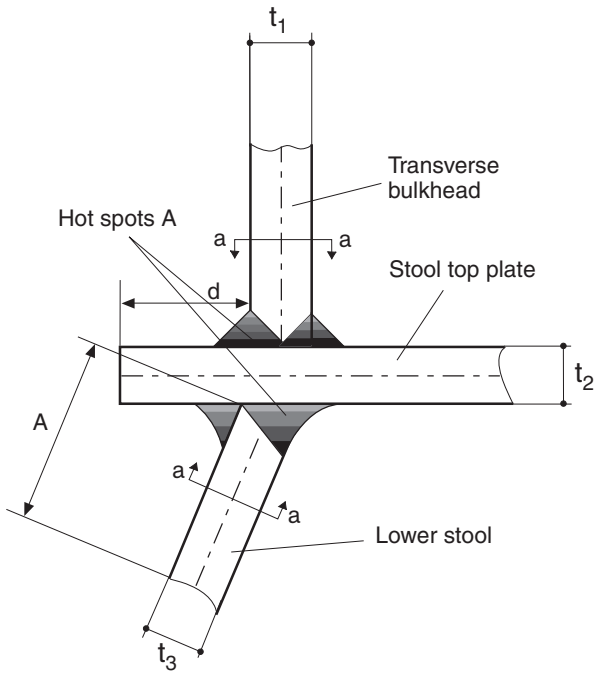
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm ≥ $9 + 0{,}03\ L_1\ k^{1/2}$.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ $t_A / 3$. • Misalignment (median lines) between floor and hopper transverse web ≤ $t_B / 3$. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

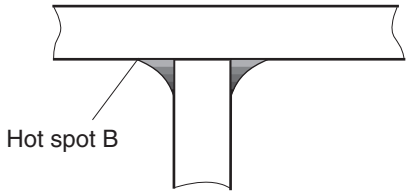
WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected (see sketches):
    - with full penetration welding to the inner bottom for a length ≥ 300 mm,
    - with partial penetration welding to the girder for a length ≥ 300 mm,
    - with continuous fillet welding in the remaining areas,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding,
  - weld finishing of butt welds well faired to the inner bottom plating on ballast tank,
  - fair shape of fillet at hot spots.
- Material requirements:
  - the radiused construction may be accepted provided that the bent plate is of grade D or DH and the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

Table 39 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	Sheet 5.1





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between bulkhead plating and stool side plating ≤ t_A / 3. • Misalignment (median lines) between members above and below stool top plate ≤ t_B / 3.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

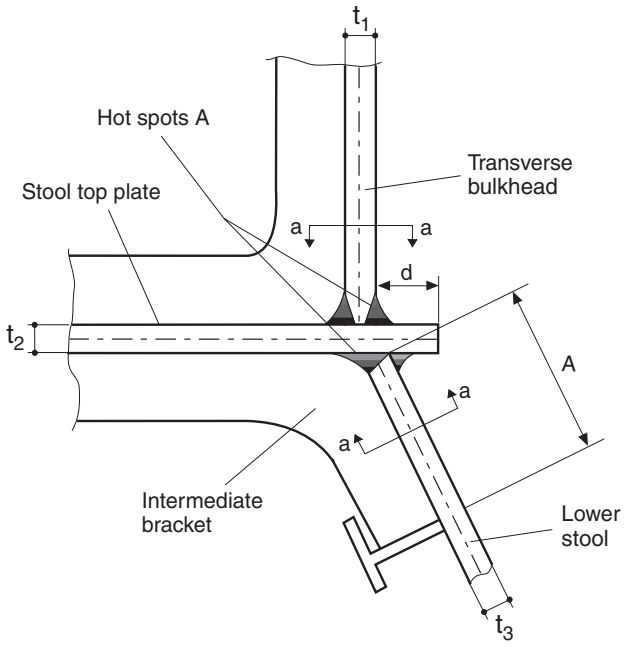
WELDING AND MATERIALS:

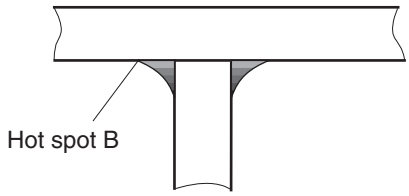
- Welding requirements:
  - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate,
  - weld finishing well faired to the stool top plate.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 40 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets	Sheet 5.2





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above stool top plate $\leq t_B / 3$. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool side plating and the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

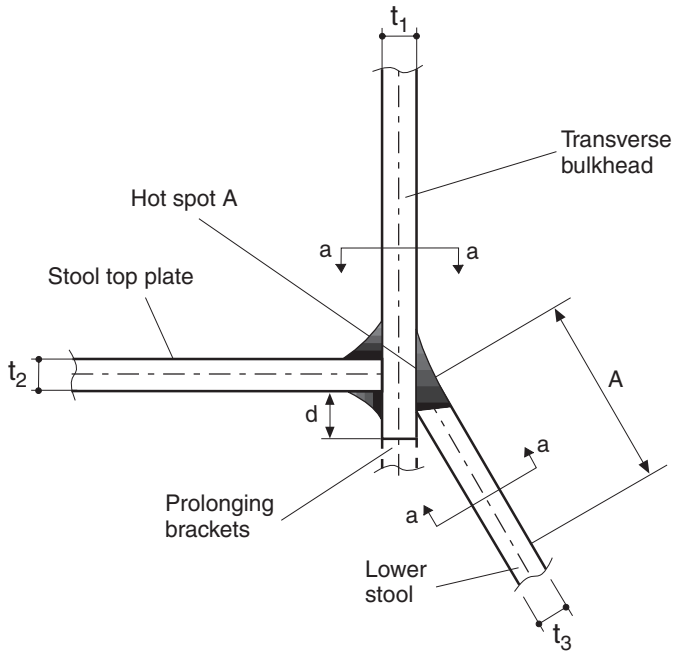
WELDING AND MATERIALS:

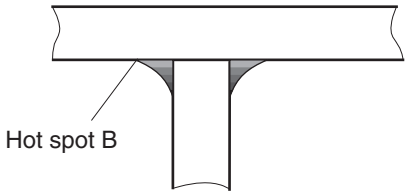
- Welding requirements:
  - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate,
  - weld finishing well faired to the stool top plate.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 41 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Prolonging brackets	Sheet 5.3





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:	FATIGUE:
• d ≥ 50 mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of prolonging brackets ≥ t_1. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between stool top plate and stool side plating ≤ t_A / 3. • Misalignment (median lines) between members above and below stool top plate ≤ t_B / 3.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

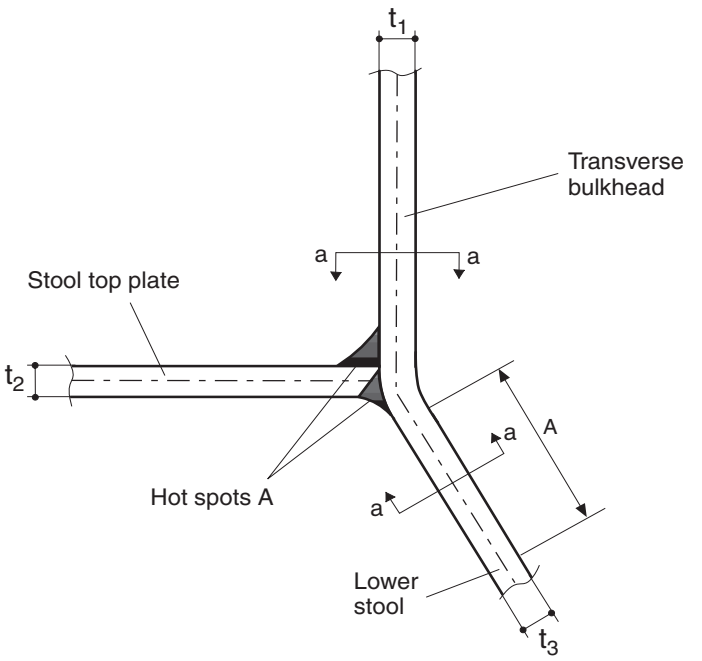
WELDING AND MATERIALS:

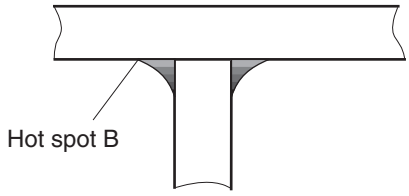
- Welding requirements:
  - stool side plating to be connected with full penetration welding to the bulkhead plating. Root gap to be checked along the production steps as appropriate,
  - brackets to be connected with full penetration welding to transverse bulkhead plating,
  - full penetration weld of stool side plating to bulkhead plating to be welded first,
  - welding sequence against the risk of lamellar tearing in the bulkhead plating is recommended.
- Material requirements:
  - the lower strake of transverse bulkhead plating is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating,
  - material properties of prolonging brackets to be not less than those of the bulkhead plating.

Table 42 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Radiused construction	Sheet 5.4





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

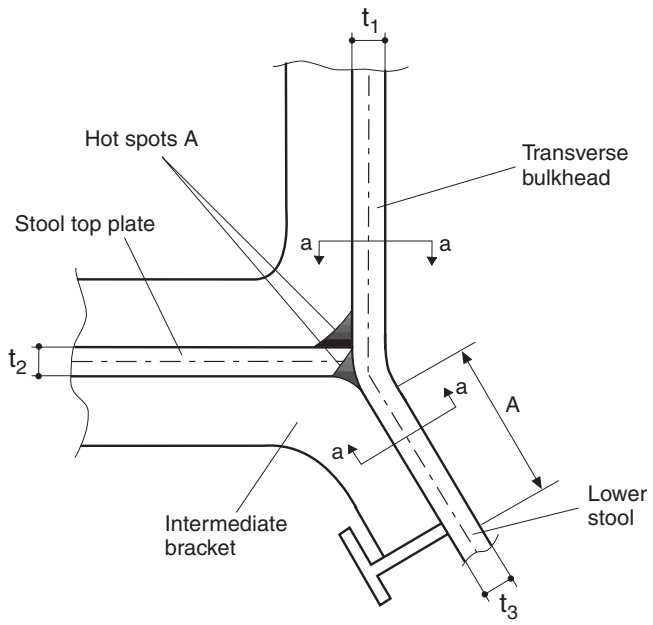
WELDING AND MATERIALS:

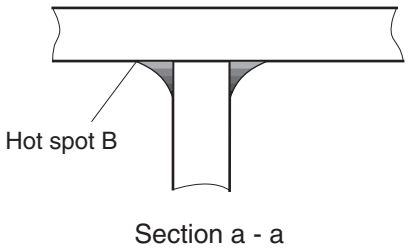
- Welding requirements:
  - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended,
  - weld finishing well faired to the bulkhead plating and stool side plating.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 43 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.5





A = distance to be taken not less than the spacing of bulkhead vertical webs

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between stool top plate and stool side plating ≤ t_A / 3. • Misalignment (median lines) between intermediate bracket and member below stool top plate ≤ t_B / 3. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

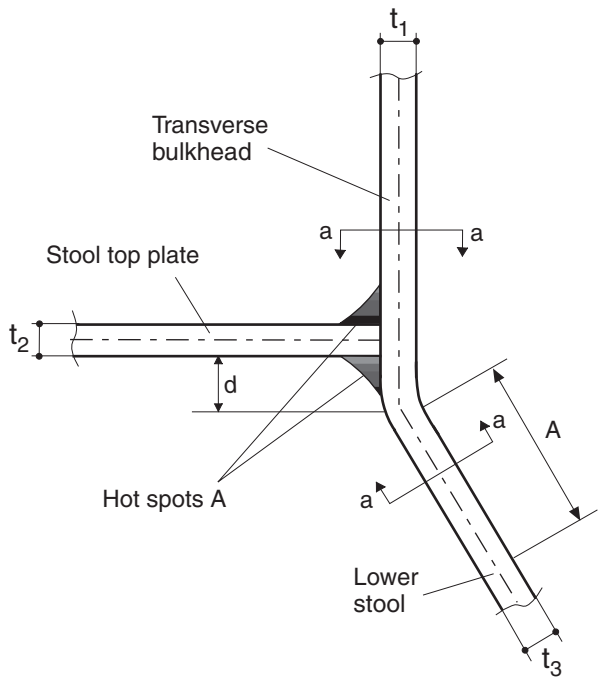
WELDING AND MATERIALS:

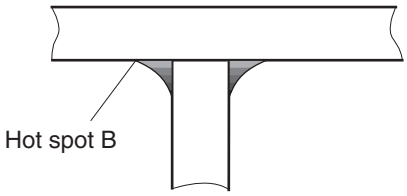
- Welding requirements:
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended,
  - weld finishing well faired to the bulkhead plating and stool side plating.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 44 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Radiused construction	Sheet 5.6





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

t = minimum among:
- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • d ≤ 40 mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between members above and below stool top plate ≤ t / 3. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

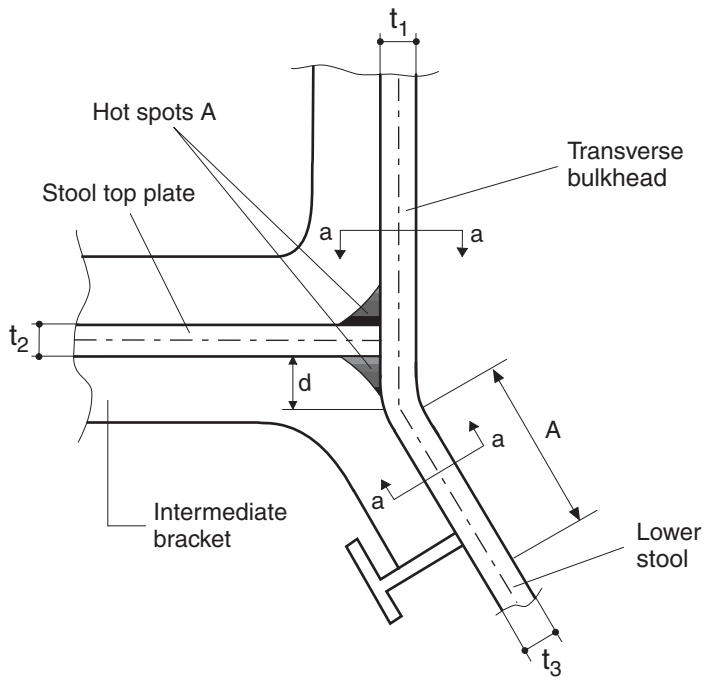
WELDING AND MATERIALS:

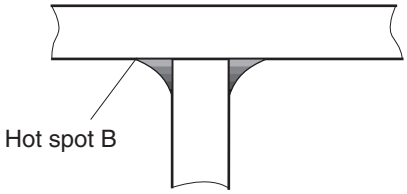
Material requirements:
- where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of:
  - the stool top plate,
  - the portion A of the stool side plating,

  to be not less than those of the transverse bulkhead plating.

Table 45 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.7





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

t = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between intermediate bracket and member above stool top plate ≤ t / 3. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

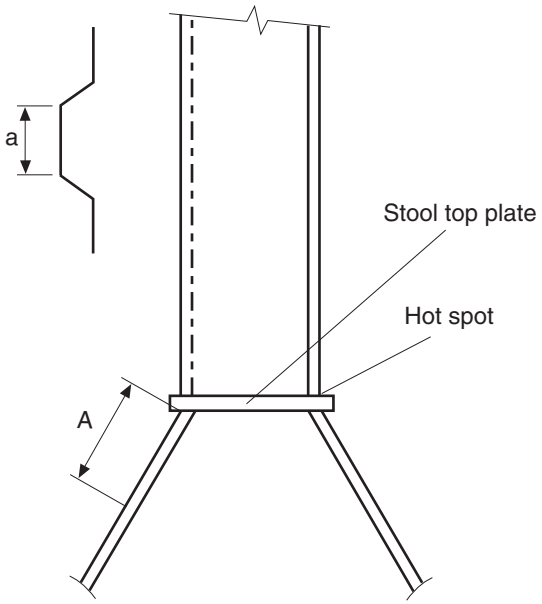
Material requirements:

- where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of:
  - the stool top plate,
  - the portion A of the stool side plating,

  to be not less than those of the transverse bulkhead plating.

Table 46 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads	Sheet 5.8



$A \geq a$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,

$t = \min (t_F , t_T , t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating ≤ t / 3. • Distance from the edge of the stool top plate to the surface of the corrugation flanges ≥ 1,5 t_F. • Corrugation radius according to Ch 13, Sec 1, [3.2.1].	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

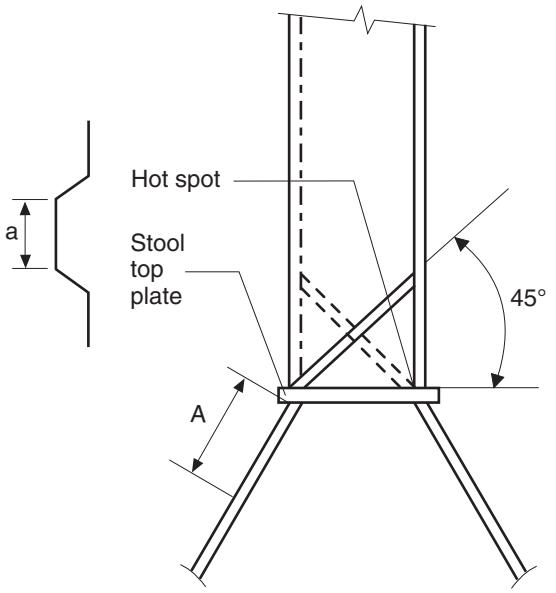
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 47 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45°	Sheet 5.9



$A \geq a$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F , t_T , t_S)$

$t_B = \min (t_{SH} , t_T , t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75\ t_F$.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

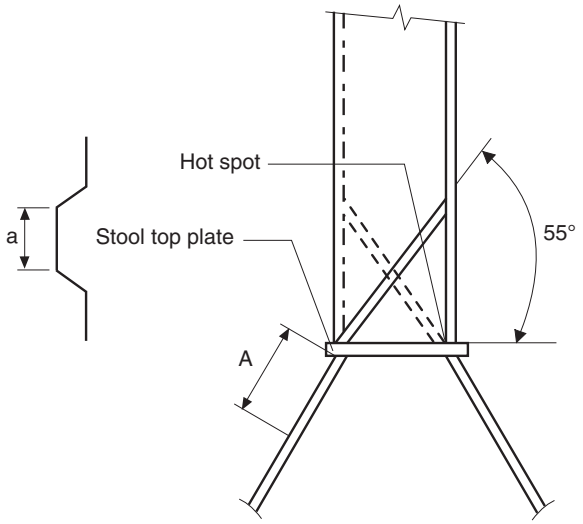
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 48 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 55°	Sheet 5.10



$A \geq a$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F , t_T , t_S)$,

$t_B = \min (t_{SH} , t_T , t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75\ t_F$.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

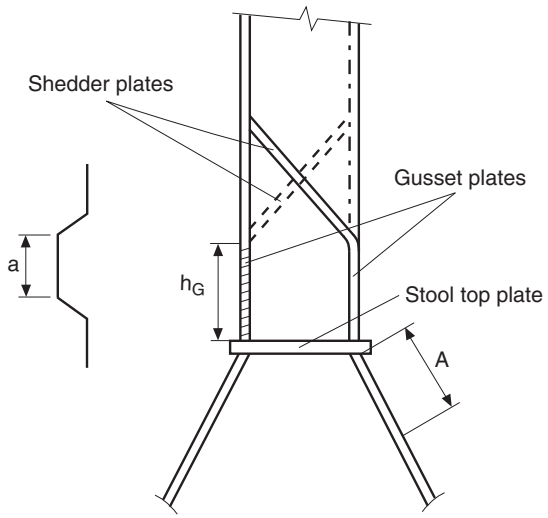
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 49 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates	Sheet 5.11



$A \geq a$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_G = gusset plate thickness,
t_{SH} = shedder plate thickness,

$t_A = \min(t_F, t_T, t_S)$,

$t_B = \min(t_G, t_T, t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_G \geq t_F$. • $t_{SH} \geq 0,75\ t_F$. • $h_G \geq a / 2$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

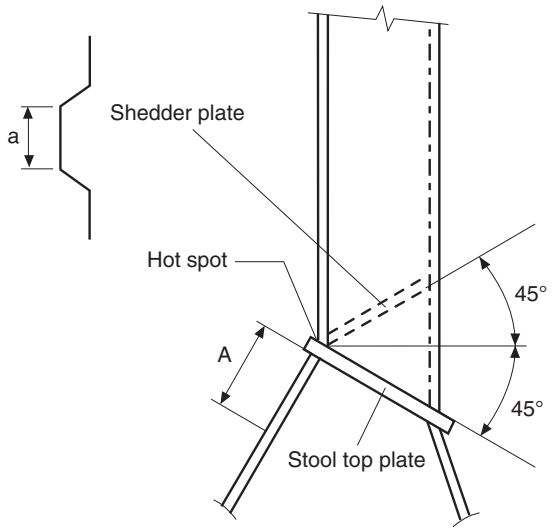
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - gusset plates generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings) and with one side penetration, or equivalent, to corrugations and shedder plates,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the gusset plates,
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 50 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Sloping stool top plate	Sheet 5.12



$A \geq a$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F , t_T , t_S)$.

$t_B = \min (t_{SH} , t_T , t_S)$.

SCANTLINGS:

- $t_T \geq t_F$.
- $t_S \geq t_F$ in portion A.
- $t_{SH} \geq 0,75\ t_F$.

FATIGUE:

Fatigue check to be carried out according to NI611.

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$.
- Corrugation radius according to Ch 13, Sec 1, [3.2.1].
- In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

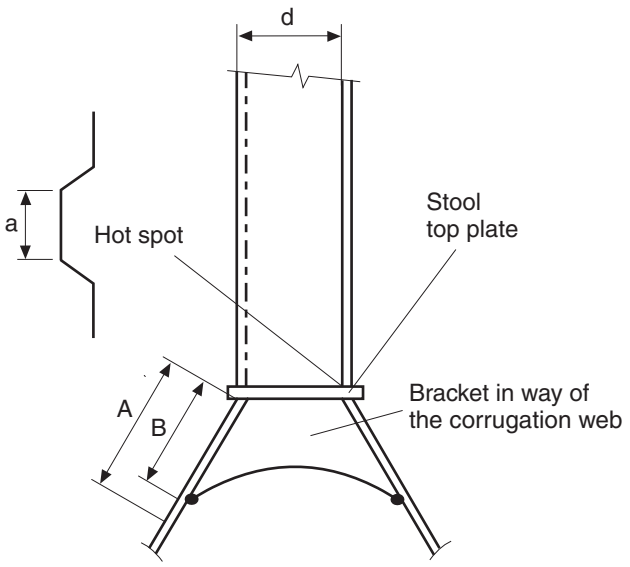
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 51 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Brackets below stool top plate	Sheet 5.13



$A \geq a$,
B = bracket dimension.

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_B = bracket thickness,

$t_A = \min(t_F, t_T, t_S)$.

$t_B = \min(t_W, t_T, t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$ • $t_S \geq t_F$ in portion A • $t_B \geq t_W$ • $B \geq d$	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_B / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1].	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

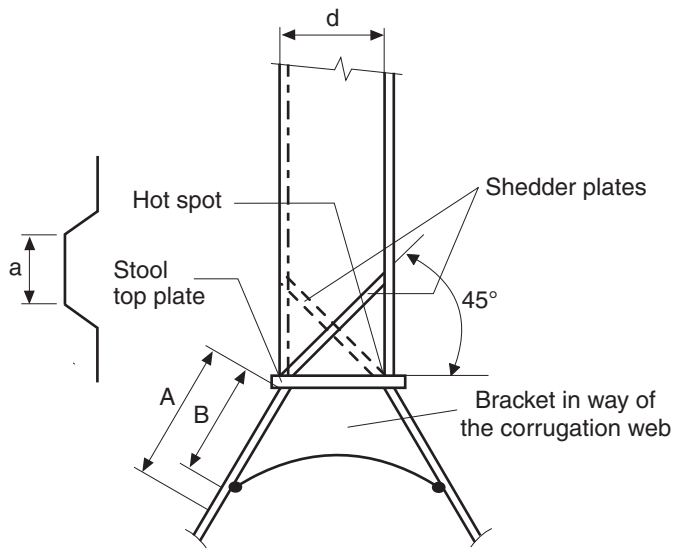
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 52 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45° and brackets below stool top plate	Sheet 5.14



$A \geq a$,
B = bracket dimension.

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,
t_B = bracket thickness,

$t_A = \min(t_F, t_T, t_S)$
$t_B = \min(t_{SH}, t_T, t_S)$
$t_C = \min(t_W, t_T, t_B)$.

SCANTLINGS:

- $t_T \geq t_F$
- $t_{SH} \geq 0{,}75\ t_F$
- $t_S \geq t_F$ in portion A
- $t_B \geq t_W$
- $B \geq d$

FATIGUE:

Fatigue check to be carried out according to NI611.

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1{,}5\ t_F$.
- Corrugation radius according to Ch 13, Sec 1, [3.2.1].
- In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

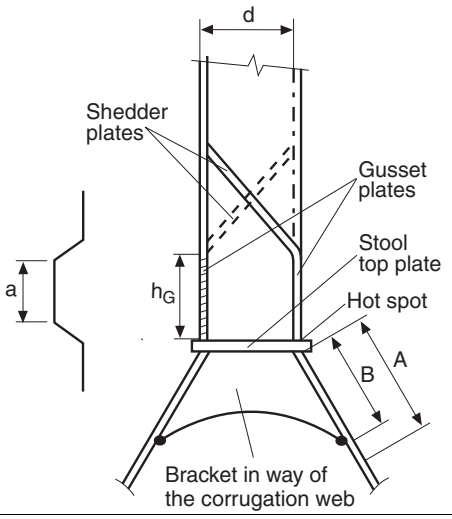
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 53 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates and brackets below stool top plate	Sheet 5.15



$A \geq a$,
B = bracket dimension.

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_G = gusset plate thickness,
t_{SH} = shedder plate thickness,
t_B = bracket thickness,

$t_A = \min(t_F, t_T, t_S)$
$t_B = \min(t_G, t_T, t_S)$
$t_C = \min(t_W, t_T, t_B)$.

SCANTLINGS:

- $t_T \geq t_F$
- $t_S \geq t_F$ in portion A
- $t_G \geq t_F$
- $t_{SH} \geq 0,75\ t_F$
- $t_B \geq t_W$
- $h_G \geq a / 2$
- $B \geq d$

FATIGUE:

Fatigue check not required.

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$.
- Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$.
- Corrugation radius according to Ch 13, Sec 1, [3.2.1].
- In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

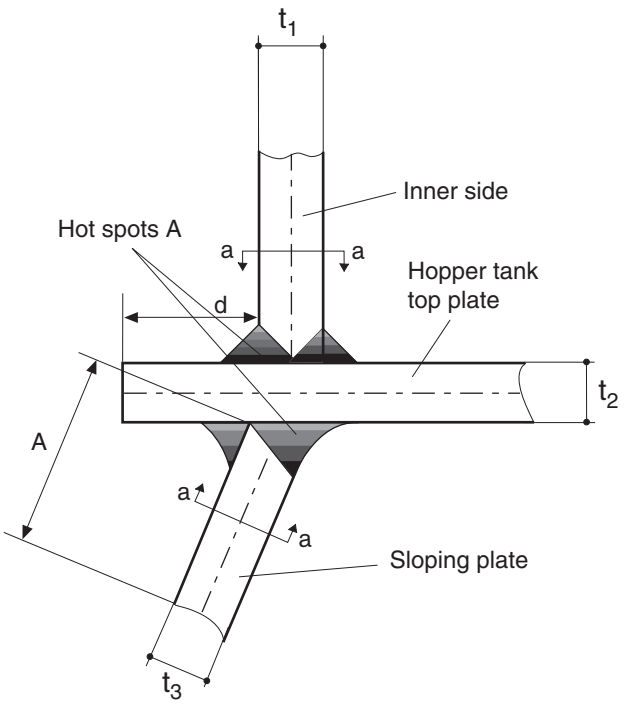
WELDING AND MATERIALS:

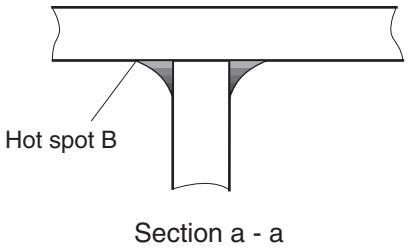
- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - gusset plates generally to be connected with full penetration to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings) and with one side penetration, or equivalent, to corrugations and shedder plates,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the gusset plates,
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 54 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.1





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

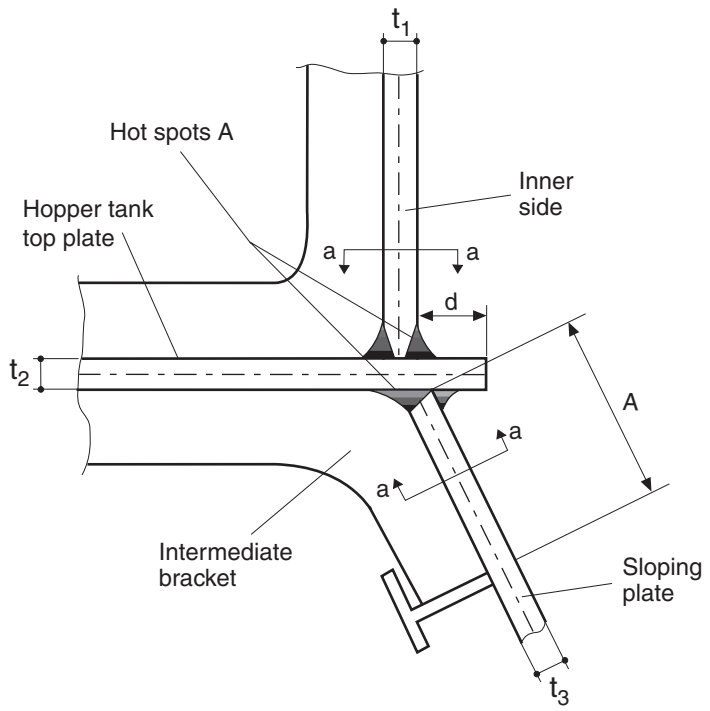
SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

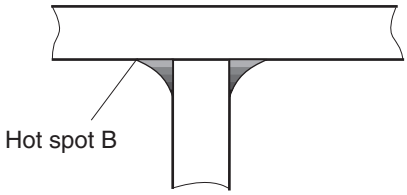
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 55 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.2





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

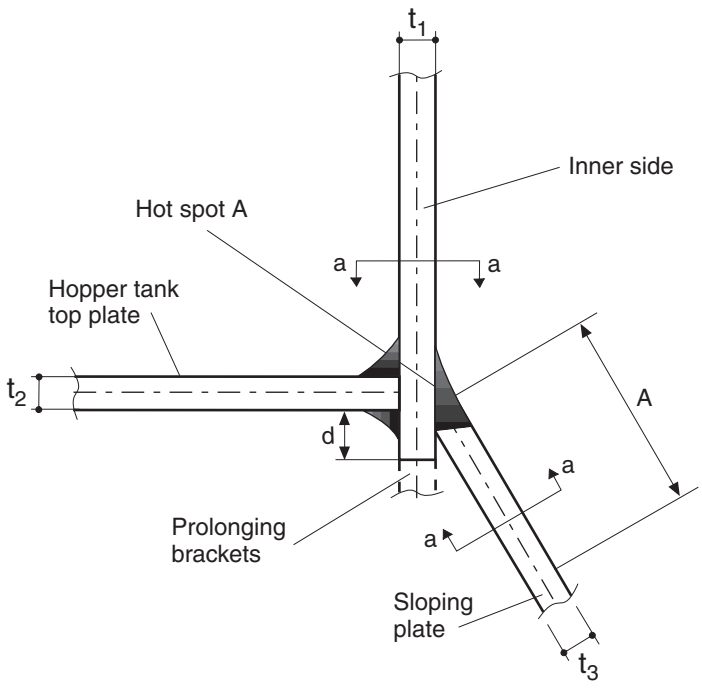
SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between inner side plating and hopper tank sloping plate ≤ t_A / 3. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t_B / 3. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

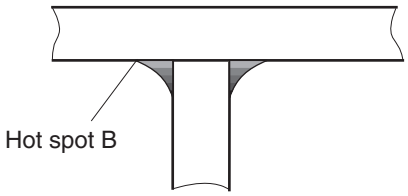
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 56 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Prolonging brackets	Sheet 6.3





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

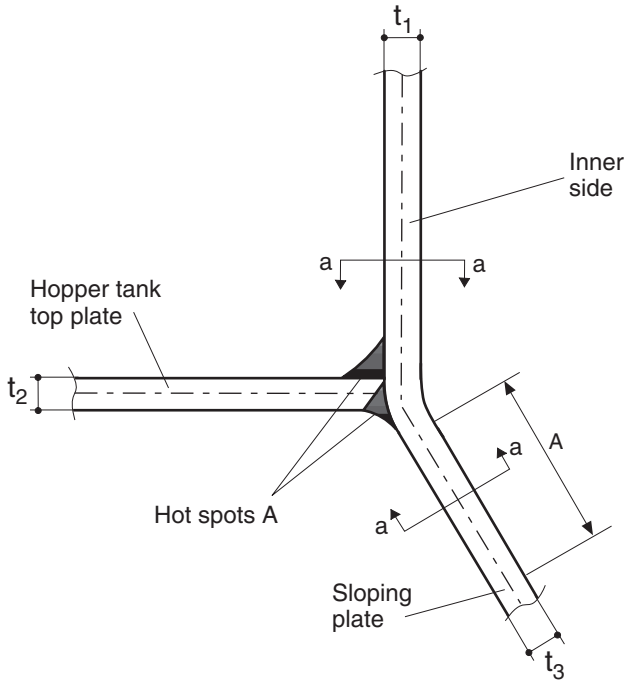
SCANTLINGS:	FATIGUE:
• d ≥ 50 mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of prolonging brackets ≥ t_1 . • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate ≤ t_A / 3. • Misalignment (median lines) between members above and below hopper tank top plate ≤ t_B / 3.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

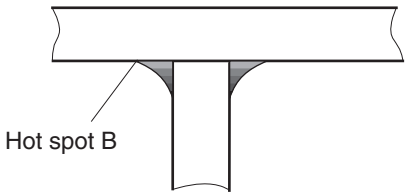
WELDING AND MATERIALS:

- Welding requirements:
  - hopper tank sloping plate to be connected with full penetration welding to the inner side plating. Root gap to be checked along the production steps as appropriate,
  - prolonging brackets to be connected with full penetration welding to inner side plating,
  - full penetration weld of hopper tank sloping plate to inner side plating to be welded first,
  - welding sequence against lamellar tearing in the inner side plating is recommended.
- Material requirements:
  - the lower strake of inner side plating is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating,
  - material properties of prolonging brackets to be not less than those of the inner side plating.

Table 57 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Radiused construction	Sheet 6.4





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

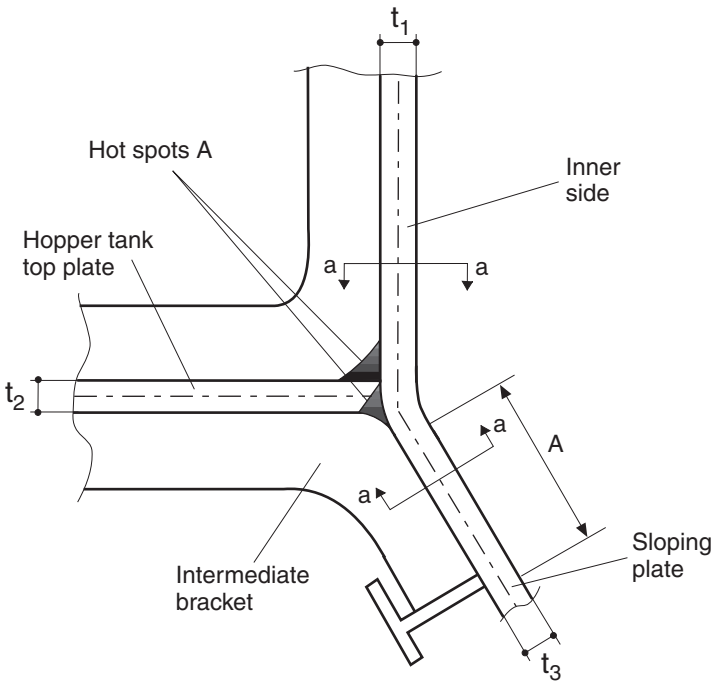
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

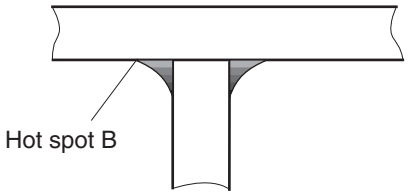
WELDING AND MATERIALS:

- Welding requirements:
  - welding sequence against the risk of lamellar tearing in the inner side plate is recommended,
  - weld finishing well faired to the inner side plating and hopper tank sloping plate.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 58 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.5





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

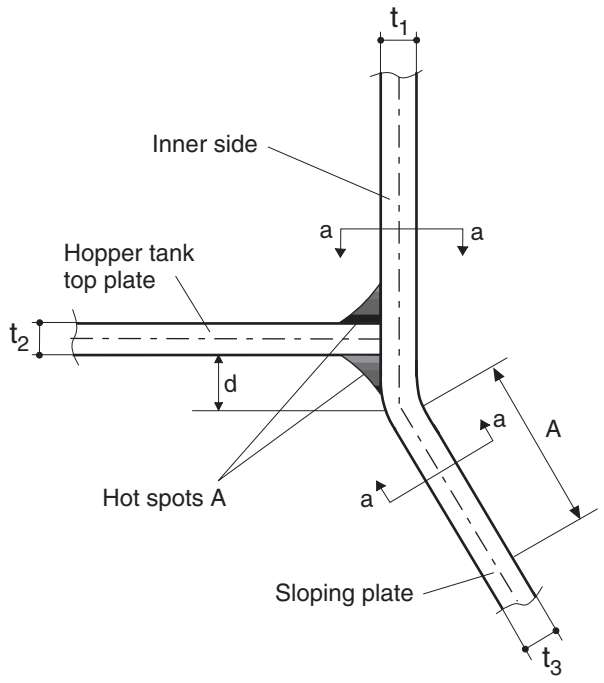
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate ≤ t_A / 3. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t_B / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

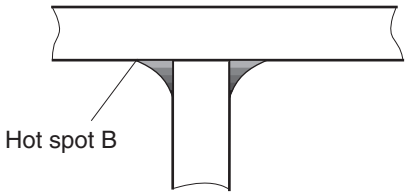
WELDING AND MATERIALS:

- Welding requirements:
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - welding sequence against the risk of lamellar tearing in the inner side plate is recommended,
  - weld finishing well faired to the inner side plating and hopper tank sloping plate.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 59 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Radiused construction	Sheet 6.6





Section a - a

A = distance to be taken not less than the spacing of side transverses

t = minimum among:
- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

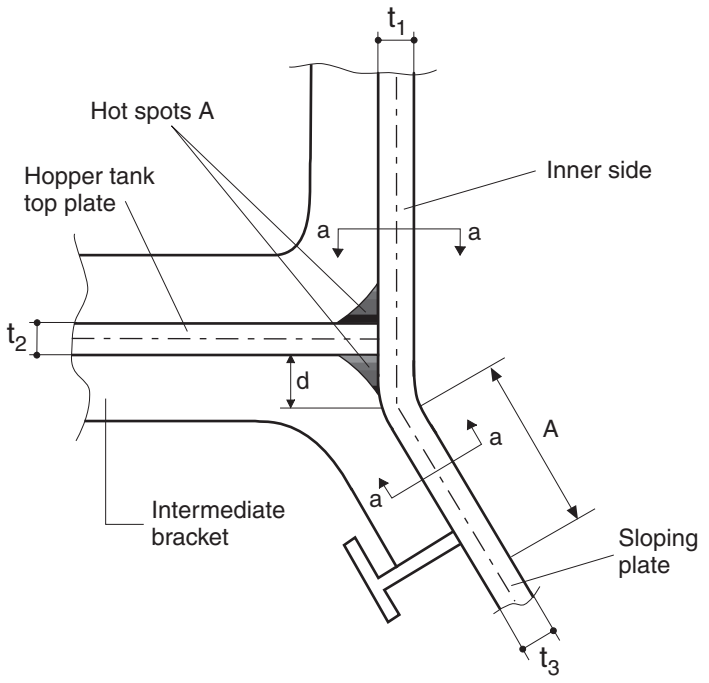
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between members above and below hopper tank top plate ≤ t / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

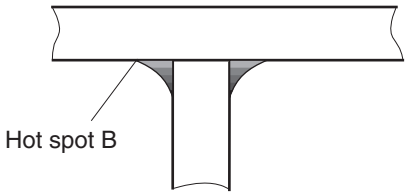
WELDING AND MATERIALS:

Material requirements:
- where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation
- material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 60 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.7





Section a - a

A = distance to be taken not less than the spacing of side transverses

t = minimum among:
- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

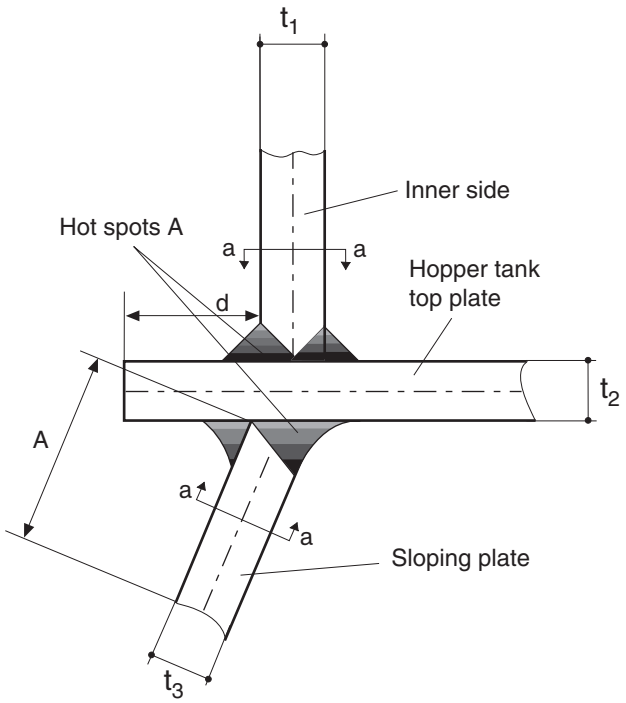
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

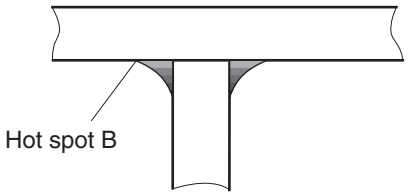
WELDING AND MATERIALS:

Material requirements:
- where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation
- material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 61 : LIQUEFIED GAS CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.8





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

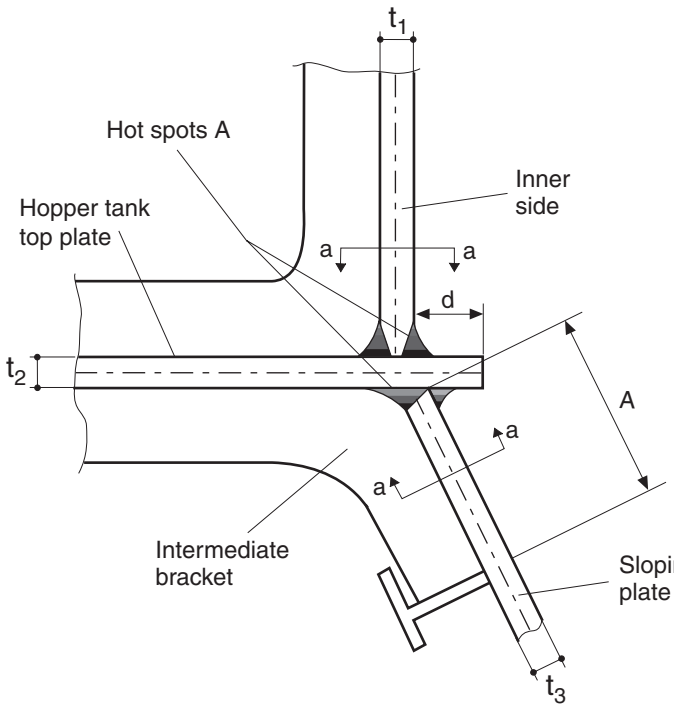
SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between inner side plating and hopper tank sloping plate ≤ t_A / 3, max 6 mm. • Misalignment (median lines) between members above and below hopper tank top plate ≤ t_B / 3, max 6 mm.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

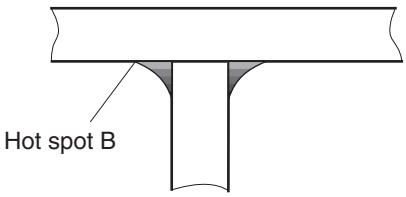
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate to be connected with full penetration welding to hopper tank top plate, except in way of void spaces where partial penetration may be accepted,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 62 : LIQUEFIED GAS CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.9





Section a - a

A = distance to be taken not less than the spacing of side transverses

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

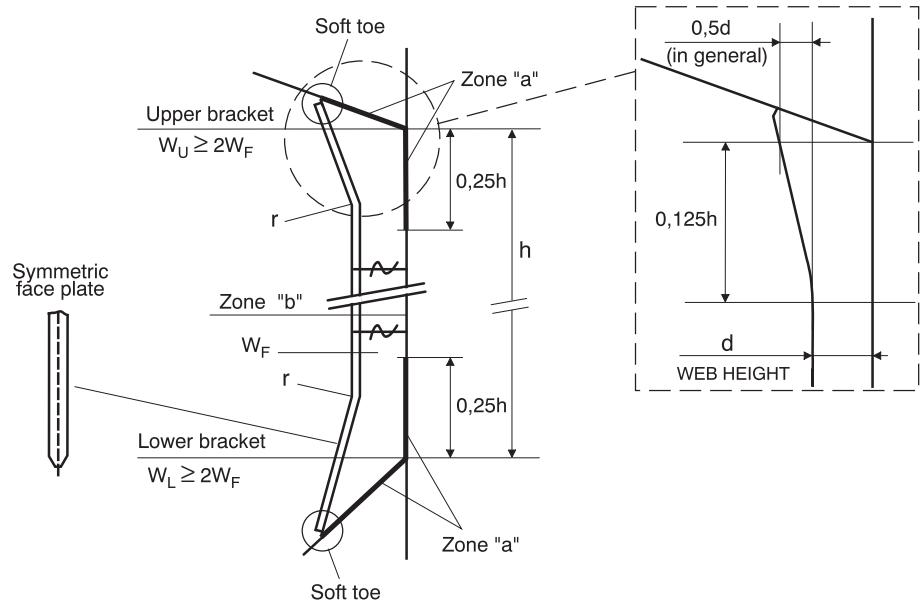
SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out according to NI611.
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between inner side plating and hopper tank sloping plate ≤ t_A / 3, max 6 mm. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t_B / 3, max 6 mm. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate to be connected with full penetration welding to hopper tank top plate, except in way of void spaces where partial penetration may be accepted,
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 63 : BULK CARRIERS

AREA 7: Side frames	Connection of side frames with hopper and topside tanks - Symmetric face plate frame with integral brackets	Sheet 7.1



t_w = fitted thickness, in mm, of side frame web

b_F = bracket flange width, in mm

$t_{w,min} = (7,0 + 0,03\ L_1)$ mm

t_F = bracket flange thickness, in mm.

SCANTLINGS:

- Thickness of lower bracket, in mm, ≥ max (t_w , $t_{w,\ min}$ + 2).
- Thickness of upper bracket, in mm, ≥ max (t_w , $t_{w,\ min}$).
- Section modulus of the frame with the upper or lower bracket, at the locations shown in the sketch, to be not less than twice the section modulus required for the frame mid-span area.
- Dimensions of lower and upper brackets to be not less than those shown in the sketch.
- Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper tanks and upper wing tanks by connecting brackets.
- Frame flange to be curved (not knuckled) at the connection with the end brackets, $r \geq 0,4\ b_F^2 / t_F$.
- Ends of flange to be sniped.

FATIGUE:

Fatigue check not required.

CONSTRUCTION:

- Misalignment between frame web and the connecting brackets inside hopper tank and upper wing tank ≤ t / 3, where t is the minimum thickness among those of the connected elements.
- Soft toe: tapering of frame flange at ends: thickness 1:3, width 1:5.

NDE:

The following NDE are required:

- VE 100%, with particular care for fillet shape and undercuts on the plating at the soft toes,
- ME or dye penetrant depending on the results of VE.

WELDING AND MATERIALS:

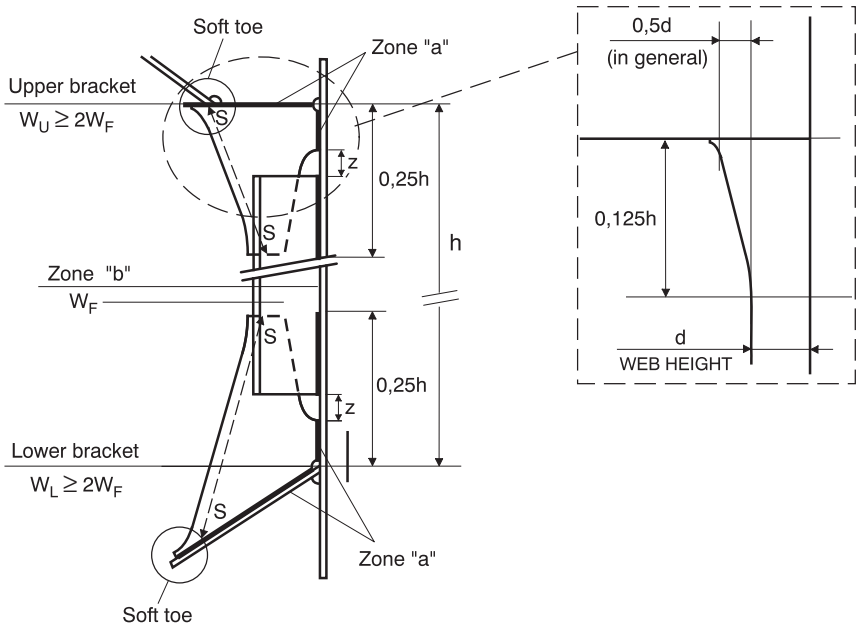
Welding requirements:

- frames and brackets to be connected with continuous fillet welding to side plating, hopper tank and upper wing tank plating, with throat thickness to be not less than:
  - 0,45 t in “zone a”,
  - 0,40 t in “zone b”,

  where t is the minimum thickness between those of the two connected elements,
- welding sequence to minimise restraints at the frame butt joints, i.e.:
  - leaving about 200 mm unwelded, each side of butt joint, of the connections between frame web and side plating and between frame web and flange,
  - performing the frame butt joints,
  - completing the fillet welding,
- turn the fillet weld all around the end of integral brackets and scallops giving an elongated shape, well faired to the plating,
- avoid burned notches at the scallops, if existing, in way of frame flange butt joints; if scallops not adopted, care to be taken to avoid end defects at web butt joints.

Table 64 : BULK CARRIERS

AREA 7: Side frames	Connection of side frames with hopper and topside tanks - Non symmetric face plate frame with separate brackets	Sheet 7.2



This solution is permitted only for ships less than 190 m in length with side frames built in normal strength steel.

t_w = fitted thickness, in mm, of side frame web

$t_{w,min} = (7,0 + 0,03\ L_1)$ mm

b_F = bracket flange width, in mm

t_F = bracket flange thickness, in mm.

SCANTLINGS:

- Thickness of lower bracket, in mm, ≥ max (t_w , $t_{w,\ min}$ + 2).
- Thickness of upper bracket, in mm, ≥ max (t_w , $t_{w,\ min}$).
- Section modulus of the frame with the upper or lower bracket, at the locations shown in the sketch, to be not less than twice the section modulus required for the frame mid-span area.
- Dimensions of lower and upper brackets to be not less than those shown in the sketch.
- Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper tanks and upper wing tanks by connecting brackets.
- Ends of flange to be sniped.
- z ≤ 50 mm.

FATIGUE:

Fatigue check not required.

CONSTRUCTION:

- Misalignment between frame brackets and the connecting brackets inside hopper tank and upper wing tank ≤ t / 3, where t is the minimum thickness among those of the connected elements.
- Bracket overlap: ≥ 1,5 d, in mm.
- Soft toe: tapering of frame flange at ends: thickness 1:3, width 1:5.

NDE:

The following NDE are required:

- VE 100%, with particular care for fillet shape and undercuts on the plating at the soft toes,
- ME or dye penetrant depending on the results of VE.

WELDING AND MATERIALS:

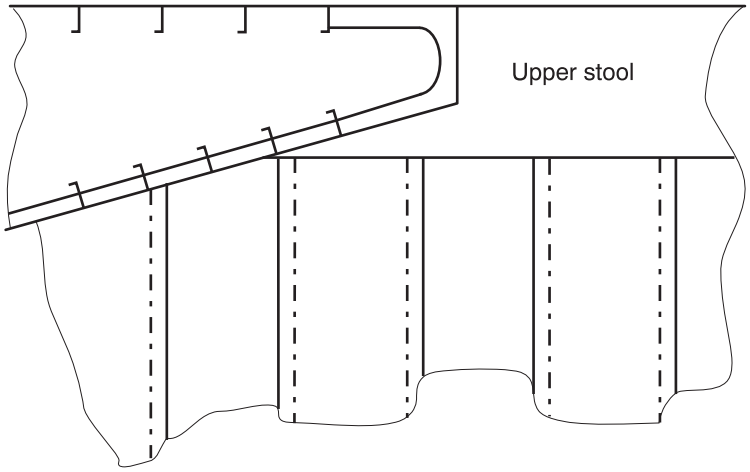
Welding requirements:

- frames and brackets to be connected with continuous fillet welding to side plating, hopper tank and upper wing tank plating, with throat thickness to be not less than:
  - 0,45 t in “zone a”,
  - 0,40 t in “zone b”,

  where t is the minimum thickness between those of the two connected elements,
- brackets to be connected with continuous fillet welding to frames, with throat thickness to be not less than half thickness of brackets,
- welding procedure of frame butt joint, if any, to be approved with particular care for the welding of the bulbs and of the corner in case of L sections,
- welding sequence to minimise restraints at the frame butt joints, i.e.:
  - leaving about 200 mm unwelded, each side of butt joint, of the connections between frame web and side plating and between frame web and flange,
  - performing the frame butt joints,
  - completing the fillet welding,
- turn the fillet weld all around the end of integral brackets and scallops giving an elongated shape, well faired to the plating,
- avoid burned notches at fillet welds of overlapped joints and at scallops.

Table 65 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 8: Topside tanks	Connection of transverse corrugated bulkheads with topside tanks	Sheet 8.1



t = minimum thickness among those of the connected elements.

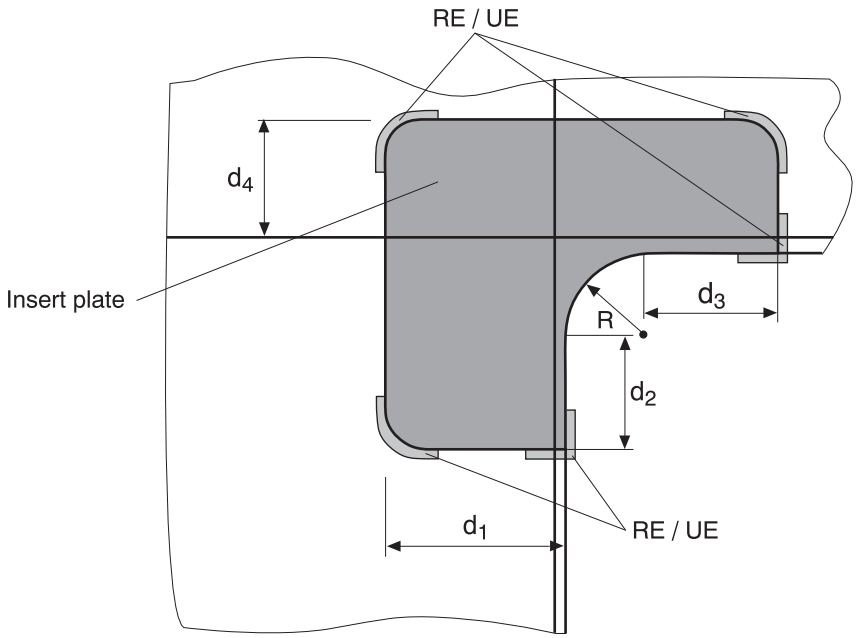
SCANTLINGS:	FATIGUE:
A transverse web or an intercostal reinforcement is to be fitted inside the topside tank in line with the flanges of corrugation and the upper stool side plating. Its arrangement is to be indicated in the approved plan.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
Misalignments between: - transverse web or intercostal reinforcement fitted inside the upper wing tank and corrugation flanges, - transverse web or intercostal reinforcement fitted inside the upper wing tank and upper stool side plating, - upper stool side plating and corrugation flanges, are to be ≤ t / 3.	The following NDE are required: • VE 100%, with particular care for fillet shape and undercuts on the plating, • UE 100% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- bulkhead plating to be connected with continuous fillet welding to topside plating and upper stool plating, full penetration weld is recommended in way of corner of vertical and inclined plating of upper wing tank,
- throat thickness = 0,45 t, where t is the minimum thickness between those of the two connected elements,
- gap at T joint reduced to the minimum,
- welding sequence to minimise restraints.

Table 66 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS, CONTAINER SHIPS

AREA 9: Hatch corners	Deck plating in way of hatch corners	Sheet 9.1



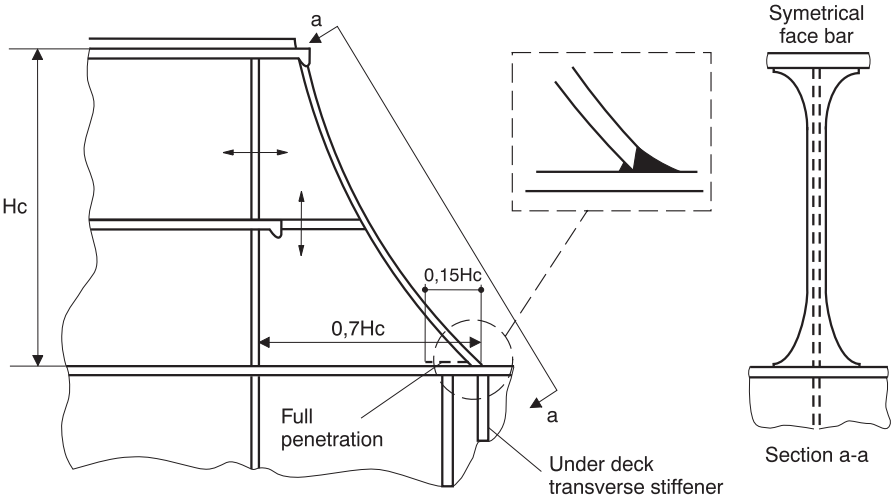
SCANTLINGS:	FATIGUE:
• Insert plates with circular profiles in general to be fitted in way of corners of hatchways located within the cargo area. The radius of circular corners to be in accordance with Ch 4, Sec 5, [6.5.1] • Insert plates not required in way of corners of hatchways located in the above positions, where corners have an elliptical or parabolic profile according to Ch 4, Sec 5, [6.5.2]. • Where insert plates are required, their thickness to be defined according to Ch 4, Sec 5, [6.5.3] and their extension to be such that d_1, d_2, d_3 and $d_4 \geq s$, s being the ordinary frame spacing.	Fatigue check to be carried out according to NI611
CONSTRUCTION:	**NDE:**
• Corners of insert plates to be rounded, unless corresponding to joints of deck strakes. • Insert cut edges to be carefully executed.	The following NDE are required: • VE 100%, • RE / UE in areas indicated in the sketch.

WELDING AND MATERIALS:

- Welding requirements:
  - welds recommended to be continued on auxiliary pieces temporarily fitted at the free end of each joint, to be cut away; the joint ends are to be carefully ground.
- Materials requirements:
  - insert plate material of same or higher quality than the adjacent deck plating, depending on the insert thickness according to Ch 4, Sec 1, [2].

Table 67 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS, CONTAINER SHIPS

AREA 9: Hatch corners	Ends of longitudinal hatch coamings - Bracket welded to deck plating	Sheet 9.2



t_A = minimum among:
- thickness of bracket flange at lower end,
- deck plating thickness,
- under deck transverse stiffener web thickness,

t_B = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.

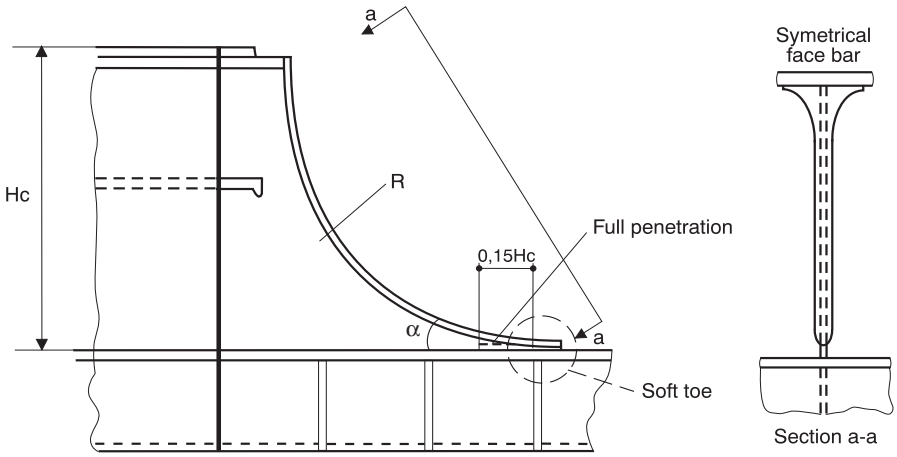
SCANTLINGS:	FATIGUE:
An additional under deck transverse stiffener is to be fitted in way of termination bracket toe, where the toe is clear of normal stiffener.	Fatigue check to be carried out according to NI611
CONSTRUCTION:	**NDE:**
• Misalignment between bracket flange and under deck transverse stiffener ≤ t_A / 3. • Misalignment between bracket and under deck longitudinal ≤ t_B / 3.	The following NDE are required: • VE 100%, with particular care for the weld shape and undercuts on deck plating at the bracket flange connection, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- bracket flange to be connected with full penetration welding to deck plating, with half V bevel and weld shape elongated on deck plating (see sketch),
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel,
- under deck transverse stiffener to be connected with full penetration welding to deck plating in way of the bracket flange,
- care is to be taken to ensure soundness of the crossing welds at the bracket toe, if the case, adopting small scallop to be closed by welding.

Table 68 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS, CONTAINER SHIPS

AREA 9: Hatch corners	Ends of longitudinal hatch coamings - Bracket sniped at deck plating	Sheet 9.3



t = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.

SCANTLINGS:	FATIGUE:
R ≥ 500 mm. α ≤ 30°.	Fatigue check to be carried out according to NI611
CONSTRUCTION:	**NDE:**
• Misalignment between bracket and under deck longitudinal ≤ t_B / 3. • Soft toe: tapering of bracket flange at ends: thickness 1:3, width 1:5.	The following NDE are required: • VE 100%, with particular care for the weld shape and undercuts on deck plating, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel.

NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part C
Machinery, Electricity, Automation and Fire Protection

Chapter 1	Machinery
Chapter 2	Electrical Installations
Chapter 3	Automation
Chapter 4	Fire Protection, Detection and Extinction

July 2025

Table of Content

Chapter 1 Machinery

Section 1 General Requirements

1 General 39

1.1 Application
1.2 Additional requirements
1.3 Documentation to be submitted
1.4 Definitions

2 Design and construction 39

2.1 General
2.2 Materials, welding and testing
2.3 Vibrations
2.4 Ambient conditions - Inclinations
2.5 Ambient conditions - Temperatures
2.6 Ambient conditions - Ship accelerations and motions
2.7 Evaluation of equipment suitability
2.8 Installation and operation
2.9 Power of machinery
2.10 Astern power
2.11 Safety devices
2.12 Fuels

3 Arrangement and installation on board 42

3.1 General
3.2 Floor plating and gratings
3.3 Bolting down
3.4 Safety devices on moving parts
3.5 Gauges
3.6 Ventilation in machinery spaces
3.7 Hot surfaces and fire protection
3.8 Machinery remote control, alarms and safety systems

4 Tests and trials 44

4.1 Works tests
4.2 Trials on board

Section 2 Diesel Engines

1 General 45

1.1 Application
1.2 Documentation flow for diesel engine
1.3 Definitions

2 Design and construction 50

2.1 Materials and welding
2.2 Crankshaft
2.3 Crankcase
2.4 Scavenge manifolds
2.5 Systems
2.6 Starting air system
2.7 Control and monitoring

3 Arrangement and installation 58

3.1 Starting arrangements
3.2 Turning gear
3.3 Trays
3.4 Exhaust gas system

Table of Content

4 Type tests, material tests, workshop inspection and testing, certification 59

4.1 Type testing
4.2 Material and non-destructive tests for engine components
4.3 Factory Acceptance Test
4.4 Certification

Section 3 Pressure Equipment

1 General 71

1.1 Principles
1.2 Application
1.3 Definitions
1.4 Classes
1.5 Applicable Rules
1.6 Documentation to be submitted

2 Design and construction - Scantlings of pressure parts 76

2.1 General
2.2 Materials
2.3 Permissible stresses
2.4 Cylindrical, spherical and conical shells with circular cross-sections subject to internal pressure
2.5 Dished heads subject to pressure on the concave (internal) side
2.6 Dished heads subject to pressure on the convex (external) side
2.7 Flat heads
2.8 Openings and branches (nozzles)
2.9 Regular pattern openings - Tube holes
2.10 Water tubes, superheaters and economiser tubes of boilers
2.11 Additional requirements for fired pressure vessels
2.12 Additional requirements for vertical boilers and fire tube boilers
2.13 Bottles containing pressurised gases
2.14 Heat exchangers

3 Design and construction - Equipment 105

3.1 All pressure vessels
3.2 Boilers and steam generators
3.3 Thermal oil heaters and thermal oil installation
3.4 Special types of pressure vessels
3.5 Other pressure vessels

4 Design and construction - Fabrication and welding 110

4.1 General
4.2 Welding design
4.3 Miscellaneous requirements for fabrication and welding
4.4 Preparation of parts to be welded
4.5 Tolerances after construction
4.6 Preheating
4.7 Post-weld heat treatment
4.8 Welding samples
4.9 Specific requirements for class 1 vessels
4.10 Specific requirements for class 2 vessels
4.11 Specific requirements for class 3 vessels

5 Design and construction - Control and monitoring 121

5.1 Boiler control and monitoring system
5.2 Pressure vessel instrumentation
5.3 Thermal oil heater control and monitoring
5.4 Control and monitoring requirements

6 Additional requirements for shell type exhaust gas heated economizers that may be isolated from the steam plant system 126

6.1 Application
6.2 Design and construction
6.3 Pressure relief
6.4 Pressure indication
6.5 Lagging
6.6 Feed water
6.7 Operating instructions

7 Design requirements for boil-off gas combustion units 127

7.1 Operating cases
7.2 Availability
7.3 Gas combustion equipment
7.4 Gas supply
7.5 Instrumentation and safeties

8 Arrangement and installation 128

8.1 Foundations
8.2 Boilers
8.3 Pressure vessels
8.4 Thermal oil heaters

9 Material test, workshop inspection and testing, certification 129

9.1 Material testing
9.2 Workshop inspections
9.3 Hydrostatic tests
9.4 Certification

Section 4 Steam Turbines

1 General 132

1.1 Application
1.2 Documentation to be submitted

2 Design and construction 132

2.1 Materials
2.2 Design and constructional details
2.3 Welded fabrication
2.4 Control, monitoring and shut-off devices

3 Arrangement and installation 136

3.1 Foundations
3.2 Jointing of mating surfaces
3.3 Piping installation
3.4 Hot surfaces
3.5 Alignment
3.6 Circulating water system
3.7 Gratings
3.8 Drains
3.9 Instruments

4 Material tests, workshop inspection and testing, certification 136

4.1 Material tests
4.2 Inspections and testing during construction
4.3 Certification

Section 5 Gas Turbines

1 General 139

1.1 Application
1.2 Definition of rated power
1.3 Documentation to be submitted

Table of Content

2 Design and Construction 140

2.1 Materials
2.2 Stress analyses
2.3 Design and constructional details
2.4 Welded fabrication
2.5 Control, monitoring and shut-off devices

3 Arrangement and installation 143

3.1 Foundations
3.2 Joints of mating surfaces
3.3 Piping installation
3.4 Hot surfaces
3.5 Alignment
3.6 Gratings
3.7 Drains
3.8 Instruments

4 Material tests, workshop inspection and testing, certification 144

4.1 Type tests - General
4.2 Type tests of turbines not admitted to an alternative inspection scheme
4.3 Type tests of turbines admitted to an alternative inspection scheme
4.4 Material tests
4.5 Inspections and testing during construction
4.6 Certification

5 Additional requirements for dual fuel (DF) gas turbines 148

5.1 Design principles
5.2 Control, alarms and safety systems
5.3 Type tests

Section 6 Gearing

1 General 150

1.1 Application
1.2 Documentation to be submitted

2 Design of gears - Determination of the load capacity of cylindrical gears 153

2.1 Symbols, units, definitions
2.2 Principle
2.3 General influence factors
2.4 Calculation of surface durability
2.5 Calculation of tooth bending strength
2.6 Calculation of scuffing resistance

3 Design of gears - Determination of the load capacity of bevel gears 178

3.1 Symbols, units, definitions
3.2 Principle
3.3 General influence factors
3.4 Calculation of surface durability
3.5 Calculation of tooth bending strength
3.6 Calculation of scuffing resistance

4 Design and construction - except tooth load capacity 191

4.1 Materials
4.2 Teeth
4.3 Wheels and pinions
4.4 Shafts and bearings
4.5 Casings
4.6 Lubrication
4.7 Control and monitoring

5 Installation 195

5.1 General
5.2 Fitting of gears

Table of Content

6 Certification, inspection and testing 195

6.1 General
6.2 Workshop inspection and testing

Section 7 Main Propulsion Shafting

1 General 196

1.1 Application
1.2 Documentation to be submitted

2 Design and construction 197

2.1 Materials
2.2 Shafts - Scantling
2.3 Liners
2.4 Stern tube bearings
2.5 Couplings
2.6 Design of oil control systems for clutches
2.7 Monitoring

3 Arrangement, installation and shaft alignment 203

3.1 General
3.2 Protection of propeller shaft against corrosion
3.3 Shaft alignment

4 Material tests, workshop inspection and testing, certification 206

4.1 Material and non-destructive tests, workshop inspections and testing
4.2 Certification

Section 8 Propellers

1 General 207

1.1 Application
1.2 Definitions
1.3 Documentation to be submitted

2 Design and construction 209

2.1 Materials
2.2 Solid propellers - Blade thickness
2.3 Built-up propellers and controllable pitch propellers
2.4 Skewed propellers
2.5 Ducted propellers
2.6 Features

3 Arrangement and installation 213

3.1 Fitting of propeller on the propeller shaft

4 Testing and certification 216

4.1 Material tests
4.2 Testing and inspection
4.3 Certification

Section 9 Shaft Vibrations

1 General 217

1.1 Application

2 Design of systems in respect of vibrations 217

2.1 Principle
2.2 Modifications of existing plants

3 Torsional vibrations 217
3.1 Documentation to be submitted
3.2 Definitions, symbols and units
3.3 Calculation principles
3.4 Permissible limits for torsional vibration stresses in crankshaft, propulsion shafting and other transmission shafting
3.5 Permissible vibration levels in components other than shafts
3.6 Torsional vibration measurements
4 Bending vibrations 222
4.1 Application
4.2 Documentation to be submitted
4.3 Calculation principles
4.4 Bending vibration measurements
5 Axial vibrations 224
5.1 General
5.2 Documentation to be submitted
5.3 Calculation principles
5.4 Axial vibration measurements
Section 10 Piping Systems
1 General 226
1.1 Application
1.2 Documentation to be submitted
1.3 Definitions
1.4 Symbols and units
1.5 Class of piping systems
2 General requirements for design and construction 229
2.1 Materials
2.2 Thickness of pressure piping
2.3 Calculation of high temperature pipes
2.4 Junction of pipes
2.5 Protection against overpressure
2.6 Flexible hoses and expansion joints
2.7 Valves and accessories
2.8 Sea inlets and overboard discharges
2.9 Control and monitoring
3 Welding of steel piping 246
3.1 Application
3.2 General
3.3 Design of welded joints
3.4 Preparation of elements to be welded and execution of welding
3.5 Post-weld heat treatment
3.6 Inspection of welded joints
4 Bending of pipes 250
4.1 Application
4.2 Bending process
4.3 Heat treatment after bending
5 Arrangement and installation of piping systems 251
5.1 General
5.2 Location of tanks and piping system components
5.3 Passage through bulkheads or decks
5.4 Independence of lines
5.5 Prevention of progressive flooding
5.6 Provision for expansion
5.7 Supporting of the pipes
5.8 Protection of pipes
5.9 Valves, accessories and fittings
5.10 Additional arrangements for flammable fluids

Table of Content

6 Bilge systems 257

6.1 Application
6.2 Principle
6.3 Design of bilge systems
6.4 Draining of cargo spaces
6.5 Draining of machinery spaces
6.6 Draining of dry spaces other than cargo holds and machinery spaces
6.7 Bilge pumps
6.8 Size of bilge pipes
6.9 Bilge accessories
6.10 Materials
6.11 Bilge piping arrangement
6.12 Water ingress detection

7 Ballast systems 266

7.1 Principles
7.2 Ballast pumping arrangement
7.3 Ballast water exchange at sea

8 Scuppers and sanitary discharges 269

8.1 Application
8.2 Principle
8.3 Drainage from spaces below the freeboard deck or within enclosed superstructures and deckhouses on the freeboard deck
8.4 Drainage of superstructures or deckhouses not fitted with efficient weathertight doors
8.5 Drainage of enclosed cargo spaces situated on the bulkhead deck or on the freeboard deck
8.6 Drainage of cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion
8.7 Drainage and pumping arrangements for vehicle, special category and ro-ro spaces protected by fixed pressure water-spraying systems
8.8 Arrangement of discharges led overboard
8.9 Summary table of overboard discharge arrangements
8.10 Valves and pipes
8.11 Arrangement of scuppers and sanitary discharge piping

9 Air, sounding and overflow pipes 274

9.1 Air pipes
9.2 Sounding pipes
9.3 Overflow pipes
9.4 Constructional requirements applying to sounding, air and overflow pipes

10 Cooling systems 281

10.1 Application
10.2 Principle
10.3 Design of sea water cooling systems
10.4 Design of fresh water cooling systems
10.5 Design of oil cooling systems
10.6 Control and monitoring
10.7 Arrangement of cooling systems

11 Fuel oil systems 284

11.1 Application
11.2 Principle
11.3 General
11.4 Design of fuel oil filling and transfer systems
11.5 Arrangement of fuel oil tanks and bunkers
11.6 Design of fuel oil tanks and bunkers
11.7 Design of fuel oil heating systems
11.8 Design of fuel oil treatment systems
11.9 Design of fuel supply systems
11.10 Control and monitoring
11.11 Construction of fuel oil piping systems
11.12 Arrangement of fuel oil piping systems

Table of Content

12 Lubricating oil systems 292

12.1 Application
12.2 Principle
12.3 General
12.4 Design of engine lubricating oil systems
12.5 Design of steam turbine lubrication systems
12.6 Design of lubricating oil tanks
12.7 Control and monitoring
12.8 Construction of lubricating oil piping systems

13 Thermal oil systems 295

13.1 Application
13.2 Principle
13.3 General
13.4 Design of thermal oil heaters and heat exchangers
13.5 Design of storage, expansion and draining tanks
13.6 Design of circulation and heat exchange systems
13.7 Control and monitoring
13.8 Construction of thermal oil piping systems
13.9 Thermal oil piping arrangements

14 Hydraulic systems 298

14.1 Application
14.2 Principles
14.3 General
14.4 Design of hydraulic pumps and accessories
14.5 Design of hydraulic tanks and other components
14.6 Control and monitoring

15 Steam systems 300

15.1 Application
15.2 Principle
15.3 Design of steam lines

16 Boiler feed water and condensate systems 301

16.1 Application
16.2 Principle
16.3 Design of boiler feed water systems
16.4 Design of condensate systems
16.5 Control and monitoring
16.6 Arrangement of feed water and condensate piping
16.7 Arrangement of feed water system for shell type exhaust gas heated economizer

17 Compressed air systems 303

17.1 Application
17.2 Principle
17.3 Design of starting air systems
17.4 Design of compressed air systems for essential services
17.5 Design of air compressors
17.6 Control and monitoring of compressed air systems
17.7 Materials
17.8 Arrangement of compressed air piping systems

18 Exhaust gas systems 306

18.1 General
18.2 Design of exhaust systems
18.3 Materials
18.4 Arrangement of exhaust piping systems

19 Oxyacetylene welding systems 308

19.1 Application
19.2 Definitions
19.3 Design of oxyacetylene welding systems
19.4 Arrangement of oxyacetylene welding systems

Table of Content

20 Certification, inspection and testing of piping systems 310

20.1 Application
20.2 Type tests of flexible hoses and expansion joints
20.3 Type tests of air pipe closing appliances
20.4 Testing of materials
20.5 Hydrostatic testing of piping systems and their components
20.6 Testing of piping system components during manufacturing
20.7 Inspection and testing of piping systems

Section 11 Exhaust Gas Pollution Prevention System

1 General 318

1.1 Application
1.2 Definitions
1.3 Documents to be submitted

2 Installation requirements 319

2.1 General
2.2 Installation requirements
2.3 Availability
2.4 Arrangement
2.5 Certification, Inspection and testing

3 Storage and use of SCR reductant 321

3.1 Application
3.2 Storage tank
3.3 Ventilation
3.4 Piping
3.5 Materials
3.6 Protection of crew members

4 Chemical treatment fluids used for exhaust gas cleaning systems 322

4.1 Application
4.2 Storage tank
4.3 Ventilation
4.4 Piping
4.5 Exhaust Gas Cleaning Systems discharge water pipeline
4.6 Materials
4.7 Containment of leakage
4.8 Protection of crew members
4.9 Safety measures against the residues which have hazardous properties

5 Storage and use of other substances mentioned in IMDG Code 324

5.1 Application
5.2 Risk analysis
5.3 Containment of leakage
5.4 Storage tank
5.5 Ventilation
5.6 Piping

Section 12 Onboard Carbon Capture and Storage Systems

1 General 326

1.1 Application
1.2 Documentation to be submitted
1.3 Definitions
1.4 Risk analysis

2 Design and construction of the carbon capture and storage system 329

2.1 General
2.2 Materials
2.3 Design and construction of the separation system
2.4 Design and construction of the solvent filling, storage, transfer, cooling and heating systems
2.5 Design and construction of the CO2 separation system
2.6 Design of the CO2 compression, liquefaction and storage systems
2.7 Control and monitoring

3 Arrangement and installation of the solvent components 332

3.1 Solvent tanks and piping system
3.2 Absorbers
3.3 Solvent leakage detection
3.4 Bilge system and scuppers
3.5 Ventilation
3.6 Fire safety

4 Arrangement and installation of the CO2 system components 333

4.1 CO2 tanks
4.2 CO2 vapour detection
4.3 Ventilation

5 Personal protection 334

5.1 Protective equipment
5.2 Emergency equipment

6 Certification and surveys at works 334

6.1 General
6.2 Type approval
6.3 Inspection and testing

Section 13 Ballast Water Management Systems

1 General 336

1.1 Application
1.2 Acronyms
1.3 Definitions
1.4 Documents to be submitted

2 Installation 341

2.1 General requirements
2.2 Location and arrangement of BWMR and chemical substance storage rooms
2.3 Location of chemical substance storage tanks
2.4 Piping systems
2.5 Electrical and automation systems
2.6 Hazardous areas
2.7 Inert gas systems
2.8 Ventilation systems
2.9 Safe locations for venting
2.10 Personal equipment

3 Additional requirements for tankers and offshore service vessels 346

3.1 Application
3.2 Location of BWMS
3.3 Independent BWMS
3.4 Case of tankers where the fore peak ballast tank and other ballast tanks within the cargo area are served by a common piping system
3.5 Isolation means
3.6 Sampling arrangements
3.7 Acceptability of single BWMS installation on tankers

4 Special requirements for BWMS generating dangerous gas or dealing with dangerous liquids 352

4.1 Application
4.2 BWMS involving the generation of a dangerous gas
4.3 Piping conveying dangerous gas or liquid
4.4 Handling and storage of chemicals and preparations used to treat ballast water

5 Certification 354

5.1 Type approval and design review
5.2 Risk assessment
5.3 Inspection and testing

Section 14 Steering Gear

1 General 357

1.1 Application
1.2 Documentation to be submitted
1.3 Definitions
1.4 Symbols

2 Design and construction 360

2.1 General
2.2 Strength, performance and power operation of the steering gear
2.3 Control of the steering gear
2.4 Availability
2.5 Mechanical components
2.6 Hydraulic system
2.7 Electrical systems
2.8 Alarms and indications

3 Design and construction - Requirements for ships equipped with several rudders 371

3.1 Principle
3.2 Synchronisation

4 Design and construction - Requirements for ships equipped with thrusters as steering means 371

4.1 Principle
4.2 Steering arrangements
4.3 Use of water-jets

5 Arrangement and installation 373

5.1 Steering gear room arrangement
5.2 Rudder actuator installation
5.3 Overload protections
5.4 Means of communication
5.5 Operating instructions

6 Certification, inspection and testing 374

6.1 Type tests of hydraulic pumps
6.2 Testing of materials
6.3 Inspection and tests during manufacturing
6.4 Inspection and tests after completion

Section 15 Thrusters

1 General 376

1.1 Application
1.2 Definitions
1.3 Thrusters intended for propulsion
1.4 Documentation to be submitted

Table of Content

2 Design and Construction 378

2.1 Materials
2.2 Transverse thrusters and azimuth thrusters
2.3 Water-jets
2.4 Alarm, monitoring and control systems

3 Testing and certification 380

3.1 Material tests
3.2 Testing and inspection
3.3 Certification

Section 16 Refrigerating Installations

1 General 381

1.1 Application

2 Minimum design requirements 381

2.1 Refrigerating installation components
2.2 Refrigerants
2.3 Special requirements for ammonia (R717)

Section 17 Turbochargers

1 General 384

1.1 Application
1.2 Documentation to be submitted

2 Design and construction 385

2.1 General
2.2 Containment
2.3 Disc-shaft shrinkage fit
2.4 Alarms and monitoring

3 Certification, inspection and testing 386

3.1 Type tests
3.2 Workshop inspections and testing
3.3 Certification

Section 18 Tests on Board

1 General 388

1.1 Application
1.2 Purpose of shipboard tests
1.3 Documentation to be submitted

2 General requirements for shipboard tests 388

2.1 Trials at the moorings
2.2 Sea trials

3 Shipboard tests for machinery 388

3.1 Conditions of sea trials
3.2 Starting from dead ship conditions
3.3 Navigation and manoeuvring tests
3.4 Tests of boilers
3.5 Tests of diesel engines
3.6 Test of air starting system for main and auxiliary engines
3.7 Tests of steam turbines
3.8 Tests of gas turbines
3.9 Tests of electric propulsion system
3.10 Tests of gears
3.11 Tests of main propulsion shafting and propellers
3.12 Tests of piping systems
3.13 Tests of steering gear

Table of Content

4 Inspection of machinery after sea trials 397

4.1 General
4.2 Diesel engines

Appendix 1 Calculation for Internal Combustion Engine Crankshafts

1 General 400

1.1 Application
1.2 Documentation to be submitted
1.3 Principles of calculation

2 Calculation of alternating stresses 404

2.1 Calculation of alternating stresses due to bending moments and radial forces
2.2 Calculation of alternating torsional stresses

3 Evaluation of stress concentration factors (SCF) 407

3.1 General

4 Additional bending stresses 409

4.1 General

5 Calculation of equivalent alternating stress 410

5.1 General
5.2 Equivalent alternating stresses

6 Calculation of fatigue strength 410

6.1 General

7 Acceptability criteria 411

7.1

8 Calculation of shrink-fits of semi-built crankshaft 411

8.1 General
8.2 Maximum permissible hole in journal pin
8.3 Necessary minimum oversize of shrink-fit
8.4 Maximum permissible oversize of shrink-fit

9 Guidance for calculation of stress concentration factors in the web fillet radii of crankshafts by utilizing FEM 412

9.1 General
9.2 Model requirements
9.3 Load cases

10 Guidance for evaluation of fatigue tests 417

10.1 Introduction
10.2 Evaluation of test results
10.3 Small specimen testing
10.4 Full size testing
10.5 Use of existing results for similar crankshafts

11 Guidance for calculation of surface treated fillets and oil bore outlets 423

11.1 Introduction
11.2 Definition of surface treatment
11.3 Calculation principles
11.4 Introduction hardening
11.5 Nitriding
11.6 Cold forming

12 Calculation of stress concentration factors in the oil bore outlets of crankshafts through utilization of the finite element method 430

12.1 General
12.2 Model requirements
12.3 Load cases and assessment of stress

Table of Content

Appendix 2 Reciprocating Internal Combustion Engines Fuelled by Natural Gas

1 General 433

1.1 Scope
1.2 Definitions
1.3 Documents to be submitted
1.4 Risk analysis

2 Design Requirements 436

2.1 General Principles
2.2 Gas piping

3 Specific design requirements 439

3.1 DF Engines
3.2 GF engines
3.3 Pre-mixed engines
3.4 Two-stroke engines

4 Type testing, factory acceptance tests and shipboard trials 439

4.1 Type Testing
4.2 Factory acceptance test
4.3 Shipboard trials

5 Certification of Engine Components 442

5.1 General
5.2 Additional requirements for DF and GF engines

Appendix 3 Plastic Pipes

1 General 444

1.1 Application
1.2 Use of plastic pipes
1.3 Specifications
1.4 Terms and conditions

2 General requirements 445

2.1 Strength
2.2 Axial strength
2.3 Impact resistance
2.4 Temperature
2.5 Requirements depending on service and/or location

3 Material approval and quality control during manufacture 449

3.1 General

4 Arrangement and installation of plastic pipes 449

4.1 Supports
4.2 Expansion
4.3 External loads
4.4 Strength of connections
4.5 Installation of conductive pipes
4.6 Application of fire protection coatings
4.7 Penetration of fire divisions and watertight bulkheads or decks
4.8 Control during installation
4.9 Testing after installation on board

5 Test specification for plastic pipes 451

5.1 Scope
5.2 Documentation
5.3 Testing

Table of Content

Appendix 4 Type Testing Procedure for Crankcase Explosion Relief Valves

1 General 454

1.1 Scope
1.2 Recognised standards
1.3 Purpose
1.4 Approval

2 Type testing procedure 454

2.1 Test facilities
2.2 Explosion test process
2.3 Valves to be tested
2.4 Method
2.5 Assessment and records
2.6 Design series qualification
2.7 Report

Appendix 5 Type Approval of Mechanical Joints

1 General 458

1.1 Scope
1.2 Documentation
1.3 Materials

2 Testing, procedures and requirements 458

2.1 Aim of the tests
2.2 Test fluid
2.3 Test program
2.4 Selection of test specimen
2.5 Mechanical joint assembly
2.6 Test results acceptance criteria
2.7 Methods of tests

Appendix 6 Special Approval of Alloy Steel used for Intermediate Shaft Material

1 General 464

1.1 Application
1.2 Torsional fatigue test
1.3 Cleanliness requirements
1.4 Inspection

Appendix 7 Exhaust Gas Back Pressure Analysis

1 General 466

1.1 Scope
1.2 Required analysis
1.3 Input data
1.4 Exhaust gas back pressure assessment

Appendix 8 Type Testing Procedure of Explosion Relief Devices for Combustion Air Inlet and Exhaust Gas Manifolds of I.C. Engines Using Gas as Fuel

1 General 468

1.1 Scope
1.2 Definitions
1.3 Documentation to be submitted

2 Tests 469

2.1 Test specimens of ERD
2.2 Test for Demonstration of opening pressure
2.3 Explosion test
2.4 Check of ERD components

3 Assessment and approval 471
3.1 Assessment
3.2 Approval

Chapter 2 Electrical Installations

Section 1 General

1 Application 473
1.1 General
1.2 References to other regulations and standards

2 Documentation to be submitted 473
2.1

3 Definitions 474
3.1 General
3.2 Black out situation
3.3 Certified safe-type equipment
3.4 Dead ship condition
3.5 Distribution board
3.6 Earthing
3.7 Emergency condition
3.8 Emergency source of electrical power
3.9 Emergency switchboard
3.10 Environmental categories
3.11 Essential services
3.12 Final sub-circuit
3.13 Hazardous areas
3.14 High fire risk areas
3.15 High-voltage systems
3.16 Insulation
3.17 Low-voltage systems
3.18 Main generating station
3.19 Main source of electrical power
3.20 Main switchboard
3.21 Normal operational and habitable condition
3.22 Safety voltage
3.23 Section boards
3.24 Services for habitability
3.25 Voltage and frequency transient

4 Type approved components 479
4.1 General

Section 2 General Design Requirements

1 Environmental conditions 480
1.1 General
1.2 Ambient air temperatures
1.3 Humidity
1.4 Sea water temperatures
1.5 Salt mist
1.6 Inclinations
1.7 Vibrations

2 Quality of power supply 481
2.1 General
2.2 a.c. distribution systems
2.3 d.c. distribution systems
2.4 Harmonic distortions

3 Electromagnetic susceptibility 482

3.1

4 Materials 483

4.1 General
4.2 Insulating materials for windings
4.3 Insulating materials for cables

5 Construction 483

5.1 General
5.2 Degree of protection of enclosures

6 Protection against explosion hazard 484

6.1 Protection against explosive gas or vapour atmosphere hazard
6.2 Protection against combustible dust hazard

Section 3 System Design

1 Supply systems and characteristics of the supply 485

1.1 Supply systems
1.2 Maximum voltages

2 Sources of electrical power 486

2.1 General
2.2 Main source of electrical power
2.3 Emergency source of electrical power
2.4 Use of emergency generator in port

3 Distribution 490

3.1 Earthed distribution systems
3.2 Insulated distribution systems
3.3 Distribution systems with hull return
3.4 General requirements for distribution systems
3.5 Main distribution of electrical power
3.6 Emergency distribution of electrical power
3.7 Shore supply
3.8 Supply of motors
3.9 Specific requirements for special power services
3.10 Power supply to heaters
3.11 Reefer containers
3.12 Power supply to final sub-circuits: socket outlet and lighting
3.13 Navigation lights
3.14 General emergency alarm system
3.15 Public address system
3.16 Combined general emergency alarm-public address system
3.17 Control and indication circuits
3.18 Power supply to the speed control systems of main propulsion engines
3.19 Power supply to the speed control systems of generator sets
3.20 Installation of water-based local application fire-fighting systems (FWBLAFFS)
3.21 Integrated cargo and ballast systems on tankers
3.22 Harmonic distortion for ship electrical distribution system without harmonics filters
3.23 Harmonic distortion for ship electrical distribution system including harmonics filters

4 Degrees of protection of the enclosures 497

4.1 General
4.2 Installation of electrical and electronic equipment in engine rooms protected by fixed water-based local application fire-fighting systems (FWBLAFFS)

5 Diversity (demand) factors 499

5.1 General

6 Environmental categories of the equipment 499

6.1 Environmental categories

Table of Content

7 Electrical protection 500

7.1 General requirements for overcurrent protection
7.2 Short-circuit currents
7.3 Selection of equipment
7.4 Protection against short-circuit
7.5 Continuity of supply and continuity of service
7.6 Protection against overload
7.7 Localisation of overcurrent protection
7.8 Protection of generators
7.9 Protection of circuits
7.10 Protection of motors
7.11 Protection of storage batteries
7.12 Protection of shore power connection
7.13 Protection of measuring instruments, pilot lamps and control circuits
7.14 Protection of transformers
7.15 Lightning protection

8 System components 505

8.1 General

9 Electrical cables 505

9.1 General
9.2 Choice of insulation
9.3 Choice of protective covering
9.4 Cables in refrigerated spaces
9.5 Cables in areas with a risk of explosion
9.6 Cables in circuits required to be operable under fire condition
9.7 Cables for submerged bilge pumps
9.8 Internal wiring of switchboards and other enclosures for equipment
9.9 Current carrying capacity of cables
9.10 Minimum nominal cross-sectional area of conductors
9.11 Choice of cables

10 Electrical installations in hazardous areas 512

10.1 General
10.2 Electrical equipment
10.3 Certified safe type documentation
10.4 Marking
10.5 Electrical cables
10.6 Electrical installations in battery rooms
10.7 Electrical installations in paint stores or enclosed spaces leading to paint stores
10.8 Electrical installations in stores for welding gas (acetylene) bottles
10.9 Specific ships or installations

Section 4 Rotating Machines

1 Constructional requirements for generators and motors 518

1.1 Mechanical construction
1.2 Sliprings, commutators and brushes
1.3 Terminal connectors
1.4 Electrical insulation

2 Special requirements for generators 518

2.1 Prime movers, speed governors and overspeed protection
2.2 A.c. generators
2.3 Approval of generating sets

3 Testing of rotating machines 519

3.1 General
3.2 Shaft material
3.3 Tests

4 Description of test 521
4.1 Technical documentation and visual inspection
4.2 Insulation resistance measurement
4.3 Winding resistance measurement
4.4 Verification of the voltage regulation
4.5 Rated load test and temperature rise measurements
4.6 Overcurrent/overtorque test
4.7 Verification of the steady short circuit current
4.8 Overspeed test
4.9 Dielectric strength test
4.10 No load test
4.11 Verification of degree of protection
4.12 Verification of bearings
5 Additional tests for rotating machines used as propulsion motor or thruster 524
5.1 General

Section 5 Transformers
1 Constructional requirements 525
1.1 Construction
1.2 Terminals
1.3 Voltage variation, short-circuit conditions and parallel operation
1.4 Electrical insulation and temperature rise
2 Testing 526
2.1 General
2.2 Tests on transformers
2.3 Insulation tests

Section 6 Semiconductor Converters
1 Constructional requirements 528
1.1 Construction
1.2 Protection
1.3 Parallel operation with other power sources
1.4 Temperature rise
1.5 Creepage and clearance distances
2 Requirements for uninterruptible power system (UPS) units as alternative and/or transitional power 529
2.1 Application
2.2 Definitions
2.3 Design and construction
2.4 Location
2.5 Performance
3 Testing 531
3.1 General
3.2 Tests on converters
3.3 Additional testing and survey for uninterruptible power system (UPS) units as alternative and/or transitional power
3.4 Insulation test

Section 7 Battery Energy Storage Systems and Chargers
1 Batteries 533
1.1 General
1.2 Definitions
1.3 Battery pack
1.4 Battery maintenance
1.5 Testing and certification process for batteries
1.6 Battery cells
1.7 Battery packs and associated BMS
1.8 Equipment used in battery systems

2 Non Li-ion batteries 536
2.1 Vented batteries
2.2 Valve-regulated batteries
3 Li-ion batteries 536
3.1 Li Ion batteries above 20kWh
3.2 Li Ion batteries below 20kWh
3.3 Li Ion batteries used as emergency source or transitional source
4 Chargers 537
4.1 General
4.2 Testing
5 Requirements for the additional service feature battery systems 538
5.1 Application
5.2 Documents to be submitted
5.3 System considered
5.4 Qualification of the battery system
5.5 General requirements
5.6 Availability of power
5.7 Test and certification process for batteries

Section 8 Switchgear and Controlgear Assemblies
1 Constructional requirements for main and emergency switchboards 540
1.1 Construction
1.2 Documents to be submitted
1.3 Busbars and bare conductors
1.4 Internal wiring
1.5 Switchgear and controlgear
1.6 Auxiliary circuits
1.7 Instruments
1.8 Synchronisation of generators
2 Constructional requirements for section boards and distribution boards 543
2.1 Construction
3 Testing 543
3.1 General
3.2 Visual Inspection
3.3 Functional Testing
3.4 High-voltage test
3.5 Measurement of insulation resistance

Section 9 Cables
1 General 545
1.1 Type approval
2 Constructional requirements 545
2.1 Construction
2.2 Conductors
2.3 Insulating materials
2.4 Inner covering, fillers and binders
2.5 Protective coverings (armour and sheath)
2.6 Identification
3 Testing 546
3.1 Type tests
3.2 Routine tests

Table of Content

Section 10 Miscellaneous Equipment

1 Switchgear and controlgear, protective devices 547

1.1 General
1.2 Circuit-breakers
1.3 Protection devices

2 Electrical slip ring assemblies 547

2.1 General requirements
2.2 Construction
2.3 Testing
2.4 Description of tests

3 Lighting fittings 550

3.1 Applicable requirements
3.2 Construction

4 Accessories 550

4.1 Applicable requirements
4.2 Construction

5 Plug-and-socket connections 550

5.1 Applicable requirements

6 Heating and cooking appliances 551

6.1 Applicable requirements
6.2 General
6.3 Space heaters
6.4 Cooking appliances
6.5 Fuel oil and lube oil heaters
6.6 Water heaters

Section 11 Location

1 General 552

1.1 Location
1.2 Areas with a risk of explosion
1.3 Electrical equipment in environmentally controlled spaces

2 Main electrical system 552

2.1 Location in relation to the emergency system
2.2 Main switchboard

3 Emergency electrical system 553

3.1 Spaces for the emergency source
3.2 Location in relation to the main electrical system
3.3 Emergency switchboard
3.4 Emergency battery

4 Distribution boards 553

4.1 Distribution boards for cargo spaces and similar spaces
4.2 Distribution board for navigation lights

5 Cable runs 553

5.1 General
5.2 Location of cables in relation to the risk of fire and overheating
5.3 Location of cables in relation to electromagnetic interference
5.4 Services with a duplicate feeder
5.5 Emergency circuits
5.6 Electrical distribution in passenger ships

6 Storage batteries 554

6.1 General requirements for arrangements
6.2 Arrangement of large vented batteries
6.3 Arrangement of moderate vented batteries
6.4 Arrangement of small vented batteries
6.5 Arrangement of Li-ion batteries above 20kWh
6.6 General requirements for ventilation
6.7 Additional requirement for vented batteries ventilation
6.8 Additional requirement for valve regulated batteries ventilation
6.9 Additional requirement for Li-Ion batteries above 20kWh ventilation
6.10 Hazardous area classification

Section 12 Installation

1 General 558

1.1 Protection against injury or damage caused by electrical equipment
1.2 Protection against damage to electrical equipment
1.3 Accessibility

2 Earthing of non-current carrying parts 558

2.1 Parts which are to be earthed
2.2 Methods of earthing
2.3 Earthing connections
2.4 Connection to the ship's structure
2.5 Earthed distribution systems
2.6 Aluminium superstructures

3 Rotating machines 560

3.1

4 Semiconductor converters 560

4.1 Semiconductor power converters

5 Batteries 560

5.1 Vented batteries
5.2 Li Ion batteries above 20kWh

6 Switchgear and controlgear assemblies 561

6.1 Main switchboard
6.2 Emergency switchboard
6.3 Section boards and distribution boards

7 Cables 561

7.1 General
7.2 Radius of bend
7.3 Fixing of cables
7.4 Mechanical protection
7.5 Penetrations of bulkheads and decks
7.6 Expansion joints
7.7 Cables in closed pipes or conduits
7.8 Cables in casings or trunking and conduits with removable covers
7.9 Cable ends
7.10 Joints and tappings (branch circuit)
7.11 Earthing and continuity of metal coverings of cables
7.12 Earthing and continuity of metal pipes, conduits and trunking or casings
7.13 Precautions for single-core cables for a.c.
7.14 Cables in refrigerated spaces
7.15 Cables in areas with a risk of explosion
7.16 Cables and apparatus for services required to be operable under fire conditions
7.17 Cables in the vicinity of radio equipment
7.18 Cables for submerged bilge pumps
7.19 Cable trays/protective casings made of plastics materials
7.20 Cables in environmentally controlled spaces

Table of Content

8 Various appliances 568

8.1 Lighting fittings
8.2 Heating appliances
8.3 Heating cables and tapes or other heating elements

Section 13 High-voltage Installations

1 General 569

1.1 Field of application
1.2 Nominal system voltage
1.3 High-voltage, low-voltage segregation

2 System design 569

2.1 Distribution
2.2 Degrees of protection
2.3 Insulation
2.4 Protection

3 Rotating machinery 570

3.1 Stator windings of generators
3.2 Temperature detectors
3.3 Tests

4 Power transformers 571

4.1 General

5 Cables 571

5.1 General

6 Switchgear and controlgear assemblies 571

6.1 General
6.2 Construction
6.3 Auxiliary systems
6.4 High-voltage test

7 Installation 572

7.1 Electrical equipment
7.2 Cables

Section 14 Electric Propulsion Plant

1 General 574

1.1 Applicable requirements
1.2 Operating conditions

2 Design of the propulsion plant 574

2.1 General
2.2 Power supply
2.3 Auxiliary machinery
2.4 Electrical Protection
2.5 Excitation of synchronous electric propulsion motor

3 Contruction of rotating machines, semiconductor converters and braking resistors 575

3.1 Ventilation
3.2 Protection against moisture and condensate
3.3 Rotating machines
3.4 Semiconductor converters
3.5 Braking resistors

4 Control and monitoring 576
4.1 General
4.2 Power plant control systems
4.3 Indicating instruments
4.4 Alarm system
4.5 Reduction of power
5 Installation 578
5.1 Ventilation of spaces
5.2 Cable runs
6 Tests 578
6.1 Test of rotating machines
6.2 Test of braking resistors
7 Specific requirements for PODs 579
7.1 General
7.2 Electrical slip ring assemblies
7.3 Electric motor
7.4 Instrumentation and associated devices
7.5 Additional tests and tests on board

Section 15 Testing
1 General 580
1.1 Rule application
1.2 Insulation-testing instruments
2 Insulation resistance 580
2.1 Lighting and power circuits
2.2 Internal communication circuits
2.3 Switchboards
2.4 Generators and motors
3 Earth 580
3.1 Electrical constructions
3.2 Metal-sheathed cables, metal pipes or conduits
4 Operational tests 581
4.1 Generating sets and their protective devices
4.2 Switchgear
4.3 Harmonic filters
4.4 Consuming devices
4.5 Communication systems
4.6 Installations in areas with a risk of explosion
4.7 Voltage drop
4.8 Batteries

Appendix 1 Indirect Test Method for Synchronous Machines
1 General 583
1.1 Test method

Appendix 2 Indirect Test Method for Induction Machines (Static Torque Method)
1 General 585
1.1 Test method

Chapter 3 Automation

Section 1 General Requirements

1 General 587

1.1 Field of application
1.2 Regulations and standards
1.3 Definitions
1.4 General

2 Documentation 588

2.1 Documents to be submitted
2.2 Documents for type approval of equipment

3 Environmental and supply conditions 589

3.1 General
3.2 Power supply conditions

4 Materials and construction 589

4.1 General

Section 2 Design Requirements

1 General 590

1.1

2 Power supply of automation systems 590

2.1

3 Control systems 590

3.1 General
3.2 Local control
3.3 Remote control systems
3.4 Automatic control systems

4 Control of propulsion machinery 591

4.1 Application
4.2 Remote control
4.3 Remote control from navigation bridge
4.4 Remote control from navigation bridge for gas fuelled ship
4.5 Automatic control
4.6 Automatic control of propulsion and manoeuvring units
4.7 Clutches
4.8 Brakes

5 Communications 593

5.1 Communications between navigation bridge and machinery space
5.2 Engineers' alarm

6 Remote control of valves 593

6.1

7 Alarm system 594

7.1 General requirements
7.2 Alarm functions

8 Safety system 594

8.1 Design
8.2 Function
8.3 Shutdown
8.4 Standby systems
8.5 Testing

Table of Content

Section 3 Computer Based Systems

1 General requirements 596

1.1 Scope
1.2 Exclusion
1.3 References
1.4 Structure
1.5 Definition of abbreviations and terminology
1.6 Documentation to be submitted
1.7 Test witnessing and survey

2 Approval of system and components 600

2.1 System certification
2.2 Type approval of computer-based systems

3 System categories 600

3.1 System category definitions
3.2 Scope of verification by the Society
3.3 System category examples

4 Requirements on development and certification of computer-based system 601

4.1 General requirement
4.2 Requirements on the System Supplier
4.3 Requirements on the Systems Integrator

5 Requirements on maintenance of computer-based systems 605

5.1 Requirements on the Owner
5.2 Requirements on the Systems Integrator
5.3 Requirements on the System Supplier

6 Management of change 606

6.1 General
6.2 Documented change management procedures
6.3 Agreement between relevant stakeholders
6.4 Approved software to be under change management
6.5 Unique identification of system and software versions
6.6 Handling of software master files
6.7 Backup and restoration of onboard software
6.8 Impact analysis before change is made
6.9 Roll-back in case of failed software changes
6.10 Verification and validation of system changes
6.11 Change records
6.12 Verification of change management by the Society

7 Technical requirements on computer-based systems 607

7.1 Reporting of system and software identification and version
7.2 Data links
7.3 Verification of technical requirements by the Society
7.4 Requirements for hardware regarding construction
7.5 Response time
7.6 Human-Machine Interface (HMI)
7.7 Integrated systems

8 Additional service feature SW-Registry 610

8.1 Software registry
8.2 Software inventory
8.3 Logical map of networks
8.4 Inventory of integrated systems components
8.5 Cyber security events

Table of Content

Section 4 Constructional Requirements

1 General 614

1.1 General
1.2 Materials
1.3 Component design
1.4 Environmental and supply conditions

2 Electrical and/or electronic systems 614

2.1 General
2.2 Electronic system
2.3 Electrical system

3 Pneumatic systems 615

3.1

4 Hydraulic systems 615

4.1

5 Automation consoles 615

5.1 General
5.2 Indicating instruments
5.3 VDU's and keyboards

Section 5 Installation Requirements

1 General 617

1.1

2 Sensors and components 617

2.1 General
2.2 Temperature elements
2.3 Pressure elements
2.4 Level switches

3 Cables 617

3.1 Installation
3.2 Cable terminations

4 Pipes 618

4.1

5 Automation consoles 618

5.1 General

Section 6 Testing

1 General 619

1.1 General

2 Type approval 619

2.1 General
2.2 Hardware type approval
2.3 Software type approval
2.4 Loading instruments
2.5 Oil mist detection system

3 Acceptance testing 628

3.1 General
3.2 Hardware testing
3.3 Software testing

4 Onboard tests 628

4.1 General

Appendix 1 Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment

1 General 629

1.1 Scope
1.2 Reference
1.3 Purpose
1.4 Test facilities

2 Testing 629

2.1 Equipment testing
2.2 Functional tests
2.3 Detectors and alarm equipment to be tested
2.4 Method
2.5 Assessment
2.6 Design series qualification
2.7 Test report
2.8 Acceptance

Chapter 4 Fire Protection, Detection and Extinction

Section 1 General

1 Application 634

1.1 General
1.2 National regulations
1.3 Applicable requirements depending on ship type
1.4 Documentation to be submitted
1.5 Type approved products

2 Definitions 636

2.1 A class divisions
2.2 Accommodation spaces
2.3 Atriums
2.4 B class divisions
2.5 Bulkhead decks
2.6 C class divisions
2.7 Cabin balconies
2.8 Calorific value
2.9 Cargo ship
2.10 Cargo spaces
2.11 Central control station
2.12 Chemical tankers
2.13 Closed ro-ro spaces
2.14 Closed vehicle spaces
2.15 Combination carriers
2.16 Continuous B class ceilings or linings
2.17 Continuously manned central control stations
2.18 Control stations
2.19 Dangerous goods
2.20 Deadweight
2.21 Fire damper
2.22 Fire Test Procedures Code
2.23 Gas carriers
2.24 Helicopter facility
2.25 Helicopter landing area
2.26 Helideck
2.27 Lightweight
2.28 Low flame-spread
2.29 Machinery spaces
2.30 Machinery spaces of category A

2.31 Main vertical zones
2.32 Non-combustible material
2.33 Non-sparking fan
2.34 Oil fuel unit
2.35 Open ro-ro spaces
2.36 Open vehicle spaces
2.37 Passenger ship
2.38 Public spaces
2.39 Rooms containing furniture and furnishings of restricted fire risk
2.40 Ro-ro passenger ship
2.41 Ro-ro spaces
2.42 Safety centre
2.43 Sauna
2.44 Semi-enclosed space
2.45 Service spaces
2.46 Smoke damper
2.47 Special category spaces
2.48 Standard fire test
2.49 Steel or other equivalent material
2.50 Tanker
2.51 Vehicle carrier
2.52 Vehicle spaces
2.53 Weather decks
2.54 Winching area

Section 2 Prevention of Fire

1 Probability of ignition 644

1.1 Arrangements for fuel oil, lubrication oil and other flammable oils
1.2 Arrangements for gaseous fuel for domestic purposes
1.3 Miscellaneous items of ignition sources and ignitability

2 Fire growth potential 645

2.1 Control of air supply and flammable liquid to the space
2.2 Fire protection materials

3 Smoke generation potential and toxicity 647

3.1 Paints, varnishes and other finishes
3.2 Primary deck coverings

Section 3 Suppression of Fire: Detection and Alarm

1 General 648

1.1 Passenger ships
1.2 Minimum number of detectors

2 Initial and periodical tests 648

2.1 General

3 Protection of machinery spaces 648

3.1 Installation
3.2 Design

4 Protection of accommodation and service spaces and control stations 648

4.1 Application
4.2 Smoke detectors in accommodation spaces
4.3 Requirements for passenger ships carrying more than 36 passengers
4.4 Requirements for passenger ships carrying not more than 36 passengers
4.5 Protection of atriums
4.6 Protection of cabin balconies on passenger ships
4.7 Cargo ships

5 Protection of cargo spaces 650

5.1 Application and general requirements

6 Manually operated call points 650

6.1 General requirements

7 Inspection hatches 650

7.1 Application
7.2 Inspection hatches

8 Fire alarm signalling systems 650

8.1 Application
8.2 Control panel
8.3 Passenger ships carrying more than 36 passengers
8.4 Special alarm

9 Protection of battery rooms 651

9.1 Li-ion batteries above 20kWh

Section 4 Suppression of Fire: Control of Smoke Spread

1 General 652

1.1 Application

2 Protection of control stations outside machinery spaces 652

2.1 General

3 Release of smoke from machinery spaces 652

3.1 Release of smoke
3.2 Controls

4 Draught stops 652

4.1

5 Smoke extraction systems 652

5.1 Atriums

Section 5 Suppression of Fire: Containment of Fire

1 Thermal and structural boundaries 653

1.1 Application
1.2 Thermal and structural subdivision
1.3 Passenger ships
1.4 Cargo ships except tankers
1.5 Tankers

2 Penetrations in fire-resisting divisions and prevention of heat transmission 668

2.1 Penetrations in A class divisions
2.2 Penetrations in B class divisions
2.3 Pipes penetrating A or B class divisions
2.4 Prevention of heat transmission

3 Protection of openings in fire-resisting divisions 668

3.1 Application
3.2 Openings in bulkheads and decks
3.3 Doors in fire-resisting divisions

4 Protection of openings in machinery space boundaries 671

4.1 Application
4.2 Protection of openings in machinery space boundaries

5 Protection of cargo space boundaries 671

5.1 Application
5.2 Passenger ships carrying more than 36 passengers
5.3 Indicators

6 Ventilation systems 671

6.1 Application
6.2 General
6.3 Arrangement of ducts
6.4 Details of fire dampers and duct penetrations
6.5 Ventilation systems for passenger ships carrying more than 36 passengers
6.6 Exhaust ducts from galley ranges
6.7 Ventilation rooms serving machinery spaces of category A containing internal combustion machinery
6.8 Ventilation systems for laundries in passenger ships carrying more than 36 passengers

Section 6 Suppression of Fire: Fire Fighting

1 Water supply systems 676

1.1 General
1.2 Fire mains and hydrants
1.3 Fire pumps
1.4 Fire hoses and nozzles

2 Portable fire extinguishers 680

2.1 Type and design
2.2 Arrangement of fire extinguishers

3 Fixed fire-extinguishing systems 680

3.1 Types of fixed fire-extinguishing systems
3.2 Closing appliances for fixed gas fire-extinguishing systems
3.3 Storage rooms of fire-extinguishing medium
3.4 Water pumps for other fire-extinguishing systems

4 Fire-extinguishing arrangements in machinery spaces 681

4.1 Machinery spaces arrangement
4.2 Machinery spaces containing oil-fired boilers or oil fuel units
4.3 Machinery spaces of category A containing internal combustion machinery
4.4 Machinery spaces containing steam turbines or enclosed steam engines
4.5 Other machinery spaces
4.6 Additional requirements for passenger ships
4.7 Fixed local application fire-extinguishing systems

5 Fire-extinguishing arrangements in control stations, accommodation and service spaces 683

5.1 Sprinkler and water-spray systems in passenger ships
5.2 Sprinkler systems for cargo ships
5.3 Spaces containing flammable liquid
5.4 Deep-fat cooking equipment

6 Fire-extinguishing arrangements in cargo spaces 684

6.1 Fixed gas fire-extinguishing systems for general cargo
6.2 Fixed gas fire-extinguishing systems for dangerous goods
6.3 Firefighting for ships designed to carry containers on or above the weather deck

7 Fire-extinguishing arrangements for ballast water management rooms 685

7.1 Fixed fire-extinguishing system
7.2 Portable fire-fighting equipment

8 Fire-extinguishing arrangements for battery rooms 686

8.1 Li Ion-type batteries above 20kWh

Section 7 Suppression of Fire: Structural Integrity

1 Application 687

1.1 General

2 Material of hull, superstructures, structural bulkheads, decks and deckhouses 687

2.1 General

3 Structure of aluminium alloy 687
3.1 General
4 Machinery spaces of category A 687
4.1 Crowns and casings
4.2 Floor plating
5 Materials of overboard fittings 687
5.1 General
6 Protection of cargo tank structure against pressure or vacuum 688
6.1 Reference to Part D

Section 8 Escape
1 Notification of crew and passengers 689
1.1 Application
1.2 General emergency alarm system
1.3 Special alarm to summon the crew
1.4 Public address systems
2 Means of escape 689
2.1 General requirements
2.2 Means of escape from control stations, accommodation spaces and service spaces
2.3 Means of escape from machinery spaces
2.4 Means of escape on passenger ships from special category and open ro-ro spaces to which any passengers carried can have access
2.5 Means of escape from ro-ro spaces
2.6 Additional requirements for ro-ro passenger ships

Section 9 Fire Control Plans
1 Application 696
1.1 General
2 Fire control plans 696
2.1 Compilation of the fire control plans
2.2 Location of the fire control plans

Section 10 Helicopter Facilities
1 General 698
1.1 Application
2 Structure 698
2.1 Construction of steel or other equivalent materials
2.2 Construction of aluminium or other low melting point metals
2.3 Means of escape
3 Fire-fighting appliances 698
3.1 General
3.2 Drainage facilities
4 Helicopter refuelling and hangar facilities (if fitted) 699
4.1 Helicopter fuel system and refuelling facilities
4.2 Arrangement of hangar facilities and spaces containing the refuelling installations
5 Occasional and emergency helicopter operations 699
5.1 General
6 Operations manual 700
6.1 General

Table of Content

Section 11 Fuel for Auxiliary Vehicles

1 General 701

1.1 Application
1.2 Definitions
1.3 Segregation
1.4 Storage arrangement
1.5 Vapour detection
1.6 Marking and instructions

2 Jettisonable fuel tanks 702

2.1 Storage arrangement
2.2 Tank design

3 Fixed fuel installations 703

3.1 Tank design
3.2 Tank location and protection
3.3 Cofferdams
3.4 Piping
3.5 Drainage
3.6 Fuel handling
3.7 Filling station
3.8 Refuelling station

4 Prevention of explosion 707

4.1 Electrical bonding
4.2 Source of ignition
4.3 Hazardous areas
4.4 Ventilation of hazardous spaces
4.5 Ventilation and door openings of non-hazardous spaces

Section 12 Carriage of Dangerous Goods

1 General requirements 710

1.1 Application

2 Special requirements 710

2.1 General
2.2 Water supplies
2.3 Sources of ignition
2.4 Detection system
2.5 Ventilation arrangement
2.6 Bilge pumping
2.7 Personnel protection
2.8 Portable fire extinguishers
2.9 Insulation of machinery space boundaries
2.10 Water-spray system
2.11 Separation of ro-ro spaces

Section 13 Protection of Vehicle, Special Category and Ro-ro Spaces

1 General requirements 716

1.1 Application
1.2 Basic principles for passenger ships

2 Precaution against ignition of flammable vapours in closed vehicle spaces, closed ro-ro spaces and special category spaces 716

2.1 Ventilation systems
2.2 Electrical equipment and wiring
2.3 Electrical equipment and wiring in exhaust ventilation ducts
2.4 Other ignition sources
2.5 Scuppers and discharges

3 Detection and alarm 718
3.1 Fixed fire detection and fire alarm systems
3.2 Sample extraction smoke detection systems
3.3 Special category spaces
4 Structural protection 718
4.1 General
5 Fire extinction 718
5.1 Fixed fire-extinguishing systems
5.2 Portable fire extinguishers
6 Vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion 719
6.1 Spaces intended for carriage of motor vehicles with compressed natural gas in their tanks
6.2 Spaces intended for carriage of motor vehicles with compressed hydrogen in their tanks
6.3 Detection

Section 14 Safety Centre on Passenger Ships
1 General 720
1.1 Application
1.2 Location and arrangement
2 Layout and ergonomic design 720
2.1
3 Communications 720
3.1
4 Control and monitoring of safety systems 720
4.1

Section 15 Fire Safety Systems
1 General 721
1.1 Application
1.2 Use of toxic extinguishing media
2 International shore connections 721
2.1 Engineering specifications
3 Fire extinguishers 722
3.1 Type approval
3.2 Engineering specifications
4 Fixed gas fire-extinguishing systems 722
4.1 Engineering specifications
4.2 Equivalent fixed gas fire-extinguishing systems
4.3 Requirements of steam systems
5 Fixed foam fire-extinguishing systems 727
5.1 General
5.2 Fixed high-expansion foam fire-extinguishing systems
5.3 Fixed low-expansion foam fire-extinguishing systems
6 Fixed pressure water spraying and water-mist fire-extinguishing systems 731
6.1 Engineering specifications
7 Automatic sprinkler, fire detection and fire alarm systems 732
7.1 Engineering specifications
8 Fixed fire detection and fire alarm systems 734
8.1 Definitions
8.2 Engineering specifications

Table of Content

9	Sample extraction smoke detection systems	738
	9.1 Engineering specifications	
10	Low-location lighting systems	739
	10.1 Application 10.2 Engineering specification	
11	Fixed emergency fire pumps	739
	11.1 Engineering specifications	
12	Arrangement of means of escape	741
	12.1 Passenger ships 12.2 Cargo ships	
13	Inert gas systems	745
	13.1 Application 13.2 Definitions 13.3 Requirements for all systems 13.4 Requirements for flue gas and inert gas generator systems 13.5 Requirements for nitrogen generator systems	
14	Helicopter facility foam firefighting appliances	750
	14.1 Application 14.2 Definitions 14.3 Engineering specifications for helidecks and helicopter landing areas	

CHAPTER 1
MACHINERY

Section 1	General Requirements
Section 2	Diesel Engines
Section 3	Pressure Equipment
Section 4	Steam Turbines
Section 5	Gas Turbines
Section 6	Gearing
Section 7	Main Propulsion Shafting
Section 8	Propellers
Section 9	Shaft Vibrations
Section 10	Piping Systems
Section 11	Exhaust Gas Pollution Prevention System
Section 12	Onboard Carbon Capture and Storage Systems
Section 13	Ballast Water Management Systems
Section 14	Steering Gear
Section 15	Thrusters
Section 16	Refrigerating Installations
Section 17	Turbochargers
Section 18	Tests on Board
Appendix 1	Calculation for Internal Combustion Engine Crankshafts
Appendix 2	Reciprocating Internal Combustion Engines Fuelled by Natural Gas

Appendix 3 Plastic Pipes

Appendix 4 Type Testing Procedure for Crankcase Explosion Relief Valves

Appendix 5 Type Approval of Mechanical Joints

Appendix 6 Special Approval of Alloy Steel used for Intermediate Shaft Material

Appendix 7 Exhaust Gas Back Pressure Analysis

Appendix 8 Type Testing Procedure of Explosion Relief Devices for Combustion Air Inlet and Exhaust Gas Manifolds of I.C. Engines Using Gas as Fuel

Section 1 General Requirements

1 General

1.1 Application

1.1.1 Part C, Chapter 1 applies to the design, construction, installation, tests and trials of main propulsion and essential auxiliary machinery systems and associated equipment, boilers and pressure vessels, piping systems, and steering and manoeuvring systems installed on board classed ships, as indicated in each Section of this Chapter and as far as class is concerned only.

For computerized machinery systems, requirements contained in Part C, Chapter 3 shall be referred to.

1.2 Additional requirements

1.2.1 Additional requirements for machinery are given in:

- Part D and Part E for the assignment of the service notations
- Part F, for the assignment of additional class notations.

1.3 Documentation to be submitted

1.3.1 The Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in the relevant Sections of this Chapter.

1.3.2 The documents and information required in [2.6.2] [2.7.1], [2.8.1] [2.8.2] are to be submitted for information.

1.4 Definitions

1.4.1 Continuity of service

The Shipyard is to give special consideration to the reliability of single essential propulsion components. This *may require a separate source of propulsion power sufficient to give the ship a navigable speed, especially in the case of unconventional arrangements.*

1.4.2 Dead ship condition

Dead ship condition is the condition under which the whole propulsion system, including the main power supply, is not in operation and auxiliary means for bringing the main propulsion machinery into operation and for the restoration of the main power supply, such as compressed air and starting current from batteries, are not available, but assuming that means are available to start the emergency generator at all times.

2 Design and construction

2.1 General

2.1.1 *The machinery, boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.*

The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

2.2 Materials, welding and testing

2.2.1 General

Materials, welding and testing procedures are to be in accordance with the requirements of NR216 Materials and Welding, and those given in the other Sections of this Chapter. In addition, for machinery components fabricated by welding the requirements given in [2.2.2] apply.

2.2.2 Welded machinery components

Welding processes and welders are to be approved by the Society in accordance with NR216 Materials and Welding, Chapter 12 and NR476 Approval testing of welders.

References to welding procedures adopted are to be clearly indicated on the plans submitted for approval.

Joints transmitting loads are to be either:

- full penetration butt-joints welded on both sides, except when an equivalent procedure is approved
- full penetration T- or cruciform joints.

For joints between plates having a difference in thickness greater than 3 mm, a taper having a length of not less than 4 times the difference in thickness is required. Depending on the type of stress to which the joint is subjected, a taper equal to three times the difference in thickness may be accepted.

T-joints on scalloped edges are not permitted.

Lap-joints and T-joints subjected to tensile stresses are to have a throat size of fillet welds equal to 0,7 times the thickness of the thinner plate on both sides.

In the case of welded structures including cast pieces, the latter are to be cast with appropriate extensions to permit connection, through butt-welded joints, to the surrounding structures, and to allow any radiographic and ultrasonic examinations to be easily carried out.

Where required, preheating and stress relieving treatments are to be performed according to the welding procedure specification.

2.2.3 Non-destructive testing suppliers

Where required in these Rules, independent NDT service suppliers have to comply with the requirements set out in NR669 "Requirements for non-destructive testing suppliers".

2.3 Vibrations

2.3.1 Shipyards and manufacturers are to give *special consideration to the design, construction and installation of propulsion machinery systems* and auxiliary machinery *so that any mode of their vibrations shall not cause undue stresses in this machinery in the normal operating ranges.*

2.4 Ambient conditions - Inclinations

2.4.1 *Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the ship,* as well as other equipment and appliances listed in Tab 1*, as fitted in the ship, are to be designed to operate when the ship is upright and when inclined at any angle of list either way and trim by bow or stern as stated in Tab 1.*

The Society may permit deviations from angles given in Tab 1, taking into consideration the type, size and service conditions of the ship.

2.5 Ambient conditions - Temperatures

2.5.1 Machinery and systems covered by the Rules are to be designed to operate properly under the ambient conditions specified in Tab 2, unless otherwise specified in each Section of this Chapter.

2.6 Ambient conditions - Ship accelerations and motions

2.6.1 Machinery operation under the effect of accelerations and motions

Main propulsion and steering machinery and auxiliary machinery that is essential to the propulsion and steering, and the safety of the ship, is to be capable of operation under the effects of acceleration and motions.

The requirements in [2.6.2], [2.7] and [2.8] apply where documented evidence of equipment suitability is specifically required by the Rules for such equipment. They apply in particular to LNG fuel pumps and gas compressors fitted to liquefied gas carriers (refer to Pt D, Ch 9, Sec 5, [13.2]) and to gas-fuelled ships (refer to NR529, [9.9.2]).

2.6.2 Ship accelerations and motions

Ship builders are to identify and document the ship accelerations and motions periods to which machinery and equipment might be subjected to. The expected accelerations and ship motions periods are to be within machinery and equipment manufacturers requirements. The estimations are to consider vessel type, machinery or equipment location and expected service conditions.

Table 1 : Inclinations of ship

Installations, components	Angle of inclination (degrees) **(1)** **(4)**			
	Athwartship		Fore and aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22,5	5	7,5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices Switch gear, electrical and electronic appliances **(3)** and remote control systems	22,5 **(2)**	22,5 **(2)**	10	10

(1) Athwartship and fore-and-aft inclinations may occur simultaneously.

(2) In ships for the carriage of liquefied gases and of chemicals, the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°.

(3) No undesired switching operations or operational changes are to occur

(4) Where the length of the ship exceeds 100m, the fore-and-aft static angle of inclination may be taken as 500/L degrees, where L is the length of the ship, in metres, as defined in Pt B, Ch 1, Sec 3, [2.1.1]

Table 2 : Ambient conditions - Temperatures

AIR TEMPERATURE	
Location, arrangement	Temperature range, in °C
In enclosed spaces	between 0 and +45 **(2)**
On machinery components, boilers In spaces subject to higher or lower temperatures	According to specific local conditions
On exposed decks	between –25 and +45 **(1)**

WATER TEMPERATURE	
Coolant	Temperature, in °C
Sea water , including sea water at charge air coolant inlet, where applicable	up to +32

(1) Electronic appliances are to be designed for an air temperature up to 55°C (for electronic appliances see also Part C, Chapter 2).

(2) Different temperatures may be accepted by the Society in the case of ships intended for restricted service.

2.7 Evaluation of equipment suitability

2.7.1 Machinery and equipment manufacturers are to submit evidence to the Society that their machinery or equipment can operate under the required static and dynamic conditions stated in [2.4.1] and at least at the levels of shipboard accelerations as stated in [2.6.2] and/or specified in the relevant sections of the Rules. Documentation of satisfactory performance is to take the form of:

- report of testing under representative conditions; or
- report of theoretical verification using recognised computational techniques accompanied by detailed and relevant validation data; or
- historical data which provides relevant demonstration of satisfactory experience in service.

2.8 Installation and operation

2.8.1 Machinery and equipment manufacturers are to submit details of the requirements /recommendations for installation of the machinery and equipment onboard to ensure satisfactory operation in service under the required static and dynamic conditions as described in [2.4.1] and at least at the levels of shipboard accelerations as stated in [2.6.2] and/or specified in the relevant sections of the Rules.

2.8.2 Shipbuilders are to submit details demonstrating that the installation of the machinery and equipment onboard is in accordance with manufacturer's requirements /recommendations.

2.8.3 Consideration should be given for positioning machinery in order to minimize the dynamic load on bearings due to ship motion. Machinery with a horizontal rotation axis is generally to be fitted on board with such axis arranged alongships. If this is not possible, the Manufacturer is to be informed at the time the machinery is ordered.

2.9 Power of machinery

2.9.1 Unless otherwise stated in each Section of this Chapter, where scantlings of components are based on power, the values to be used are determined as follows:

- for main propulsion machinery, the power/rotational speed for which classification is requested
- for auxiliary machinery, the power/rotational speed which is available in service.

2.10 Astern power

2.10.1 *Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.*

In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolutions.

Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70% of the ahead revolutions for a period of at least 15 minutes.

For main propulsion systems with reversing gears, controllable pitch propellers or electrical propeller drive, running astern is not to lead to an overload of propulsion machinery.

During the sea trials, the ability of the main propulsion machinery to reverse the direction of thrust of the propeller is to be demonstrated and recorded (see also Ch 1, Sec 18).

2.11 Safety devices

2.11.1 *Where risk from overspeeding of machinery exists, means are to be provided to ensure that the safe speed is not exceeded.*

2.11.2 *Where main or auxiliary machinery including pressure vessels or any parts of such machinery are subject to internal pressure and may be subject to dangerous overpressure, means shall be provided, where practicable, to protect against such excessive pressure.*

2.11.3 *Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shut-off arrangements in the case of failures, such as lubricating oil supply failure, which could lead rapidly to complete breakdown, serious damage or explosion.*

The Society may permit provisions for overriding automatic shut-off devices.

See also the specific requirements given in the other Sections of this Chapter.

2.12 Fuels

2.12.1 Fuel oils employed for engines and boilers are, in general, to have a flashpoint (determined using the closed cup test) of not less than 60°C, except as otherwise permitted in items a) and b).

a) Fuel oils having a flashpoint of less than 60°C but not less than 43°C may be accepted:

- *in emergency generators;*
- *for feeding the emergency fire pump's engines and the auxiliary machines which are not located in the machinery spaces of category A; or*
- for ships assigned with a restricted navigation notation which are not intended to comply with IMO SOLAS Convention, and provided that:
  - Special precautions are taken to the Society's satisfaction including a demonstration that the temperature of spaces where fuel oil is stored or employed will remain at least 10°C below the fuel oil flashpoint at all times; and
  - This arrangement is also acceptable to the Flag Administration.

b) For installations specially approved for use of natural gas or other low-flashpoint fuel as fuel for boilers or propulsion engines, in the scope of the additional service features **LNGfuel**, **CNGfuel**, **LPGfuel** or, as relevant, other additional service features defined in Pt A, Ch 1, Sec 2, [4.16.4] and subject to the corresponding requirements.

2.12.2 *Machineries and piping systems for the usage of fuel oil having a flashpoint less than 60°C are also to comply with the following:*

a) For oil fuel having a flashpoint of less than 60°C but not less than 43°C, oil tanks except those arranged in double bottom compartments shall be located outside of machinery spaces of category A

b) For oil fuel having a flashpoint of less than 43°C, where permitted, oil tanks are to be located outside machinery spaces and the arrangements adopted have to be specially approved by the Society

c) Provisions for the measurement of oil temperature should be provided on the suction pipe of oil fuel pump

d) Stop valves and/or cocks are to be provided to the inlet side and outlet side of the oil fuel strainers

e) Pipe joints of welded construction or of circular cone type or spherical type union joint are to be applied as much as possible.

3 Arrangement and installation on board

3.1 General

3.1.1 *Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery, including boilers and pressure vessels.*

Easy access to the various parts of the propulsion machinery is to be provided by means of metallic ladders and gratings fitted with strong and safe handrails.

Spaces containing main and auxiliary machinery are to be provided with adequate lighting and ventilation.

3.2 Floor plating and gratings

3.2.1 The floor plating and gratings in machinery spaces are to be metallic, divided into easily removable panels.

3.2.2 *The floor plating of normal passageways in machinery spaces of category A shall be made of steel.*

3.3 Bolting down

3.3.1 Bedplates of machinery are to be securely fixed to the supporting structures by means of foundation bolts which are to be distributed as evenly as practicable and of a sufficient number and size so as to ensure proper fitting.

Where the bedplates bear directly on the inner bottom plating, the bolts are to be fitted with suitable gaskets so as to ensure a tight fit and are to be arranged with their heads within the double bottom.

Continuous contact between bedplates and foundations along the bolting line is to be achieved by means of chocks of suitable thickness, carefully arranged to ensure a complete contact.

The same requirements apply to thrust block and shaft line bearing foundations.

Particular care is to be taken to obtain levelling and general alignment between the propulsion engines and their shafting (see Ch 1, Sec 7).

3.3.2 Chocking resins are to be type approved.

3.3.3 Where stays are provided for fixing the upper part of engines to the ship's structure in order, for example, to reduce the amplitude of engine vibrations, such stays are to be so designed as to prevent damage to these engines further to deformation of the shell plating in way of the said stays. The stays are to be connected to the hull in such a way as to avoid abnormal local loads on the structure of the ship.

3.4 Safety devices on moving parts

3.4.1 Suitable protective devices on access restrictions are to be provided in way of moving parts (flywheels, couplings, etc.) in order to avoid accidental contact of personnel with moving parts.

3.5 Gauges

3.5.1 All gauges are to be grouped, as far as possible, near each manoeuvring position; in any event, they are to be clearly visible.

3.6 Ventilation in machinery spaces

3.6.1 *Machinery spaces of Category A shall be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. Any other machinery space shall be adequately ventilated appropriate for the purpose of that machinery space.*

The ventilation of machinery spaces is to be supplied through suitably protected openings arranged in such a way that they can be used in all weather conditions, taking into account Reg. 17(3) and Reg. 19 of the 1966 Load Line Convention as amended by the Protocol of 1988.

Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces. The quantity and distribution of air are to be such as to satisfy machinery requirements for developing maximum continuous power.

The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

3.7 Hot surfaces and fire protection

3.7.1 Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

Surfaces of machinery with temperatures above 220°C, e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers, are to be effectively insulated with non-combustible material or equivalently protected to prevent the ignition of combustible materials coming into contact with them. Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation is to be encased in steel sheathing or equivalent material.

Fire protection, detection and extinction is to comply with the requirements of Part C, Chapter 4.

3.7.2 Specific requirements on fire protection related to engine, turbine and gearbox installations

Materials other than steel may be assessed in relation to the risk of fire associated with the component and its installation when engines, turbines and gearboxes are considered.

The use of materials other than steel is considered acceptable for the following applications:

- internal pipes which cannot cause any release of flammable fluid onto the machinery or into the machinery space in case of failure (this does not cover double sheeted pipes), or
- components that are only subject to liquid spray on the inside when the machinery is running, such as machinery covers, rocker box covers, camshaft end covers, inspection plates and sump tanks. It is a condition that the pressure inside these components and all the elements contained therein is less than 0,18 N/mm^2 and that wet sumps have a volume not exceeding 100 litres, or
- components attached to machinery which satisfy fire test criteria according to standard ISO 19921:2005 / 19922:2005 or other standards acceptable to the Society and which retain mechanical properties adequate for the intended installation.

3.7.3 Incinerators (except those exclusively intended to burn oil residue), as well as thermal fluid heaters, are to be located in rooms other than the following spaces:

- rooms containing parts of the propulsion plant and auxiliary equipment
- steering gear room
- rooms containing electric generating sets (including the emergency generating set) or containing the main or the emergency switchboard
- rooms containing hydraulic equipment
- engine control room
- engineers' and electricians' workshops.

Alternatively the incinerator may be located in the Engine Room or other machinery spaces of category A, provided:

- It is located away from possible sources of flammable oil leakage or other combustible products
- Hot surfaces of the incinerator are insulated according to the provisions of [3.7.1].

A local fixed fire-extinguishing system as required by Ch 4, Sec 6, [4.7] is to be provided, capable of being activated manually from the machinery control position or from another suitable location.

3.7.4 As far as practicable, the hydraulic power units are not to be located in machinery spaces containing the boilers, main engine, its auxiliaries or other sources of ignition. Unless otherwise specified, the hydraulic systems are to comply with the provision of Ch 1, Sec 10, [14].

3.8 Machinery remote control, alarms and safety systems

3.8.1 For remote control systems of main propulsion machinery and essential auxiliary machinery and relevant alarms and safety systems, the requirements of Part C, Chapter 3 apply.

4 Tests and trials

4.1 Works tests

4.1.1 Equipment and its components are subjected to works tests which are detailed in the relevant Sections of this Chapter. The Surveyor is to be informed in advance of these tests.

Where such tests cannot be performed in the workshop, the Society may allow them to be carried out on board, provided this is not judged to be in contrast either with the general characteristics of the machinery being tested or with particular features of the shipboard installation. In such cases, the Surveyor is to be informed in advance and the tests are to be carried out in accordance with the provisions of NR216 Materials and Welding, relative to incomplete tests.

All boilers, all parts of machinery, all steam, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure shall be subjected to appropriate tests including a pressure test before being put into service for the first time as detailed in the other Sections of this Chapter.

4.2 Trials on board

4.2.1 Trials on board of machinery are detailed in Ch 1, Sec 18.

Section 2 Diesel Engines

1 General

1.1 Application

1.1.1 Diesel engines listed below are to be designed, constructed, installed, tested and certified in accordance with the requirements of this Section, under the supervision and to the satisfaction of the Society's Surveyors:

a) main propulsion engines

b) engines driving electric generators, including emergency generators

c) engines driving other auxiliaries essential for safety and navigation and cargo pumps in tankers, when they develop a power of 110 kW and over.

All other engines are to be designed and constructed according to sound marine practice, with the equipment required in [2.3.4], and delivered with the relevant works' certificate (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]).

Engines intended for propulsion of lifeboats and compression ignition engines intended for propulsion of rescue boats are to comply with the relevant Rule requirements.

Additional requirements for control and safety systems for dual fuel engines are given in Ch 1, App 2.

In addition to the requirements of this Section, those given in Ch 1, Sec 1 apply.

1.2 Documentation flow for diesel engine

1.2.1 Document flow for obtaining a type approval certificate

- For the initial engine type, the engine designer prepares the documentation in accordance with requirements in Tab 1 and Tab 2 and forwards to the Society according to the agreed procedure for review.

  In addition, the documents and drawing listed in Ch 1, App 2, Tab 1 are to be submitted for approval of DF engines
- Upon review and approval of the submitted documentation (evidence of approval), it is returned to the engine designer.
- The engine designer arranges for a Surveyor to attend an engine type test and upon satisfactory testing the Society issues a type approval certificate.

1.2.2 Document flow for engine certificate

a) The engine type must have a type approval certificate. For the first engine of a type, the type approval process and the engine certification process (ECP) may be performed simultaneously.

b) Engines to be installed in specific applications may require the engine designer/licensor to modify the design or performance requirements. The modified drawings are forwarded by the engine designer to the engine builder/licensee to develop production documentation for use in the engine manufacture in accordance with Tab 3.

c) The engine builder/licensee develops a comparison list of the production documentation to the documentation listed in Tab 1 and Tab 2.

   If there are differences in the technical content on the licensee's production drawings/documents compared to the corresponding licensor's drawings, the licensee must obtain agreement to such differences from the licensor.

   If the designer acceptance is not confirmed, the engine is to be regarded as a different engine type and is to be subjected to the complete type approval process by the licensee.

d) The engine builder/licensee submits the comparison list and the production documentation to the Society according to the agreed procedure for review/approval.

e) The Society returns documentation to the engine builder/licensee with confirmation that the design has been approved. This documentation is intended to be used by the engine builder/licensee and their subcontractors and attending Surveyors. As the attending Surveyors may request the engine builder/licensee or their subcontractors to provide the actual documents indicated in the list, the documents are necessary to be prepared and available for the Surveyors.

f) The attending Surveyors, at the engine builder/licensee/subcontractors, will issue product certificates as necessary for components manufactured upon satisfactory inspections and tests.

g) The engine builder/licensee assembles the engine, tests the engine with a Surveyor present. An engine certificate is issued by the Surveyor upon satisfactory completion of assembly and tests.

1.2.3 Approval of diesel engine components

Components of engine designer's design which are covered by the type approval certificate of the relevant engine type are regarded as approved whether manufactured by the engine manufacturer or sub-supplied. For components of subcontractor's design, necessary approvals are to be obtained by the relevant suppliers (e.g. exhaust gas turbochargers, charge air coolers, etc.).

Table 1 : Document to be submitted for information, as applicable

No.	Item
1	Engine particulars (e.g. Data sheet with general engine information, Project Guide, Marine Installation Manual)
2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly **(1)**
6	Frame/frame box/gearbox of cast design **(2)**
7	Tie rod
8	Connecting rod
9	Connecting rod, assembly **(3)**
10	Crosshead, assembly **(3)**
11	Piston rod, assembly **(3)**
12	Piston, assembly **(3)**
13	Cylinder jacket/ block of cast design **(2)**
14	Cylinder cover, assembly **(3)**
15	Cylinder liner
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly **(3)**
18	Flywheel
19	Fuel oil injection pump
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
21 22 23	For electronically controlled engines, construction and arrangement of: • Control valves • High-pressure pumps • Drive for high pressure pumps
24	Operation and service manuals **(4)**
25	FMEA (for engine control system) **(5)**
26	Production specifications for castings and welding (sequence)
27	Evidence of quality control system for engine design and in service maintenance
28	Quality requirements for engine production
29	Type approval certification for environmental tests, control components **(6)**

(1) If integral with engine and not integrated in the bedplate.

(2) Only for one cylinder or one cylinder configuration.

(3) Including identification (e.g. drawing number) of components.

(4) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.

(5) Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine.

(6) Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions (see Ch 3, Sec 6, [2]).

Table 2 : Documentation to be submitted for approval, as applicable

No	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions **(1) (2)**
2	Thrust bearing bedplate of welded design, with welding details and welding instructions **(1)**
3	Bedplate/oil sump welding drawings **(1)**
4	Frame/framebox/gearbox of welded design, with welding details and instructions **(1) (2)**
5	Engine frames, welding drawings **(1) (2)**
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to the attached data sheet and Ch 1, App 1
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests **(3)**
	Schematic layout or other equivalent documents on the engine of:
12	• Starting air system
13	• Fuel oil system
14	• Lubricating oil system
15	• Cooling water system
16	• Hydraulic system
17	• Hydraulic system (for valve lift)
18	• Engine control and safety system
19	Shielding of high pressure fuel pipes, assembly **(4)**
20	Construction of accumulators (for electronically controlled engine)
21	Construction of common accumulators (for electronically controlled engine)
22	Arrangement and details of the crankcase explosion relief valve (see [2.3]) **(5)**
23	Calculation results for crankcase explosion relief valves ([2.3])
24	Details of the type test program and the type test report) **(6)**
25	High pressure parts for fuel oil injection system **(7)**
26	Oil mist detection and/or alternative alarm arrangements (see [2.3])
27	Details of mechanical joints of piping systems (Ch 1, Sec 10, [2.4])
28	Documentation verifying compliance with inclination limits (see Ch 1, Sec 1, [2.4])
29	Documents as required in Ch 3, Sec 3, as applicable

(1) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
(2) For each cylinder for which dimensions and details differ.
(3) For comparison with Society requirements for material, NDT and pressure testing as applicable.
(4) All engines.
(5) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m3 or more.
(6) The type test report may be submitted shortly after the conclusion of the type test.
(7) The documentation to contain specifications for pressures, pipe dimensions and materials.

Table 3 : Documentation for the inspection of components and systems

No	Item
1	Engine particulars
2	Material specifications of main parts with information on non-destructive material tests and pressure tests **(1)**
3	Bedplate and crankcase of welded design, with welding details and welding instructions **(2)**
4	Thrust bearing bedplate of welded design, with welding details and welding instructions **(2)**
5	Frame/framebox/gearbox of welded design, with welding details and instructions **(2)**
6	Crankshaft, assembly and details
7	Thrust shaft or intermediate shaft (if integral with engine)
8	Shaft coupling bolts
9	Bolts and studs for main bearings
10	Bolts and studs for cylinder heads and exhaust valve (two stroke design)
11	Bolts and studs for connecting rods

No	Item
12	Tie rods
	Schematic layout or other equivalent documents on the engine of: **(3)**
13	• Starting air system
14	• Fuel oil system
15	• Lubricating oil system
16	• Cooling water system
17	• Hydraulic system
18	• Hydraulic system (for valve lift)
19	• Engine control and safety system
20	Shielding of high pressure fuel pipes, assembly **(4)**
21	Construction of accumulators for hydraulic oil and fuel oil
22	High pressure parts for fuel oil injection system **(5)**
23	Arrangement and details of the crankcase explosion relief valve (see [2.3]) **(6)**
24	Oil mist detection and/or alternative alarm arrangements (see [2.3])
25	Cylinder head
26	Cylinder block, engine block
27	Cylinder liner
28	Counterweights (if not integral with crankshaft), including fastening
29	Connecting rod with cap
30	Crosshead
31	Piston rod
32	Piston, assembly **(7)**
33	Piston head
34	Camshaft drive, assembly **(7)**
35	Flywheel
36	Arrangement of foundation (for main engines only)
37	Fuel oil injection pump
38	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
39	Construction and arrangement of dampers
	For electronically controlled engines, assembly drawings or arrangements of:
40	• Control valves
41	• High-pressure pumps
42	• Drive for high pressure pumps
43	• Valve bodies, if applicable
44	Operation and service manuals **(8)**
45	Test program resulting from FMEA (for engine control system) **(9)**
46	Production specifications for castings and welding (sequence)
47	Type approval certification for environmental tests, control components **(10)**
48	Quality requirements for engine production

(1) For comparison with Society requirements for material, NDT and pressure testing as applicable.

(2) For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.

(3) Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.

(4) All engines.

(5) The documentation to contain specifications for pressures, pipe dimensions and materials.

(6) Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m3 or more.

(7) Including identification (e.g. drawing number) of components.

(8) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.

(9) Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves.

(10) Documents modified for a specific application are to be submitted to the Society for information or approval, as applicable. See [1.2.2], item b).

1.3 Definitions

1.3.1 Engine type

In general, the type of an engine is defined by the following characteristics:

- the cylinder diameter
- the piston stroke
- the method of injection (direct or indirect injection)
- the kind of fuel (liquid, gaseous or dual-fuel)
- the working cycle (4-stroke, 2-stroke)
- the gas exchange (naturally aspirated or supercharged)
- the maximum continuous power per cylinder at the corresponding speed and/or brake mean effective pressure corresponding to the above-mentioned maximum continuous power
- the method of pressure charging (pulsating system or constant pressure system)
- the charging air cooling system (with or without intercooler, number of stages, etc.)
- cylinder arrangement (in-line or V-type).

1.3.2 Engine power

The maximum continuous power is the maximum power at ambient reference conditions (see [1.3.3]) which the engine is capable of delivering continuously, at nominal maximum speed, in the period of time between two consecutive overhauls.

Power, speed and the period of time between two consecutive overhauls are to be stated by the Manufacturer and agreed by the Society.

The rated power is the maximum power at ambient reference conditions (see [1.3.3]) which the engine is capable of delivering as set after works trials (fuel stop power) at the maximum speed allowed by the governor.

The rated power for engines driving electric generators is the nominal power, taken at the net of overload, at ambient reference conditions (see [1.3.3]), which the engine is capable of delivering as set after the works trials (see [4.3]).

1.3.3 Ambient reference conditions

The power of engines as per [1.1.1], items a), b) and c) is to be referred to the following conditions:

- barometric pressure = 0,1 MPa
- relative humidity = 60%
- ambient air temperature = 45°C
- sea water temperature (and temperature at inlet of sea water cooled charge air cooler) = 32°C.

In the case of ships assigned with a navigation notation other than unrestricted navigation, different temperatures may be accepted by the Society.

The engine Manufacturer is not expected to provide the above ambient conditions at a test bed. The rating is to be adjusted according to a recognised standard accepted by the Society.

1.3.4 Same type of engines

Two diesel engines are considered to be of the same type when they do not substantially differ in design and construction characteristics, such as those listed in the engine type definition as per [1.3.1], it being taken for granted that the documentation concerning the essential engine components listed in Tab 1, Tab 2 and Tab 3, and associated materials employed has been submitted, examined and, where necessary, approved by the Society.

1.3.5 Substantive modifications or major modifications or major changes

Design modifications, which lead to alterations in the stress levels, operational behaviour, fatigue life or an effect on other components or characteristics of importance such as emissions.

1.3.6 Low-Speed Engines means diesel engines having a rated speed of less than 300 rpm.

Medium-Speed Engines means diesel engines having a rated speed of 300 rpm and above, but less than 1400 rpm.

High-Speed Engines means diesel engines having a rated speed of 1400 rpm and above.

2 Design and construction

2.1 Materials and welding

2.1.1 Crankshaft materials

In general, crankshafts are to be of forged steel having a tensile strength not less than 400 N/mm^2 and not greater than 1000 N/mm^2.

The use of forged steels of higher tensile strength is subject to special consideration by the Society in each case.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may accept crankshafts made of cast carbon steel, cast alloyed steel of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

a) between 400 N/mm^2 and 560 /mm^2 for cast carbon steel

b) between 400 N/mm^2 and 700 N/mm^2 for cast alloyed steel.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may also accept crankshafts made of cast iron for engines of a nominal power not exceeding 110 kW with a significative in-service behaviour either in marine or industry. The cast iron is to be of "SG" type (spheroidal graphite) of appropriate quality and manufactured by a suitable procedure.

2.1.2 Welded frames and foundations

Steels used in the fabrication of welded frames and bedplates are to comply with the requirements of NR216 Materials and Welding.

Welding is to be in accordance with the requirements of Ch 1, Sec 1, [2.2].

2.2 Crankshaft

2.2.1 Check of the scantling

The check of crankshaft strength is to be carried out in accordance with Ch 1, App 1.

2.3 Crankcase

2.3.1 Strength

Crankcase construction and crankcase doors are to be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by [2.3.4]. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

2.3.2 Ventilation and drainage

Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted.

Vent pipes, where provided, are to be as small as practicable. If provision is made for the forced extraction of gases from the crankcase (e.g. for detection of explosive mixtures), the vacuum in the crankcase is not to exceed:

$2{,}5\ 10^{-4}$ MPa

To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

2.3.3 Warning notice

A warning notice is to be fitted, preferably on a crankcase door on each side of the engine, or alternatively on the control stand.

This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling of the crankcase.

2.3.4 Crankcase explosion relief valves

a) Diesel engines of a cylinder diameter of 200 mm and above or a crankcase gross volume of 0,6 m^3 and above are to be provided with crankcase explosion relief valves in accordance with the following requirements.

b) Engines having a cylinder bore not exceeding 250 mm, are to have at least one valve near each end, but over eight crankthrows, an additional valve is to be fitted near the middle of the engine. Engines having a cylinder bore exceeding 250 mm, but not exceeding 300 mm, are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves. Engines having a cylinder bore exceeding 300 mm are to have at least one valve in way of each main crankthrow.

c) Additional relief valves are to be fitted on separate spaces of the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces is 0,6 m^3 or above.

d) The free area of each relief valve is not to be less than 45 cm^2.

e) The combined free area of the valves fitted on an engine is not to be less than 115 cm^2 per cubic metre of the crankcase gross volume. (See Note 1).

f) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent any inrush of air thereafter.

g) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

h) Crankcase explosion relief valves are to be designed and constructed to open quickly and to be fully open at a pressure not greater than 0,02 MPa.

i) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

j) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine.

The purpose of type testing crankcase explosion valves is:

- to verify the effectiveness of the flame arrester
- to verify that the valve closes after an explosion
- to verify that the valve is gas/air tight after an explosion
- to establish the level of overpressure protection provided by the valve.

Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

Type testing procedure is to comply with Ch 1, App 4.

k) Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual is to contain the following information:

- description of valve with details of function and design limits
- copy of type test certification
- installation instructions
- maintenance in service instructions to include testing and renewal of any sealing arrangements
- actions required after a crankcase explosion.

l) A copy of the installation and maintenance manual required in i) above is to be provided on board the unit.

m) Valves are to be provided with suitable markings that include the following information:

- name and address of manufacturer
- designation and size
- month/year of manufacture
- approved installation orientation.

Note 1: The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

2.3.5 Oil mist detection

a) Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required:

- for alarm and slow down purposes for low speed diesel engines of 2250 kW and above or having cylinders of more than 300 mm bore
- for alarm and automatic shutoff purposes for medium and high speed diesel engines of 2250 kW and above or having cylinders of more than 300 mm bore

Oil mist detection arrangements are to be of a type approved and tested in accordance with Ch 3, App 1 and comply with b) to c) below. Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by the Society for such purposes

Note 1: An equivalent device for high speed engines could be interpreted as measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.

b) The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

- Schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector
- Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate
- The manufacturer's maintenance and test manual
- Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment

c) A copy of the oil mist detection equipment maintenance and test manual required by item b) is to be provided on board ship

d) Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine

e) Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm

f) Oil mist detection and alarm systems are to be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions in accordance with test procedures that are acceptable to the Society

g) The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements

h) The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication

i) Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with individual Society requirements for such systems

j) Plans showing details and arrangements of oil mist detection and alarm arrangements are to be submitted for approval in accordance with Tab 2 under item 18

k) The equipment together with detectors is to be tested when installed on the test bed and on board ship to demonstrate that the detection and alarm system functionally operates. The testing arrangements are to be to the satisfaction of the Society

l) Where sequential oil mist detection arrangements are provided the sampling frequency and time is to be as short as reasonably practicable

m) Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase details are to be submitted for consideration of individual Societies. The following information is to be included in the details to be submitted for consideration:

- Engine particulars – type, power, speed, stroke, bore and crankcase volume
- Details of arrangements prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements
- Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience
- Operating instructions and the maintenance and test instructions

n) Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted to the Society for consideration.

2.3.6 When materials other than steel are used for crankcase, requirements in Ch 1, Sec 1, [3.7.2] are to be referred to.

2.4 Scavenge manifolds

2.4.1 Fire extinguishing

For two-stroke crosshead type engines, scavenge spaces in open connection (without valves) to the cylinders are to be connected to a fixed fire-extinguishing system, which is to be entirely independent of the fire-extinguishing system of the machinery space.

2.4.2 Blowers

Where a single two-stroke propulsion engine is equipped with an independently driven blower, alternative means to drive the blower or an auxiliary blower are to be provided ready for use.

2.4.3 Relief valves

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves in accordance with [2.3.4].

2.5 Systems

2.5.1 General

In addition to the requirements of the present sub-article, those given in Ch 1, Sec 10 and in Ch 1, Sec 1, [3.7.2] are to be satisfied.

Flexible hoses in the fuel and lubricating oil system are to be limited to the minimum and are to be type approved.

Unless otherwise stated in Ch 1, Sec 10, propulsion engines are to be equipped with external connections for standby pumps for:

- fuel oil supply
- lubricating oil and cooling water circulation.

2.5.2 Fuel oil system

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

In fuel oil systems for propulsion machinery, filters are to be fitted and arranged so that an uninterrupted supply of filtered fuel oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

a) External high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure.

A jacketed pipe incorporates an outer pipe into which the high pressure fuel pipe is placed, forming a permanent assembly.

The jacketed piping system is to include a means for collection of leakages and arrangements are to be provided with an alarm in case of a fuel line failure.

If flexible hoses are used for shielding purposes, these are to be approved by the Society.

When in fuel oil return piping the pulsation of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required as above.

b) For ships assigned with a restricted navigation notation, the requirements under item a) may be relaxed at the Society's discretion.

2.5.3 Lubricating oil system

Efficient filters are to be fitted in the lubricating oil system when the oil is circulated under pressure.

In such lubricating oil systems for propulsion machinery, filters are to be arranged so that an uninterrupted supply of filtered lubricating oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

The relief valves may be omitted provided that the filters can withstand the maximum pressure that the pump may develop.

Where necessary, the lubricating oil is to be cooled by means of suitable coolers.

2.5.4 Charge air system

a) Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers are given in Ch 1, Sec 17.

b) When two-stroke propulsion engines are supercharged by exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering turbocharger casings and causing damage to blades and nozzle rings.

2.6 Starting air system

2.6.1 The requirements given in [3.1] apply.

2.7 Control and monitoring

2.7.1 General

In addition to those of this item, the general requirements given in Part C, Chapter 3 apply.

2.7.2 Alarm

The lubricating oil system of diesel engines with a power equal to or in excess of 37 kW is to be fitted with alarms to give audible and visual warning in the event of an appreciable reduction in pressure of the lubricating oil supply.

2.7.3 Governors of main and auxiliary engines

Each engine, except the auxiliary engines for driving electric generators for which [2.7.6] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

2.7.4 Overspeed protective devices of main and auxiliary engines

In addition to the speed governor, each:

- main propulsion engine having a rated power of 220 kW and above, which can be declutched or which drives a controllable pitch propeller, and
- auxiliary engine having a rated power of 220 kW and above, except those for driving electric generators, for which [2.7.6], item f) applies,

is to be fitted with a separate overspeed protective device so adjusted that the engine cannot exceed the rated speed n by more than 20%; arrangements are to be made to test the overspeed protective device.

Equivalent arrangements may be accepted subject to special consideration by the Society in each case.

The overspeed protective device, including its driving mechanism or speed sensor, is to be independent of the governor.

2.7.5 Use of electronic governors

a) Type approval

Electronic governors and their actuators are to be type approved by the Society.

b) Electronic governors for main propulsion engines

If an electronic governor is fitted to ensure continuous speed control or resumption of control after a fault, an additional separate governor is to be provided unless the engine has a manually operated fuel admission control system suitable for its control.

A fault in the governor system is not to lead to sudden major changes in propulsion power or direction of propeller rotation.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors not in compliance with the above requirements will be considered by the Society on a case by case basis, when fitted on ships with two or more main propulsion engines.

c) Electronic governors forming part of a remote control system

When electronic speed governors of main internal combustion engines form part of a remote control system, they are to comply with the following conditions:

- If lack of power to the governor may cause major and sudden changes in the present speed and direction of thrust of the propeller, back up power supply is to be provided;
- Local control of the engines is always to be possible even in the case of failure in any part of the automatic or remote control systems. To this purpose, from the local control position it is to be possible to disconnect the remote signal, bearing in mind that the speed control according to [2.7.3] is not available unless an additional separate governor is provided for such local mode of control.

d) Electronic governors for auxiliary engines driving electric generators

In the event of a fault in the electronic governor system the fuel admission is to be set to “zero”.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case by case basis.

2.7.6 Governors for auxiliary engines driving electric generators

a) Prime movers for driving generators of the main and emergency sources of electrical power are to be fitted with a speed governor which will prevent transient frequency variations in the electrical network in excess of ±10% of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by item f).

b) At all loads between no load and rated power, the permanent speed variation is not to be more than 5% of the rated speed.

c) Prime movers are to be selected in such a way that they meet the load demand within the ship’s mains and, when running at no load, can satisfy the requirement in item a) above if suddenly loaded to 50% of the rated power of the generator, followed by the remaining 50% after an interval sufficient to restore speed to steady state. Steady state conditions (see Note 1) are to be achieved in not more than 5 s.

Note 1: Steady state conditions are those at which the envelope of speed variation does not exceed ± 1% of the declared speed at the new power.

d) Application of the electrical load in more than 2 load steps can only be allowed if the conditions within the ship's mains permit the use of those auxiliary engines which can only be loaded in more than 2 load steps (see Fig 1 for guidance on 4-stroke diesel engines expected maximum possible sudden power increase) and provided that this is already allowed for in the designing stage.

This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected.

This also applies to generators to be operated in parallel and where the power is to be transferred from one generator to another, in the event that any one generator is to be switched off.

e) Emergency generator sets must satisfy the governor conditions as per items a) and b) when:

- their total consumer load is applied suddenly, or
- their total consumer load is applied in steps, subject to:
  - the total load is supplied within 45 seconds since power failure on the main switchboard
  - the maximum step load is declared and demonstrated
  - the power distribution system is designed such that the declared maximum step loading is not exceeded
  - the compliance of time delays and loading sequence with the above is to be demonstrated at ship's trials

f) In addition to the speed governor, auxiliary engines of rated power equal to or greater than 220 kW driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

This device is to automatically shut down the engine.

g) For alternating current generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

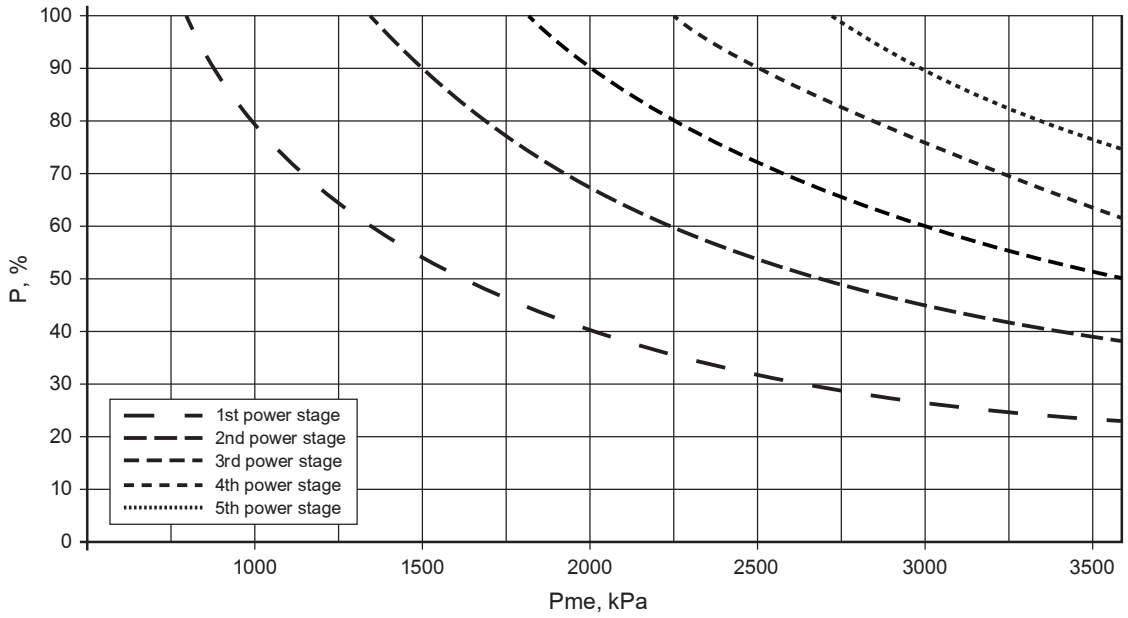
For alternating current generating sets intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.7.7 Engine Power Limitation (EPL) and Shaft Power Limitation (ShaPoLi) systems

a) The Overridable Engine Power Limitation (EPL) systems and Overridable Shaft Power Limitation (SHaPoLi) systems are to be of a type approved by the Society. These systems, in particular those of a mechanical type, may also be considered on a case-by-case basis by the Society.

b) Where technically possible, EPL and SHaPoLi systems are to be controlled from the navigation bridge without the crew's attendance in the machinery space.

Figure 1 : Reference values for maximum possible sudden power increases P as a function of brake mean effective pressure, P_{me}, at declared power (four-stroke diesel engines)



P: power increase referred to declared power at site conditions; P_{me}: declared power mean effective pressure

2.7.8 Summary tables

Diesel engines installed on ships without automation notations are to be equipped with monitoring equipment as detailed in Tab 4 or Tab 5 for main propulsion, in Tab 6 for auxiliary services and in Tab 7 for emergency respectively.

For ships assigned with a restricted navigation notation, the acceptance of a reduction in the monitoring equipment required in Tab 4, Tab 5 and Tab 6 may be considered.

The alarms are to be visual and audible.

The indicators are to be fitted at a normally attended position (on the engine or at the local control station).

Table 4 : Monitoring of main propulsion cross-head (slow speed) diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L	local					
	LL			X			
Lubricating oil to cross-head bearing pressure when separate	L	local					
	LL			X			
Lubricating oil to camshaft pressure when separate	L	local					
	LL			X			
Turbocharger lubricating oil inlet pressure		local					
Lubricating oil inlet temperature		local					
Thrust bearing pads or bearing outlet temperature	H	local					
Main, crank, cross-head bearing, oil outlet temp	H						
Oil mist concentration in crankcase (or engine bearing temperature monitors or equivalent devices) **(5)**	H		X				
Cylinder fresh cooling water system inlet pressure	L	local **(3)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature		local					
Piston coolant inlet pressure on each cylinder **(1)**	L	local					
Piston coolant outlet temperature on each cylinder **(1)**		local					
Piston coolant outlet flow on each cylinder **(1)** **(2)**	L						
Speed of turbocharger		local					
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local **(4)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) Not required, if the coolant is oil taken from the main cooling system of the engine
(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
(3) For engines of 220 KW and above
(4) Indication is required after each cylinder, for engines of 500 kW/cylinder and above
(5) For engine of 2250 KW and above or having cylinders of more than 300 mm bore

Table 5 : Monitoring of main propulsion trunk-piston (medium or high speed) engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L	local					
	LL			X			
Lubricating oil filter differential pressure	H	local					
Turbocharger lubricating oil inlet pressure **(1)**		local					
Lubricating oil inlet temperature		local					
Oil mist concentration in crankcase (or engine bearing temperature monitors or equivalent devices) **(3)**	H			X			
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature		local					
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local **(2)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) If without integrated self-contained oil lubrication system
(2) Indication is required after each cylinder, for engines of 500 kW/cylinder and above
(3) For engine of 2250 KW and above or having cylinders of more than 300 mm bore

Table 6 : Monitoring of trunk-piston diesel engines used for auxiliary services

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil viscosity or temperature before injection (for engine running on heavy fuel)		local					
Fuel oil pressure		local					
Fuel oil leakage from high pressure pipes	H						
Lubricating oil pressure	L	local		X			
Oil mist concentration in crankcase (or engine bearing temperature monitors or equivalent devices) **(1)**	H			X			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X			
Fault in the electronic governor system	X						

(1) For engine of 2250 KW and above or having cylinders of more than 300 mm bore

Table 7 : Monitoring of emergency diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil leakage from high pressure pipes (fuel injection pipes and common rails)	X	local					
Lubricating oil temperature **(1)**	H	local					
Lubricating oil pressure	L	local					
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: • the engine main and crank bearing oil outlet; or • the engine main and crank bearing) **(2)**	H	local					
Pressure or flow of cooling water **(1)**	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X **(1)**			

(1) Not applicable to emergency generator of less than 220 kW

(2) For engines having a power of more than 2250kW or a cylinder bore of more than 300 mm

Note 1: The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.

Note 2: Regardless of the engine output, if shutdowns additional to those above specified except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

Note 3: The alarm system is to function in accordance with AUT notation, with additional requirements that grouped alarms are to be arranged on the bridge.

Note 4: In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

Note 5: The local indications are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

3 Arrangement and installation

3.1 Starting arrangements

3.1.1 Mechanical air starting

a) Air starting the main and auxiliary engines is to be arranged in compliance with Ch 1, Sec 10, [17.3.1].

b) The total capacity of air compressors and air receivers is to be in compliance with Ch 1, Sec 10, [17.3.2] and Ch 1, Sec 10, [17.3.3].

c) The main starting air arrangements for main propulsion or auxiliary diesel engines are to be adequately protected against the effects of backfiring and internal explosion in the starting air pipes. To this end, the following safety devices are to be fitted:

- An isolating non-return valve, or equivalent, at the starting air supply connection to each engine.
- A bursting disc or flame arrester:
  - in way of the starting valve of each cylinder, for direct reversing engines having a main starting air manifold
  - at least at the supply inlet to the starting air manifold, for non-reversing engines.

  The bursting disc or flame arrester above may be omitted for engines having a bore not exceeding 230 mm.

Other protective devices will be specially considered by the Society.

The requirements of this item c) do not apply to engines started by pneumatic motors.

d) Compressed air receivers are to comply with the requirements of Ch 1, Sec 3. Compressed air piping and associated air compressors are to comply with the requirements of Ch 1, Sec 10.

3.1.2 Electrical starting

a) Where main internal combustion engines are arranged for electrical starting, at least two separate batteries are to be fitted.

The arrangement is to be such that the batteries cannot be connected in parallel.

Each battery is to be capable of starting the main engine when in cold and ready to start condition.

The combined capacity of batteries is to be sufficient to provide within 30 min, without recharging, the number of starts required in [3.1.1] b) in the event of air starting.

b) Electrical starting arrangements for auxiliary engines are to have two separate storage batteries or may be supplied by two separate circuits from main engine storage batteries when these are provided. In the case of a single auxiliary engine, one battery is acceptable. The combined capacity of the batteries is to be sufficient for at least three starts for each engine.

c) The starting batteries are only to be used for starting and for the engine's alarm and monitoring. Provision is to be made to maintain the stored energy at all times.

d) Each charging device is to have at least sufficient rating for recharging the required capacity of batteries within 6 hours.

3.1.3 Special requirements for starting arrangements for emergency generating sets

a) Emergency generating sets are to be capable of being readily started in their cold condition at a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, provision acceptable to the Society shall be made for the maintenance of heating arrangements, to ensure ready starting of the generating sets.

b) Each emergency generating set arranged to be automatically started shall be equipped with starting devices approved by the Society with a stored energy capability of at least three consecutive starts.

The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy shall be provided for an additional three starts within 30 minutes, unless manual starting can be demonstrated to be effective.

c) The stored energy is to be maintained at all times, as follows:

- *electrical and hydraulic starting systems shall be maintained from the emergency switchboard*
- *compressed air starting systems shall be provided in accordance with Ch 1, Sec 10, [17.3.4].*

d) Where automatic starting is not required, manual starting, such as manual cranking, inertia starters, manually charged hydraulic accumulators, or powder charge cartridges, is permissible where this can be demonstrated as being effective.

e) When manual starting is not practicable, the requirements of b) and c) are to be complied with, except that starting may be manually initiated.

3.2 Turning gear

3.2.1 Each engine is to be provided with hand-operated turning gear; where deemed necessary, the turning gear is to be both hand and mechanically-operated.

The turning gear engagement is to inhibit starting operations.

3.3 Trays

3.3.1 Trays fitted with means of drainage are to be provided in way of the lower part of the crankcase and, in general, in way of the parts of the engine, where oil is likely to spill in order to collect the fuel oil or lubricating oil dripping from the engine.

3.4 Exhaust gas system

3.4.1 In addition to the requirements given in Ch 1, Sec 10, the exhaust system is to be efficiently cooled or insulated in such a way that the surface temperature does not exceed 220°C (see also Ch 1, Sec 1, [3.7]).

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type testing

4.1.1 Objectives

The type testing is to be arranged to represent typical foreseen service load profiles, as specified by the engine builder, as well as to cover for required margins due to fatigue scatter and reasonably foreseen in-service deterioration. This applies to:

- Parts subjected to high cycle fatigue (HCF) such as connecting rods, cams, rollers and spring tuned dampers where higher stresses may be provided by means of elevated injection pressure, cylinder maximum pressure, etc.
- Parts subjected to low cycle fatigue (LCF) such as "hot" parts when load profiles such as idle - full load - idle (with steep ramps) are frequently used.
- Operation of the engine at limits as defined by its specified alarm system, such as running at maximum permissible power with the lowest permissible oil pressure and/or highest permissible oil inlet temperature.

4.1.2 Validity

a) Type testing is required for every new engine type intended for installation onboard ships subject to classification.

b) A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to the Society.

c) A type of engine is defined by:

- bore and stroke
- injection method (direct or indirect)
- valve and injection operation (by cams or electronically controlled)
- kind of fuel (liquid, dual-fuel, gaseous)
- working cycle (4-stroke, 2-stroke)
- turbo-charging system (pulsating or constant pressure)
- the charging air cooling system (e.g. with or without intercooler)
- cylinder arrangement (in-line or V) (see Note 1)
- cylinder power, speed and cylinder pressures (see Note 2)

Note 1: One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. At the discretion of the Society, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher.

Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.

Note 2: The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR).

Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if design approved, only crankshaft calculation and crankshaft drawings, if modified) may be permitted without a new type test if the increase from the type tested engine is within:

- 5% of the maximum combustion pressure, or
- 5% of the mean effective pressure, or
- 5% of the rpm

Providing maximum power is not increased by more than 10%, an increase of maximum approved power may be permitted without a new type test provided engineering analysis and evidence of successful service experience in similar field applications (even if the application is not classified) or documentation of internal testing are submitted if the increase from the type tested engine is within:

- 10% of the maximum combustion pressure, or
- 10% of the mean effective pressure, or
- 10% of the rpm

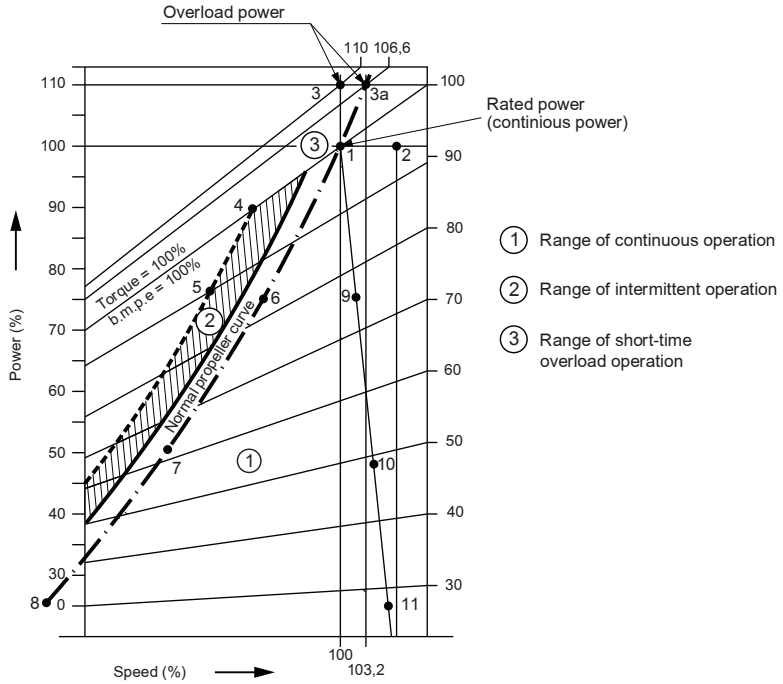
d) De-rated engine

If an engine has been design approved, and internal testing per Stage A (see [4.1.4]) is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/bmep/rpm upon submission of an Extended Delivery Test Report at:

- Test at over speed (only if nominal speed has increased)
- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1 (see Fig 2), 2 measurements with one running hour in between
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 (see Fig 2) or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a (see Fig 2), 0,5 hour
- 100% power at maximum permissible speed corresponding to load point 2 (see Fig 2), 0,5 hour.

e) An integration test demonstrating that the response of the complete mechanical, hydraulic and electronic system is as predicted maybe carried out for acceptance of sub-systems (Turbo Charger, Engine Control System, Dual Fuel, Exhaust Gas treatment…) separately approved. The scope of these tests is to be proposed by the designer/licensor taking into account of impact on engine.

Figure 2 : Load points



4.1.3 Safety precautions

a) Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.

b) This applies especially to crankcase explosive conditions protection, but also over-speed protection and any other shut down function.

c) The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in [4.1.7], item i) is also to be carried out before the test runs.

d) Interlock test of turning gear is to be performed when installed.

4.1.4 Test programme

a) The type testing is divided into 3 stages:

- Stage A - internal tests.

  This includes some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by the Society or stipulated by the designer are to be presented to the Society before starting stage B.

- Stage B - witnessed tests.

  This is the testing made in the presence of the Surveyor.

- Stage C - component inspection.

  This is the inspection of engine parts to the extent as required by the Society.

b) The complete type testing program is subject to approval by the Society. The extent the Surveyor's attendance is to be agreed in each case, but at least during stage B and C.

c) Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program.

d) Upon completion of complete type testing (stage A through C), a type test report is to be submitted to the Society for review. The type test report is to contain:

- overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to the Society.
- detailed description of the load and functional tests conducted during stage B.
- inspection results from stage C.

e) High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in [4.1.2].

Propulsion engines for ships having the service notation **HSC-CAT A**, **HSC-CAT B**, **HSC**, **high speed craft** or **light ship**, high speed craft or light ship that may be used for frequent load changes from idle to full are normally to be tested with at least 500 cycles (idle - full load - idle) using the steepest load ramp that the control system (or operation manual if not automatically controlled) permits. The duration at each end is to be sufficient for reaching stable temperatures of the hot parts.

4.1.5 Measurements and recordings

a) During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

b) As a minimum, the following engine data are to be measured and recorded:

- Engine r.p.m.
- Torque
- Maximum combustion pressure for each cylinder (see Note 1)
- Mean indicated pressure for each cylinder (see Note 1)
- Charging air pressure and temperature
- Exhaust gas temperature
- Fuel rack position or similar parameter related to engine load
- Turbocharger speed
- All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

Note 1: For engines where the standard production cylinder heads are not designed for such measurements, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as part of Stage A and are to be properly documented. Where deemed necessary e.g. for dual fuel engines, the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the reliability of the method is documented.

Calibration records for the instrumentation used to collect data as listed above are to be presented to - and reviewed by the attending Surveyor.

Additional measurements may be required in connection with the design assessment.

4.1.6 Stage A - internal tests

a) During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval programme.

b) At least the following conditions are to be tested:

- Normal case:

  The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.
- The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
- For high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment.
- Specific tests of parts of the engine, required by the Society or stipulated by the designer.

4.1.7 Stage B - witnessed tests

a) The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.

b) The over-speed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or without load during the speed overshoot.

c) The engine is to be operated according to the power and speed diagram (see Fig 2). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in [4.1.5]. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0,5 hour can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.

d) The load points (see Fig 2) are:

- Rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 hours with data collection with an interval of 1 hour. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test should be made here
- 100% power at maximum permissible speed corresponding to load point 2
- Minimum permissible speed at 100% torque, corresponding to load point 4
- Minimum permissible speed at 90% torque corresponding to load point 5 (Applicable to propulsion engines only).
- Part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine
- Crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.

e) During all these load points, engine parameters are to be within the specified and approved values.

f) Operation with damaged turbocharger:

For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.

Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m.) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. (The test can be performed by either bypassing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor).

g) Functional tests:

- Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water- brake). During this operation, no alarm shall occur.
- Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.
- Governor tests: tests for compliance with [2.7] are to be carried out.

h) Integration test:

For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in Tab 1.

i) Fire protection measures:

Screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:

- The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
- Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by the Society. Readings obtained are to be randomly verified by use of contact thermometers.

4.1.8 Stage C - Opening up for Inspections

a) The crankshaft deflections are to be measured in the specified (by designer) condition (except for engines where no specification exists).

b) High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.

c) For all the other engines, after the test run the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection as follows (engines with long service experience from non-marine fields can have a reduced extent of opening):

- piston removed and dismantled
- crosshead bearing dismantled
- guide planes
- connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides)
- main bearing dismantled
- cylinder liner in the installed condition
- cylinder head, valves disassembled
- cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.)

d) For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.

e) If deemed necessary by the surveyor, further dismantling of the engine may be required.

4.1.9 If an electronically controlled diesel engine has been type tested as a conventional engine the Society may waive tests required by this article provided the results of the individual tests would be similar.

4.2 Material and non-destructive tests for engine components

4.2.1 List of components

Engine components are to be tested in accordance with Tab 8 and with the requirements of NR216 Materials and Welding.

Symbols used on Tab 8 are defined as below:

C : Society certificate

Cc : Chemical composition

CD : Crack detection by MPI (magnetic particul inspection) or DP (dye penetration inspection)

CH : Crosshead engines

D : Cylinder bore diameter (mm)

GJL : Gray cast iron

GJS : Spheroidal graphite cast iron

GS : Cast steel

M : Mechanical properties

TR : Test report

UT : Ultrasonic testing

W : Work certificate

X : Visual examination of accessible surfaces by the Surveyor.

For components and materials not listed in Tab 8, consideration shall be given by the Society upon full details being submitted and reviewed.

Table 8 : Summary of required documentation for engine components

No.	Part **(1) (2) (3) (4) (5)**	Material properties **(6)**	Non-destructive examination **(7)**	Hydraulic testing **(8)**	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines:	Component certificate
1	Welded bedplate	W(Cc+M)	W(UT+CD)			fit-up + post-welding	All	C
2	Bearing transverse girders GS	W(Cc+M)	W(UT+CD)			X	All	C
3	Welded frame box	W(Cc+M)	W(UT+CD)			fit-up + post-welding	All	C
4	Cylinder block GJL			W **(9)**			> 400 kW/cyl	
5	Cylinder block GJS			W **(9)**			> 400 kW/cyl	
6	Welded cylinder frames	W(Cc+M)	W(UT+CD)			fit-up + post-welding	CH	C
7	Engine block GJL			W **(9)**			> 400 kW/cyl	
8	Engine block GJS	W(M)		W **(9)**			> 400 kW/cyl	
9	Cylinder liner	W(Cc+M)		W **(9)**			D > 300mm	
10	Cylinder head GJL			W			D > 300mm	
11	Cylinder head GJS			W			D > 300mm	
12	Cylinder head GS	W(Cc+M)	W(UT+CD)	W		X	D > 300mm	C
13	Forged cylinder head	W(Cc+M)	W(UT+CD)	W		X	D > 300mm	C
14	Piston crown GS	W(Cc+M)	W(UT+CD)			X	D > 400mm	C
15	Forged piston crown	W(Cc+M)	W(UT+CD)			X	D > 400mm	C
16	Crankshaft: made in one piece	C(Cc+M)	W(UT+CD)		W	Random, of fillets and oil bores	All	C
17	Semi-built Crankshaft (Crankthrow, forged main journal and journals with flange)	C(Cc+M)	W(UT+CD		W	Random, of fillets and shrink fittings	All	C
18	Exhaust gas valve cage			W			CH	
19	Piston Rod, if applicable	C(Cc+M)	W(UT+CD			Random	D > 400mm CH	C
20	Cross head	C(Cc+M)	W(UT+CD)			Random	CH	C

No.	Part **(1) (2) (3) (4) (5)**	Material properties **(6)**	Non-destructive examination **(7)**	Hydraulic testing **(8)**	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines:	Component certificate
21	Connecting rod with cap	C(Cc+M)	W(UT+CD)		W	Random, of all surfaces, in particular those shot peened	All	C
22	Coupling bolts for crankshaft	C(Cc+M)	W(UT+CD)		W	Random, of interference fit	All	C
23	Bolts and studs for main bearings	W(Cc+M)	W(UT+CD)				D > 300mm	
24	Bolts and studs for cylinder heads	W(Cc+M)	W(UT+CD)				D > 300mm	
25	Bolts and studs for connecting rods	W(Cc+M)	W(UT+CD)		TR of thread making		D > 300mm	
26	Tie rod	W(Cc+M)	W(UT+CD)		TR of thread making	Random	CH	C
27	High pressure fuel injection pump body **(10)**	W(Cc+M)		W			D > 300mm	W **(10)**
		W(Cc+M)		TR			D ≤ 300mm	
28	High pressure fuel injection valves (only for those not autofretted) **(10)**			W			D > 300mm	W **(10)**
				TR			D ≤ 300mm	
29	High pressure fuel injection pipes including common fuel rail **(10)**	W(Cc+M)		W for those that are not autofretted			D > 300mm	W **(10)**
		W(Cc+M)		TR for those that are not autofretted			D ≤ 300mm	
30	High pressure common servo oil system **(10)**	W(Cc+M)		W			D > 300mm	W **(10)**
		W(Cc+M)		TR			D ≤ 300mm	
31	Cooler, both sides **(10) (11)**	W(Cc+M)		W			D > 300mm	W **(12)**
32	Accumulator **(10)**	W(Cc+M)		W			All engines with accumulators with a capacity of > 0,5 l	W **(12)**
33	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable **(10)**	W(Cc+M)		W			> 800 kW/cyl	
34	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 27 and 33 **(10)**			W			> 800 kW/cyl	
35	Bearings for main, crosshead, and crankpin	TR(Cc)	TR (UT for full contact between base material and bearing metal)		W		> 800 kW/cyl	

No.	Part **(1) (2) (3) (4) (5)**	Material properties **(6)**	Non-destructive examination **(7)**	Hydraulic testing **(8)**	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines:	Component certificate

Note 1: Symbols used in this Table are listed in [4.2.1]

(1) For turbochargers, see Ch 1, Sec 17

(2) Crankcase explosion relief valves are to be type tested in accordance with Ch 1, App 4 and documented according to [2.3.4]

(3) Oil mist detection systems are to be type tested in accordance with Ch 3, App 1and documented according to [2.3.5]

(4) For Speed governor and overspeed protective devices, see [2.7]

(5) Explosion Relief Devices for Air inlet and Exhaust of engines using natural gas as Fuel are to be type tested in accordance with Ch 1, App 8

(6) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force)

(7) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP. When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see [4.4.3], item b)

(8) Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1,5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1,5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(9) Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner

(10) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply unless alternative requirements are given in Ch 1, Sec 10, Tab 40

(11) Charge air coolers need only be tested on the water side

(12) Material and component certifications are to follow the requirements given in Ch 1, Sec 3 for pressure vessels. Depending on their class, a design assessment may be required

4.3 Factory Acceptance Test

4.3.1 Safety precautions

a) Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.

b) This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function.

c) The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point shall be verified by the surveyor.

4.3.2 General

a) Before any official testing, the engines shall be run-in as prescribed by the engine manufacturer.

b) Adequate test bed facilities for loads as required in [4.3.3] shall be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts. This applies to all fluids used temporarily or repeatedly for testing purposes only.

c) Engines are to be inspected for:

- Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
- Screening of pipe connections in piping containing flammable liquids.
- Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This shall be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, the Society may request temperature measurements as required by [4.1.7], item g).

d) These inspections are normally to be made during the works trials by the manufacturer and the attending surveyor, but at the discretion of the Society parts of these inspections may be postponed to the shipboard testing.

4.3.3 Works trials (Factory Acceptance Test)

a) Objectives

The purpose of the works trials is to verify design premises such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), and functionality and to establish reference values or base lines for later reference in the operational phase.

b) Records

1) The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

2) For each required load point, the following parameters are normally to be recorded:

- Power and speed
- Fuel index (or equivalent reading)
- Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement)
- Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in Ch 1, Sec 17 and [2.7])
- Charge air temperature
- Charge air pressure
- Turbocharger speed (to the extent that monitoring is required in Ch 1, Sec 17).

3) Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

4) For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

5) In each case, all measurements conducted at the various load points are to be carried out at steady state operating conditions. However, for all load points provision should be made for time needed by the Surveyor to carry out visual inspections. The readings for MCR, i.e. 100% power (rated maximum continuous power at corresponding rpm) are to be taken at least twice at an interval of normally 30 minutes.

c) Test loads

1) Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

Note 1: Alternatives to the detailed tests may be agreed between the manufacturer and the Society when the overall scope of tests is found to be equivalent.

2) Propulsion engines driving propeller or impeller only:

- 100% power (MCR) at corresponding speed n_0: at least 60 min.
- 110% power at engine speed $1{,}032n_0$: Records to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter.

Note 2: 110% test load is only required once for each different engine/turbocharger configuration.

- Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer.
- Reversing manoeuvres (if applicable).

Note 3: After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by the Society. In that case, the fuel delivery system is to be blocked to that power.

3) Engines driving generators for electric propulsion:

- 100% power (MCR) at corresponding speed n_0: at least 60 min.
- 110% power at engine speed n_0: 15 min. - after having reached steady conditions.
- Governor tests for compliance with [2.7] are to be carried out.
- 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note 4: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard.

The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and also so that the protection system utilised in the electric distribution system can be activated before the engine stalls.

4) Engines driving generators for auxiliary purposes:

Tests to be performed as in item c) 3).

5) Propulsion engines also driving power take off (PTO) generator:
   - 100% power (MCR) at corresponding speed n_0: at least 60 min.
   - 110% power at engine speed n_0: 15 min. - after having reached steady conditions.
   - Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
   - 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n_0, the sequence to be selected by the engine manufacturer.

Note 5: After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power.

6) Engines driving auxiliaries:
   - 100% power (MCR) at corresponding speed n_0: at least 30 min.
   - 110% power at engine speed n_0: 15 min. - after having reached steady conditions.
   - Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
   - For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

Note 6: After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

d) Turbocharger matching with engine

1) Compressor chart

Turbochargers shall have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation.

For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.

In this item, surging and continuous surging are defined as follows:
- Surging means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.
- Continuous surging means that surging happens repeatedly and not only once.

2) Surge margin verification

Category C turbochargers used on propulsion engines are to be checked for surge margins during the engine workshop testing as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

- For 4-stroke engines:

  The following shall be performed without indication of surging:
  - With maximum continuous power and speed (=100%), the speed shall be reduced with constant torque (fuel index) down to 90% power.
  - With 50% power at 80% speed (= propeller characteristic for fixed pitch), the speed shall be reduced to 72% while keeping constant torque (fuel index).
- For 2-stroke engines:

  The surge margin shall be demonstrated by at least one of the following methods:
  - The engine working characteristic established at workshop testing of the engine shall be plotted into the compressor chart of the turbocharger (established in a test rig). There shall be at least 10% surge margin in the full load range, i.e. working flow shall be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations), or,
  - Sudden fuel cut-off to at least one cylinder shall not result in continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds. For applications with more than one turbocharger the fuel shall be cut-off to the cylinders closest upstream to each turbocharger.

    This test shall be performed at two different engine loads:
    - The maximum power permitted for one cylinder misfiring.
    - The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).
  - No continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

e) Integration tests

For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in Tab 1

f) Component inspections

Random checks of components to be presented for inspection after works trials are left to the discretion of the Surveyor.

4.4 Certification

4.4.1 Type approval certificate

a) For each type of engine that is required to be approved, a type approval certificate is to be obtained by the engine designer. The process details for obtaining a type approval certificate are given below (see also [1.2]). This process consists of the engine designer obtaining from the Society:

- drawing and specification approval
- conformity of production
- approval of type testing programme
- type testing of engines
- review of the obtained type testing results
- evaluation of the manufacturing arrangements
- issue of a type approval certificate.

The manufacturing facility of the engine presented for the type approval test is to be assessed in accordance with NR320.

b) Type approval certificate renewal

A renewal of type approval certificates will be granted upon:

- The submission of modified documents or new documents with substantial modifications replacing former documents compared to the previous submission(s), or alternatively,
- A declaration that no substantial modifications have been applied since the last issuance of the type approval certificate.

c) Validity of type approval certificate

The limit of the duration facility of the type approval certificate shall comply with requirements of NR 320. The maximum period of validity of a type approval certificate is 5 years.

The type approval certificate will be invalid if there are substantial modifications in the design, in the manufacturing or control processes or in the characteristics of the materials unless approved in advance by the Society.

4.4.2 Engine certificate

a) Each diesel engine manufactured for a shipboard application is to have an engine certificate. This process consists of the engine builder/licensee obtaining design approval of the engine application specific documents, submitting a comparison list of the production drawings to the previously approved engine design drawings referenced in [4.4.1] forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary, engine testing and upon satisfactorily meeting the Rule requirements, the issuance of an engine certificate.

For those cases when a licensor – licensee agreement does NOT apply, an “engine designer” shall be understood as the entity that has the design rights for the engine type or is delegated by the entity having the design rights to modify the design.

b) Society’s requirements for production facilities comprising manufacturing facilities and processes, machining tools, quality assurance, testing facilities, etc. shall be assessed according to NR320 requirements.

4.4.3 Certification of engine components

a) The engine manufacturer is to have a quality control system that is suitable for the actual engine types to be certified by the Society. The quality control system is also to apply to any sub-suppliers. The Society reserves the right to review the system or parts thereof. Materials and components are to be produced in compliance with all the applicable production and quality instructions specified by the engine manufacturer. The Society requires that certain parts are verified and documented by means of Society Certificate (C), Work Certificate (W) or Test Report (TR).

b) Society Certificate (C)

This is a document issued by the Society stating:

- conformity with Rule requirements
- that the tests and inspections have been carried out on the finished certified component itself, or on samples taken from earlier stages in the production of the component, when applicable
- that the inspection and tests were performed in the presence of the Surveyor or in accordance with an Alternative Survey Scheme according to NR320.

c) Work’s Certificate (W)

This is a document signed by the manufacturer stating:

- conformity with requirements
- that the tests and inspections have been carried out on the finished certified component itself, or on samples taken from earlier stages in the production batch of the component, when applicable
- that the tests were witnessed and signed by a qualified representative of the applicable department of the manufacturer.

A Work's Certificate may be considered equivalent to a Society Certificate and endorsed by the Society under the following cases:

- the test was witnessed by the Society Surveyor; or
- an Alternative Survey Scheme according to NR320 is in place between the Society and the manufacturer or material supplier; or
- the Work's certificate is supported by tests carried out by an accredited third party that is accepted by the Society and independent from the manufacturer and/or material supplier.

d) Test Report (TR)

This is a document signed by the manufacturer stating:

- conformity with requirements
- that the tests and inspections have been carried out on samples from the current production batch.

e) The documents above are used for product documentation as well as for documentation of single inspections such as crack detection, dimensional check, etc. If agreed to by the Society, the documentation of single tests and inspections may also be arranged by filling in results on a control sheet following the component through the production.

f) The Surveyor is to review the TR and W for compliance with the agreed or approved specifications. C means that the Surveyor also witnesses the testing, batch or individual, unless an Alternative Survey Scheme, according to NR320, provides other arrangements.

g) The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by the Society.

The manufacturing process and equipment is to be set up and maintained in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

Section 3 Pressure Equipment

1 General

1.1 Principles

1.1.1 Scope of the Rules

The boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and is to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards. The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

So these Rules apply to “pressure equipment” for the following requirements:

- be safe in sight of pressure risk
- be safe in sight of other risks, moving parts, hot surfaces
- ensure capability of propulsion and other essential services.

“Pressure equipment” means pressure vessels, piping (Ch 1, Sec 10), safety accessories and pressure accessories.

1.1.2 Overpressure risk

Where main or auxiliary boilers and other pressure vessels or any parts thereof may be subject to dangerous overpressure, means are to be provided where practicable to protect against such excessive pressure.

1.1.3 Propulsion capability

Means are to be provided whereby normal operation of main boilers can be sustained or restored even through one of the essential auxiliaries become inoperative. Special consideration is to be given to the malfunctioning of:

- the source of steam supply
- the boiler feed water systems
- the fuel oil supply system for boilers
- the mechanical air supply for boilers.

However the Society, having regard to overall safety considerations, may accept a partial reduction in propulsion capability from normal operation.

1.1.4 Tests

All boilers and other pressure vessels including their associated fittings which are under internal pressure are to be subjected to appropriate tests including a pressure test before being put into service for the first time (see also [9]).

1.2 Application

1.2.1 Pressure vessels covered by the Rules

The requirements of this Section apply to:

- all fired or unfired pressures vessels of metallic construction, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2]
- all boilers and other steam generators, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2].

1.2.2 Pressure vessels not covered by the Rules

Among others the following boilers and pressure vessels are not covered by the Rules and are to be considered on a case by case basis:

a) boilers with design pressure p > 10 MPa

b) pressure vessel intended for radioactive material

c) equipment comprising casings or machinery where the dimensioning, choice of material and manufacturing rules are based primarily on requirements for sufficient strength, rigidity and stability to meet the static and dynamic operational effects or other operational characteristics and for which pressure is not a significant design factor. Such equipment may include:
   - engines including turbines and internal combustion engines
   - steam engines, gas/steam turbines, turbo-generators, compressors, pumps and actuating devices

d) small pressure vessels included in self-contained domestic equipment.

1.3 Definitions

1.3.1 Pressure vessel

"Pressure vessel" means a housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber.

1.3.2 Fired pressure vessel

Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases or otherwise heated pressure vessel with a risk of overheating.

a) Boiler

Boiler is one or more fired pressure vessels and associated piping systems used for generating steam or hot water at a temperature above 120°C.

Any equipment directly connected to the boiler, such as economisers, superheaters and safety valves, is considered as part of the boiler, if it is not separated from the steam generator by means of any isolating valve. Piping connected to the boiler is considered as part of the boiler upstream of the isolating valve and as part of the associated piping system downstream of the isolating valve.

b) Thermal oil heater

Thermal oil heater is one or more fired pressure vessels and associated piping systems in which organic liquids (thermal oils) are heated. When heated by electricity thermal oil heater is considered as an unfired pressure vessel.

1.3.3 Unfired pressure vessel

Any pressure vessel which is not a fired pressure vessel is an unfired pressure vessel.

a) Heat exchanger

A heat exchanger is an unfired pressure vessel used to heat or cool a fluid with an another fluid. In general heat exchangers are composed of a number of adjacent chambers, the two fluids flowing separately in adjacent chambers. One or more chambers may consist of bundles of tubes.

b) Steam generator

A steam generator is a heat exchanger and associated piping used for generating steam. In general in these Rules, the requirements for boilers are also applicable for steam generators, unless otherwise indicated.

1.3.4 Safety accessories

"Safety accessories" means devices designed to protect pressure equipment against the allowable limits being exceeded. Such devices include:

- devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure relief systems, and
- limiting devices, which either activate the means for correction or provide for shutdown or shutdown and lockout, such as pressure switches or temperature switches or fluid level switches and safety related measurement control and regulation devices.

1.3.5 Design pressure

The design pressure is the pressure used by the manufacturer to determine the scantlings of the vessel. This pressure cannot be taken less than the maximum working pressure and is to be limited by the set pressure of the safety valve, as prescribed by the applicable Rules. Pressure is indicated as gauge pressure above atmospheric pressure, vacuum is indicated as negative pressure.

1.3.6 Design temperature

a) Design temperature is the actual metal temperature of the applicable part under the expected operating conditions, as modified in Tab 1. This temperature is to be stated by the manufacturer and is to take in account of the effect of any temperature fluctuations which may occur during the service.

b) The design temperature is not to be less than the temperatures stated in Tab 1, unless specially agreed between the manufacturer and the Society on a case by case basis.

1.3.7 Volume

Volume V means the internal volume of a chamber, including the volume of nozzles to the first connection or weld and excluding the volume of permanent internal parts.

1.3.8 Boiler heating surface

Heating surface is the area of the part of the boiler through which the heat is supplied to the medium, on the side exposed to fire or hot gases.

1.3.9 Maximum steam output

Maximum steam output is the maximum quantity of steam than can be produced continuously by the boiler or steam generator operating under the design steam conditions.

Table 1 : Minimum design temperature

Type of vessel	Minimum design temperature
Pressure parts of pressure vessels and boilers not heated by hot gases or adequately protected by insulation	Maximum temperature of the internal fluid
Pressure vessel heated by hot gases	25°C in excess of the temperature of the internal fluid
Water tubes of boilers mainly subjected to convection heat	25°C in excess of the temperature of the saturated steam
Water tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to convection heat	35°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Economiser tubes	35°C in excess of the temperature of the internal fluid
For combustion chambers of the type used in wet-back boilers	50°C in excess of the temperature of the internal fluid
For furnaces, fire-boxes, rear tube plates of dry-back boilers and other pressure parts subjected to similar rate of heat transfer	90°C in excess of the temperature of the internal fluid

1.3.10 Toxic and corrosive substances

Toxic and corrosive substances are those which are listed in the IMO "International Maritime Dangerous Goods Code (IMDG Code)", as amended.

1.3.11 Liquid and gaseous substances

a) liquid substances are liquids having a vapour pressure at the maximum allowable temperature of not more than 0,5 bar above normal atmospheric pressure

b) gaseous substances are gases, liquefied gases, gases dissolved under pressure, vapours and also those liquids whose vapour pressure at the maximum allowable temperature is greater than 0,5 bar above normal atmospheric pressure.

1.3.12 Ductile material

For the purpose of this Section, ductile material is a material having an elongation over 12%.

1.3.13 Incinerator

Incinerator is a shipboard facility for incinerating solid garbage approximating in composition to household garbage and liquid garbage deriving from the operation of the ship (e.g. domestic garbage, cargo-associated garbage, maintenance garbage, operational garbage, cargo residue, and fishing gear), as well as for burning sludge with a flash point above 60°C.

These facilities may be designed to use the heat energy produced.

Incinerators are not generally pressure vessels, however when their fittings are of the same type than those of boilers the requirements for these fittings apply.

1.3.14 Gas combustion unit (GCU)

A gas combustion unit (GCU) is an equipment fitted on gas carriers or gas-fuelled ships, allowing the disposal of the excess vapour from tanks by thermal oxidation.

Gas combustion units are not generally pressure vessels; however when their fittings are of the same type than those of boilers the requirements for these fittings apply.

1.4 Classes

1.4.1 Significant parameters

Pressure vessels are classed in three class in consideration of:

- the type of equipment: pressure vessel or steam generator
- the state (gaseous or liquid) of the intended fluid contents
- the substances listed or not in the IMDG Code
- the design pressure p, in MPa
- the design temperature T, in °C
- the actual thickness of the vessel t_A, in mm
- the volume V, in litres.

1.4.2 Pressure vessel classification

Pressure vessels are classed as indicated in Tab 2.

Table 2 : Pressure vessel classification

Equipment	Class 1	Class 2	Class 3
Steam generators or boilers	p > 3,2 and V > 2 or p V > 20 and V > 2	if not class 1 or class 3	p V ≤ 5 or V ≤ 2
Pressure vessels for toxic substances	all	–	–
Pressure vessels for corrosive substances	p > 20 or p V > 20 or T > 350	if not in class 1	–
Pressure vessels for gaseous substances	p > 100 or p V > 300	V > 1 and p V > 100 and not in class 1	all pressure vessels which are not class 1 or class 2
Pressure vessels for liquid substances	V > 10 and p V > 1000 and p > 50	V ≤ 10 and p > 100 or 1 < p ≤ 50 and p V > 1000	all pressure vessels and heat exchangers which are not class 1 or class 2
Pressure vessels for thermal oil	p > 1,6 or T > 300	if not class 1 or class 3	p ≤ 0,7 and T ≤ 150
Pressure vessels for fuel oil, lubricating oil or flammble hydraulic oil	p > 1,6 or T > 150	if not class 1 or class 3	p ≤ 0,7 and T ≤ 60
Whatever type of equipment	t_A > 40	15 < t_A ≤ 40	–
Note 1: Whenever the class is defined by more than one characteristic, the equipment is to be considered belonging to the highest class of its characteristics, independently of the values of the other characteristics.			

1.4.3 Implication of class

The class of a pressure vessel has, among others, implication in:

- design
- material allowance
- welding design
- efficiency of joints
- examination and non-destructive tests
- thermal stress relieving.

See Tab 26.

1.5 Applicable Rules

1.5.1 Alternative standards

a) Boilers and pressure vessels are to be designed, constructed, installed and tested in accordance with the applicable requirements of this Section.

b) The acceptance of national and international standards as an alternative to the requirements of this Section may be considered by the Society on a case by case basis.

1.6 Documentation to be submitted

1.6.1 General

Documents mentioned in the present sub-article are to be submitted for class 1 and class 2 and not for class 3, unless the equipment is considered as critical.

1.6.2 Boilers and steam generators

The plans listed in Tab 3 are to be submitted.

The drawings listed in Tab 3 are to contain:

- the constructional details of all pressure parts, such as shells, headers, tubes, tube plates, nozzles
- strengthening members, such as stays, brackets, opening reinforcements and covers
- installation arrangements, such as saddles and anchoring system

as well as the information and data indicated in Tab 4.

1.6.3 Pressure vessels

The plans listed in Tab 5 are to be submitted.

The drawings listed in Tab 5 are to contain the constructional details of:

- pressure parts, such as shells, headers, tubes, tube plates, nozzles, opening reinforcements and covers
- strengthening members, such as stays, brackets and reinforcements.

Table 3 : Drawings to be submittedfor boilers and steam generators

No.	A/I	Item
1	I	General arrangement plan, including valves and fittings
2	A	Material specifications
3	A	Sectional assembly
4	A	Evaporating parts
5	A	Superheater
6	A	De-superheater
7	A	Economiser
8	A	Air heater
9	A	Tubes and tube plates
10	A	Nozzles and fittings
11	A	Safety valves and their arrangement
12	A	Boiler seating
13	I	Fuel oil burning arrangement
14	I	Forced draught system
15	I	Refractor or insulation arrangement
16	A	Boiler instrumentation, monitoring and control system
17	A	Type of safety valves and their lift, discharge rate and setting
18	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatment
Note 1: A = to be submitted for approval ; I = to be submitted for information		

Table 4 : Information and data to be submittedfor boilers and steam generators

No.	Item
1	Design pressure and temperature
2	Pressure and temperature of the superheated steam
3	Pressure and temperature of the saturated steam
4	Maximum steam production per hour
5	Evaporating surface of the tube bundles and water-walls
6	Heating surface of the economiser, superheater and air-heater
7	Surface of the furnace
8	Volume of the combustion chamber
9	Temperature and pressure of the feed water
10	Type of fuel to be used and fuel consumption at full steam production
11	Number and capacity of burners

Table 5 : Drawings, information and data to be submitted for pressure vessels and heat exchangers

No.	A/I	Item
1	I	General arrangement plan, including nozzles and fittings
2	A	Sectional assembly
3	A	Safety valves (if any) and their arrangement
4	A	Material specifications
5	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatments
6	I	Design data, including at least design pressure and design temperatures (as applicable)
7	A	For seamless (extruded) pressure vessels, the manufacturing process, including: • a description of the manufacturing process with indication of the production controls normally carried out in the manufacturer's works • details of the materials to be used (specification, yield point, tensile strength, impact strength, heat treatment) • details of the stamped marking to be applied
8	I	Type of fluid or fluids contained
Note 1: A = to be submitted for approval ; I = to be submitted for information		

1.6.4 Incinerators

Incinerators are to be considered on a case by case basis, based on their actual arrangement, using the applicable requirements for boilers and pressure vessels.

1.6.5 Gas combustion units

Gas combustion units are to be considered on a case by case basis, based on their actual arrangement, using the applicable requirements for boilers and pressure vessels.

The documents listed in Tab 6 are to be submitted.

Table 6 : Documentation to be submitted for gas combustion units

No.	I/A **(1)**	Document **(2)**
1	A	General arrangement plan
2	I	For each intended operating case: • description, including firing and shut-off sequences, purging sequence, etc. • minimum and maximum allowed gas flow rate • maximum flue gas temperature
3	I	Material specification
4	A	Details of refractor or insulation arrangement, as applicable
5	A	Details of combustion air and dilution air systems
6	A	Diagram of the gas supply system with details of the piping (pipe material, thickness, type of the connections)
7	A	Details of electrical equipment (including safety characteristics)
8	A	Details of control, monitoring and safety systems
9	I	Procedure for workshop and shipboard tests

(1) A = to be submitted for approval
I = to be submitted for information

(2) Diagrams are also to include, where applicable, the local and remote control systems, monitoring systems and automation systems

2 Design and construction - Scantlings of pressure parts

2.1 General

2.1.1 Application

a) In general, the formulae in the present Article do not take into account additional stresses imposed by effects other than pressure, such as stresses deriving from the static and dynamic weight of the pressure vessel and its content, external loads from connecting equipment and foundations, etc. For the purpose of the Rules these additional loads may be neglected, provided it can reasonably be presumed that the actual average stresses of the vessel, considering all these additional loads, would not increase more than 10% with respect to the stresses calculated by the formulae in this Article.

b) Where it is necessary to take into account additional stresses, such as dynamic loads, the Society reserves the right to ask for additional requirements on a case by case basis.

2.1.2 Alternative requirements

When pressure parts are of an irregular shape, such as to make it impossible to check the scantlings by applying the formulae of this Article, the approval is to be based on other means, such as burst and/or deformation tests on a prototype or by another method agreed upon between the manufacturer and the Society.

2.2 Materials

2.2.1 Materials for high temperatures

a) Materials for pressure parts having a design temperature exceeding the ambient temperature are to be selected by the Manufacturer and to have mechanical and metallurgical properties adequate for the design temperature. Their allowable stress limits are to be determined as a function of the temperature, as per [2.3.2].

b) When the design temperature of pressure parts exceeds 400°C, alloy steels are to be used. Other materials are subject of special consideration by the Society.

2.2.2 Materials for low temperatures

Materials for pressure parts having a design temperature below the ambient temperature are to have notch toughness properties suitable for the design temperature.

2.2.3 Cast iron

Grey cast iron is not to be used for:

a) class 1 and class 2 pressure vessels

b) class 3 pressure vessels with design pressure p > 1.6 MPa or product p·V > 1000, where V is the internal volume of the pressure vessel in litres

c) Bolted covers and closures of pressure vessels having a design pressure p > 1 MPa, except for covers intended for boiler shells, for which [3.2.4], item e) applies.

Spheroidal cast iron may be used subect to the agreement of the Society following special consideration. However, it is not to be used for parts, having a design temperature exceeding 350°C.

2.2.4 Valves and fittings for boilers

a) Ductile materials are to be used for valves and fittings intended to be mounted on boilers. The material is to have mechanical and metallurgical characteristics suitable for the design temperature and for the thermal and other loads imposed during the operation.

b) Grey cast iron is not to be used for valves and fittings which are subject to dynamic loads, such as safety valves and blow-down valves, and in general for fittings and accessories having design pressure p exceeding 0,3 MPa and design temperature T exceeding 220°C.

c) Spheroidal cast iron is not to be used for parts having a design temperature T exceeding 350°C.

d) Bronze is not to be used for parts having design temperature T exceeding 220°C for normal bronzes and 260°C for bronzes suitable for high temperatures. Copper and aluminium brass are not to be used for fittings with design temperature T above 200°C and copper-nickel fittings with design temperature T exceeding 300°C.

2.2.5 Alternative materials

In the case of boilers or pressure vessels constructed in accordance with one of the standards considered acceptable by the Society as per [1.5], the material specifications are to be in compliance with the requirements of the standard used.

2.3 Permissible stresses

2.3.1 The permissible stresses K, in N/mm^2, for steels, to be used in the formulae of this Article, may be determined from Tab 7, Tab 8, Tab 9 and Tab 10, where R_m is the ultimate strength of the material, in N/mm^2. For intermediate values of the temperature, the value of K is to be obtained by linear interpolation.

Table 7 : Permissible stresses K for carbon steels intended for boilers and thermal oil heaters

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm^2 Grade HA	t ≤ 15 mm	133	109	107	105	94	77	73	72
	15 mm < t ≤ 40 mm	128	106	105	101	90	77	73	72
	40 mm < t ≤ 60 mm	122	101	99	95	88	77	73	72
R_m = 360 N/mm^2 Grades HB, HD	t ≤ 15 mm	133	127	116	103	79	79	72	69
	15 mm < t ≤ 40 mm	133	122	114	102	79	79	72	69
	40 mm < t ≤ 60 mm	133	112	107	99	79	79	72	69
R_m = 410 N/mm^2 Grade HA	t ≤ 15 mm	152	132	130	126	112	94	89	86
	15 mm < t ≤ 40 mm	147	131	124	119	107	94	89	86
	40 mm < t ≤ 60 mm	141	120	117	113	105	94	89	86
R_m = 410 N/mm^2 Grades HB, HD	t ≤ 15 mm	152	147	135	121	107	95	88	84
	15 mm < t ≤ 40 mm	152	142	133	120	107	95	88	84
	40 mm < t ≤ 60 mm	152	134	127	117	107	95	88	84
R_m = 460 N/mm^2 Grades HB, HD	t ≤ 15 mm	170	164	154	139	124	111	104	99
	15 mm < t ≤ 40 mm	169	162	151	137	124	111	104	99
	40 mm < t ≤ 60 mm	162	157	147	136	124	111	104	99
R_m = 510 N/mm^2 Grades HB, HD	t ≤ 60 mm	170	170	169	159	147	134	125	112

Table 8 : Permissible stresses K for carbon steels intended for other pressure vessels

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	117	115	112	100	83	78	77
	15 mm < t ≤ 40 mm	133	114	113	108	96	83	78	77
	40 mm < t ≤ 60 mm	130	108	105	101	94	83	78	77
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	133	123	110	97	85	77	73
	15 mm < t ≤ 40 mm	133	131	122	109	97	85	77	73
	40 mm < t ≤ 60 mm	133	119	115	106	97	85	77	73
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	141	139	134	120	100	95	92
	15 mm < t ≤40 mm	152	134	132	127	114	100	95	92
	40 mm < t ≤ 60 mm	150	128	121	112	112	100	95	92
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	152	144	129	114	101	94	89
	15 mm < t ≤ 40 mm	152	152	142	128	114	101	94	89
	40 mm < t ≤ 60 mm	152	143	139	125	114	101	94	89
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	170	165	149	132	118	111	105
	15 mm < t ≤ 40 mm	170	170	161	147	132	118	111	105
	40 mm < t ≤ 60 mm	170	167	157	145	132	118	111	105
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	189	189	180	170	157	143	133	120

Table 9 : Permissible stresses K for alloy steels intended for boilers and thermal oil heaters

Alloy steel	T(°C)	≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	153	143	134	125	106	100	94	91	89	87	36			
1Cr 0,5Mo	t ≤ 60 mm	167	167	157	144	137	128	119	112	106	104	103	55	31	19	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	170	167	157	147	144	137	131	125	119	115	112	61	41	30	22
2,25Cr 1Mo **(2)**	t ≤ 60 mm	170	167	164	161	159	147	141	130	128	125	122	61	41	30	22

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered

Table 10 : Permissible stresses K for alloy steels intended for other pressure vessels

Alloy steel	T(°C)	≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	159	153	143	133	113	107	100	97	95	93	38			
1Cr 0,5Mo	t ≤ 60 mm	167	167	167	154	146	137	127	119	113	111	110	59	33	20	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	183	174	167	157	154	146	140	133	127	123	119	65	44	32	23
2,25Cr 1Mo **(2)**	t ≤ 60 mm	174	174	174	172	170	157	150	139	137	133	130	65	44	32	23

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered

2.3.2 Direct determination of permissible stress

The permissible stresses K, where not otherwise specified, may be taken as indicated below.

a) Steel:

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{2,7}$$

$$K = \frac{R_{S,MIN,T}}{A}$$

$$K = \frac{S_A}{A}$$

where:

$R_{m,20}$: Minimum tensile strength at ambient temperature (20°C), in N/mm²

$R_{S,MIN,T}$: Minimum between R_{eH} and $R_{p\,0,2}$ at the design temperature T, in N/mm²

S_A : Average stress to produce creep rupture in 100000 hours, in N/mm^2, at the design temperature T

A : Safety factor taken as follows, when reliability of $R_{S,MIN,T}$ and S_A values are proved to the Society's satisfaction:

- 1,6 for boilers and other steam generators
- 1,5 for other pressure vessels
- specially considered by the Society if average stress to produce creep rupture in more than 100000 hours is used instead of S_A

In the case of steel castings, the permissible stress K, calculated as above, is to be decreased by 20%. Where steel castings are subjected to non-destructive tests, a smaller reduction up to 10% may be taken into consideration by the Society.

b) Spheroidal cast iron:

The permissible stress is be to the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{4,8}$$

$$K = \frac{R_{S,MIN,T}}{3}$$

c) Grey cast iron:

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,20}}{10}$$

d) Copper alloys:

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,T}}{4}$$

where:

$R_{m,T}$: Minimum tensile strength at the design temperature T, in N/mm^2

e) Aluminium and aluminium alloys:

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,T}}{4}$$

$$K = \frac{R_{e,H}}{1,5}$$

where:

$R_{e,H}$: Minimum yield stress, in N/mm^2

f) Additional conditions:

- in special cases, the Society reserves the right to apply values of permissible stress K lower than those specified above, in particular for lifting appliance devices and steering gear devices
- in the case of boilers or other steam generators, the permissible stress K is not to exceed 170 N/mm^2
- for materials other than those listed above the permissible stress is to be agreed with the Society on a case by case basis.

2.4 Cylindrical, spherical and conical shells with circular cross-sections subject to internal pressure

2.4.1 Cylindrical shell thickness

a) The minimum thickness of cylindrical, spherical and conical shells with circular cross-sections is not to be less than the value t, in mm, calculated by one of the following formulae, as appropriate. Cylindrical tube plates pierced by a great number of tube holes are to have thickness calculated by the applicable formulae in [2.4.3], [2.4.4], [2.4.5] and [2.9.2].

b) The thicknesses obtained by the formulae in [2.4.3], [2.4.4] and [2.4.5] are "net" thicknesses, as they do not include any corrosion allowance. The thickness obtained by the above formulae is to be increased by 0,75 mm. See also [2.4.7].

2.4.2 Efficiency

a) The values of efficiency e to be used in the formulae in [2.4.3], [2.4.4] and [2.4.5] are indicated in Tab 11.

b) The manufacturer may propose a factor e lower than those indicated in Tab 11 where consistent with the factor used in the formulae of [2.4.3], [2.4.4] and [2.4.5] and with the provisions of specific requirements according to class as per [4.9], [4.10] or [4.11]. The proposed efficiency factor is to be agreed by the Society.

Table 11 : Efficiency of unpierced shells

Case	e
Seamless shells	1,00
Shells of class 1 vessels **(1)**	1,00
Shells of class 2 vessels (with partial radiographic examination of butt-joints)	0,85
Shells of class 2 vessels with actual thickness ≤ 15 mm (without radiographic examination of butt-joints)	0,75
(1) In special cases the Society reserves the right to take a factor e < 1, depending on the welding procedure adopted for the welded joint.	

2.4.3 Cylindrical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of cylindrical shells is given by the following formula:

$$t = \frac{pD}{(2K - p)e}$$

where:

p : Design pressure, in MPa

D : Inside diameter of vessel, in mm

K : Permissible stress, in N/mm², obtained as specified in [2.3]

e : Efficiency of welded joint, the value of which is given in [2.4.2].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

2.4.4 Spherical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of spherical shells is given by the following formula:

$$t = \frac{pD}{(4K - p)e}$$

For the meaning of the symbols, see [2.4.3].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

2.4.5 Conical shells

a) The following formula applies to conical shells of thickness not exceeding 1/6 of the external diameter in way of the large end of the cone:

$$t = \frac{pD}{(2K - p)e \cdot \cos\varphi}$$

For the meaning of the symbols, see [2.4.3].

D is measured in way of the large end of the cone and φ is the angle of slope of the conical section of the shell to the pressure vessel axis (see Fig 1). When φ exceeds 75°, the shell thickness is to be taken as required for flat heads, see [2.7].

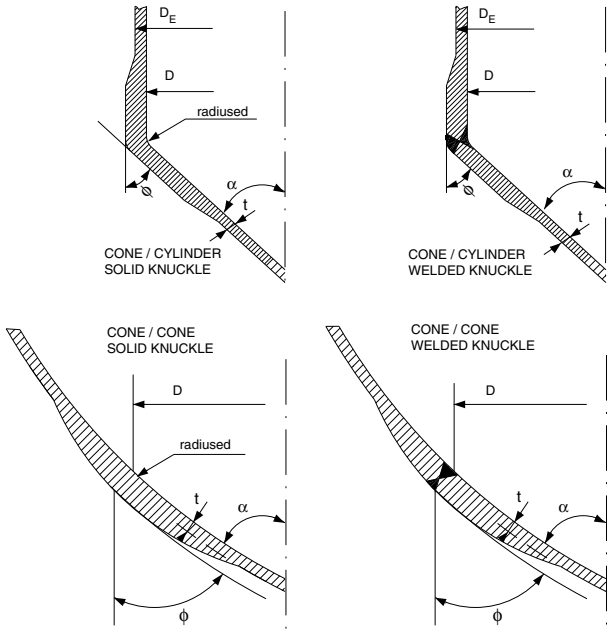
b) The minimum thickness of shells having thickness exceeding 1/6 of the external diameter in way of the large end of the cone is subject of special consideration.

c) Conical shells may be made of several ring sections of decreasing thickness. The minimum thickness of each section is to be obtained by the formula in a) using for D the maximum diameter of the considered section.

d) In general, the junction with a sharp angle between the conical shell and the cylindrical or other conical shell, having different angle of slope, is not allowed if the angle of the generating line of the shells to be assembled exceeds 30°.

e) The shell thickness in way of knuckles is subject of special consideration by the Society.

Figure 1 : Conic shells



2.4.6 Minimum thickness of shells

Irrespective of the value calculated by the formulae in [2.4.3], [2.4.4] or [2.4.5], the thickness t of shells is not to be less than one of the following values, as applicable:

- for pressure vessels: t = 3 + D/1500 mm
- for unpierced plates of boilers: t = 6,0 mm
- for boiler cylindrical tube plates: t = 9,5 mm.

No corrosion allowance needs to be added to the above values.

2.4.7 Corrosion allowance

The Society reserves the right to increase the corrosion allowance value in the case of vessels exposed to particular accelerating corrosion conditions. The Society may also consider the reduction of this factor where particular measures are taken to effectively reduce the corrosion rate of the vessel.

2.5 Dished heads subject to pressure on the concave (internal) side

2.5.1 Dished head for boiler headers

Dished heads for boiler headers are to be seamless.

2.5.2 Dished head profile

The following requirements are to be complied with for the determination of the profile of dished heads (see Fig 2 (a) and (b)).

a) Ellipsoidal heads:

$H \geq 0,2\ D$

where:

H : External depth of head, in mm, measured from the start of curvature at the base.

b) Torispherical heads:

$R_{IN} \leq D$

$r_{IN} \geq 0,1\ D$

$r_{IN} \geq 3\ t$

$H \geq 0,18\ D$

where:

R_{IN} : Internal radius of the spherical part, in mm

r_{IN} : Internal knuckle radius, in mm

H : External depth of head calculated by the following formula (see Fig 2 (b)):

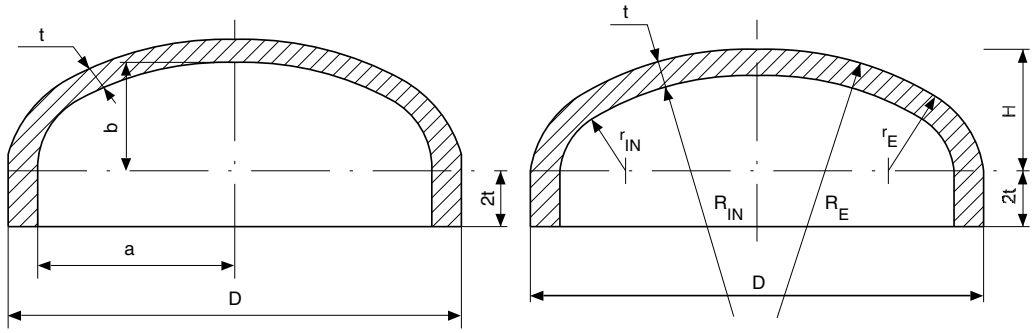
$$H = R_E - [(R_E - 0,5\ D) \cdot (R_E + 0,5\ D - 2\ r_E)]^{0,5}$$

where:

R_E : External radius of the spherical part, in mm

r_E : External knuckle radius, in mm.

Figure 2 : Dished head profiles



(a) ELLIPSOIDAL HEAD

(b) TORISPHERICAL HEAD

2.5.3 Required thickness of solid dished heads

a) The minimum thickness of solid (not pierced) hemispherical, torispherical, or ellipsoidal unstayed dished heads, subject to pressure on the concave (internal) side, is to be not less than the value t, in mm, calculated by the following formula:

$$t = \frac{pDC}{2Ke}$$

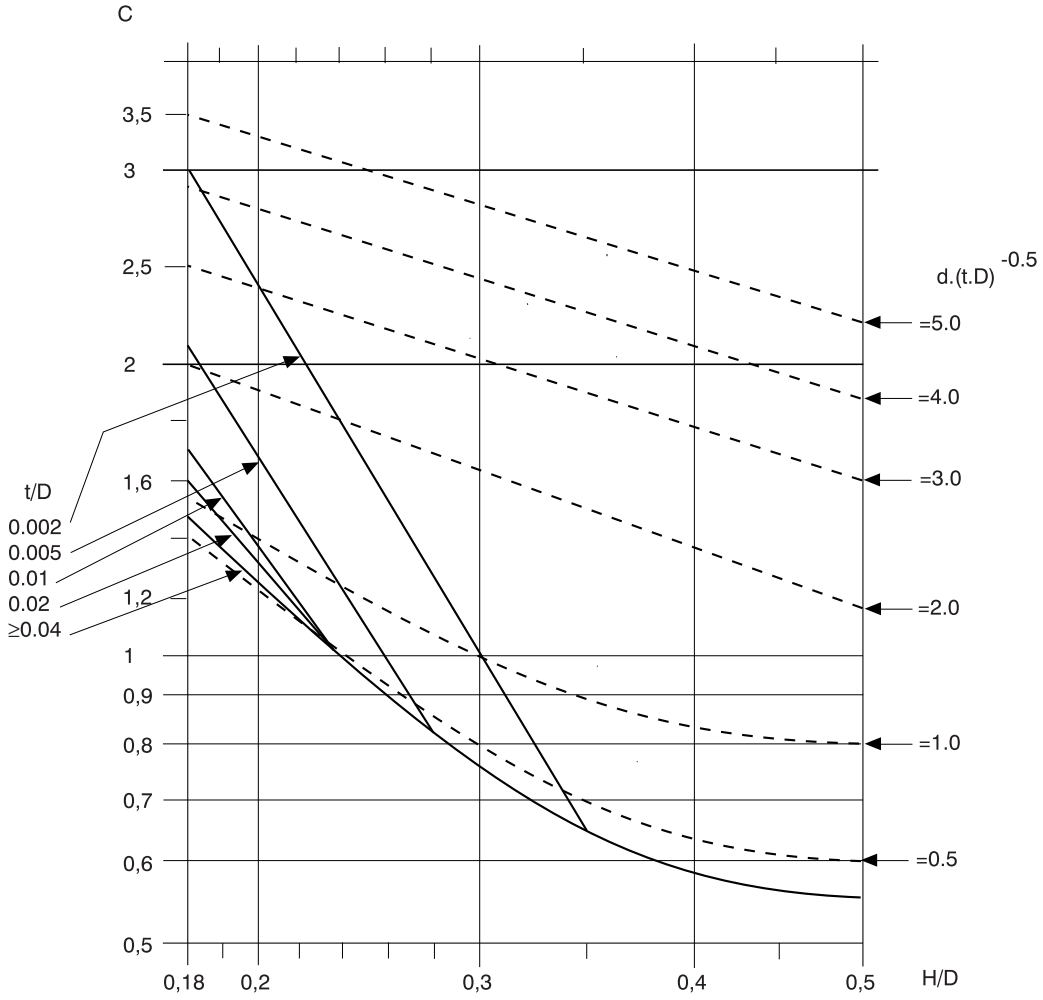
where:

C : Shape factor, obtained from the graph in Fig 3, as a function of H/D and t/D.

For other symbols, see [2.4.3].

b) The thickness obtained by the formula in item a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,75 mm. See also [2.4.7].

Figure 3 : Shape factor for dished heads



2.5.4 Composed torispherical heads

a) Torispherical heads may be constructed with welded elements of different thicknesses (see Fig 4).

b) Where a torispherical head is built in two sections, the thickness of the torispherical part is to be obtained by the formula in [2.5.3], while the thickness of the spherical part may be obtained by the formula in [2.4.4].

c) The spherical part may commence at a distance from the knuckle not less than:

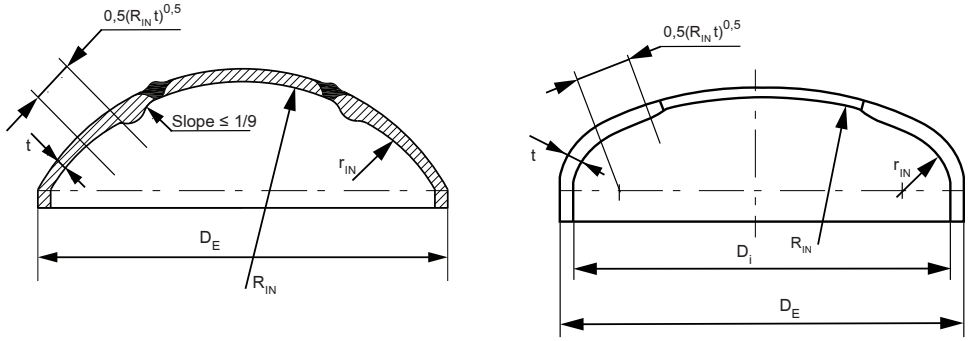
$0,5 \cdot (R_{IN} \cdot t)^{0,5}$

where:

R_{IN} : Internal radius of the spherical part, in mm

t : Knuckle thickness, in mm.

Figure 4 : Composed torispherical head



2.5.5 Minimum thickness of dished heads

Irrespective of the values calculated in [2.5.2] and [2.5.3], the thickness t of dished heads is not to be less than:

- $3 + D_E / 1500$ mm for normal pressure vessels
- 6 mm for boiler pressure vessels.

No corrosion allowance needs to be added to the above values.

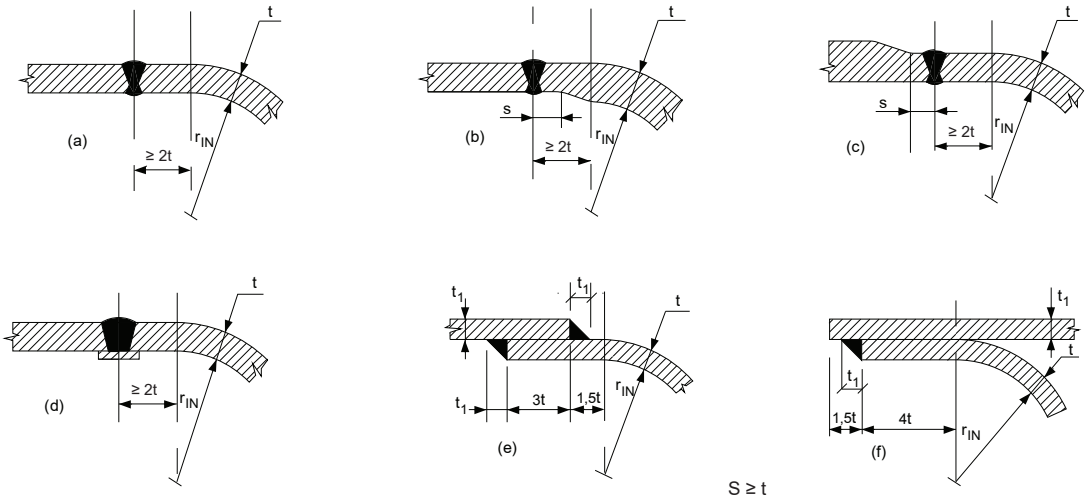
2.5.6 Connection of heads to cylindrical shells

The heads are to be provided, at their base, with a cylindrical skirt not less than 2t in length and with a thickness in no case less than the Rule thickness of a cylindrical shell of the same diameter and the same material, calculated by the formula given in [2.4.3] using the same efficiency factor e adopted for calculation of the head thickness. Fig 5 and Fig 6 show typical admissible attachments of dished ends to cylindrical shells.

In particular, hemispherical heads not provided with the above skirt are to be connected to the cylindrical shell if the latter is thicker than the head, as shown in Fig 5.

Other types of connections are subject to special consideration by the Society.

Figure 5 : Typical attachment of dished heads to cylindrical shells

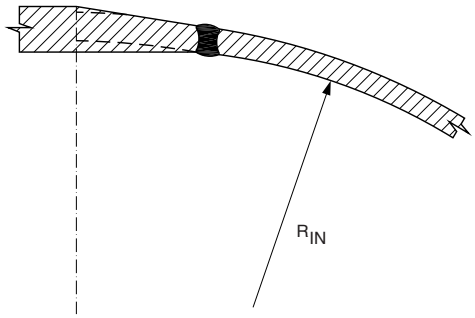


Types shown in (a), (b) and (c) are acceptable for all pressure vessels.

Type shown in (d) is acceptable for class 2 and class 3 pressure vessels.

Types shown in (e) and (f) are acceptable for class 3 pressure vessels only.

Figure 6 : Connection of hemispherical head to the cylindrical shell



2.6 Dished heads subject to pressure on the convex (external) side

2.6.1 The calculation of the minimum thickness is to be performed according to a standard accepted by the Society.

In addition, the thickness of torispherical or ellipsoidal heads under external pressure is no to be less than 1,2 times the thickness required for a head of the same shape subject to internal pressure.

2.7 Flat heads

2.7.1 Unstayed flat head minimum thickness

a) The minimum thickness of unstayed flat heads is not to be less than the value t, in mm, calculated by the following formula:

$$t = D\left(\frac{100p}{CK}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

D : Diameter of the head, in mm. For circular section heads, the diameter D is to be measured as shown in Fig 7 and Fig 8 for various types of heads. For rectangular section heads, the equivalent value for D may be obtained from the following formula:

$$D = a\left[3,4 - 2,4\left(\frac{a}{b}\right)\right]^{0,5}$$

a and b being the smaller and larger side of the rectangle, respectively, in mm

C : The values given below, depending on the various types of heads shown in Fig 7 and Fig 8:

Fig 7(a) : C = 400 for circular heads

Fig 7(b) : C = 330 for circular heads

Fig 7(c) : C = 350 for circular heads

Fig 7(d) : C = 400 for circular heads and C = 250 for rectangular heads

Fig 7(e) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 7(f) : C = 350 for circular heads

Fig 7(g) : C = 300 for circular heads

Fig 7(h) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(i) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(j) : C = 200 for circular heads

Fig 8(k) : C = 330 for circular heads

Fig 8(l) : C = 300 for circular heads

Fig 8(m) : C = 300 for circular heads

Fig 8(n) : C = 400 for circular heads

Fig 8(o) : C = value obtained from the following formula, for circular heads:

$$C = \frac{100}{0,3 + \frac{1,9Fh}{pD^3}}$$

where:

h : Radial distance, in mm, from the pitch centre diameter of bolts to the circumference of diameter D, as shown in Fig 8(o)

F : Total bolt load, in N, to be taken as the greater of the following values F_1 and F_2:

$F_1 = 0,785\ D\ p\ (D + m\ b)$

$F_2 = 9,81\ y\ D\ b$

with:

b : Effective half contact width of the gasket, in mm, calculated as follows:

$b = 0,5\ N$ for $N \leq 13$ mm, and

$b = 1,8\ N^{0,5}$ for $N > 13$ mm

where N is the geometric contact width of the gasket, in mm, as indicated in Fig 8(o)

m, y : Adimensional coefficients, whose values are given in Tab 12, depending on the type of gasket.

The adoption of one of the above-mentioned heads is subject to the Society's approval depending upon its use. Types of heads not shown in Fig 7 and Fig 8 are to be the subject of special consideration by the Society.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [2.4.7].

2.7.2 Stayed flat head minimum thickness

For the minimum thickness of stayed flat heads, see [2.12.3].

Figure 7 : Types of unstayed flat heads (1)

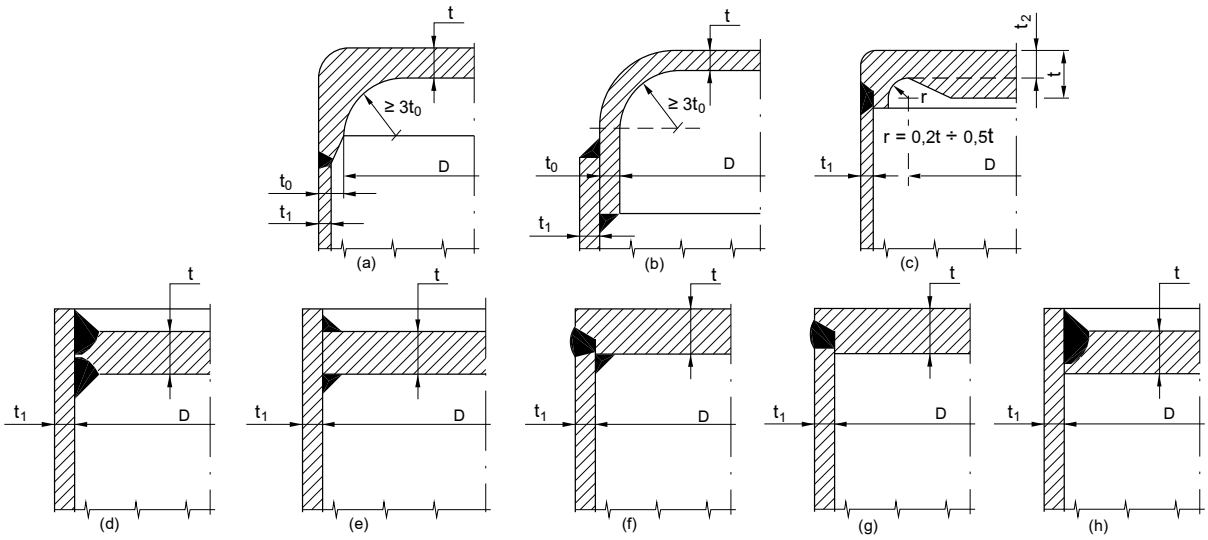


Figure 8 : Types of unstayed flat heads (2)

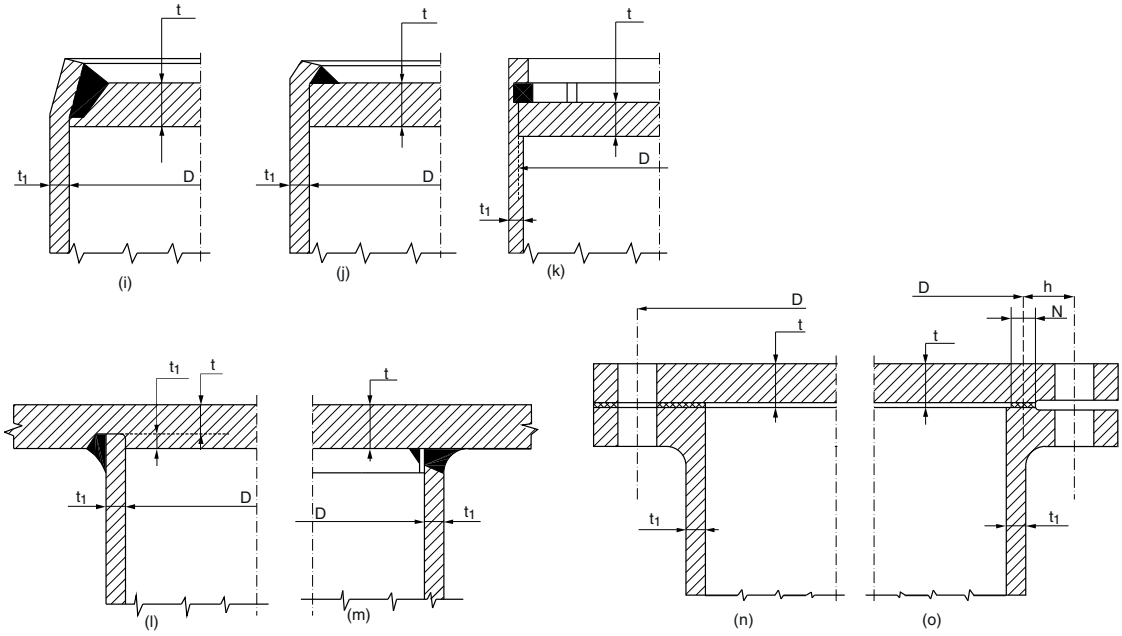


Table 12 : Coefficients m and y

Type of gasket	m	y
Self-sealing, metal or rubber (e.g. O-ring)	0	0
Rubber with cotton fabric	10	0,88
Rubber with reinforcing fabric with or without metal wire:		
- 3 layers	18	4,85
- 2 layers	20	6,4
- 1 layers	22	8,2
Synthetic fibre with suitable binders:		
- 3,0 mm thick	16	3,5
- 1,5 mm thick	22	8,2
Organic fibre	14	2,4
Metal spiral lined with synthetic fibre:		
- carbon steel	20	6,4
- stainless steel	24	9,9
Synthetic fibre with plain metal lining:		
- copper	28	14,0
- iron	30	16,8
- stainless steel	30	20,0
Solid metal:		
- copper	38	28,7
- iron	44	39,8
- stainless steel	52	57,5

2.8 Openings and branches (nozzles)

2.8.1 Nozzles thickness

a) The thickness e_b, in mm, of nozzles attached to shells and headers of boilers is not to be less than:

$$e_b = \frac{d_E}{25} + 2,5$$

where d_E is the outside diameter of nozzle, in mm.

The thickness of the nozzle is, however, to be not less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not to be greater than the thickness of the shell to which it is connected.

b) The thickness of the nozzle attached to shells and headers of other pressure vessels is not to be less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not be greater than the thickness of the shell to which it is connected.

c) Where a branch is connected by screwing, the thickness of the nozzle is to be measured at the root of the thread.

2.8.2 Nozzle connection to vessel shell

a) In general, the axis of the nozzle is not to form an angle greater than 15° with the normal to the shell.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show some typical acceptable connections of nozzles to shells. Other types of connections are to be considered by the Society on a case by case basis.

2.8.3 Openings in shells

a) In general, the largest dimensions of the openings in shells are not to exceed:

- for shells up to 1500 mm in diameter D_E:

  1/2 D_E, but not more than 500 mm

- for shells over 1500 mm in diameter D_E:

  1/3 D_E, but not more than 1000 mm,

where D_E is the vessel external diameter, in mm.

Greater values may be considered by the Society on a case by case basis.

b) In general, in oval or elliptical openings the ratio major diameter/minor diameter is not to exceed 2.

2.8.4 Openings compensation in cylindrical shells

a) Compensation methods

For cylindrical shells with openings, the efficiency of the main body is to be satisfied by one of the following methods:

- by increasing the wall thickness of main body compared with that of the cylindrical shell without opening: see Fig 9
- by branches which have been provided with a wall thickness of that required on account of the internal pressure: see Fig 10 and Fig 11
- by reinforcing pads or rings analogous to increasing the wall thickness: see Fig 12 and Fig 13
- by a combination of previous reinforcement

b) Definitions

Effective lengths ℓ_{rs} required for calculation of efficiency and of compensations is to be taken as:

$$\ell_{rs} = \min(\sqrt{Dt_a}, \ell_{s1})$$

where:

D : Outside diameter, in mm

t_a : Available thickness, in mm

ℓ_{s1} : Transition length, in mm, according to Fig 9 and Fig 10

Figure 9 : Reinforcement by increasing the wall thickness of the main body with opening

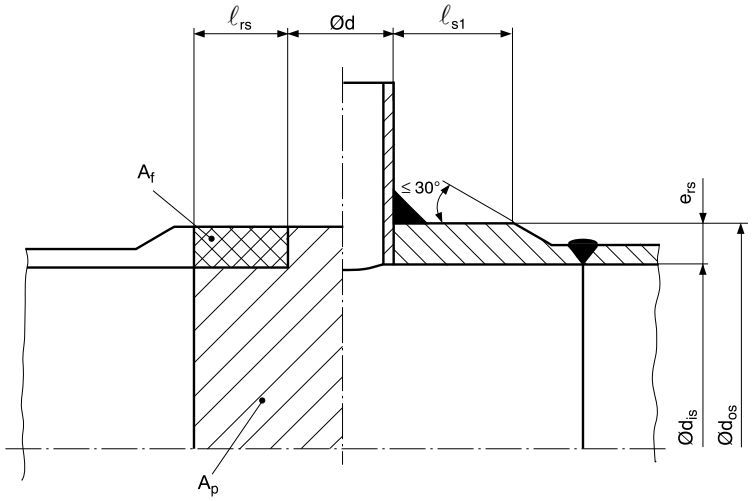


Figure 10 : Reinforcement by set-through and full penetration welded branch

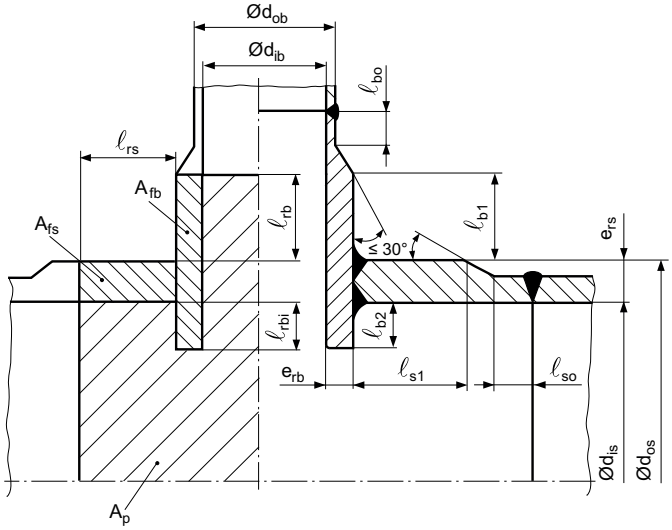


Figure 11 : Reinforcement by welded on branch

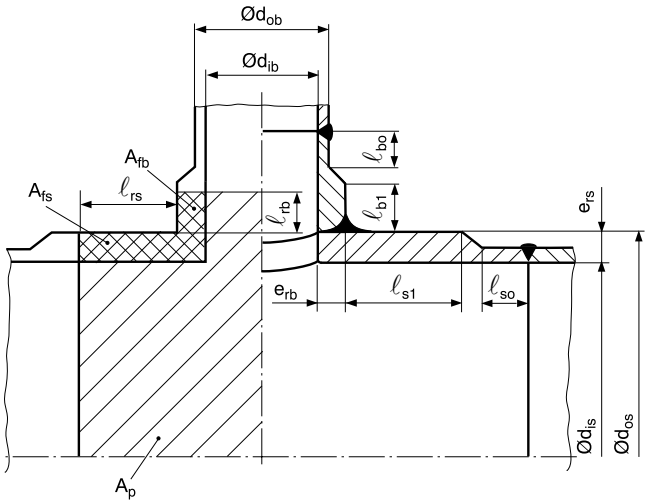


Figure 12 : Opening with reinforcing pad

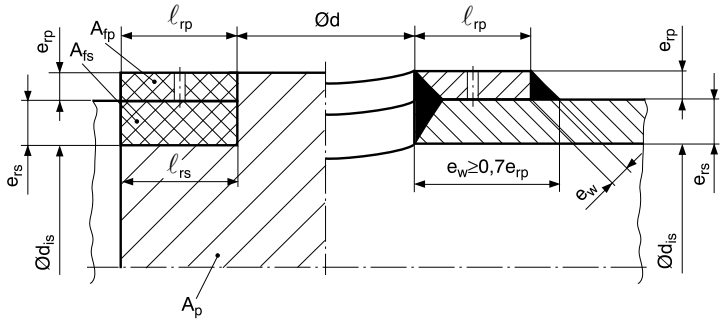
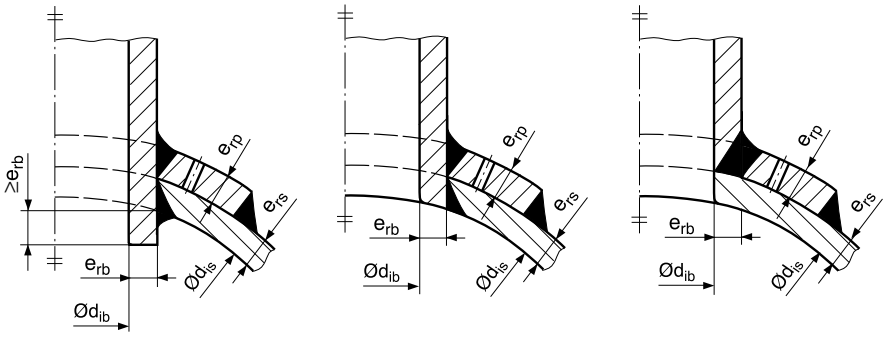


Figure 13 : Opening with reinforcing pad and full penetration branch



a) set through welded branch b) set in welded branch c) set on welded branch

c) Basic calculation

The required wall thickness without allowance of a cylindrical shell is determined with the following formula (see [2.4.3]):

$$t = \frac{pD}{(2K - p)e}$$

With the available thickness t_a, we obtain the available efficiency e_a and the maximum diameter d_{obmax} of an unreinforced opening when the average stress of the main body is equal to the permissible stress K:

$$e_a = \frac{pD_i}{(2K - p)t_a}$$

$$d_{obmax} = 2\left[\frac{\ell_{rs}}{e_a} - \ell_{rs}\right]$$

where:

D_i : Internal diameter of the main body, in mm

d) Isolated opening reinforcement

The reinforcement of isolated openings as indicated in Fig 9 to Fig 13 are to be in respect with:

- If the design stress of the branch is equal or greater than the shell's design stress:

$$\frac{A_p}{A_f} \leq \frac{K}{p} - 0,5$$

where:

K : Permissible stress in the shell, in N/mm^2

A_f : Total area of cross section (wall and branch and pad)

A_p : Total area under pressure p.

- If the design stress of the branch is less than the shell's design stress:

$$\frac{2A_p + A_{fs} + A_{fb}}{2\left(A_{fs} + \frac{K_b}{K}A_{fb}\right)} \leq \frac{K}{p}$$

K : Permissible stress in the shell, in N/mm^2

K_b : Permissible stress in the branch, in N/mm^2

A_{fs} : Total area of the wall cross section

: Total area of the branch cross section

A_p : Total area under pressure p.

In Fig 9 to Fig 13, ℓ_{rs}, ℓ_{rb} and ℓ_{rbi} are effective lengths for calculation of efficiencies and compensation, equal to:

- for shell:

$$\ell_{rs} = \min(\sqrt{(D + e_{rs})e_{rs}}, \ell_{s1})$$

- for external branch projection:

$$\ell_{rb} = \min(\sqrt{(d_{ib} + e_{rb})e_{rb}}, \ell_{b1})$$

- for internal branch projection:

$$\ell_{rbi} = \min(0,5\sqrt{(d_{ib} + e_{rb})e_{rb}}, \ell_{b2})$$

e) Condition of isolated openings

- Full case

Adjacent openings are to be treated as isolated openings if the centre distance P_ϕ, in accordance with Fig 16, is not less than:

$$\frac{\left(\frac{d_{ib1}}{2} + e_{rb1}\right)}{\cos\Psi_1} + \frac{\left(\frac{d_{ib2}}{2} + e_{rb2}\right)}{\cos\Psi_2} + 2\sqrt{(d_{is} + e_{rs})e_{rs}}$$

For variable definition see Fig 14 and Fig 15.

- Simplification

  - For openings without branch:

    $e_{rb} = 0$ and $\Psi = 0$

  - For openings with nozzles perpendicular to shell:

    The openings are to be treated as isolated openings if the centre distance P_ϕ in accordance with Fig 16 is not less than:

$$\left(\frac{d_{ib1}}{2} + e_{rb1}\right) + \left(\frac{d_{ib2}}{2} + e_{rb2}\right) + 2\sqrt{(d_{is} + e_{rs})e_{rs}}$$

Figure 14 : Angle definition for cylindrical shell with oblique branch

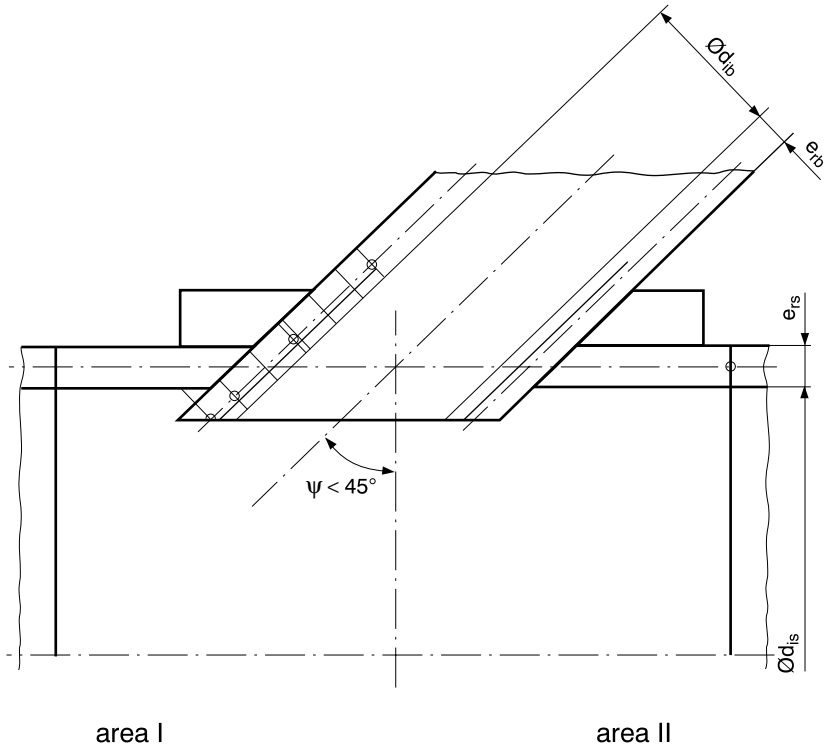
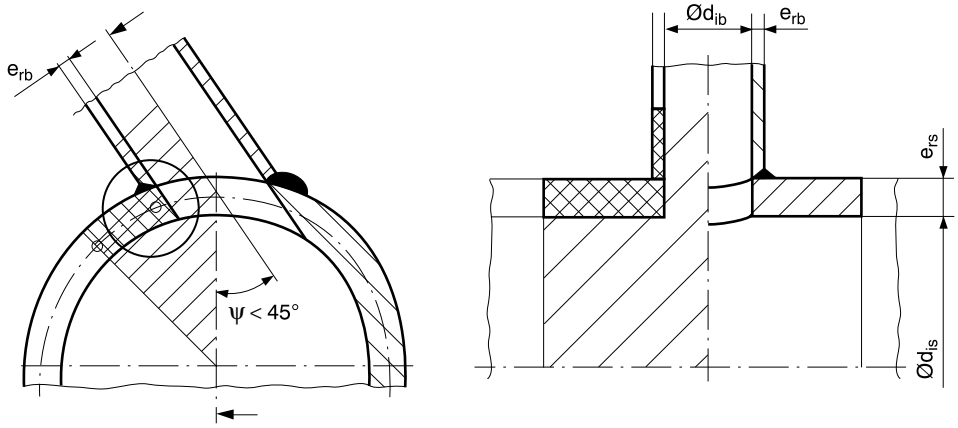


Figure 15 : Angle definition for cylindrical shell with non-radial branch



f) Adjacent openings

Where the condition of isolated openings is not fulfilled, the compensation is to be calculated, using Fig 16, as per the following formula:

- If the design stress of the branch is equal or greater than the shell's design stress:

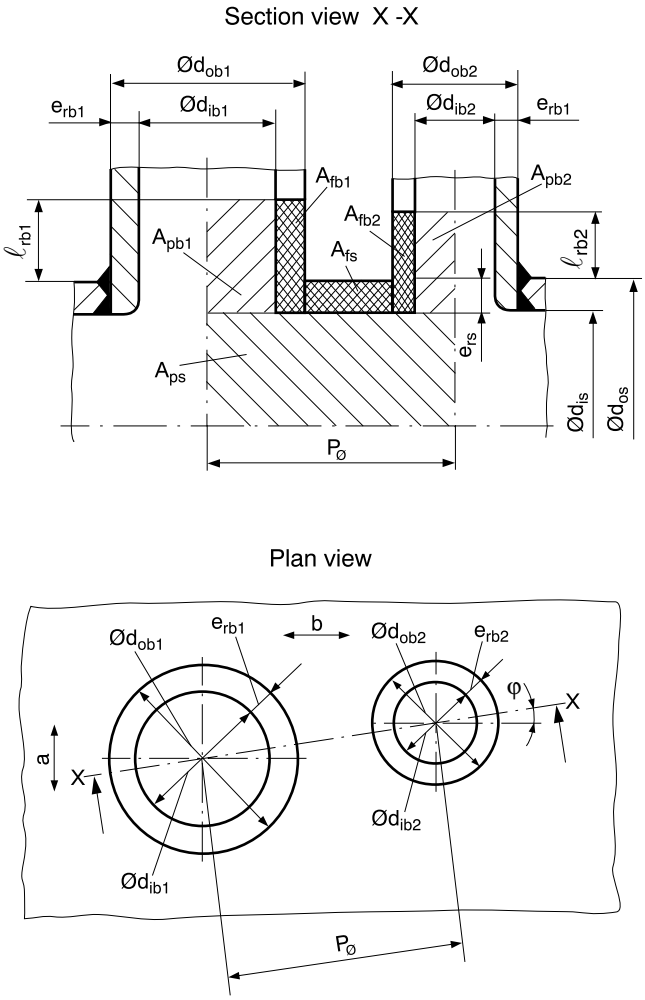
$$\frac{A_p}{A_f} \leq \frac{K}{p} - 0,5$$

- If the design stress of the branch is less than the shell's design stress:

$$\frac{2A_{ps} + 2A_{pb1} + 2A_{pb2} + A_{fs} + A_{fb1} + A_{fb2}}{2\left(A_{fs} + \frac{K_{b1}}{K}A_{fb1} + \frac{K_{b2}}{K}A_{fb2}\right)} \leq \frac{K}{p}$$

Note 1: Adjacent openings are to be calculated additionally as isolated openings.

Figure 16 : Load diagram for cylindrical shell with adjacent branches



a : Circumferential direction

b : Longitudinal direction

2.8.5 Openings in dished heads

a) The openings in dished heads may be circular, elliptical or oval.

b) The largest diameter of the non-compensated opening is not to exceed one half of the external diameter of the head.

c) The opening is to be so situated that its projection, or its reinforcement projection in the case of compensated openings, is completely contained inside a circle having its centre at the centre of the head and a diameter of 0,8 D, D being the external diameter of the head (see Fig 17). However, a small reinforced opening for drainage may be accepted outside the indicated area.

d) In the case of non-compensated openings (for this purpose, flanged openings are also to be considered as non-compensated), the head thickness is not to be less than that calculated by the formula in [2.5.3] using the greatest of the shape factors C obtained from the graph in Fig 3 as a function of:

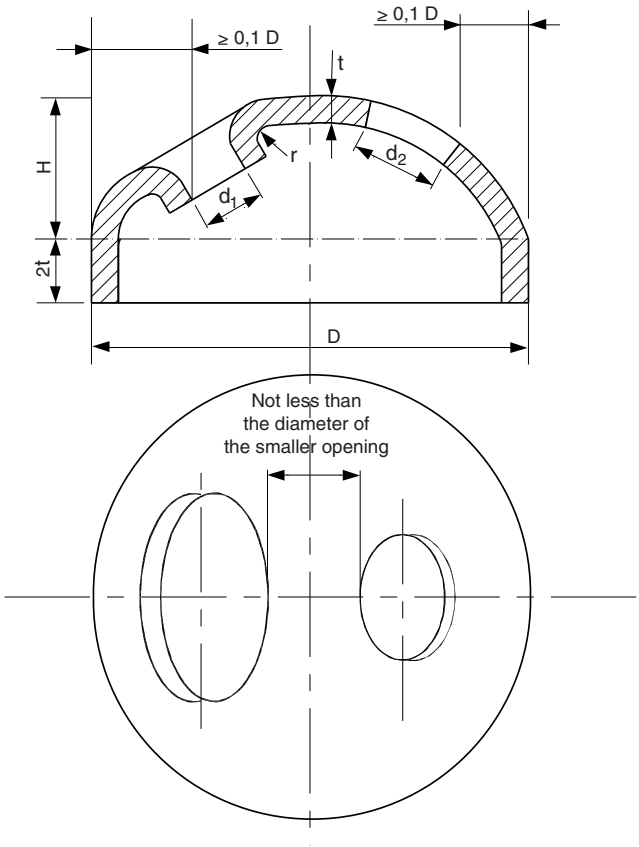
H/D and t/D or H/D and $d \cdot (t \cdot D)^{-0,5}$,

where d is the diameter of the largest non-compensated opening in the head, in mm. For oval and elliptical openings, d is the width of the opening in way of its major axis.

e) In all cases the diameter D of the head base, the head thickness t and the diameter d of the largest non-compensated opening are to be such as to meet the following requirements:

- the position of non-compensated openings in the heads is to be as shown in Fig 17
- for flanged openings, the radius r of the flanging (see Fig 17) is not to be less than 25 mm
- the thickness of the flanged part may be less than the Rule thickness.

Figure 17 : Openings on dished heads



2.8.6 Opening compensation in dished heads

a) Where openings are cut in dished heads and the proposed thickness of the head is less than that calculated by the formula in [2.5.3] with the greatest of the shape factor C according to [2.5.3] the opening is to be compensated.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show typical connections of nozzles and compensating rings.

c) The opening is considered sufficiently compensated when the head thickness t is not less than that calculated in accordance with [2.5.3] and using the shape-factor C obtained from the graph in Fig 3 using the value:

$$\left(d - \frac{A}{t}\right) \cdot (t \cdot D)^{-0,5}$$

instead of:

$d \cdot (t \cdot D)^{-0,5}$

where:

A : Area, in mm^2, of the total transverse section of the compensating parts

t : Actual thickness of the head, in mm, in the zone of the opening under consideration.

d) When A/t > d, the coefficient C is to be determined using the curve corresponding to the value:

$d \cdot (t \cdot D)^{-0,5} = 0$

e) If necessary, calculations are to be repeated.

2.8.7 Compensation criteria

In the evaluation of the area A, the following is also to be taken into consideration:

a) The material that may be considered for compensating an opening is that located around the opening up to a distance l from the edge of the opening. The distance l, in mm, is the lesser obtained from the following formulae:

$l = 0,5\ d$

$l = (2 \cdot R_{IN} \cdot t)^{0,5}$

where:

d : Diameter of the opening, in mm

R_{IN} : Internal radius of the spherical part, in mm, in the case of hemispherical or torispherical heads

In the case of ellipsoidal heads, R_{IN} is to be calculated by the following formula (see Fig 2 (a):

$$R_{IN} = \frac{[a^4 - x^2(a^2 - b^2)]^{3/2}}{a^4 b}$$

where;

a : Half the major axis of the elliptical meridian section of the head, in mm

b : Half the minor axis of the above section, in mm

x : Distance between the centre of the hole and the rotation axis of the shell, in mm.

b) In the case of nozzles or pads welded in the hole, the section corresponding to the thickness in excess of that required is to be considered for the part which is subject to pressure and for a depth h, in mm, both on the external and internal sides of the head, not greater than:

$(d_B \cdot t_B)^{0,5}$

where d_B and t_B are the diameter of the opening and the thickness of the pad or nozzle, in mm, respectively.

c) The area of the welding connecting nozzle and pad reinforcements may be considered as a compensating section.

d) If the material of reinforcement pads, nozzles and collars has a permissible stress lower than that of the head material, the area A, to be taken for calculation of the coefficient C, is to be reduced proportionally.

2.8.8 Openings in flat end plates

The maximum diameter of an unreinforced opening in a flat end plate is to be determined from the equation:

$$d_{max} = 8e_{rh}\left[1,5\frac{e_{rh}^2}{e_{ch}^2} - 1\right]$$

where:

e_{rh} : Actual thickness of the flat end, in mm

e_{ch} : Required calculated thickness of the flat end, in mm.

2.8.9 Opening compensation in flat end plate

Reinforcement of branch openings is to be achieved by taking account of locally disposed material, including the attachment welds, in excess of the minimum requirements for end plate and branch thickness as shown in Fig 18. The branch thickness is to be increased where required. Compensation is to be considered adequate when the compensating area Y is equal to or greater than the area X requiring compensation.

Area X is to be obtained by multiplying 25% of the inside radius of the branch by the thickness of the flat end plate, calculated for the part of the end plate under consideration.

Area Y is to be measured in a plane through the axis of the branch parallel to the surface of the flat end plate, and is to be calculated as follows:

a) for that part of the branch which projects outside the boiler, calculate the full sectional area of the branch up to a distance ℓ_b from the actual outer surface of the flat end plate and deduct from it the sectional area that the branch would have within the same distance if its thickness were calculated in accordance with equation given in [2.4.3]

b) add to it the full sectional area of that part of the branch that projects inside the boiler (if any) up to a distance ℓ_b from the inside surface of the flat end plate

c) add to it the sectional area of the fillet welds

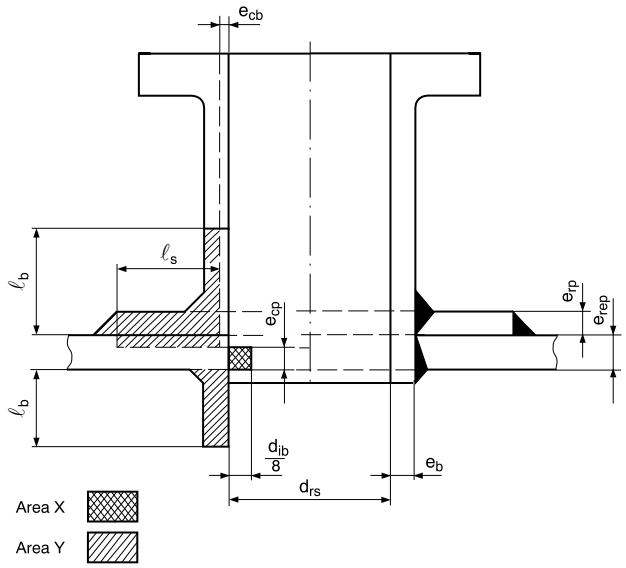
d) add to it the area obtained by multiplying the difference between the actual flat end plate thickness and its thickness calculated for the part of the end plate under consideration by the length ℓ_s

e) add to it the area of the compensating plate (if any) within the limits of reinforcement shown in Fig 18.

Where material having a lower allowable stress than that of the flat end plate is taken as compensation, its effective area is to be reduced in the ratio of the allowable stresses at the calculation temperature. No credit is to be taken for the additional strength of material having a higher allowable stress than that of the flat end plate

Welds attaching branches and compensating plates are to be capable of transmitting the full strength of the reinforcing area and all other loadings to which they may be subjected.

Figure 18 : Compensation for branch in flat end plate



e_{cp} : Thickness calculated in accordance with equation in [2.8.1] for the part under consideration

e_{cb} : Thickness calculated taking efficiency = 1

ℓ_b : The smaller of the two values:

$2,5\ e_{rep}$ and $(2,5\ e_b + e_{rp})$

ℓ_s : The greater of the two values:

$(e_{rep} + 75)$ and $(d_{ib} / 4)$

Area Y is not to be less than area X.

Note 1 : The compensating plate is required only in cases where area Y would otherwise be less than area X.

2.8.10 Covers

a) Circular, oval and elliptical inspection openings are to be provided with steel covers. Inspection openings with a diameter not exceeding 150 mm may be closed by blind flanges.

b) The thickness of the opening covers is not to be less than the value t, in mm, given by the following formula:

$$t = 1,22 \cdot a \cdot \left(\frac{pC}{K}\right)^{0,5}$$

where:

a : The minor axis of the oval or elliptical opening, measured at half width of gasket, in mm

b : The major axis of the oval or elliptical opening, measured at half width of the gasket, in mm

C : Coefficient in Tab 13 as a function of the ratio b/a of the axes of the oval or elliptical opening, as defined above. For intermediate values of the ratio b/a, the value of C is to be obtained by linear interpolation.

For circular openings the diameter d, in mm, is to be used in the above formula instead of a.

c) The thickness obtained by the formula in item a) is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm for classification purpose. See also [2.4.7].

Table 13 : Coefficient C for oval or elliptical covers

b/a	1,00	1,05	1,10	1,15	1,20	1,25	1,30	1,40	1,50	1,60
C	0,206	0,220	0,235	0,247	0,259	0,271	0,282	0,302	0,321	0,333
b/a	1,70	1,80	1,90	2,00	2,50	3,00	3,50	4,00	4,50	5,00
C	0,344	0,356	0,368	0,379	0,406	0,433	0,449	0,465	0,473	0,480

2.9 Regular pattern openings - Tube holes

2.9.1 Definition

Openings may be considered as regular pattern openings when not less than three non isolated openings are disposed in regularly staggered rows in longitudinal or circular direction of a shell.

In such a case, instead of a direct calculation of the compensation of openings, the thickness of the shell could be calculated by application of applicable formulae given in [2.4], [2.5] with a reduced efficiency e as indicated in [2.9.2] and [2.9.3].

This requirement apply for pressure vessels and for boiler.

2.9.2 Efficiency factor of tube holes in cylindrical tube plates

The efficiency factor e of pipe holes in cylindrical shells pierced by tube holes is to be determined by direct calculation or by another suitable method accepted by the Society. In the case of cylindrical holes of constant diameter and radial axis, the efficiency factor e may be determined by the following formula (see Fig 19):

$$e = \frac{1}{\frac{s}{s-d} \cdot (1 - (0,5 \cdot \sin^2\alpha)) + m \cdot \sin 2\alpha}$$

where:

s : Pitch of the hole row considered, in mm

d : Diameter of holes, in mm. The hole diameter d may be reduced by the amount Y/e_{cp} where Y is the compensating area, in mm², of nozzle and welds and e_{cp} the calculated unpierced shell thickness, see [2.8.9] and Fig 18

α : Angle between the axis of hole row considered and the axis of the cylinder ($\alpha = 0°$ if the hole row is parallel to the cylinder generating line; $\alpha = 90°$ for circumferential hole row)

m : Coefficient depending upon the ratio d/s, as obtained from Tab 14. For intermediate values of d/s, the value of m is to be obtained by linear interpolation.

The value of e actually used is to be the smallest calculated value for either longitudinal, diagonal or circumferential rows of holes.

Figure 19 : Hole pattern in cylindrical shells

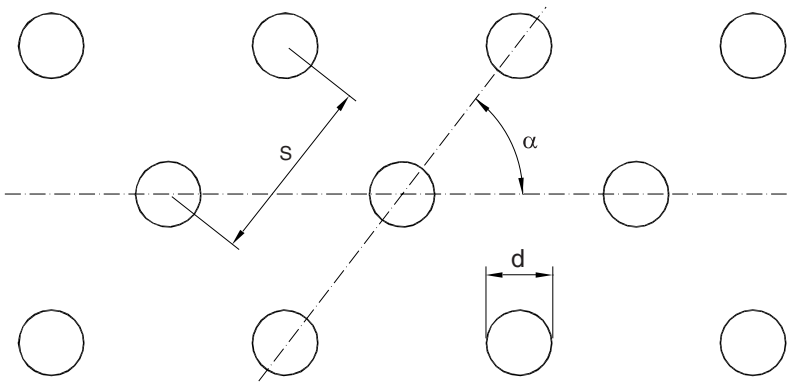


Table 14 : Coefficient m

d/s	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0.65	0,70	0,75	0,80
m	0,137	0,175	0,220	0,274	0,342	0,438	0,560	0,740	1,010	1,420	2,060

2.9.3 Welded shells with tube holes and efficiency factor of different hole patterns

Where shells have welding butts and/or different groups of hole patterns, the value to be assumed for the efficiency e in the formulae is the minimum of the values calculated separately for each type of welding (as per [2.4.2]) and for each configuration of holes (as per [2.9.1]).

2.9.4 Rectangular section headers

a) For seamless type headers of rectangular section design, the wall thickness t, in mm, in way of corner fillets and the thickness t_1, in mm, of any drilled wall is not to be less than those given by the following formulae, as appropriate (see Fig 20):

$$t = \left(\frac{100pM_1}{K}\right)^{0,5}$$

$$t_1 = \left(\frac{100pM_2}{eK}\right)^{0,5}$$

where (see also Fig 20):

t : Wall thickness at the corners, in mm

t_1 : Thickness of drilled wall, in mm

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

a : Internal half width of the header, in a direction parallel to the wall under consideration, in mm

b : Internal half width of the header, in a direction normal to the wall under consideration, in mm

c : Distance between the axis of the hole row considered and the centreline of the header wall, in mm

e : Efficiency factor of holes in the wall, determined by the following formulae:

$$e = \frac{s-d}{s} \qquad \text{for } d < a$$

$$e = \frac{s-0,67d}{s} \qquad \text{for } a \le d < 1,3a$$

$$e = \frac{s-0,33d}{s} \qquad \text{for } d \ge 1,3a$$

where:

s : Pitch of the holes, in mm, of the longitudinal or diagonal row under consideration. For a staggered pattern of holes the pitch of the diagonal row is to be considered

d : Diameter of the holes, in mm

M_1 : Coefficient to be calculated by the following formula:

$$M_1 = \frac{a^2 + b^2 - ab}{50}$$

M_2 : Coefficient (to be taken always positive) to be calculated by one of the following formulae, as appropriate:

- For a non-staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab + \frac{3}{2}c^2}{50}$$

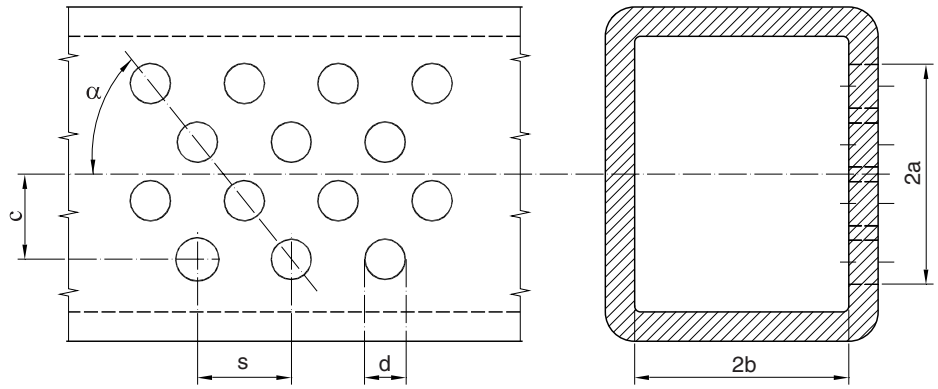
- For a staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab}{50}\cos\alpha$$

where α is the angle between the axis of the diagonal row of the holes under consideration and the axis of the header, in the case of a staggered pattern of holes.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1,5 mm. See also [2.4.7].

Figure 20 : Rectangular section headers



2.10 Water tubes, superheaters and economiser tubes of boilers

2.10.1

a) The thickness of tubes of evaporating parts, economisers and superheaters exposed to gases which are subject to internal pressure is not to be less than the value t given by the following formula:

$$t = \frac{pd}{2K + p} + 0,3$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

d : Outside diameter of tube, in mm.

However, irrespective of the value calculated by the formulae in item a), the thickness t of tubes is not to be less than the values given in Tab 15.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in item a) is to be increased by 12,5% to take into account the manufacturing tolerance. For bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the formula.

c) Whenever abnormal corrosion and erosion may occur during service, the corrosion constant of 0,3 in the formula may be increased to the satisfaction of the Society.

d) The thickness of tubes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes (see Ch 1, Sec 10, [15]).

Table 15 : Minimum thickness of water tubes

Outside diameter, in mm	Minimum thickness in mm of tubes subject to internal pressure of cylindrical boilers and water tube boilers having the feed water system	
	Closed type, if equipped with suitable devices for reducing the oxygen concentration in the water	Open type, not equipped with suitable devices for reducing the oxygen concentration in the water
< 38	1,8	2,9
38 - 48,3	2,0	2,9
51 - 63,5	2,4	2,9
70	2,6	3,2
76,1 - 88,9	2,9	3,2
101,6 - 127	3,6	–

2.11 Additional requirements for fired pressure vessels

2.11.1 Insulation for headers and combustion chambers

Those parts of headers and/or combustion chambers which are not protected by tubes and are exposed to radiant heat or to high temperature gases are to be covered by suitable insulating material.

2.11.2 Connections of tubes to drums and tube plates

Tubes are to be adequately secured to drums and/or tube plates by expansion, welding or other appropriate procedure.

a) Where the tubes are secured by expanding or equivalent process, the height of the shoulder bearing the tube, measured parallel to the tube axis, is to be at least 1/5 of the hole diameter, but not less than 9 mm for tubes normal to the tube plate or 13 mm for tubes angled to the tube plate. The tubes ends are not to project over the other face of the tube plate more than 6 mm.

b) The tube ends intended to be expanded are to be partially annealed when the tubes have not been annealed by the manufacturer.

2.12 Additional requirements for vertical boilers and fire tube boilers

2.12.1 General

The scantlings of the shells of vertical boilers and fire tube boilers are to be determined in accordance with [2.4].

2.12.2 Ends of vertical boilers

a) The minimum thickness of the dished ends forming the upper part of vertical boilers and subject to pressure on their concave face is to be determined in accordance with [2.5].

b) When the end is supported in its centre by an uptake, the minimum thickness t, in mm, is to be calculated with the following formula:

$$t = 0,77 \cdot \frac{pR_I}{K}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

R_I : Radius of curvature at the centre of the end measured internally. R_I is not to exceed the external diameter of the shell.

c) The thickness obtained by the formula in item b) is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,7 mm. See also [2.4.7].

d) For ends supported by an uptake at their centre, the corner radius measured internally is not to be less than 4 times the end thickness or 65 mm, whichever is the lesser and the inside radius of curvature on the flange to uptake is not to be less than twice the end thickness or 25 mm, whichever is the lesser.

2.12.3 Supported flat head

a) Breathing space

- Stays are to give breathing space around the furnace tube connections and tube nests and equally divide the unstayed areas. Breathing space between furnace tube and tube nests are to be a minimum of 50 mm or 5% of the shell outside diameter, whichever is the larger, but need not be more than 100 mm.
- Breathing space between furnace tube and shell depends on the thickness of the plate of the type of end and of the dimensions of the boiler but is to be not less than 50 mm or, for bowling hoop furnaces tubes, not less than 75 mm.

b) The thickness of stayed flat heads, or of heads supported by flanges, is not to be less than the value t, in mm, given by the following formula:

$$t = D\left[\frac{100p}{CC_1K(1 + C_2B^2)}\right]^{0,5}$$

where:

B : Ratio of the thickness of the large washer or doubler, where fitted, to the thickness of the plate:
$B = t_1 / t$
The value of B is to be taken between 0,67 and 1

K : Permissible stress, in N/mm², obtained as specified in [2.3]

C : C = 1 when the plate is not exposed to flame
C = 0,88 when the plate is exposed to flame

C_1 : C_1 = 462 when the plate is supported by welded stays
C_1 = 704 for plates supported by flanges or equivalent

C_2 : C_2 = 0 when no doublers are fitted
C_2 = 0,85 when a complete doubling plate is fitted, adequately joined to the base plate.

The value of D is to be in accordance with the following provisions:

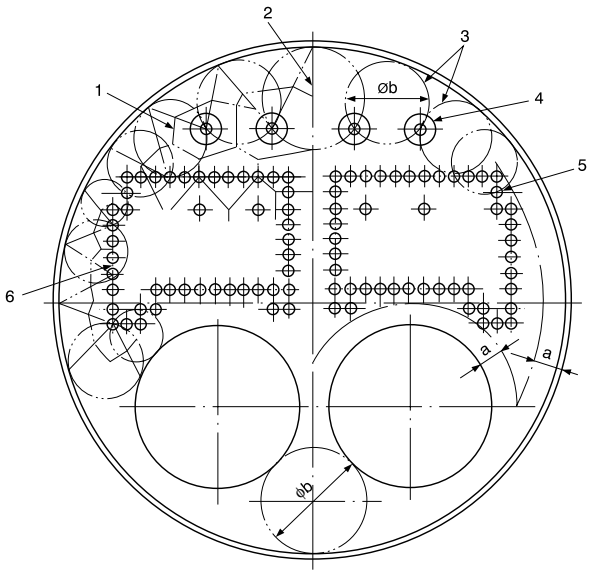
- In the parts of the flat heads between the stays:

D : D = diameter, in mm, of the largest circle which can be drawn through the centre of at least three stays without enclosing any other stay, where the stays are not evenly spaced (see Fig 21); or
$D = (a^2 + b^2)^{0,5}$ where the stays are evenly spaced, considering the most unfavourable condition,
where:

a : Distance between two adjacent rows of stays, in mm

b : Pitch of stays in the same row, in mm

Figure 21 :



Key:

1 : Boundaries of areas supported by individual stays

2 : To establish the area supported by bar stays or stay tubes in boundary rows, the boundary of the loaded area is to terminate at the centre of the associated main circle

3 : Main circles, diameter b

4 : Bar stays

5 : Stay tubes

6 : Termination of boundary areas where stay tubes are situated in the boundary rows only.

- In the parts of the flat heads between the stays and the boundaries, where flat heads are generally supported by flanges or shapes, or connected to other parts of the boiler:

  D : Diameter, in mm, of the largest circle which can be drawn through not less than three points of support (stay centres or points of tangency of the circle with the contour line). To this end, the contour of the part under consideration is to be drawn at the beginning of the flanging or connection curve if its inside radius does not exceed 2,5 times the thickness of the plate, or, where such radius is greater, at the above-mentioned distance (of 2,5 times the thickness of the plate) from the ideal intersection with other surfaces (see Fig 21).

c) When applying the formulae for calculation of thickness of heads covered by this sub-article, the position of plates in the most unfavourable condition is to be considered.

d) Where various types of supports are provided, the value of C_1 should be the arithmetic mean of the values of C_1 appropriate to each type of support.

e) The thickness obtained by the formulae in a), is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [2.4.7].

2.12.4 Flat tube plates

a) Flat tube plates in tube bundles

The thickness of the parts of flat tube plates contained in the tube bundle and supported by stay tubes is not to be less than the value t, in mm, given by the following formula:

$$t = s\left(\frac{p}{2,8K}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

s : Pitch of stay tubes, taken as the greatest mean pitch of the stay tubes supporting a quadrilateral portion of the plate, in mm.

Moreover the spacing of tube holes (diameter d) is to be such that the minimum width, in mm, of any ligament between the tube holes is to be not less than:

- for expanded tubes:

  (0,125 d + 12,5) mm

- for welded tubes:
  - for gas entry temperatures greater than 800°C:

    (0,125 d + 9) mm, but need not exceed 15 mm
  - for gas entry temperatures less than or equal to 800°C:

    0,125 d + 7) mm, but need not exceed 15 mm.

Moreover the calculated thickness of tube plates is to be not less than the following:

- 12 mm where the tubes are expanded into the tube plate when the diameter of the tube hole does not exceed 50 mm, or 14 mm when the diameter of the tube hole is greater than 50 mm, or
- 6 mm where the tubes are attached to the tube plate by welding only.

b) Flat tube plates of combustion chamber in vertical boilers

Where tube plates contained in the tube bundle are simultaneously subject to compression due to the pressure in the combustion chamber, their thickness, as well as complying with the requirements in item a) is not to be less than the value t, in mm, given by the following formula:

$$t = \frac{pls_1}{1,78(s_1 - d)K}$$

where:

l : Depth of the combustion chamber, in mm

s_1 : Horizontal pitch of tubes, in mm

d : Inside diameter of plain tubes, in mm.

For the meaning of other symbols, see item a).

c) Tube plates outside tube bundles

For those parts of tube plates which are outside the tube bundle, the formula in [2.13.3] is to be applied, using the following coefficients C_1 and C_2:

$C_1 = 390$

$C_2 = 0,55$

Doublers are only permitted where the tube plate does not form part of a combustion chamber.

d) Tube plates not supported by stays

Flat tube plates which are not supported by stay tubes (e.g. in heat exchangers), are subject of special consideration by the Society (see also [2.14]).

e) Stay and stay tube scantling

- the diameter of solid stays of circular cross-section is not to be less than the value d calculated by the following formula:

$$d = \left(\frac{pA}{K}\right)^{0,5}$$

where:

d : Minimum diameter, in mm, of the stay throughout its length

A : Area supported by the stay, in mm^2

K : $K = R_m / 7$

R_m : Minimum ultimate tensile strength of the stay material, in N/mm^2.

The cross section of tube stays is to be equivalent to that of a solid stay supporting the same area, whose diameter is calculated by the above formula.

Stays which are not perpendicular to the supported surface are to be of an adequately increased diameter depending on the component of the force normal to the plate.

- where articulated stays are used, articulation details are to be designed assuming a safety factor for articulated elements not less than 5 with respect to the value of R_m and a wear allowance of 2 mm.

The articulation is to be of the fork type and the clearance of the pin in respect of the holes is not to exceed 1,5 mm. The pin is to bear against the jaws of the fork and its cross-sectional area is not to be less than 80% of the cross-sectional area of the stay. The width of material around the holes is not to be less than 13 mm.

- where stays are flanged for joining to the plate, the thickness of the flange is not to be less than one half the diameter of the stay.
- for welded connections of stays to tube plates, see Fig 37.

f) Stay and stay tubes construction:

- in general, doublers are not to be fitted in plates exposed to flame
- as far as possible, stays are to be fitted perpendicularly to the supported surface
- long stays in double front boilers and, in general, stays exceeding 5 m in length, are to be supported at mid-length
- where the ends of stay tubes are of increased thickness, the excess material is to be obtained by forging and not by depositing material by means of welding
- after forging, the ends of stay tubes are to be stress relieved.

g) Gusset stays

Tube plate may be supported by gussets stays with full penetration welds to plate and shell.

The general shape and the scantling are to be in accordance with a standard accepted by the Society.

h) Girders

Where tops of combustion chambers, or similar structures, are supported by girders of rectangular section associated with stays, the thickness of the single girder or the aggregate thickness of all girders, at mid-length, is not to be less than the value t determined by the appropriate formula below, depending upon the number of stays.

- In case of an odd number of stays:

$$t = \frac{pL(L-s)l}{0,25R_m a^2} \cdot \frac{n+1}{n}$$

- In case of an even number of stays:

$$t = \frac{pL(L-s)l}{0,25R_m a^2} \cdot \frac{n+2}{n+1}$$

where:

p : Design pressure, in MPa

a : Depth of the girder plate at mid-length, in mm

L : Length of girder between supports, in mm

s : Pitch of stays, in mm

n : Number of stays on the girder

l : Distance between centres of girders, in mm

R_m : Minimum ultimate tensile strength of the material used for the plates, in N/mm^2.

The above formulae refer to the normal arrangement where:

- the stays are regularly distributed over the length L
- the distance from the supports of the outer stays does not exceed the uniform pitch s
- when the tops of the combustion chambers are connected to the sides with curved parts with an external radius less than 0,5 l, the distance of end girders from the inner part of the side surface does not exceed l
- when the curvature radius mentioned under item just above exceeds 0,5 l, the distance of the end girders from the beginning of the connection does not exceed 0,5 l.

In other cases a direct calculation is to be made using a safety factor not less than 5, with respect to the minimum value of the tensile strength R_m.

i) Ogee rings

The thickness of ogee rings connecting the furnaces to the shell in vertical auxiliary boilers (see Fig 22), where the latter support the weight of the water above the furnace, is not to be less than the value t, in mm, given by the following formula:

$$t = [1{,}02 \cdot 10^{-3} \cdot pD_A \cdot (D_A - d_A)]^{0,5} + 1$$

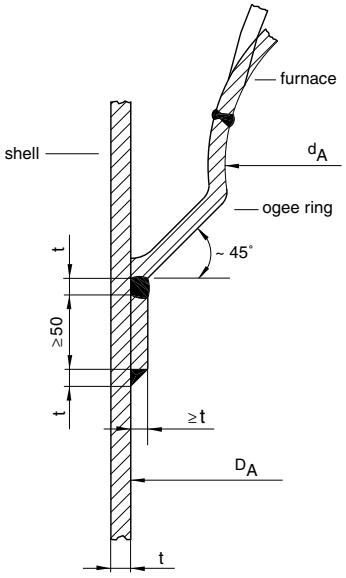
where:

p : Design pressure, in MPa

D_A : Inside diameter of boiler shell, in mm

d_A : Inside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

Figure 22 : Ogee ring



2.12.5 Fire tubes

a) The thickness of fire tubes subject to external pressure in cylindrical boilers is not to be less than the value t, in mm, calculated by the following formula:

$$t = \frac{pd}{0{,}15R_m} + 1{,}8$$

where:

p : Design pressure, in MPa

d : Outside diameter of tube, in mm

R_m : Minimum ultimate tensile strength of the tube material, in N/mm^2.

The minimum acceptable thickness is given in Tab 16.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in a) is to be increased by 12,5% to take into account the manufacturing tolerance. In the case of bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the above formula.

c) Whenever abnormal corrosion and erosion may occur during service the corrosion constant of 1,8 in the formula may be increased to the satisfaction of the Society.

Table 16 : Minimum thickness of fire tubes

Nominal outside diameter	Lowest nominal thickness t
d ≤ 88,9	3,00
88,9 < d ≤ 114,3	3,15
114,3 < d ≤139,7	3,50
139,7 < d ≤168,3	3,99

2.12.6 Furnaces general points

a) Thermal design of furnace tubes.

The heat input for a given furnace tube inside diameter is not to exceed a value compatible with the chosen design temperature. Burners with a fixed firing rate are not to be used for heat inputs exceeding 1 MW per furnace tube.

b) The minimum thickness of furnaces is to be calculated for elastic buckling and plastic deformation in accordance with the requirements of a Standard for pressure vessels subject to external pressure accepted by the Society.

c) However, the minimum thicknesses of furnaces and cylindrical ends of combustion chambers of fire tube boilers are to be not less than the value t given by the appropriate formulae in [2.12.7], [2.12.8] and [2.12.9].

d) The thickness of furnaces is not to be less than 8 mm for plain furnace and 10 mm for corrugated furnace and the stays are to be spaced such that the thickness does not exceed 22 mm.

e) All the thicknesses obtained for furnaces by the formulae in [2.12.7], [2.12.8], [2.12.9] and [2.12.4] are “net” thicknesses, as they do not include any corrosion allowance. The thicknesses obtained by the above formulae are to be increased by 1 mm. See also [2.4.7].

2.12.7 Plain furnace tubes

a) Plain furnace tube

The minimum thickness t of plain cylindrical furnaces is to be not less than the greater value, in mm, obtained from the following formulae:

$$t = \frac{B}{2}\left[1 + \sqrt{1 + \frac{0,12D \cdot u}{(1 + 5D/L)B}}\right]$$

$$t = D^{0,6}[(LS_2p)/(2,6E)]^{0,4}$$

where:

$$B = \frac{pDS_1}{2R_{S,MIN,T}(1 + 0,1D/L)}$$

S_1 : Safety factor, equal to 2,5

L : Unstayed length of furnace, in mm

u : Departure from circularity, in %, equal to:

$$u = \frac{2(D_{max} - D_{min})}{D_{max} + D_{min}} \times 100$$

u is to be taken as 1,5% for plain furnace tubes

S_2 : Safety factor for buckling, equal to:

- 3 for u ≤1,5%
- 4 for 1,5% < u ≤ 2%

E : Elastic modulus, in MPa, at design temperature T, in °C, and equal to:

E = 208800 – 93,4 T

b) Stiffeners

Stiffeners welded to furnaces tubes according to a standard accepted by the Society may be considered as providing effective stiffening (reduction of L in upper formulae).

2.12.8 Corrugated furnace tubes

The minimum thickness of corrugated furnace tubes, in mm, is to be determined by:

$$t = \frac{pD_E}{0,26R_m}$$

where:

D_E : External diameter of the furnace, in mm, measured at the bottom of the corrugation.

This formula apply for Fox and Morisson type furnaces tubes. The scantling of furnaces of other types and the use of stiffeners are to be especially considered by the Society.

2.12.9 Hemispherical furnaces

The minimum thickness t, in mm, of hemispherical furnaces is not to be less than the value given by the following equation:

$$t = \frac{pD_E}{120}$$

2.13 Bottles containing pressurised gases

2.13.1 General

a) The following requirements apply to bottles intended to contain pressurised and/or liquefied gases at ambient temperature, made by seamless manufacturing processes.

b) In general, such bottles are to have an outside diameter not exceeding 420 mm, a length not exceeding 2000 mm and capacity not exceeding 150 litres (see also [3.4.1]).

c) For bottles exceeding the above capacity and dimensions, the following requirements may be applied at the discretion of the Society.

2.13.2 Cylindrical shell

The wall thickness of the cylindrical shell is not to be less than the value t, in mm, determined by the following formula:

$$t = \frac{p_H D_E}{2K + p_H}$$

where:

p_H : Hydrostatic test pressure, in MPa. This pressure is to be taken as 1,5 times the setting pressure of the safety valves with the following exceptions:

- in addition, for CO_2 bottles, this pressure is not to be less than 25 MPa
- for refrigerants, the value of hydrostatic test pressure is given in Part F, Chapter 7

D_E : Outside diameter of tube, in mm

$K = R_{S,MIN} / 1,3$

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), at the ambient temperature, in N/mm^2. In no case is the value $R_{S,MIN}$ to exceed:

- 0,75 R_m for normalised steels
- 0,90 R_m for quenched and tempered steels.

2.13.3 Dished heads

Dished ends are to comply with the following requirements:

a) Hemispherical ends: the thickness of the ends is to be not less than the thickness calculated for spherical shells in accordance with [2.4.4]

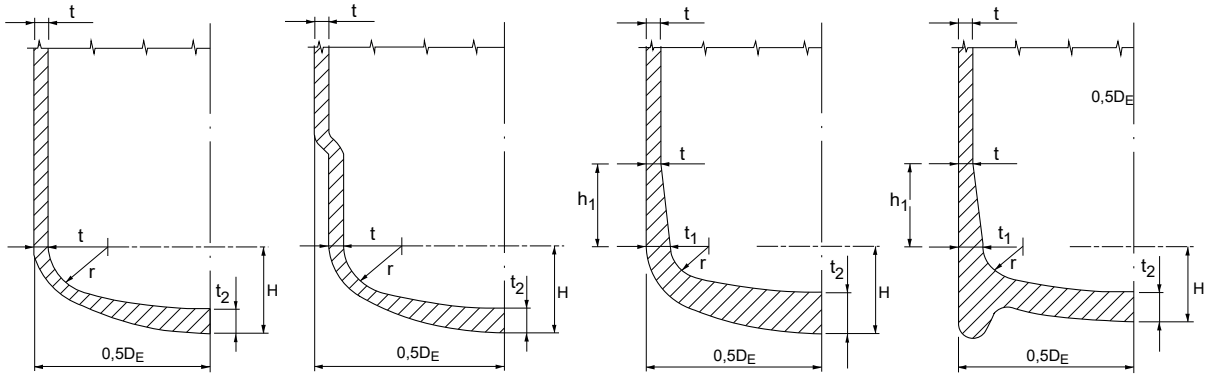
b) Convex ends: see Fig 23

c) Concave base ends: see Fig 24

d) Ends with openings: see Fig 25

e) Other types of ends are to be specially considered by the Society.

Figure 23 : Dished convex ends



$H/D_E \geq 0,20$ $r \geq 0,075\ D_E$ $t_1 \geq 1,25\ t$ $t_2 \geq 1,5\ t$ $h_1 \geq 6\ t$

Figure 24 : Dished concave ends

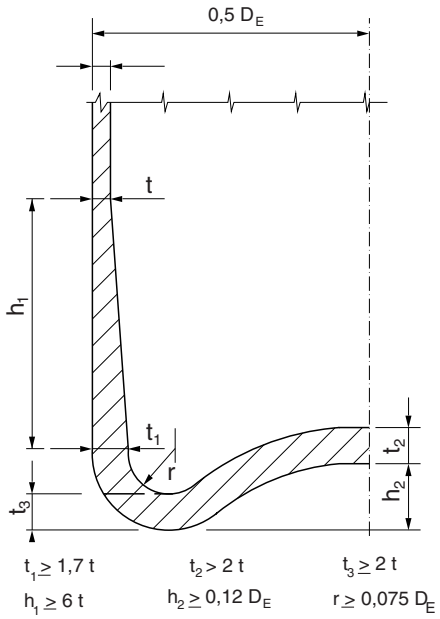
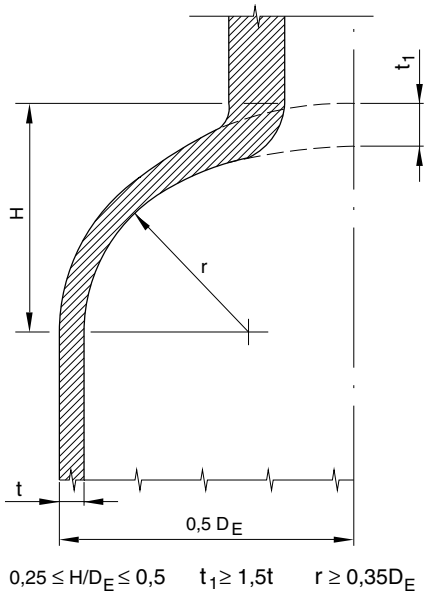


Figure 25 : Heads with openings



2.14 Heat exchangers

2.14.1 Scantlings

a) Vessels are to be designed in accordance with the applicable requirements stated in [2.4] and [2.5].

b) Tubes are to be designed in accordance with [2.10.1].

c) Tube plates are to be designed in accordance with a standard accepted by the Society.

2.14.2 Thermal oil heat exchangers

The provisions of [2.14.1] apply also to thermal oil heat exchangers. However, irrespective of the thickness obtained by the formula in [2.10.1], the tube thickness of oil fired and exhaust fired thermal oil heaters is to be not less than the values indicated in Tab 17.

Table 17 : Minimum thickness ofthermal oil heat exchanger tubes

Outside diameter, in mm	Minimum thickness, in mm, of tubes subject to internal pressure of oil fired and exhaust fired thermal oil heaters
< 63,5	2,4
70 - 89	2,9
> 89	3,6

3 Design and construction - Equipment

3.1 All pressure vessels

3.1.1 Drainage

a) Each air pressure vessel is to be fitted with a drainage device allowing the evacuation of any oil or water accumulated in the vessel.

b) Drainage devices are also to be fitted on other vessels, in particular steam vessels, in which condensation water is likely to accumulate.

3.2 Boilers and steam generators

3.2.1 Safety valve arrangement

a) Every steam boiler and every steam generator with a total heating surface of 50 m^2 and above is to be provided with not less than two spring loaded safety valves of adequate capacity. For steam boilers and steam generators having heating surface less than 50 m^2, only one safety valve need be fitted.

b) Where a superheater is an integral part of the boiler, at least one safety valve is to be located on the steam drum and at least one at the superheater outlet. The valves fitted at the superheater outlet may be considered as part of the boiler safety valves required in item a), provided that their capacity does not account for more than 25% of the total capacity required in [3.2.2], unless specially considered by the Society.

c) Where fitted, superheaters which may be shut-off from the boiler are to be provided with at least one safety valve; such valve(s) cannot be considered as part of the boiler safety valves required in item a).

d) In the case of boilers fitted with a separate steam accumulator, safety valves may be fitted on the accumulator if no shut-off is provided between it and the boiler and if the connecting pipe is of a size sufficient to allow the whole steam production to pass through, without increasing the boiler pressure more than 10% above the design pressure.

3.2.2 Relieving capacity of safety valves

a) The relieving capacity of each safety valve Q, in kg/h, is to be determined by the appropriate formula below in order that:

$Q \geq W$

- saturated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1{,}05)}{100}$$

- superheated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1{,}05)}{100} \times \sqrt{\frac{v}{v_s}}$$

where:

W : Maximum steam production, in kg/h, as defined by the maximum power of the heating equipment; otherwise the value of W is to be based on evaporating capacities (referring to evaporating surfaces of the boiler concerned) less than the following:

- 14 kg/(m^2·h) for exhaust gas heated boilers
- 29 kg/(m^2·h) for oil fired boilers
- 60 kg/(m^2·h) for water walls of oil fired boilers

A : Aggregate area, in mm^2, of the orifices in way of the seat of the valve, deducting the obstructions corresponding to the guides and the conformation of the valve in full lift position

p : Maximum working pressure of the boiler or other steam generator, in MPa. For superheated steam safety valves, P is to be the pressure at the superheater outlet

C : Coefficient with the following values:

- 4,8 for ordinary safety valves, i.e. where the valve lift is at least 1/24 of the internal diameter of the seat
- 10 for high lift safety valves, i.e. where the valve lift is at least 1/12 of the internal diameter of the seat
- 20 for full lift safety valves, i.e. where the valve lift is at least 1/4 of the internal diameter of the valve

Higher values of coefficient C may be admitted for safety valves of approved type and having undergone, in the presence of the Surveyor or according to a procedure considered as equivalent by the Society, capacity tests with conditions of pressure and temperature comparable to those of the plant considered. In such a case, coefficient C is to be, as a rule, taken as 90% of the resulting value from the capacity test

v : Specific volume of saturated steam at the pressure corresponding to the superheater outlet

v_S : Specific volume of superheated steam at the temperature corresponding to the superheater outlet.

b) When the safety valves are fitted at the superheater outlet. Their relieving capacity is to be such that, during the discharge of safety valves, a sufficient quantity of steam is circulated through the superheater to avoid damage.

c) The orifice diameter in way of the safety valves seat is not to be less than 40 mm. Where only one safety valve need be fitted, the orifice minimum diameter is not to be less than 50 mm. Valves of large relieving capacity with 15 mm minimum diameter may be accepted for boilers with steam production not exceeding 2000 kg/h.

d) Independently of the above requirements, the aggregate capacity of the safety valves is to be such as to discharge all the steam that can be generated without causing a transient pressure rise of more than 10% over the design pressure.

3.2.3 Miscellaneous safety valve requirements

a) Safety valves operated by pilot valves

The arrangement on the superheater of large relieving capacity safety valves, operated by pilot valves fitted in the saturated steam drum, is to be specially considered by the Society.

b) Safety valve setting

- safety valves are to be set under steam in the presence of the Surveyor to a pressure not higher than 1,03 times the design pressure
- safety valves are to be so constructed that their setting may not be increased in service and their spring may not be expelled in the event of failure. In addition, safety valves are to be provided with simple means of lifting the plug from its seat from a safe position in the boiler or engine room
- where safety valves are provided with means for regulating their relieving capacity, they are to be so fitted that their setting cannot be modified when the valves are removed for surveys.

c) Safety valve fitting on boiler

- the safety valves of a boiler are to be directly connected to the boiler and separated from other valve bodies
- where it is not possible to fit the safety valves directly on the superheater headers, they are to be mounted on a strong nozzle fitted as close as practicable to the superheater outlet. The cross-sectional area for passage of steam through restricted orifices of the nozzles is not to be less than 1/2 the aggregate area of the valves, calculated with the formulae of [3.2.2] when $C \leq 10$, and not less than the aggregate area of the valves when $C > 10$
- safety valve bodies are to be fitted with drain pipes of a diameter not less than 20 mm for double valves, and not less than 12 mm for single valves, leading to the bilge or to the hot well. Valves or cocks are not to be fitted on drain pipes.

d) Exhaust pipes

- the minimum cross-sectional area of the exhaust pipes of safety valves which have not been experimentally tested is not to be less than C times the aggregate area A
- the cross-sectional area of the exhaust manifold of safety valves is to be not less than the sum of the areas of the individual exhaust pipes connected to it
- silencers fitted on exhaust manifolds are to have a free passage area not less than that of the manifolds
- the strength of exhaust manifolds and pipes and associated silencers is to be such that they can withstand the maximum pressure to which they may be subjected, which is to be assumed not less than 1/4 of the safety valve setting pressure
- in the case that the discharges from two or more valves are led to the same exhaust manifold, provision is to be made to avoid the back pressure from the valve which is discharging influencing the other valves
- exhaust manifolds are to be led to the open and are to be adequately supported and fitted with suitable expansion joints or other means so that their weight does not place an unacceptable load on the safety valve bodies.

e) Steam generator heated by steam

Steam heated steam generators are also to be protected against possible damage resulting from failure of the heating coils. In this case, the area of safety valves calculated as stated in [3.2.2] may need to be increased to the satisfaction of the Society, unless suitable devices limiting the flow of steam in the heating coils are provided.

3.2.4 Access arrangement

a) Boilers are to be provided with openings in sufficient number and size to permit internal examination, cleaning and maintenance operations. In general, all pressure vessels which are part of a boiler with inside diameter exceeding 1200 mm, and those with inside diameter exceeding 800 mm and length exceeding 2000 mm, are to be provided with access manholes.

b) Manholes are to be provided in suitable locations in the shells, headers, domes, and steam and water drums, as applicable. The “net” (actual hole) dimension of elliptical or similar manholes is to be not less than 300mm x 400mm. The “net” diameter of circular manholes (actual hole) cannot be less than 400 mm. The edges of manholes are to be adequately strengthened to provide compensation for vessel openings in accordance with [2.8.4], [2.8.6] and [2.8.9], as applicable.

c) In pressure vessels which are part of a boiler and are not covered by the requirement in item a) above, or where an access manhole cannot be fitted, at least the following openings are to be provided, as far as practicable:

- head holes: minimum dimensions:

  220mm x 320mm (320 mm diameter if circular)

- handholes: minimum dimensions: 87mm x 103mm
- sight holes: minimum diameter: 50 mm.

d) Sight holes may only be provided when the arrangement of manholes, head holes, or handholes is impracticable.

e) Covers for manholes and other openings are to be made of ductile steel, dished or welded steel plates or other approved design. Grey cast iron may be used only for small openings, such as handholes and sight holes, provided the design pressure p does not exceed 1 MPa and the design temperature T does not exceed 220°C.

f) Covers are to be of self-closing internal type. Small opening covers of other type may be accepted by the Society on a case by case basis.

g) Covers of the internal type are to have a spigot passing through the opening. The clearance between the spigot and the edge of the opening is to be uniform for the whole periphery of the opening and is not to exceed 1,5 mm.

h) Closing devices of internal type covers, having dimensions not exceeding 180mm x 230mm, may be fitted with a single fastening bolt or stud. Larger closing devices are to be fitted with at least two bolts or studs.

i) Covers are to be designed so as to prevent the dislocation of the required gasket by the internal pressure. Only continuous ring gaskets may be used for packing.

3.2.5 Fittings

a) In general, cocks and valves are to be designed in accordance with the requirements in Ch 1, Sec 10, [2.7.2].

b) Cocks, valves and other fittings are to be connected directly or as close as possible to the boiler shell.

c) Cocks and valves for boilers are to be arranged in such a way that it can be easily seen when they are open or closed and so that their closing is obtained by a clockwise rotation of the actuating mechanism.

3.2.6 Boiler burners

Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

3.2.7 Allowable water levels

a) In general, for water tube boilers the lowest permissible water level is just above the top row of tubes when the water is cold. Where the boiler is designed not to have fully submerged tubes, when the water is cold, the lowest allowable level indicated by the manufacturer is to be indicated on the drawings and submitted to the Society for consideration.

b) For fire tube boilers with combustion chamber integral with the boiler, the minimum allowable level is to be at least 50 mm above the highest part of the combustion chamber.

c) For vertical fire tube boilers the minimum allowable level is 1/2 of the length of the tubes above the lower tube sheet.

3.2.8 Steam outlets

a) Each boiler steam outlet, if not serving safety valves, integral superheaters and other appliances which are to have permanent steam supply during boiler operation, is to be fitted with an isolating valve secured either directly to the boiler shell or to a standpipe of substantial thickness, as short as possible, and secured directly to the boiler shell.

b) The number of auxiliary steam outlets is to be reduced to a minimum for each boiler.

c) Where several boilers supply steam to common mains, the arrangement of valves is to be such that it is possible to positively isolate each boiler for inspection and maintenance. In addition, for water tube boilers, non-return devices are to be fitted on the steam outlets of each boiler.

d) Where steam is used for essential auxiliaries (such as whistles, steam operated steering gears, steam operated electric generators, etc.) and when several boilers are fitted on board, it is to be possible to supply steam to these auxiliaries with any one of these boilers out of operation.

e) Each steam stop valve exceeding 150 mm nominal diameter is to be fitted with a bypass valve.

3.2.9 Feed check valves

a) Each fired boiler supplying steam to essential services is to be fitted with at least two feed check valves connected to two separate feed lines. For unfired steam generators a single feed check valve may be allowed.

b) Feed check valves are to be secured directly to the boiler or to an integral economiser. Water inlets are to be separated. Where, however, feed check valves are secured to an economiser, a single water inlet may be allowed provided that each feed line can be isolated without stopping the supply of feed water to the boiler.

c) Where the economisers may be bypassed and cut off from the boiler, they are to be fitted with pressure-limiting type valves, unless the arrangement is such that excessive pressure cannot occur in the economiser when cut off.

d) Feed check valves are to be fitted with control devices operable from the stokehold floor or from another appropriate location. In addition, for water tube boilers, at least one of the feed check valves is to be arranged so as to permit automatic control of the water level in the boiler.

e) Provision is to be made to prevent the feed water from getting in direct contact with the heated surfaces inside the boiler and to reduce, as far as possible and necessary, the thermal stresses in the walls.

3.2.10 Drains

Each superheater, whether or not integral with the boiler, is to be fitted with cocks or valves so arranged that it is possible to drain it completely.

3.2.11 Water sample

a) Every boiler is to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

b) For this purpose, boilers are to be fitted with at least one water sample cock or valve. This device is not to be connected to the water level standpipes.

c) Suitable inlets for water additives are to be provided in each boiler.

3.2.12 Marking of boilers

a) Each boiler is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):

- the design pressure
- the design temperature
- the test pressure and the date of the test.

b) Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.

c) For lagged vessels, these markings are also to appear on a similar plate fitted above the lagging.

3.3 Thermal oil heaters and thermal oil installation

3.3.1 General

a) The following requirements apply to thermal oil heaters in which organic liquids (thermal oils) are heated by oil fired burners, exhaust gases or electricity to temperatures below their initial boiling point at atmospheric pressure.

b) Thermal oils are only to be used within the limits set by the manufacturer.

c) Means are to be provided for manual operation. During manual operation, the automated functioning of at least the temperature control device on the thermal oil side as well as the flow monitoring is to be maintained.

d) Means are to be provided to take samples of thermal oil.

3.3.2 Thermal oil heater design

a) Heaters are to be so constructed that neither the surfaces nor the thermal oil becomes excessively heated at any point. The flow of the thermal oil is to be ensured by forced circulation.

b) The surfaces which come into contact with the thermal oil are to be designed for the design pressure, subject to the minimum pressure of 1 MPa.

c) Copper and copper alloys are not permitted.

d) Heaters heated by exhaust gas are to be provided with inspection openings at the exhaust gas intake and outlet.

e) Oil fired heaters are to be provided with inspection openings for examination of the combustion chamber. The opening for the burner may be considered as an inspection opening, provided its size is sufficient for this purpose.

f) Heaters are to be fitted with means enabling them to be completely drained.

g) Thermal oil heaters heated by exhaust gas are to be fitted with a permanent system for extinguishing and cooling in the event of fire, for instance a pressure water spraying system.

3.3.3 Safety valves of thermal oil heaters

Each heater is to be equipped with at least one safety valve having a discharge capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During discharge the pressure may not increase above 10% over the design pressure.

3.3.4 Pressure vessels of thermal oil heaters

The design pressure of all vessels which are part of a thermal oil system, including those open to the atmosphere, is to be taken not less than 0,2 MPa.

3.3.5 Equipment of the expansion, storage and drain tanks

For the equipment to be installed on expansion, storage and drain tanks, see Ch 1, Sec 10, [13].

3.3.6 Marking

Each thermal oil heater and other pressure vessels which are part of a thermal oil installation are to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):

- Heaters
  - maximum allowable heating power
  - design pressure
  - maximum allowable discharge temperature
  - minimum flow rate
  - liquid capacity
- Vessels
  - design pressure
  - design temperature
  - capacity.

3.4 Special types of pressure vessels

3.4.1 Seamless pressure vessels (bottles)

Each bottle is to be marked with the following information:

- name or trade name of the manufacturer
- serial number
- type of gas
- capacity
- test pressure
- empty weight
- test stamp.

3.4.2 Steam condensers

a) The water chambers and steam spaces are to be fitted with doors for inspection and cleaning.

b) Where necessary, suitable diaphragms are to be fitted for supporting tubes.

c) Condenser tubes are to be removable.

d) High speed steam flow, where present, is to be prevented from directly striking the tubes by means of suitable baffles.

e) Suitable precautions are to be taken in order to avoid corrosion on the circulating water side and to provide an efficient grounding.

3.5 Other pressure vessels

3.5.1 Safety valves arrangement

a) General:

- pressure vessels which are part of a system are to be provided with safety valves, or equivalent devices, if they are liable to be isolated from the system safety devices. This provision is also to be made in all cases in which the vessel pressure can rise, for any reason, above the design pressure
- in particular, air pressure vessels which can be isolated from the safety valves ensuring their protection in normal service are to be fitted with another safety device, such as a rupture disc or a fusible plug, in order to ensure their discharge in case of fire. This device is to discharge to the open
- safety devices ensuring protection of pressure vessels in normal service are to be rated to operate before the pressure exceeds the maximum working pressure by more than 5%
- where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

b) Heat exchangers

Special attention is to be paid to the protection against overpressure of vessels, such as heat exchangers, which have parts that are designed for a pressure which is below that to which they might be subjected in the case of rupture of the tubular bundles or coils contained therein and that have been designed for a higher pressure.

3.5.2 Other requirements

a) Access arrangement

The access requirements for boilers stated in [3.2.4] are also applicable for other pressure vessels.

b) Corrosion protection

Vessels and equipment containing media that might lead to accelerated corrosion are to be suitably protected.

c) Marking:

- each pressure vessel is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):
  - the design pressure
  - the design temperature
  - the test pressure and the date of the test
- markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service
- for smaller pressure vessels the indication of the design pressure only may be sufficient.

4 Design and construction - Fabrication and welding

4.1 General

4.1.1 Base materials

a) These requirements apply to boilers and pressure vessels made of steel of weldable quality.

b) Fabrication and welding of vessels made of other materials are to be the subject of special consideration.

4.1.2 Welding

a) Weldings are to be performed in accordance with welding procedures approved by the Society.

b) Manual and semi-automatic welding is to be performed by welders qualified by the Society.

c) The conditions under which the welding procedures, welding equipment and welders operate are to correspond to those specified in the relevant approvals or qualifications.

d) Both ordinary and special electric arc welding processes are covered in the following requirements.

4.1.3 Cutting of plates

a) Plates are to be cut by flame cutting, mechanical machining or a combination of both processes. For plates having a thickness less than 25 mm, cold shearing is admitted provided that the sheared edge is removed by machining or grinding for a distance of at least one quarter of the plate thickness with a minimum of 3 mm.

b) For flame cutting of alloy steel plates, preheating is to be carried out if necessary.

c) The edges of cut plates are to be examined for laminations, cracks or any other defect detrimental to their use.

4.1.4 Forming of plates

a) The forming processes are to be such as not to impair the quality of the material. The Society reserves the right to require the execution of tests to demonstrate the suitability of the processes adopted. Forming by hammering is not allowed.

b) Unless otherwise justified, cold formed shells are to undergo an appropriate heat treatment if the ratio of internal diameter after forming to plate thickness is less than 20. This heat treatment may be carried out after welding.

c) Before or after welding, hot formed plates are to be normalised or subjected to another treatment suitable for their steel grade, if hot forming has not been carried out within an adequate temperature range.

d) Plates which have been previously butt-welded may be formed under the following conditions:

- Hot forming

  After forming, the welded joints are to be subjected to X-ray examination or equivalent. In addition, mechanical tests of a sample weld subjected to the same heat treatment are to be carried out.

- Cold forming

  Cold forming is only allowed for plates having a thickness not exceeding:

  - 20 mm for steels having minimum ultimate tensile strength R_m between 360 N/mm² and 410 N/mm²
  - 15 mm for steels having R_m between 460 N/mm² and 510 N/mm² as well as for steels 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.

  Cold forming is not allowed for steels 1Cr0,5Mo and 2,25Cr1Mo.
- Weld reinforcements are to be carefully ground smooth prior to forming.
- A proper heat treatment is to be carried out after forming, if the ratio of internal diameter to thickness is less than 36, for steels: 460 N/mm², 510 N/mm², 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.
- After forming, the joints are to be subjected to X-ray examination or equivalent and to a magnetic particle or liquid penetrant test.
- Refer to Fig 26 for definition of thickness to be taken in account.

4.2 Welding design

4.2.1 Main welded joints

a) All joints of class 1 and 2 pressure parts of boilers and pressure vessels are to be butt-welded, with the exception of welding connecting flat heads or tube sheets to shells, for which partial penetration welds or fillet welds may be accepted.

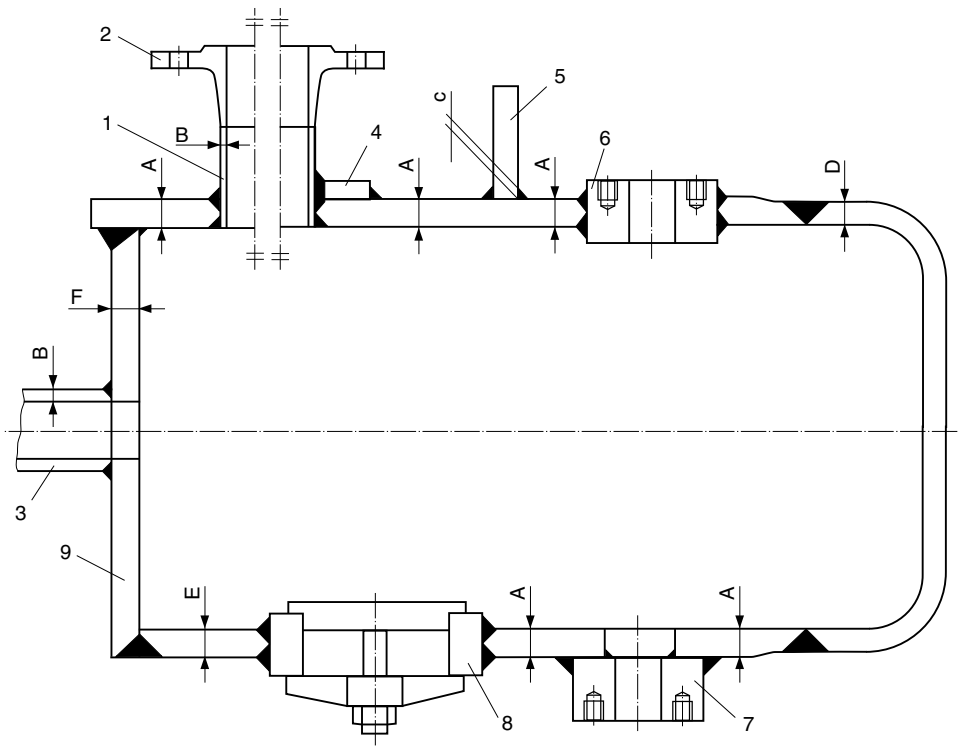
Fig 26 show examples of acceptable welding for class 1 and 2 pressure vessels.

b) Joints of class 3 pressure vessels are also subject to the requirement in a), however connection of dished heads to shells by lap welds may be accepted. Fig 27 shows some acceptable details of circumferential lap welds for class 3 pressure vessels.

4.2.2 Shell longitudinal and circumferential welds

Longitudinal and circumferential joints are to be welded from both sides of the plate. Welding from one side may be allowed only when there is evidence that the welding process permits a complete penetration and a sound weld root. If a backing strip is used, it is to be removed after welding and prior to any non-destructive examination. However, the backing strip may be retained in circumferential joints of class 2 vessels, having a thickness not exceeding 15 mm, and of class 3 vessels, provided that the material of the backing strip is such as not to adversely affect the weld.

Figure 26 : Example of acceptable joints and thickness to be considered for forming and post-weld heat treatment

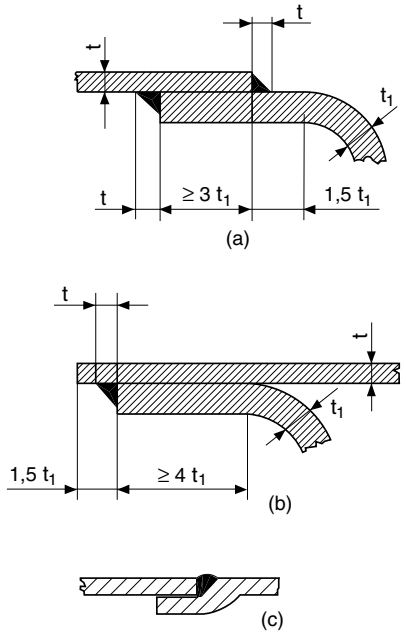


Key

1 : Nozzle (set in); **2** : Flange; **3** : Nozzle (set on); **4** : Reinforcing plate; **5** : Non-pressure part;

6 : Pad (set in); **7** : Pad (set on); **8** : Manhole frame; **9** : Flat plate.

Figure 27 : Example of acceptable lap-joints



Details (b) and (c) may be used only for pressure vessels having internal diameter less than 600mm.

4.2.3 Plates of unequal thickness

a) If plates of unequal thickness are butt-welded and the difference between thicknesses is more than 3 mm, the thicker plate is to be smoothly tapered for a length equal to at least four times the offset, including the width of the weld. For longitudinal joints the tapering is to be made symmetrically on both sides of the plate in order to obtain alignment of middle lines.

b) If the joint is to undergo radiographic examination, the thickness of the thicker plate is to be reduced to that of the thinner plate next to the joint and for a length of at least 30 mm.

4.2.4 Dished heads

a) For connection of a hemispherical end with a cylindrical shell, the joint is to be arranged in a plane parallel to that of the largest circle perpendicular to the axis of the shell and at such a distance from this plane that the tapering of the shell made as indicated in [2.5.6] is wholly in the hemisphere.

b) For torispherical ends made of parts assembled by welding, no welded joint is normally admitted along a parallel in the knuckle nor at a distance less than 50 mm from the beginning of the knuckle.

4.2.5 Welding location

The location of main welded joints is to be chosen so that these joints are not submitted to appreciable bending stresses.

4.2.6 Accessories and nozzles

a) Attachment of accessories by welds crossing main welds or located near such welds is to be avoided; where this is impracticable, welds for attachment of accessories are to completely cross the main welds rather than stop abruptly on or near them.

b) Openings crossing main joints or located near main joints are also to be avoided as far as possible.

c) Doubling plates for attachment of accessories such as fixing lugs or supports are to be of sufficient size to ensure an adequate distribution of loads on pressure parts; such doubling plates are to have well rounded corners. Attachment of accessories such as ladders and platforms directly on the walls of vessels such that they restrain their free contraction or expansion is to be avoided.

d) Welded connections of nozzles and other fittings, either with or without local compensation, are to be of a suitable type, size and preparation in accordance with the approved plans.

4.2.7 Connections of stays to tube plates

a) Where stays are welded, the cross-sectional area of the weld is to be at least 1,25 times the cross-section of the stay.

b) The cross-sectional area of the end welding of welded stay tubes is to be not less than 1,25 times the cross-sectional area of the stay tube.

4.2.8 Type of weldings

Fig 28, Fig 29, Fig 30, Fig 31, Fig 32, Fig 33, Fig 34, Fig 35, Fig 36 and Fig 37 indicate the type and size of weldings of typical pressure vessel connections. Any alternative type of welding or size is to be the subject of special consideration by the Society.

Figure 28 : Types of joints for unstayed flat heads (1)

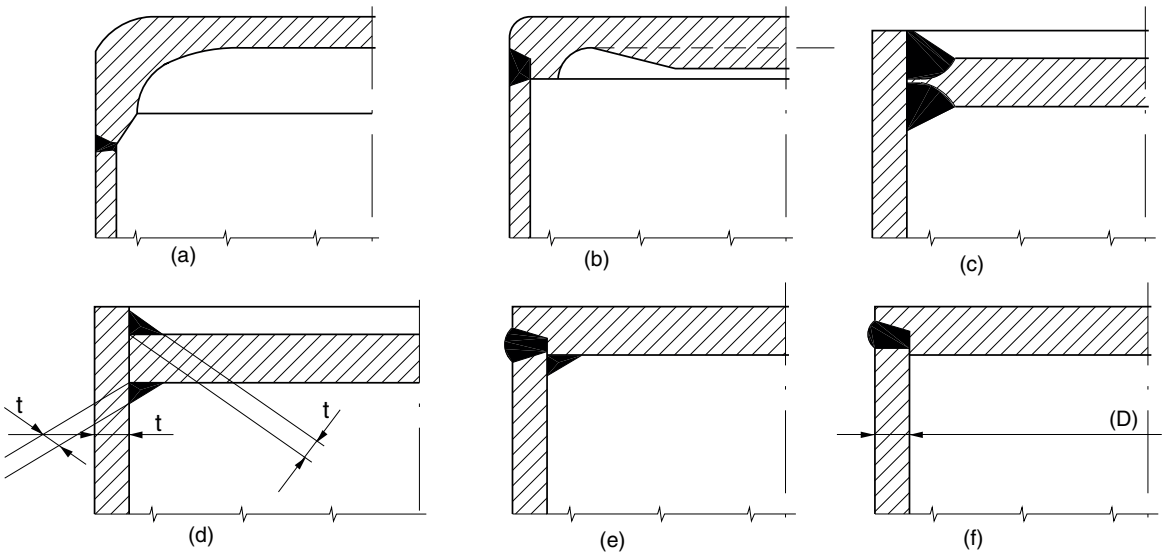


Figure 29 : Types of joints for unstayed flat heads (2)

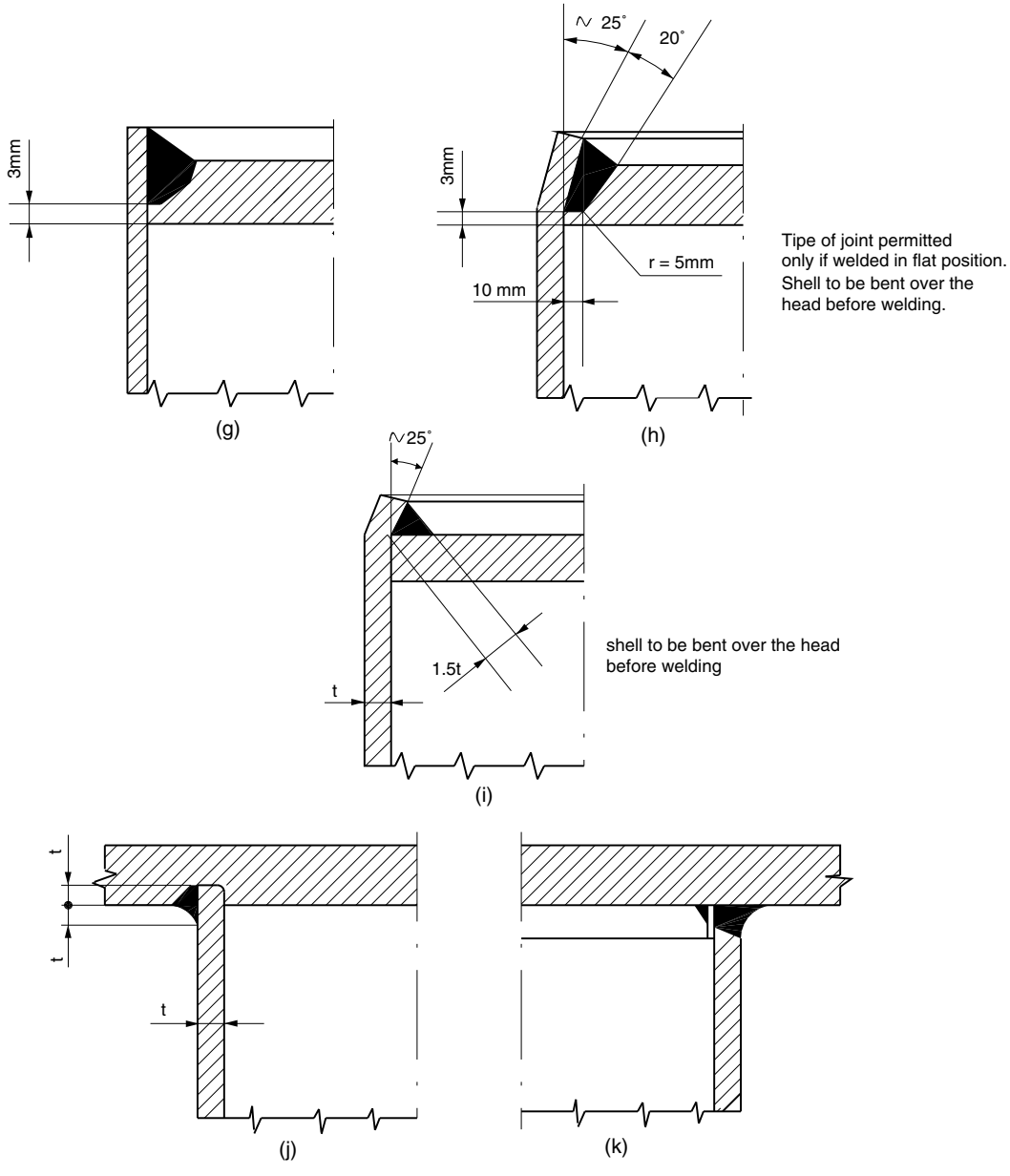


Figure 30 : Types of joints for nozzles and reinforced rings (1)

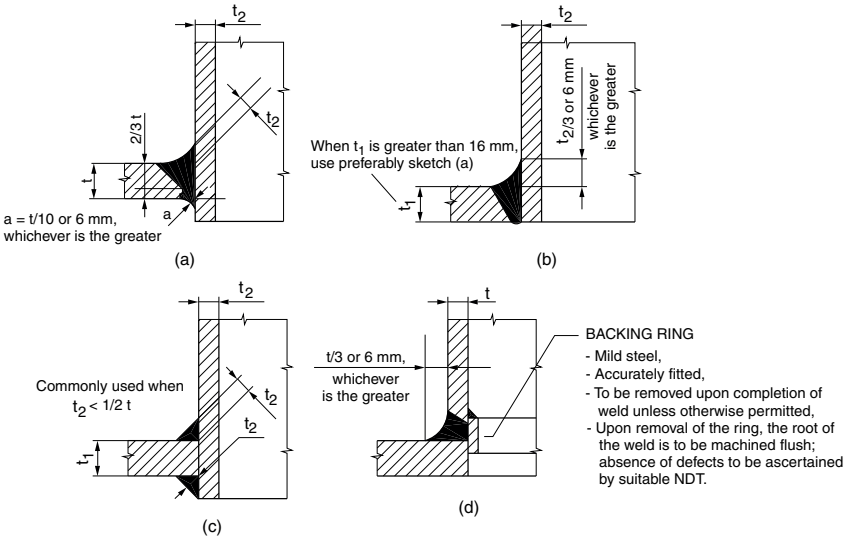


Figure 31 : Types of joints for nozzles and reinforcing rings (2)

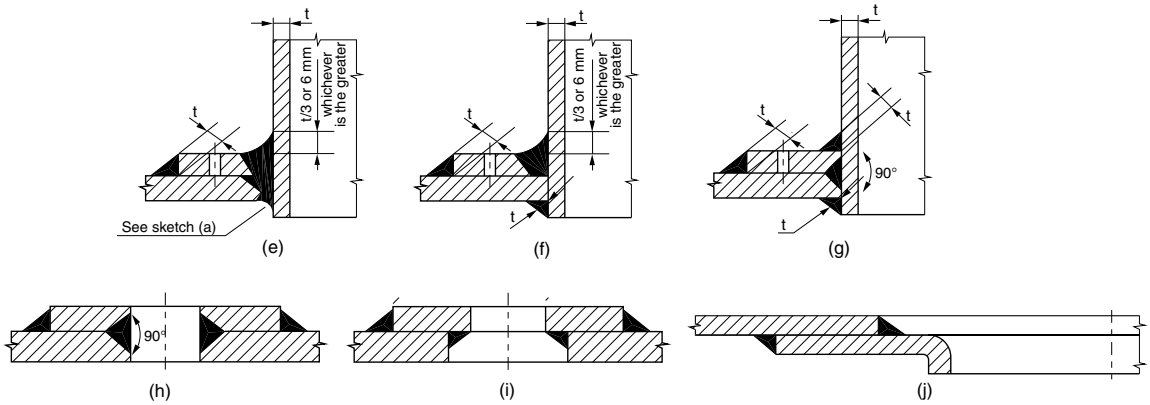


Figure 32 : Types of joints for nozzles and reinforcing rings (3)

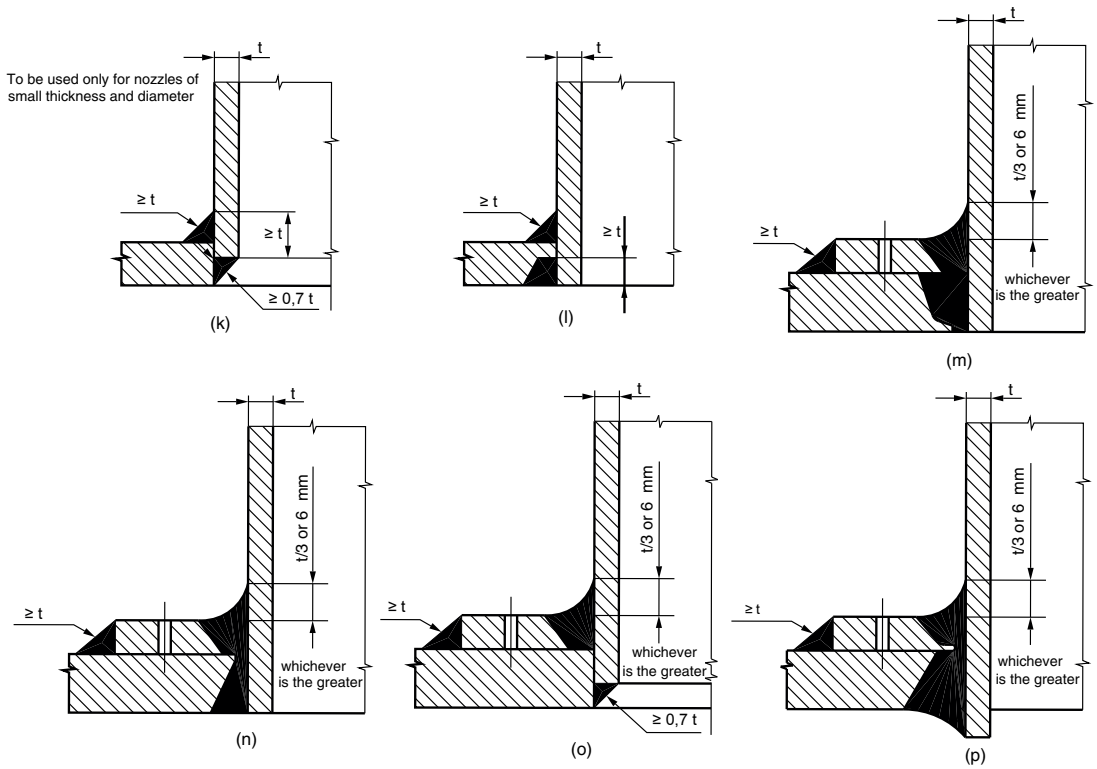
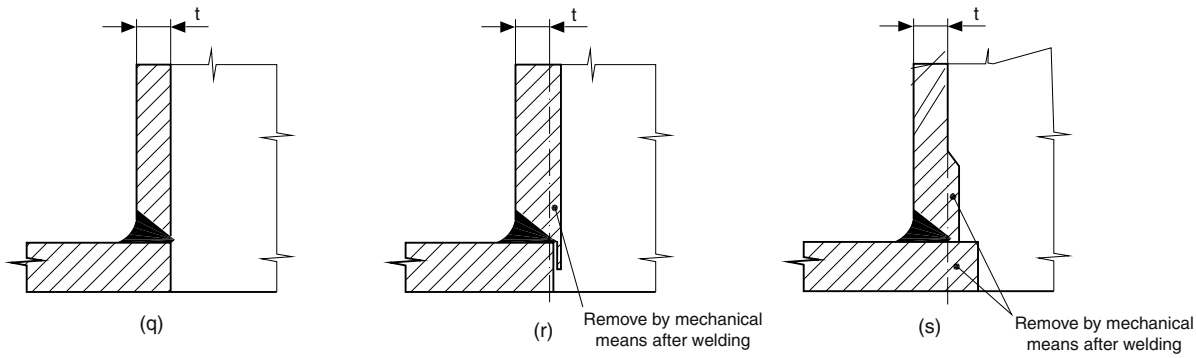


Figure 33 : Types of joints for nozzles (4)



Note: Where preparations of Fig 33 are carried out, the shell is to be carefully inspected to ascertain the absence of lamination.

Figure 34 : Types of joints for flanges to nozzles

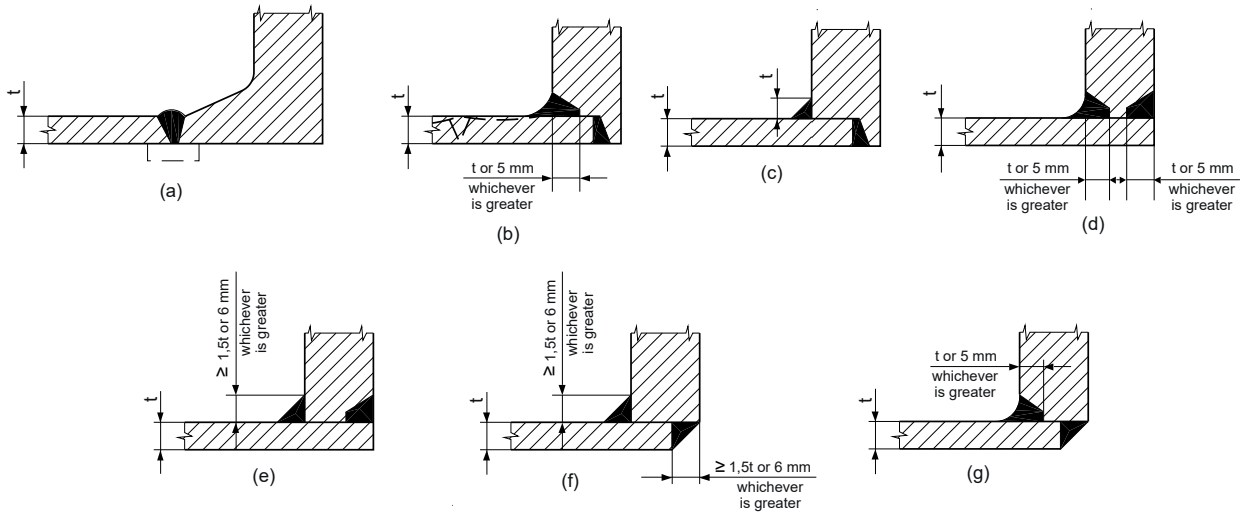


Figure 35 : Types of joints for tubesheets to shell (1)

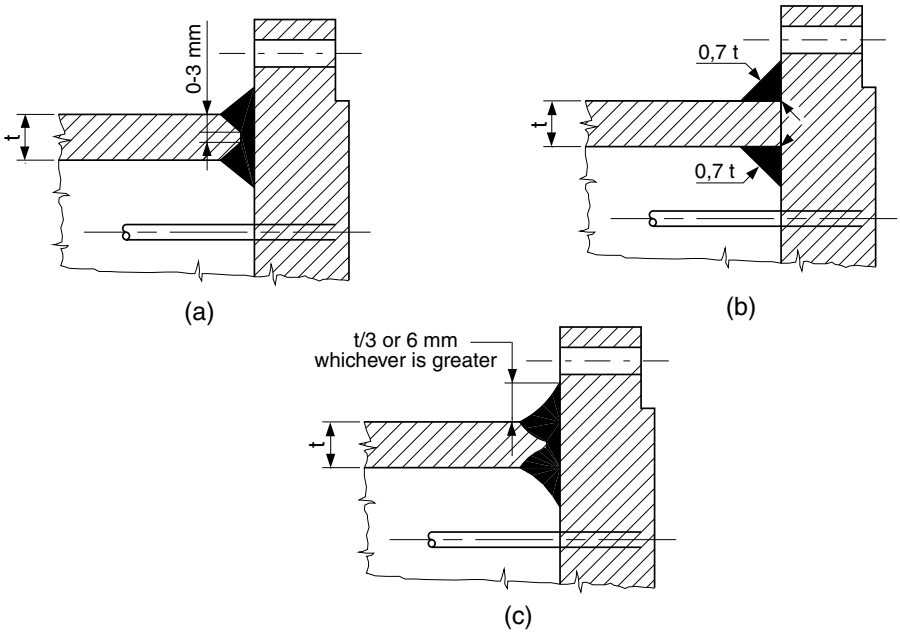


Figure 36 : Types of joints for tubesheets to shells (2)

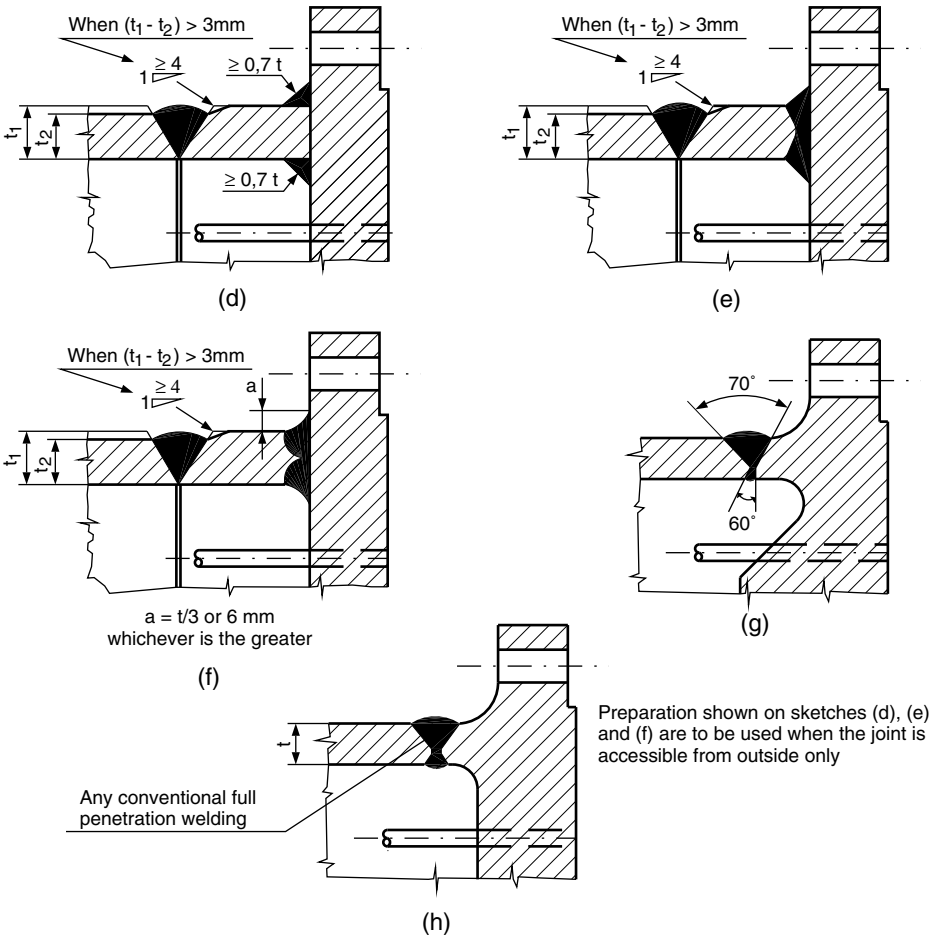
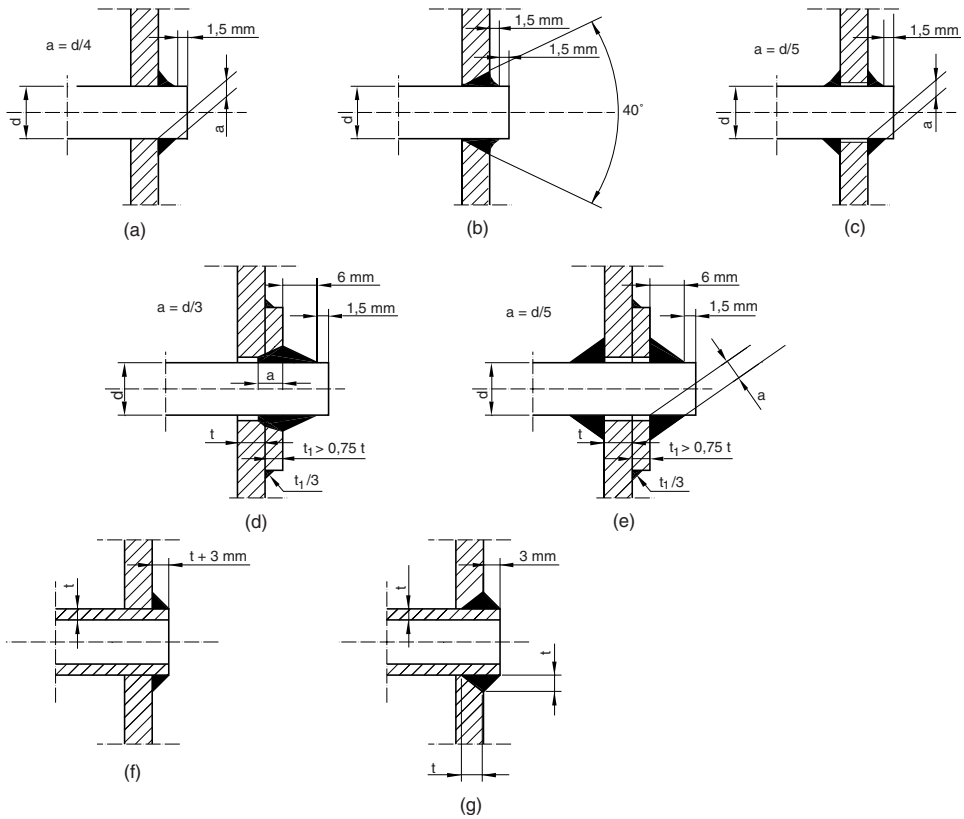


Figure 37 : Type of joints for stays and stay tubes



4.3 Miscellaneous requirements for fabrication and welding

4.3.1 Welding position

a) As far as possible, welding is to be carried out in the downhand horizontal position and arrangements are to be foreseen so that this can be applied in the case of circumferential joints.

b) When welding cannot be performed in this position, tests for qualification of the welding process and the welders are to take account thereof.

4.3.2 Cleaning of parts to be welded

a) Parts to be welded are, for a distance of at least 25 mm from the welding edges, to be carefully cleaned in order to remove any foreign matter such as rust, scale, oil, grease and paint.

b) If the weld metal is to be deposited on a previously welded surface, all slag or oxide is to be removed to prevent inclusions.

4.3.3 Protection against adverse weather conditions

a) Welding of pressure vessels is to be done in a sheltered position free from draughts and protected from cold and rain.

b) Unless special justification is provided, no welding is to be performed if the temperature of the base metal is less than 0°C.

4.3.4 Interruption in welding

If, for any reason, welding is stopped, care is to be taken on restarting to obtain a complete fusion.

4.3.5 Backing weld

When a backing weld is foreseen, it is to be carried out after suitable chiseling or chipping at the root of the first weld, unless the welding process applied does not call for such an operation.

4.3.6 Appearance of welded joints

a) Welded joints are to have a smooth surface without under-thickness; their connection with the plate surface is to be gradual without undercutting or similar defects.

b) The weld reinforcement of butt welds, on each side of the plate, is not to exceed the following thickness:

- 2,5 mm for plates having a thickness not exceeding 12 mm
- 3 mm for plates having a thickness greater than 12 mm but less than 25 mm
- 5 mm for plates having a thickness at least equal to 25 mm.

4.4 Preparation of parts to be welded

4.4.1 Preparation of edges for welding

a) Grooves and other preparations of edges for welding are to be made by machining, chipping or grinding. Flame cutting may also be used provided that the zones damaged by this operation are removed by machining, chipping or grinding. For alloy steel plates, preheating is to be provided, if needed, for flame cutting.

b) Edges prepared are to be carefully examined to check that there are no defects detrimental to welding.

4.4.2 Abutting of parts to be welded

a) Abutting of parts to be welded is to be such that surface misalignment of plates does not exceed:

- 10% of the thickness of the plate with a maximum of 3 mm for longitudinal joints
- 10% of the thickness of the plate plus 1 mm with a maximum of 4 mm for circumferential joints.

b) For longitudinal joints, middle lines are to be in alignment within 10% of the thickness of the thinner plate with a maximum of 3 mm.

c) Plates to be welded are to be suitably retained in position in order to limit deformation during welding. The arrangements are to be such as to avoid modification of the relative position of parts to be welded and misalignment, after welding, exceeding the limits indicated above.

d) Temporary welds for abutting are to be carried out so that there is no risk of damage to vessel shells. Such welds are to be carefully removed after welding of the vessel and before any heat treatment. Non-destructive testing of the corresponding zones of the shell may be required by the Surveyor if considered necessary.

e) Accessories such as doubling plates, brackets and stiffeners are to be suitable for the surface to which they are to be attached.

4.5 Tolerances after construction

4.5.1 General

The sizes and shape of vessels are to be checked after welding for compliance with the design taking into account the tolerances given below. The Society reserves the right to stipulate smaller values for these tolerances for vessels subjected to special loads.

Any defect in shape is to be gradual and there is to be no flat area in way of welded joints.

Measurements are to be taken on the surface of the parent plate and not on the weld or other raised part.

4.5.2 Straightness

The straightness of cylindrical shells is to be such that their deviation from the straight line does not exceed 0,6% of their length, with a maximum of 15 mm for each 5 m of length.

4.5.3 Out-of-roundness

a) Out-of-roundness of cylindrical shells is to be measured either when set up on end or when laid flat on their sides; in the second case, measures of diameters are to be repeated after turning the shell through 90° about its axis and out-of-roundness is to be calculated from the average of the two measures of each diameter.

b) For any transverse section, the difference between the maximum and minimum diameters is not to exceed 1% of the nominal diameter D with a maximum of:

(D + 1250) / 200, D being expressed in mm.

For large pressure vessels, this limit may be increased by a maximum of 0,2% of the internal diameter of the vessel. Any possible out-of-roundness within the above limit is to be gradual and there are to be no localised deformations in way of the welded joints.

4.5.4 Irregularities

Irregularities in profile of cylindrical shells, checked by a 20° gauge, are not to exceed 5% of the thickness of the plate plus 3 mm. This value may be increased by 25% if the length of the irregularity does not exceed one quarter of the distance between two circumferential seams, with a maximum of 1 mm.

4.6 Preheating

4.6.1

a) Preheating, to be effectively maintained during the welding operation, may be required by the Society when deemed necessary in relation to a number of circumstances, such as the type of steel, thickness of the base material, welding procedure and technique, type of restraint, and heat treatment after welding, if any.

b) The preheating temperature is to be determined accordingly. However, a preheating temperature of approximately 150°C is required for 0,5Mo or 1Cr0,5Mo type steel, and approximately 250°C for 2,25Cr1Mo type steel.

c) These requirements also apply to welding of nozzles, fittings, steam pipes and other pipes subject to severe conditions.

4.7 Post-weld heat treatment

4.7.1 General

a) When post-weld heat treatment of a vessel is to be carried out, such treatment is to consist of:

- heating the vessel slowly and uniformly up to a temperature suitable for the grade of steel
- maintaining this temperature for a duration determined in relation to the actual thickness t_A of the vessel and the grade of steel
- slowly cooling the vessel in the furnace down to a temperature not exceeding 400°C, with subsequent cooling allowed out of the furnace in still air.

b) As far as possible, vessels are to be heat treated in a single operation. However, when the sizes of the vessels are such that heat treatment requires several operations, care is to be taken such that all the parts of the vessels undergo heat treatment in a satisfactory manner. In particular, a cylindrical vessel of great length may be treated in sections in a furnace if the overlap of the heated sections is at least 1500 mm and if parts outside the furnace are lagged to limit the temperature gradient to an acceptable value.

4.7.2 Thermal stress relieving

Upon completion of all welding, including connections of nozzles, doublers and fittings, pressure vessels of classes 1 and 2, boilers and associated parts are to be subjected to an effective stress relieving heat treatment in the following cases:

- boilers and steam generators for thicknesses higher than 20 mm or, depending upon the type of steel, for lower thicknesses as required for class 1 pressure vessels.
- pressure vessels of classes 1 and 2 containing fluids at a temperature not less than the ambient temperature, where the thickness exceeds that indicated in Tab 18

Applications at temperatures less than the ambient temperature and/or steels other than those indicated above are to be the subject of special consideration by the Society.

Stress relieving heat treatment is not to be required when the minimum temperature of the fluid is at least 30°C higher than the KV-notch impact test temperature specified for the steel; this difference in temperature is also to be complied with for welded joints (both in heat-affected zones and in weld metal).

Pressure vessels and pipes of class 3 and associated parts are not required to be stress relieved, except in specific cases.

Table 18 : Thermal stress relieving

Grade	Thickness (mm) above which post-weld heat treatment is required	
	Boilers	Unfired pressure vessels
R_m = 360 N/mm² Grade HA R_m = 410 N/mm² Grade HA	14,5	14,5
R_m = 360 N/mm² Grade HB R_m = 410 N/mm² Grade HB	20	30
R_m = 360 N/mm² Grade HD R_m = 410 N/mm² Grade HD	20	38
R_m = 460 N/mm² Grade HB R_m = 510 N/mm² Grade HB	20	25
R_m = 460 N/mm² Grade HD R_m = 510 N/mm² Grade HD	20	35
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	20	20
1Cr 0,5Mo 2,25Cr 1Mo	ALL	ALL

4.7.3 Heat treatment procedure

The temperature of the furnace at the time of introduction of the vessel is not to exceed 400°C.

a) The heating rate above 400°C is not to exceed:

- 220°C per hour if the maximum thickness is not more than 25 mm, or
- (5500 / t_A)°C per hour, with a minimum of 55°C per hour, if the maximum thickness t_A, in mm, is more than 25 mm

b) The cooling rate in the furnace is not to exceed:

- –280°C per hour if the maximum thickness is not more than 25 mm, or
- –(7000 / t_A)°C per hour, with a minimum of –55°C per hour, if the maximum thickness t_A, in mm, is more than 25 mm.

Unless specially justified, heat treatment temperatures and duration for maintaining these temperatures are to comply with the values in Tab 19.

Table 19 : Heat treatment procedure

Grade	Temperatures	Time per 25 mm of maximum thickness	Minimum time
Carbon steels	580-620°C	1 hour	1 hour
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	620-660°C	1 hour	1 hour
1Cr 0,5Mo	620-660°C	1hour	2 hours
2,25Cr 1Mo	600-750°C **(1)**	2 hours	2 hours
(1) The temperature is to be chosen, with a tolerance of ± 20°C, in this temperature range in order to obtain the required mechanical characteristics			

4.7.4 Alternatives

When, for special reasons, heat treatment is carried out in conditions other than those given in [4.7.2], all details regarding the proposed treatment are to be submitted to the Society, which reserves the right to require tests or further investigations in order to verify the efficiency of such treatment.

4.7.5 Execution of heat treatment

Furnaces for heat treatments are to be fitted with adequate means for controlling and recording temperature; temperatures are to be measured on the vessel itself. The atmosphere in the furnaces is to be controlled in order to avoid abnormal oxidation of the vessel.

4.7.6 Treatment of test plates

Test plates are normally to be heated at the same time and in the same furnace as the vessel.

When separate heat treatment of test plates cannot be avoided, all precautions are to be taken such that this treatment is carried out in the same way as for the vessel, specifically with regard to the heating rate, the maximum temperature, the duration for maintaining this temperature and the cooling conditions.

4.7.7 Welding after heat treatment

a) Normally, welding after heat treatment is only allowed if:
   - the throat of welding fillets does not exceed 10 mm
   - the largest dimension of openings in the vessel for the accessories concerned does not exceed 50 mm.

b) Any welding of branches, doubling plates and other accessories on boilers and pressure vessels after heat treatment is to be submitted for special examination by the Society.

4.8 Welding samples

4.8.1 Test plates for welded joints

a) Test plates of sufficient size, made of the same grade of steel as the shell plates, are to be fitted at each end of the longitudinal joints of each vessel so that the weld in the test plates is the continuation of these welded joints. There is to be no gap when passing from the deposited metal of the joint to the deposited metal of the test plate.

b) No test plate is required for circumferential joints if these joints are made with the same process as longitudinal joints. Where this is not the case, or if there are only circumferential joints, at least one test plate is to be welded separately using the same welding process as for the circumferential joints, at the same time and with the same welding materials.

c) Test plates are to be stiffened in order to reduce as far as possible warping during welding. The plates are to be straightened prior to their heat treatment which is to be carried out in the same conditions as for the corresponding vessel (see also [4.7.6]).

d) After radiographic examination, the following test pieces are to be taken from the test plates:
   - one test piece for tensile test on welded joint
   - two test pieces for bend test, one direct and one reverse
   - three test pieces for impact test
   - one test piece for macrographic examination.

4.8.2 Mechanical tests of test plates

a) The tensile strength on welded joint is not to be less than the minimum specified tensile strength of the plate.

b) The bend test pieces are to be bent through an angle of 180° over a former of 4 times the thickness of the test piece. There is to be no crack or defect on the outer surface of the test piece exceeding in length 1,5 mm transversely or 3 mm longitudinally. Premature failure at the edges of the test piece is not to lead to rejection. As an alternative, the test pieces may be bent through an angle of 120° over a former of 3 times the thickness of the test piece.

c) The Charpy V-notch impact test is to be made with specimens having the notch alternately located in the centre of the weld or in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches are to be in the centre of the weld. The impact energy is to be measured at the temperature prescribed for the base material being joined. The average impact energy values are not to be less than the values given in NR216 “Materials and Welding” for the steel grade concerned.

d) The test piece for macrographic examination is to permit the examination of a complete transverse section of the weld. This examination is to demonstrate good penetration without lack of fusion, large inclusions and similar defects. In case of doubt, a micrographic examination of the doubtful zone may be required.

4.8.3 Re-tests

a) If one of the test pieces yields unsatisfactory results, two similar test pieces are to be taken from another test plate.

b) If the results for these new test pieces are satisfactory and if it is proved that the previous results were due to local or accidental defects, the results of the re-tests may be accepted.

4.9 Specific requirements for class 1 vessels

4.9.1 General

The following requirements apply to class 1 pressure vessels, as well as to pressure vessels of other classes whose scantling has been determined using an efficiency of welded joint e greater than 0,90.

4.9.2 Non-destructive testing suppliers

In case of non-destructive testing carried out by an independent company from the manufacturer or shipyard, the independent NDT service supplier has to comply with the requirements set out in NR669 “Requirements for non-destructive testing suppliers”.

4.9.3 Non-destructive tests

a) All longitudinal and circumferential joints of class 1 vessels are to be subject of 100% radiographic or equivalent examination with the following exceptions:

- for pressure vessels or parts designed to withstand external pressures only, at the Society's discretion, the extent may be reduced up to approximately 30% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings
- for vessels not intended to contain toxic or dangerous matters, made of carbon steels having thickness below 20 mm when the joints are welded by approved automatic processes at the Society's discretion, the extent may be reduced up to approximately 10% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings
- for circumferential joints having an external diameter not exceeding 175 mm, at the Society's discretion, the extent may be reduced up to approximately 10% of the total length of the joints.

b) Fillet welds for parts such as doubling plates, branches or stiffeners are to undergo a spot magnetic particle test for at least 10% of their length. If magnetic particle tests cannot be used, it is to be replaced by liquid penetrant test.

c) Welds for which non destructive tests reveal unacceptable defects, such as cracks or areas of incomplete fusion, are to be rewelded and are then to undergo a new non destructive examination

4.9.4 Number of test samples

a) During production, at least one test plate for each 20 m of length (or fraction) of longitudinal weldings is to be tested as per [4.8.2].

b) During production, at least one test plate for each 30 m of length (or fraction) of circumferential welding is to be tested as per [4.8.2].

c) When several vessels made of plates of the same grade of steel, with thicknesses varying by not more than 5 mm, are welded successively, only one test plate may be accepted per each 20 m of length of longitudinal joints (or fraction) and per each 30 m of circumferential welding (or fraction) provided that the welders and the welding process are the same. The thickness of the test plates is to be the greatest thickness used for these vessels.

4.10 Specific requirements for class 2 vessels

4.10.1 General

For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1].

4.10.2 Non-destructive tests

All longitudinal and circumferential joints of class 2 vessels are to be subjected to radiographic or equivalent examination to an extent of 10% of each weld length. This examination is to cover all the junctions between welds.

This extension may be increased at the Society's discretion depending on the actual thickness of the welded plates.

For actual thickness ≤ 15 mm, this examination can be omitted. In this case, the value of the efficiency should be as indicated in Tab 11.

4.10.3 Number of test samples

In general, the same requirements of [4.9.4] apply also to class 2 pressure vessels. However, test plates are required for each 50 m of longitudinal and circumferential weldings (or fraction).

4.11 Specific requirements for class 3 vessels

4.11.1 For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1].

Heat treatment, mechanical tests and non-destructive tests are not required for welded joints of other class 3 vessels.

5 Design and construction - Control and monitoring

5.1 Boiler control and monitoring system

5.1.1 Local control and monitoring

Means to effectively operate, control and monitor the operation of oil fired boilers and their associated auxiliaries are to be provided locally. The functional condition of the fuel, feed water and steam systems and the boiler operational status are to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.1.2 Emergency shut-off

Means are to be provided to shut down boiler forced draft or induced draft fans and fuel oil service pumps from outside the space where they are located, in the event that a fire in that space makes their local shut-off impossible.

5.1.3 Water level indicators

a) Each boiler is to be fitted with at least two separate means for indicating the water level. One of these means is to be a level indicator with transparent element. The other may be either an additional level indicator with transparent element or an equivalent device. Level indicators are to be of an approved type.

b) The transparent element of level indicators is to be made of glass, mica or other appropriate material.

c) Level indicators are to be located so that the water level is readily visible at all times. The lower part of the transparent element is not to be below the safety water level defined by the builder.

d) Level indicators are to be fitted either with normally closed isolating cocks, operable from a position free from any danger in case of rupture of the transparent element or with self-closing valves restricting the steam release in case of rupture of this element.

5.1.4 Water level indicators - Special requirements for water tube boilers

a) For water tube boilers having an athwarships steam drum more than 4 m in length, a level indicator is to be fitted at each end of the drum.

b) Water tube boilers serving turbine propulsion machinery are to be fitted with a high-water-level audible and visual alarm (see also Tab 21).

5.1.5 Water level indicators - Special requirements for fire tube boilers (vertical and cylindrical boilers)

a) For cylindrical boilers, the two water level indicators mentioned in [5.1.3] are to be distributed at each end of the boiler; i.e. double front cylindrical boilers are to have two level indicators on each front.

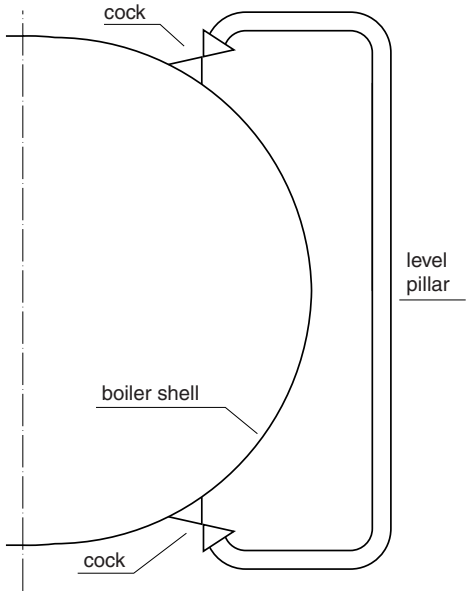
b) A system of at least two suitably located and remote controlled gauge-cocks may be considered as the equivalent device mentioned in [5.1.3] for cylindrical boilers having a design pressure lower than 1 MPa, for cylindrical boilers having a diameter lower than 2 m and for vertical boilers having height lower than 2,3 m. Gauge-cocks are to be fixed directly on the boiler shell.

c) Where level indicators are not fixed directly on the boiler shell, but on level pillars, the internal diameter of such pillars is not to be less than the value d_N given in Tab 20. Level pillars are to be either fixed directly on the boiler shell or connected to the boiler by pipes fitted with cocks secured directly to the boiler shell. The internal diameter of these pipes d_C is not to be less than the values given in Tab 20. The upper part of these pipes is to be arranged so that there is no bend where condense water can accumulate. These pipes are not to pass through smoke boxes or uptakes unless they are located inside metallic ducts having internal diameter exceeding by not less than 100 mm the external diameter of the pipes. Fig 38 shows the sketch of a level pillar arrangement.

Table 20 : Minimum internal diameters d_N and d_C

Internal diameter of the boiler	d_N (mm)	d_C (mm)
D > 3 m	60	38
2,30 m ≤ D ≤ 3 m	50	32
D < 2,30 m	45	26

Figure 38 : Level pillar arrangement



5.1.6 Pressure control devices

a) Each boiler is to be fitted with a steam pressure gauge so arranged that its indications are easily visible from the stokehold floor. A steam pressure gauge is also to be provided for superheaters which can be shut off from the boiler they serve.

b) Pressure gauges are to be graduated in units of effective pressure and are to include a prominent legible mark for the pressure that is not to be exceeded in normal service.

c) Each pressure gauge is to be fitted with an isolating cock.

d) Double front boilers are to have a steam pressure gauge arranged in each front.

5.1.7 Temperature control devices

Each boiler fitted with a superheater is to have an indicator or recorder for the steam temperature at the superheater outlet.

5.1.8 Automatic shut-off of oil fired propulsion and auxiliary boilers

a) Each burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. In the case of failure of the flame scanner, the fuel to the burner is to be shut off automatically.

b) A low water condition is to automatically shut off the fuel supply to the burners. The shut-off is to operate before the water level reaches a level so low as to affect the safety of the boiler and no longer be visible in the gauge glass. Means are to be provided to minimise the risk of shut-off provoked by the effect of roll and pitch and/or transients. This shut-off system need not be installed in auxiliary boilers which are under local supervision and are not intended for automatic operation.

c) Forced draft failure is to automatically shut off the fuel supply to the burners.

d) Loss of boiler control power is to automatically shut off the fuel supply to the burners.

5.1.9 Alarms

Any actuation of the fuel-oil shut-off listed in [5.1.8] is to operate a visual and audible alarm.

5.1.10 Additional requirements for boilers fitted with automatic control systems

a) The flame scanner required in [5.1.8], item a) is to operate within 6 seconds from the flame failure.

b) A timed boiler purge with all air registers open is to be initiated manually or automatically when boilers are fitted with an automatic ignition system. The purge time is based on a minimum of 4 air changes of the combustion chamber and furnace passes. Forced draft fans are to be operating and air registers and dampers are to be open before the purge time commences.

c) Means are to be provided to bypass the flame scanner control system temporarily during a trial-for-ignition for a period of 15 seconds from the time the fuel reaches the burners. Except for this trial-for-ignition period, no means are to be provided to bypass one or more of the burner flame scanner systems unless the boiler is locally controlled.

d) Where boilers are fitted with an automatic ignition system, and where residual fuel oil is used, means are to be provided for lighting of burners with igniters lighting properly heated residual fuel oil. In the case of flame failure, the burner is to be brought back into automatic service only in the low-firing position.

e) An alarm is to be activated whenever a burner operates outside the limit conditions stated by the manufacturer.

f) Immediately after normal shutdown, an automatic purge of the boiler equal to the volume and duration of the pre-purge is to occur. Following automatic fuel valve shut-off, the air flow to the boiler is not to automatically increase; post-purge in such cases is to be carried out under manual control.

g) Propulsion and auxiliary boilers associated with propulsion machinery intended for centralised, unattended operations are to comply with the requirements of Part C, Chapter 3.

5.2 Pressure vessel instrumentation

5.2.1

a) Pressure vessels are to be fitted with the necessary devices for checking pressure, temperature and level, where it is deemed necessary.

b) In particular, each air pressure vessel is to be fitted with a local manometer.

5.3 Thermal oil heater control and monitoring

5.3.1 Local control and monitoring

Suitable means to effectively operate, control and monitor the operation of thermal oil heaters and their associated auxiliaries are to be provided locally. The functional condition of the fuel, thermal oil circulation, forced draft and flue gas systems is to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.3.2 Flow control and monitoring

a) A flow indicator of the thermal oil is to be provided.

b) The flow detection is to be representative of the flow in each heated element.

c) The flow detection is not to be based on a measurement of the pressure-drop through the heating element.

d) Oil fired or exhaust gas heaters are to be provided with a flow monitor limit-switch. If the flow rate falls below a minimum value the firing system is to be switched off and interlocked.

5.3.3 Leakage monitoring

Oil tanks are to be equipped with a leakage detector which, when actuated, shuts down and interlocks the thermal oil firing system. If the oil fired heater is on stand-by, the starting of the burner is to be blocked if the leakage detector is actuated.

5.4 Control and monitoring requirements

5.4.1 Tab 21, Tab 22, Tab 23 and Tab 24 summarise the control and monitoring requirements for main propulsion boilers, auxiliary boilers, oil fired thermal oil heaters and exhaust gas thermal oil heaters and incinerators, respectively.

Table 21 : Main propulsion boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil							
• Fuel oil delivery pressure or flow	L						
• Fuel oil temperature after heater or viscosity fault	L+H	local					
• Master fuel oil valve position (open / close)		local					
• Fuel oil input burner valve position (open / close)		local					
Combustion							
• Flame failure of each burner	X						
• Failure of atomizing fluid	X					5	
• Boiler casing and economizer outlet smoke temperature (in order to detect possible fire out-break)	H						
	HH			X			
Air							
• Air register position		local					
General steam							
• Superheated steam pressure	L+H	local					
					X		
• Superheated steam temperature	H	local					
• Lifting of safety valve (or equivalent: high pressure alarm for instance)	X						
• Water level inside the drum of each boiler	L+H	local **(1)**					
	LL			X			
					X		
(1) Duplication of level indicator is required							

Table 22 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Water level	L+H	local					
	LL			X			
Circulation stopped (when forced circulation boiler)	X			X			
Fuel oil temperature or viscosity **(2)**	L+H	local					
Flame failure	X			X			
Temperature in boiler casing (Fire)	H						
Steam pressure	H **(1)**	local		X			

(1) When the automatic control does not cover the entire load range from zero load
(2) Where heavy fuel is used

Table 23 : Thermal oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Thermal fluid temperature heater outlet	H	local		X **(1)**			
Thermal fluid pressure pump discharge	H	local		X			
Thermal fluid flow through heating element	L LL	local		X **(1)**			
Expansion tank level	L LL	local		X **(2)**			
Expansion tank temperature	H						
Forced draft fan stopped	X			X			
Heavy fuel oil temperature or viscosity	H+L	local					
Burner flame failure	X			X			
Flue gas temperature heater outlet	H HH			X **(2)**			

(1) Shut-off of heat input only. It applies also when the thermal oil system is in manual operation.
(2) Stop of fluid flow and shut-off of heat input

Table 24 : Incinerators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Flame failure	X			X			
Furnace temperature	H			X			
Exhaust gas temperature	H						
Fuel oil pressure		local					
Fuel oil temperature or viscosity **(1)**	H+L	local					

(1) Where heavy fuel is used

6 Additional requirements for shell type exhaust gas heated economizers that may be isolated from the steam plant system

6.1 Application

6.1.1 The requirements in [6] are applicable to shell type exhaust gas heated economizers that are intended to be operated in a flooded condition and that may be isolated from the steam plant system.

6.2 Design and construction

6.2.1 Design and construction of shell type economizers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

6.3 Pressure relief

6.3.1 Where a shell type economizer is capable of being isolated from the steam plant system, it is to be provided with at least one safety valve, and when it has a total heating surface of 50 m^2 or more, it is to be provided with at least two safety valves in accordance with [3.2].

6.3.2 To avoid the accumulation of condensate on the outlet side of safety valves, the discharge pipes and/or safety valve housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economizer where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

6.3.3 Full details of the proposed arrangements to satisfy [6.3.1] to [6.3.2] are to be submitted for approval.

6.4 Pressure indication

6.4.1 Every shell type economizer is to be provided with a means of indicating the internal pressure. A means of indicating the internal pressure is to be located so that the pressure can be easily read from any position from which the pressure may be controlled.

6.5 Lagging

6.5.1 Every shell type economizer is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

6.6 Feed water

6.6.1 Every economizer is to be provided with arrangements for pre-heating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the manufacturer's recommendations.

6.7 Operating instructions

6.7.1 The manufacturer is to provide operating instructions for each economiser which is to include reference to:

- Feed water treatment and sampling arrangements
- Operating temperatures – exhaust gas and feed water temperatures
- Operating pressure
- Inspection and cleaning procedures
- Records of maintenance and inspection
- The need to maintain adequate water flow through the economizer under all operating conditions
- Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly
- Procedures for using the exhaust gas economizer in the dry condition
- Procedures for maintenance and overhaul of safety valves.

7 Design requirements for boil-off gas combustion units

7.1 Operating cases

7.1.1 Gas combustion units are to be capable of operating at least in the following conditions:

a) for gas carriers:
- normal boil-off handling in laden conditions
- reduced boil-off handling in ballast conditions
- during inerting and purging operations.

b) for gas-fuelled ships:
- boil-off handling during periods of slow steaming and/or no consumption from propulsion or other services of the ship
- during LNG bunkering, inerting and purging operations.

7.2 Availability

7.2.1 Main components of the GCU(s):
- mechanical non-static components such as fans,
- electronic cards pertaining to the control and monitoring system,

are to be duplicated so that the nominal capacity of the GCU(s) can be sustained or restored in case of single failure of such components.

7.2.2 The time necessary to restore the GCU operation in case of a component failure is to be consistent with the expected operating profile of the GCU and with the increase rate of the pressure in the tanks. In this respect, spare components ready for installation in a short time may be considered in lieu of duplicated components.

7.3 Gas combustion equipment

7.3.1 General

The gas combustion unit is to exhibit no visible flame.

7.3.2 Flue gas temperature

The flue gas temperature at the GCU outlet, after possible dilution, is not to exceed 535°C.

Note 1: The attention is drawn to certain national or international rules that may impose different temperature limits.

In case of emergency shut-down of the GCU, the flue gas temperature is not to exceed the aforementioned value. Otherwise, an emergency water cooling system is to be provided.

7.3.3 Combustion chamber

The combustion chamber is to be of suitable form such as not to present pockets where gas may accumulate.

The flame length is to remain within the gas combustion chamber in all expected operating cases, irrespective of the gas composition and gas pressure.

The combustion chamber is to be fitted with at least two flame monitoring devices, one for the alarm activation and one to shut off the gas supply in the case of flame failure.

7.3.4 Means for ignition

Each gas burner is to be fitted with at least two means for ignition, such as electrical igniters or pilot burners supplied with oil fuel.

7.4 Gas supply

7.4.1 Gas piping system

The gas piping system fitted to the GCU is to comply with the relevant provisions of IGC Code, Chapter 16 or IGF Code, Section 9, as appropriate.

7.4.2 Inerting

Provisions are to be made for inerting and gas-freeing the portion of the gas piping system located in the GCU compartment.

Where it is demonstrated that the natural gas-freeing of the GCU burner and of its gas supply piping is efficient, the connection to the inert gas system may be omitted, subject to the agreement of the flag Administration.

7.5 Instrumentation and safeties

7.5.1 The GCU control system as well as the related systems are to be of a type approved by the Society.

7.5.2 The alarm and safety systems are to be provided in accordance with Tab 25.

Table 25 : Gas combustion units alarm and safety systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring	Automatic safety actions		
Identification of system parameter	Alarms	Automatic shut down of the GCU	Activation of the master gas valve	Other automatic actions
Gas supply - pressure	L	X		
Gas supply - temperature	L+H	X		
Combustion fans, dilution fans or combined fans - failure	X			Start of the stand-by fan
Flame - loss	X	X		
Flame monitoring device - failure	X			
Flue gas at the stack outlet - temperature	H HH	 X		
GCU stop from any cause	X			Activation of the block-and-bleed valves **(1)**
Control power supply - failure	X			
Double wall gas piping system **(2)** - gas leakage	X	X	X	
Double wall gas piping system **(2)** - lost of exhaust ventilation	X	X	X	
Single wall gas piping system - gas detection in the GCU space **(3)**	X	X	X	De-energization of the non-safe electrical equipment
Single wall gas piping system - loss of ventilation in the GCU space **(3)**	X	X	X	De-energization of the non-safe electrical equipment

(1) For gas carriers and gas-fuelled ships. Refer to IGC Code, reg. 16.4.5 or IGF Code, reg. 9.4.4 as applicable

(2) For gas carriers and gas-fuelled ships. Refer to IGC Code, reg. 16.4.6.3 or IGF Code, Table 1, as applicable

(3) Only for gas-fuelled ships. Refer to IGF Code, reg. 5.6.3.3 and Table 1

8 Arrangement and installation

8.1 Foundations

8.1.1 For boilers and pressure vessels bolting down to their foundations, see Ch 1, Sec 1, [3.3.1]. Where necessary, they are also to be secured to the adjacent hull structures by suitable ties.

Where chocks are required to be fitted between the boilers and their foundations, they are to be of cast iron or steel.

8.2 Boilers

8.2.1 Thermal expansion

Means are to be provided to compensate thermal expansion of boilers.

8.2.2 Minimum distance of boilers from vertical bulkheads and fuel tanks

a) The distance between boilers and vertical bulkheads is to be not less than the minimum distance necessary to provide access for inspection and maintenance of the structure adjacent to the boiler.

b) In addition to the requirement in a), the distance of boilers from fuel oil tanks is to be such as to prevent the possibility that the temperature of the tank bulkhead may approach the flash point of the oil.

c) In any event, the distance between a boiler and a vertical bulkhead is not to be less than 450 mm.

8.2.3 Minimum distance of boilers from double bottom

a) Where double bottoms in way of boilers may be used to carry fuel oil, the distance between the top of the double bottom and the lower metal parts of the boilers is not to be less than:

- 600 mm, for cylindrical boilers
- 750 mm, for water tube boilers.

b) The minimum distance of vertical tube boilers from double bottoms not intended to carry oil may be 200 mm.

8.2.4 Minimum distance of boilers from ceilings

a) A space sufficient for adequate heat dissipation is to be provided on the top of boilers.

b) Oil tanks are not permitted to be installed in spaces above boilers.

8.2.5 Installation of boilers on engine room flats

Where boilers are installed on an engine room flat and are not separated from the remaining space by means of a watertight bulkhead, a coaming of at least 200 mm in height is to be provided on the flat. The area surrounded by the coaming may be drained into the bilge.

8.2.6 Drip trays and gutterways

Boilers are to be fitted with drip trays and gutterways in way of burners so arranged as to prevent spilling of oil into the bilge.

8.2.7 Hot surfaces

Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7.1].

8.2.8 Registers fitted in the smoke stacks of oil fired boilers

Where registers are fitted in smoke stacks, they are not to obstruct more than two thirds of the cross-sectional area of gas passage when closed. In addition, they are to be provided with means for locking them in open position when the boiler is in operation and for indicating their position and degree of opening.

8.3 Pressure vessels

8.3.1 Safety devices on multiple pressure vessels

Where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

8.4 Thermal oil heaters

8.4.1 In general, the requirements of [8.2] for boilers are also applicable to thermal oil heaters.

9 Material test, workshop inspection and testing, certification

9.1 Material testing

9.1.1 General

Materials, including welding consumables, for the constructions of boilers and pressure vessels are to be certified by the material manufacturer in accordance with the appropriate material specification.

9.1.2 Boilers, other steam generators, and oil fired and exhaust gas thermal oil heaters

In addition to the requirement in [9.1.1], testing of materials intended for the construction of pressure parts of boilers, other steam generators, oil fired thermal oil heaters and exhaust gas thermal oil heaters is to be witnessed by the Surveyor.

9.1.3 Class 1 pressure vessels and heat exchangers

In addition to the requirement in [9.1.1], testing of materials intended for the construction of class 1 pressure parts of pressure vessels and heat exchangers is to be witnessed by the Surveyor.

This requirement may be waived at the Society's discretion for mass produced small pressure vessels (such as accumulators for valve controls, gas bottles, etc.). Work (W) certificates are to be provided.

9.2 Workshop inspections

9.2.1 Boilers and individually produced class 1 and 2 pressure vessels

The construction, fitting and testing of boilers and individually produced class 1 and 2 pressure vessels are to be attended by the Surveyor, at the builder's facility.

9.2.2 Mass produced pressure vessels

Construction of mass produced pressure vessels which are type approved by the Society need not be attended by the Surveyor. Work (W) certificates are to be provided.

9.3 Hydrostatic tests

9.3.1 General

Hydrostatic tests of all class 1, 2 and 3 pressure vessels are to be witnessed by the Surveyor with the exception of mass produced pressure vessels which are built under the conditions stated in [9.2.2], and for which work (W) certificates are to be provided.

9.3.2 Testing pressure

a) Upon completion, pressure parts of boilers and pressure vessels are to be subjected to a hydraulic test under a pressure p_t defined below as a function of the design pressure p:

- $p_t = 1,5\ p$ where $p \le 4$ MPa
- $p_t = 1,4\ p + 0,4$ where $4 \text{ MPa} < p \le 25$ Mpa
- $P_t = p + 10,4$ where $p > 25$ MPa

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

c) If the design temperature exceeds 300°C, the test pressure p_t is to be as determined by the following formula:

$$p_t = 1,5 \cdot \frac{K_{100}}{K} \cdot p$$

where:

p : Design pressure, in MPa

K_{100} : Permissible stress at 100°C, in N/mm^2

K : Permissible stress at the design temperature, in N/mm^2.

d) Consideration is to be given to the reduction of the test pressure below the values stated above where it is necessary to avoid excessive stress. In any event, the general membrane stress is not to exceed 90% of the yield stress at the test temperature.

e) Economisers which cannot be shut off from the boiler in any working condition are to be submitted to a hydraulic test under the same conditions as the boilers.

f) Economisers which can be shut off from the boiler are to be submitted to a hydraulic test at a pressure determined as a function of their actual design pressure p.

9.3.3 Hydraulic test of boiler and pressure vessel accessories

a) Boilers and pressure vessel accessories are to be tested at a pressure p_t which is not less than 1,5 times the design pressure p of the vessels to which they are attached.

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

9.3.4 Hydraulic test procedure

a) The hydraulic test specified in [9.3.1] is to be carried out after all openings have been cut out and after execution of all welding work and of the heat treatment, if any. The vessel to be tested is to be presented without lagging, paint or any other lining and the pressure is to be maintained long enough for the Surveyor to proceed with a complete examination.

b) Hydraulic tests of boilers are to be carried out either after installation on board, or at the manufacturer's plant. Where a boiler is hydrotested before installation on board, the Surveyor may, if deemed necessary, request to proceed with a second hydraulic test on board under a pressure at least equal to 1,1 p. For this test, the boiler may be fitted with its lagging. However, the Surveyor may require this lagging to be partially or entirely removed as necessary.

c) For water tube boilers, the hydraulic test may also be carried out separately for different parts of the boiler upon their completion and after heat treatment. For drums and headers, this test may be carried out before drilling the tube holes, but after welding of all appendices and heat treatment. When all parts of the boiler have been separately tested and following assembly the boiler is to undergo a hydraulic test under a pressure of 1,25 p.

9.3.5 Hydraulic tests of condensers

Condensers are to be subjected to a hydrostatic test at the following test pressures:

- Steam space: 0,1 MPa
- Water space: maximum pressure which may be developed by the pump with closed discharge valve increased by 0,07 MPa. However, the test pressure is not to be less than 0,2 MPa. When the characteristics of the pump are not known, the hydrostatic test is to be carried out at a pressure not less than 0,35 MPa.

9.4 Certification

9.4.1 Certification of boilers and individually produced pressure vessels

Boilers and individually produced pressure vessels of classes 1, 2 and 3 are to be certified by the Society in accordance with the procedures stated in Part A.

9.4.2 Mass produced pressure vessels

Small mass produced pressure vessels of classes 1, 2 and 3 may be accepted provided they are type approved by the Society in accordance with the procedures stated in Part A.

Table 26 : Pressure vessel certification

Class	Drawing / Calculation		Material testing		Hydraulic test	
	Manufacturer	The Society	Manufacturer	The Society	Manufacturer	The Society
1	X	review	X	witness + workshop inspection	X	witness
2	X	review	X	review	X	witness
3	X	–	X	review	X	witness
Note 1: Certificates of the Manufacturer and the Society to be issued for all cases for pressure vessels covered by the Rules of the Society.						

Section 4 Steam Turbines

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation, or for driving cargo pumps in tankers.

1.1.2 Auxiliary turbines driving generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with those of Ch 2, Sec 4 of the Rules.

1.2 Documentation to be submitted

1.2.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans and data listed in Tab 1 are to be submitted.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of the types of materials employed.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Item
1	I	Sectional assembly
2	A	Rotors and discs, revolving and stationary blades for each turbine
3	A	Fastening details of revolving and stationary blades
4	A	Casings
5	A	Schematic diagram of control and safety devices
6	I	General specification of the turbine, including an operation and instruction manual
7	I	Maximum power and corresponding maximum rotational speed, and the values of pressure and temperature at each stage
8	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, when the service temperature exceeds 400°C, the fatigue strength, the corrosion resistance and the heat treatments
9	I	Distribution box
10	A	Strength calculations of rotors, discs and blades and blade vibration calculations
11	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding conditions, heat treatments and non-destructive examinations after welding
(1) A = to be submitted for approval I = to be submitted for information		

2 Design and construction

2.1 Materials

2.1.1 Rotating components

a) Rotors, shafts and discs of turbines are to be of forged steel. In general, the forgings are to have minimum tensile strength R_m within the limits in Tab 2.

b) Rotors of small turbines may be built of special cast steels.

c) Turbine blades are to be built of corrosion-resistant materials.

Table 2 : Limits of R_m

Steel	R_m limits (N/mm^2)
Carbon and carbon-manganese steel	$400 < R_m < 600$
Alloy steels for rotors	$500 < R_m < 800$
Alloy steels for discs and other forgings	$500 < R_m < 1000$

2.1.2 Static components

The casings and diaphragms of turbines are to be built of forged or cast steels capable of withstanding the pressures and temperatures to which they are subjected. Cast iron may be used for temperatures up to 300°C. Additionally, requirements mentioned in Ch 1, Sec 1, [3.7.2] are to be applied when other materials than steel are used for components in contact with flammable fluids

2.2 Design and constructional details

2.2.1 Rotors and stators

a) All components of turbines are to be free from defects and are to be built and installed with tolerances and clearances such as to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Particular care is to be devoted to preventing condensation water from accumulating in the blade spaces of the casings. Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easy to operate.

c) When labyrinth packings are used, the steam supply pipes to the sealing system are to be so arranged that condensed steam may not enter the turbine.

d) Particular attention is to be paid to the connection of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of section of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.2.2 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from adjacent hot parts.

b) Lubricating oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped may also be required, at the discretion of the Society.

2.2.3 Turning gear

a) Main propulsion turbines are to be equipped with turning gear for both directions of rotation. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of turning gear is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the turbine cannot be started up when the turning gear is engaged.

2.2.4 Astern power for main propulsion

a) The main propulsion turbine is to have sufficient power for running astern. The astern power is considered to be sufficient if it is able to attain astern revolutions equivalent to at least 70% of the rated ahead revolutions for a period of at least 30 minutes.

b) For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running is not to cause any overloading of the propulsion machinery.

c) During astern running, the main condenser and the ahead turbines are not to be excessively overheated.

2.2.5 Interlock

The simultaneous admission of steam to the ahead and astern turbines is to be prevented by interlocks. Brief overlapping of the ahead and astern valves during manoeuvring may be permitted.

2.2.6 Turbine exhaust

a) Sentinel valves or other equivalent means are to be provided at the exhaust end of all turbines. The valve discharge outlets are to be clearly visible and suitably guarded, as necessary.

b) Where, in auxiliary steam turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valve are designed, means to relieve the excess pressure are to be provided.

2.2.7 Water accumulation prevention

a) Non-return valves or other approved means are to be fitted in bled steam connections to prevent steam and water returning into the turbines.

b) Bends are to be avoided in steam piping in which water may accumulate.

2.2.8 Steam strainers

Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

2.2.9 Emergency arrangements

a) In single screw ships fitted with cross compound steam turbines, the arrangements are to be such as to enable safe navigation when the steam supply to any one of the turbines is required to be isolated. For this emergency operation purpose the steam may be led directly to the low pressure (L.P.) turbine and either the high pressure (H.P.) or medium pressure (M.P.) turbine can exhaust direct to the condenser.

   Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

   The necessary pipes and valves for these arrangements are to be readily available and properly marked. A fit up test of all combinations of pipes and valves is to be performed prior to the first sea trials.

   The permissible power/speeds when operating without one of the turbines (all combinations) is to be specified and information provided on board.

   The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

b) Ships classed for unrestricted service and fitted with a steam turbine propulsion plant and only one main boiler are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

2.3 Welded fabrication

2.3.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable when the plans are submitted to the Society for approval. Requirements relative to fabrication, welding, heat treatments, examinations, testing and acceptance will be stipulated on a case by case basis.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures and using approved consumables.

2.4 Control, monitoring and shut-off devices

2.4.1 Governors

a) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or electrical transmission systems are to be fitted with an additional speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed.

b) The speed increase of turbines driving electric generators -except those for electrical propeller drive- resulting from a change from full load to no-load may not exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed.

2.4.2 Overspeed devices

a) Each main and auxiliary turbine is to be provided with an overspeed protective device to prevent the rotational speed from exceeding the maximum rotational by more than 15%. The device is to be actuated by the turbine shaft.

b) Where two or more steam turbines are coupled to the same gear wheel, the Society may accept the fitting of only one overspeed device for all the coupled turbines.

c) For turbines driving electric generators, the overspeed protective device mentioned in a) is also to be fitted with a means for manual tripping.

d) Where exhaust steam from auxiliary systems is led to the main turbine, provision is to be made to cut off the steam automatically when the overspeed protective device is activated.

2.4.3 Rotor axial displacement

A quick-closing valve is to be provided which automatically shuts off the steam supply in the event of axial displacement of the rotor beyond the permissible limits stated by the manufacturer. The device controlling the valve is to be actuated by the turbine shaft.

2.4.4 Emergency oil supply

For the emergency lubricating oil supply, see Ch 1, Sec 10, [12.5].

2.4.5 Bearing lubrication failure

a) Main ahead turbines are to be provided with a quick-closing valve which automatically shuts off the steam supply in the event of a dangerous reduction in oil pressure in the bearing lubricating system.

b) This arrangement is to be such as to ensure the admission of steam to the astern turbine for braking purposes.

2.4.6 Shut-off arrangement

a) Arrangements are to be provided for shutting off the steam to the main turbines by a suitable hand trip device controlling the steam admission valve situated at the control platform and at the turbine itself.

b) Hand tripping for auxiliary turbines is to be arranged in the proximity of the turbine overspeed protective device.

c) The hand trip device is any device which is operated manually irrespective of the way the action is performed, i.e. mechanically or by means of external power.

d) The quick-closing valves are also to be manually operable at the turbine and from the control platform.

e) Re-setting of the quick-closing valve device may be effected only at the turbine or from the control platform with the control valves in the closed position.

f) Where the valves are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, at the Society's discretion, a hand-operated pump may be accepted as a standby pump.

g) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

h) A quick-closing device is to be provided which automatically shuts off the steam supply in the event of an increase in pressure or water level in the condenser beyond the permissible limits.

2.4.7 Summary Tables

Tab 3 and Tab 4 summarise the minimum control and monitoring requirements for main propulsion and auxiliary turbines, respectively.

Table 3 : Main propulsion turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Main turbine speed		local					
	H			X			
					X		
• Main turbine axial displacement	X	local		X			
• Main turbine vibration	H	local					
Lubricating oil							
• Supply pressure		local					
	L			X **(2)**			
• Level of gravity tank	L **(1)**	local					
(1) Sensor to be located near the normal level **(2)** This is not to prevent astern operation for braking							

Table 4 : Auxiliary turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Overspeed	H	local		X			
Rotor displacement	X	local		X			
Vibration	H	local					
Lubricating oil supply pressure	L			X			
Lubricating oil level in gravity tank	L						

3 Arrangement and installation

3.1 Foundations

3.1.1 Shipyards and Manufacturers are to take care that foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Jointing of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine casings are to be fitted in such a way as to minimise the thrust loads and moments.

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7].

3.5 Alignment

3.5.1 The Shipyard and the Manufacturer are to take particular care in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet.

3.6 Circulating water system

3.6.1 The circulating water system with vacuum ejectors is to be so arranged that water may not enter the low pressure turbines.

3.7 Gratings

3.7.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.8 Drains

3.8.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.9 Instruments

3.9.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts.

This check is to be performed to the Surveyor's satisfaction at the time of installation.

4 Material tests, workshop inspection and testing, certification

4.1 Material tests

4.1.1 Parts to be tested

The materials for the construction of the parts listed in Tab 5 are to be tested in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected by the Manufacturer in positions agreed upon by the Surveyor, where Manufacturer's experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there are grounds to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

4.1.2 Special auxiliary turbines

In the case of auxiliary turbines with a steam inlet temperature of up to 250°C, the extent of the tests stated in Tab 5 may be limited to the disc and shaft materials.

4.2 Inspections and testing during construction

4.2.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of the Surveyor during the construction of all turbines which are indicated in [1.1.1]. For shipboard tests, see Ch 1, Sec 18, [3.7].

- material tests, as required (see [4.1])
- welded fabrication (see [4.2.2])
- non-destructive examination of turbine blades (see [4.2.3])
- hydrostatic tests (see [4.2.4])
- safety valves (see [4.2.5])
- thermal stability test of rotor (see [4.2.6])
- rotor balancing and overspeed test (see [4.2.7] and [4.2.8])
- shop trials (see [4.2.9]).

4.2.2 Welded fabrication

Welded fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.2.3 Turbine blades

When turbine blades are calculated using a permissible stress $K > R_m/4$, all turbine rotor blades are to be checked by dye penetrants or other equivalent method.

4.2.4 Hydrostatic tests

a) Turbine and nozzle casings are to be subjected to a hydrostatic test at the greater of the following test pressures:

b) 1,5 times the working pressure

c) 1,5 times the starting pressure

d) However, the test pressure is not to be less than $0,2 N/mm^2$.

e) The turbine casings may be temporarily subdivided by diaphragms in order to obtain different pressure values for the various stages, if necessary.

f) Where it is not possible to perform hydrostatic tests, the manufacturer may submit to the Society, for consideration, alternative proposals for testing the integrity of turbine casings and the absence of defects therein.

g) For the bodies of quick-closing, safety, manoeuvring and control valves, the test pressure is to be 1,5 times the maximum allowable working pressure of the boiler (approval pressure). The sealing efficiency of these valves when closed is to be tested at 1,1 times the working pressure.

h) Intermediate coolers and heat exchangers are to be subjected to a hydrostatic test at 1,5 times the working pressure.

i) Pressure piping, valves and other fittings are to be subjected to hydrostatic tests in compliance with the normal requirements for these items.

4.2.5 Safety valves

All valves required in [2.4] are to be tested at their setting pressure in the presence of the Surveyor, as specified by the turbine manufacturer.

4.2.6 Thermal stability test of rotors

Solid forged and welded rotors of propulsion turbines are to be subjected to a thermal stability test where the service temperature exceeds 400°C. This test is to be carried out after heat treatment and rough machining or at a later stage of fabrication, in accordance with a procedure approved by the Society.

4.2.7 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.2.8 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above values of overspeed and that rotors are free from defects, as verified by means of non-destructive tests.

4.2.9 Shop trials

Where turbines are subjected to a trial run at the factory, the satisfactory functioning of the control, safety and monitoring equipment is to be verified by the Manufacturer during the trial run. Such verification is in any event to take place not later than the commissioning of the plant aboard ship.

In general, propulsion steam turbines are to be subjected to a works trial under steam but without load, up to the service rotational speed, as far as possible. In the course of the works trials, the overspeed devices for both main and auxiliary turbines are to be set.

4.3 Certification

4.3.1 Turbines required to be certified

For turbines required to be certified as per [1.1.1], Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 5 and for works trials as per [4.2.1]. Provided the manufacturer has a quality assurance system accepted by the Society, a reduced number of inspections in the presence of the Surveyor may be agreed.

4.3.2 Turbines not required to be certified

For turbines not required to be certified as per [1.1.1], manufacturer's certificates including details of tests and inspections carried out at the shop are to be submitted. The acceptance of these turbines is, however, subject to their satisfactory performance during dock and sea trials.

4.3.3 Type approved turbines

For mass produced turbines of a type as mentioned in [1.1], the tests and trials on a prototype are to be carried out in the presence of the Surveyor as stated in [4.3.1] in the scope of the type approval program of the Society. The minimum required attendance of the Surveyor at the production tests and trials will be agreed between the manufacturer and the Society on a case by case basis.

Table 5 : Material and non-destructive tests

Turbine component	Material tests (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or X Ray examination
Rotating parts (turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	sample
Stationary parts (castings and plates for casings)	all	spot as agreed between the Manufacturer and the Surveyor	–
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate Section of the Rules	as required in the appropriate Section of the Rules	as required in the appropriate Section of the Rules

Section 5 Gas Turbines

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation.

1.1.2 Turbines for auxiliary generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with the applicable requirements of Ch 3, Sec 3.

1.1.3 Dual fuel (DF) gas turbines

Specific requirements for dual fuel (DF) gas turbines are given in [5], in addition to the requirements applicable to all kinds of gas turbines given in [1] to [4].

1.1.4 Type approval

Turbines intended for propulsion and essential services are to be type approved by the Society.

1.2 Definition of rated power

1.2.1 Rated power is the maximum constant power that the turbine can develop at constant speed in the range of air inlet temperature between 0°C and 35°C. This power is to be considered with 0 intake and exhaust losses and with an air relative humidity of 60%.

1.3 Documentation to be submitted

1.3.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans listed in Tab 1 are to be submitted.

The listed constructional plans are to be complete with all dimensions and are to contain full indication of the types of materials used.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Item
1	I	Sectional assembly
2	A	Detailed drawings of rotors, casings, blades, combustion chambers and heat exchangers **(2)**
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, the fatigue strength, the corrosion resistance and the heat treatments **(2)**
4	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding procedures and sequences, heat treatments and non-destructive examinations after welding **(2)**
5	I	General specification of the turbine, including instruction manual, description of structures and specification of the properties of fuel and lubricating oil to be used
6	I	Details of operating conditions, including the pressure and temperature curves in the turbine and compressor at the rated power and corresponding rotational speeds, and details of permissible temporary operation beyond the values for the rated power
7	A	Diagrammatic layout of the fuel system, including control and safety devices, and of the lubricating oil system
8	A	Cooling system layout, if applicable

(1) A = to be submitted for approval; I = to be submitted for information

(2) As an alternative, the Society may, on a case by case basis, consider reviewing a number of selected packages relative to important and critical parts of the turbine, where all the design, construction, inspection, testing and acceptance criteria used by the manufacturer are clearly described, provided the Quality Assurance system of the manufacturer is approved and certified by the Society.

No.	A/I **(1)**	Item
9	I	Where applicable, background information on previous operating experience in similar applications
10	I	Maintenance and overhaul procedures
11	A	Stress and temperature analysis in blades, rotors and combustion chamber **(2)**
12	A	Life time calculation of hot and high stress parts **(2)**
13	A	Blade and rotor vibration analysis **(2)**
14	A	Details of automatic safety devices together with failure mode and effect analysis (FMEA) **(2)**

(1) A = to be submitted for approval; I = to be submitted for information

(2) As an alternative, the Society may, on a case by case basis, consider reviewing a number of selected packages relative to important and critical parts of the turbine, where all the design, construction, inspection, testing and acceptance criteria used by the manufacturer are clearly described, provided the Quality Assurance system of the manufacturer is approved and certified by the Society.

2 Design and Construction

2.1 Materials

2.1.1 Approved materials

a) Gas turbine materials are to fulfil the requirements imposed by the operating conditions of the individual components. In the choice of materials, account is to be taken of effects such as creep, thermal fatigue, oxidation and corrosion to which individual components are subject when in service. Evidence of the suitability of the materials is to be supplied to the Society in the form of details of their chemical and mechanical properties and of the heat treatment applied. Where composite materials are used, their method of manufacture is to be described.

b) Turbine blades are to be built of corrosion and heat-resistant materials.

c) Requirements mentioned in Ch 1, Sec 1, [3.7.2] are to be applied when other materials than steel are used for components in contact with flammable fluids

2.2 Stress analyses

2.2.1 Calculation

a) The manufacturer is to submit the results of calculation of the stresses on each rotor under the most severe service conditions.

b) Fatigue analysis on each rotor, taking into account the stress concentrations, is also to be submitted.

c) The results of previous in-service experience on similar applications may be considered by the Society as an alternative to items a) and b) above.

The calculations and analyses (see also [1.3.1]) are to be carried out in accordance with criteria agreed by the Society. Data on the design service life and test results used to substantiate calculation assumptions are also to be provided.

2.2.2 Vibrations

The range of service speeds is not to give rise to unacceptable bending vibrations or to vibrations affecting the entire installation. Calculations of the critical speeds including details of their basic assumptions are to be submitted.

2.3 Design and constructional details

2.3.1 Rotors and stators

a) All components of turbines and compressors are to be free from defects and are to be built and installed with tolerances and clearances in order to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easily operated.

c) Suitable protective devices are to be provided in order to prevent heat, noise or possible failure of rotating parts from causing injury to personnel. If, to this end, the whole gas turbine is enclosed in a protective covering, the covering is to be adequately ventilated inside.

d) Particular attention is to be paid to the connection in the casings of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of sections of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.3.2 Access and inspection openings

a) Access to the combustion chambers is to be ensured. Means are to be provided to inspect the burner cans or combustion chamber without having to remove the gas generator.

b) Inspection openings are to be provided to allow the gas turbine flow path air to be inspected with special equipment, e.g. a bore-scope or similar, without the need for dismantling.

2.3.3 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from hot gases or adjacent hot parts.

b) Lubricating oil or fuel oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped are to be provided, if necessary to prevent bearing cooking.

d) Roller bearings are to be identifiable and are to have a life adequate for their intended purpose. In any event, their life cannot be less than 40000 hours.

2.3.4 Turning gear

a) Main propulsion turbines are to be equipped with turning gear or a starter for cranking. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of the turning gear or starter is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the main turbine cannot be started up when the turning gear is engaged.

2.3.5 Cooling

The turbines and their external exhaust system are to be suitably insulated or cooled to avoid excessive outside temperature.

2.3.6 Air supply

a) The air intake ducting is to be equipped to prevent extraneous substances from entering the compressor and turbine.

b) Measures are to be taken to control the salinity of the combustion air, to meet the manufacturer's specification.

c) Cleaning equipment is to be provided to remove deposits from compressors and turbines.

d) Means are to be provided to prevent the formation of ice in the air intake.

2.3.7 Turbine exhaust arrangement

a) The gas exhaust arrangement is to be designed in such a way as to prevent the entrance of gases into the compressor.

b) Silencers or other equivalent arrangements are to be provided in the gas exhaust, to limit the airborne noise at one metre distance from the turbine to not more than 110 dB (A) in unmanned machinery spaces and not more than 90 dB (A) in manned spaces.

2.3.8 Multi-turbine installations

Multi-turbine installations are to have separate air inlets and exhaust systems to prevent recirculation through the idle turbine.

2.3.9 Fuel

a) Where the turbine is designed to burn non-distillate fuels, a fuel treatment system is to be provided to remove, as far as practicable, the corrosive constituents of the fuel or to inhibit their action in accordance with the manufacturer's specification.

b) Suitable means are to be provided to remove the deposits resulting from the burning of the fuel while avoiding abrasive or corrosive action, if applicable.

c) Gas turbines burning boil-off gases of liquefied gas cargo tanks will be specially considered by the Society taking into account the requirements of Pt D, Ch 9, Sec 16.

2.3.10 Start-up equipment

a) Gas turbines are to be fitted with start-up equipment enabling them to be started up from the "shutdown" condition.

b) Provisions are to be made so that any dangerous accumulation of liquid or gaseous fuel inside the turbines is thoroughly removed before any attempt at starting or restarting.

c) Starting devices are to be so arranged that firing operation is discontinued and the main fuel valve is closed within a pre-determined time when ignition is failed.

d) The minimum number of starts is to be such as to satisfy the requirements of Ch 1, Sec 1, [1.4.2].

2.3.11 Astern power

For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running is not to cause any overloading of the propulsion machinery.

2.3.12 Emergency operation

a) In installations with more than one propeller and connected shafting and more than one turbine, the failure of any gas turbine unit connected to a shafting line is not to affect the continued, independent operation of the remaining units.

b) In installations with only one propeller and connected shafting, driven by two or more main turbines, care is to be taken to ensure that, in the event of one of the turbines failing, the others are able to continue operation independently.

c) Ships classed for unrestricted service and fitted with only one propeller and connected shafting driven by a gas turbine are to be provided with means to ensure emergency propulsion in the event of failure of the main turbine.

2.4 Welded fabrication

2.4.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable by the Society in the plans submitted for approval.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures using approved consumables.

2.5 Control, monitoring and shut-off devices

2.5.1 Control and monitoring arrangement

For each main propulsion system, the associated control and monitoring equipment is to be grouped together at each location from which the turbine may be controlled.

2.5.2 Governors and speed control system

a) Propulsion turbines which may be operated in no-load conditions are to be fitted with a control system capable of limiting the speed to a value not exceeding 10% of the maximum continuous speed.

b) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or an electrical transmission system are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed.

c) In addition to the speed governor, turbines driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

d) The speed increase of turbines driving electric generators - except those for electrical propeller drive - resulting from a change from full load to no-load is not to exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed. Alternative requirements may be considered by the Society on a case by case basis based on the actual turbine design and arrangement.

2.5.3 Monitoring system

The main operating parameters (pressure, temperature, rpm, etc.) are to be adequately monitored and displayed at the control console.

2.5.4 Emergency shut-off

a) An emergency push-button shut-off device is to be provided at the control console.

b) Any shut-off device provided in pursuance of the above is to shut off the fuel supply as near the burners as possible.

2.5.5 Quick-closing devices

a) Gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least where required by Tab 2, unless the FMEA proves otherwise.

b) Re-setting of the quick-closing device may be effected only at the turbine or from the control platform with the fuel supply control valve in the closed position.

c) When the devices are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, a hand-operated pump may be accepted as a standby pump.

d) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

2.5.6 Automatic temperature controls

The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions within the normal operating range of the main gas turbine:

a) lubricating oil supply and discharge

b) fuel oil supply (or, alternatively, automatic control of fuel oil viscosity)

c) exhaust gas in specific locations of the flow gas path as determined by the manufacturer.

2.5.7 Indicators, alarm and shutdown

Tab 2 indicates the minimum control and monitoring requirements for main propulsion and auxiliary turbines. Alarms can be added or omitted, taking into account the result of FMEA.

Table 2 : Main propulsion and auxiliary turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Control system failure	X						
• Automatic starting failure	X						
Mechanical monitoring of gas turbine							
• Speed		local					
					X		
	H			X			
• Rotor axial displacement (Not applicable to roller bearing)		local					
	H			X			
• Vibration	H **(1)**	local		X			
• Performed number of cycle of rotating part	H						
Gas generator monitoring							
• Flame and ignition failure	X			X			
• Fuel oil supply pressure	L	local					
• Fuel oil supply temperature	H	local					
• Cooling medium temperature	H	local					
• Exhaust gas temperature or gas temperature in specific locations of flow gas path		local					
	H **(1)**			X			
• Pressure at compressor inlet		local					
	L **(1)**			X			
Lubricating oil							
• Turbine supply pressure		local					
	L **(1)**			X			
• Reduction gear supply pressure		local					
	L **(1)**			X			
(1) Alarm to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices							

3 Arrangement and installation

3.1 Foundations

3.1.1 Manufacturers and Shipyards are to arrange foundations of turbines and connected reduction gears to be so designed and built that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Joints of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine and compressor casings are to be fitted in such a way as to minimise the thrust loads and moments. If flexible hoses are used for this purpose, they are to comply with the requirements in Ch 1, Sec 10, [2.6].

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7].

3.5 Alignment

3.5.1

a) The Manufacturer is to take particular care in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

b) When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

c) Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet. Such indicators are to be fitted in an easily visible position. This requirement does not apply to turbines fitted with roller bearings.

3.6 Gratings

3.6.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.7 Drains

3.7.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.8 Instruments

3.8.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts, when necessary.

At the time of installation on board, this check is to be performed in the presence and to the satisfaction of the Surveyor.

4 Material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Upon finalisation of the design for production of every new turbine type intended for installation on board ships, one turbine is to be presented for type testing as required below.

A type test carried out for a particular type of turbine at any manufacturer's works will be accepted for all turbines of the same type built by licensees and licensors.

Turbines which are subjected to type testing are to be tested in accordance with the scope specified below, it being taken for granted that:

- the turbine is optimised as required for the conditions of the type test
- the investigations and measurements required for reliable turbine operation have been carried out during preliminary internal tests by the turbine manufacturer
- the documentation to be submitted as required in [1.3.1] has been examined and, when necessary, approved by the Society and the latter has been informed regarding the nature and extent of investigations carried out during pre-production stages.

4.2 Type tests of turbines not admitted to an alternative inspection scheme

4.2.1 General

Turbines for which the Manufacturer is not admitted to testing and inspections according to an alternative inspection scheme (see NR320, Sec 1, [3.2]), are to be type tested in the presence of the Surveyor in accordance with the following requirements.

The type test is subdivided into three stages:

a) Stage A - Preliminary internal tests carried out by the manufacturer

Stage A includes functional tests and collection of operating values including testing hours during the internal tests, the relevant results of which are to be presented to the Surveyor during the type test. Testing hours of components which are inspected are to be stated by the manufacturer.

b) Stage B - Type approval test

The type approval test is to be carried out in the presence of the Surveyor.

c) Stage C - Inspection of main turbine components.

After completion of the test programme, the main turbine components are to be inspected.

The turbine manufacturer is to compile all results and measurements for the turbine tested during the type test in a type test report, which is to be submitted to the Society.

4.2.2 Stage A - Internal tests (functional tests and collection of operating data)

a) During the internal tests the turbine is to be operated at the load points considered important by the turbine manufacturer and the relevant operating values are to be recorded.

b) The load points may be selected according to the range of application.

c) Functional tests under normal operating conditions include:

1) The load points 25%, 50%, 75%, 100% of the rated power for which type approval is requested, to be carried out:
   - along the nominal (theoretical) propeller curve and at constant speed, for propulsion turbines
   - at constant speed, for turbines intended for generating sets.

2) The limit points of the permissible operating range.

   These limit points are to be defined by the turbine manufacturer.

d) An alternative testing program may be agreed between the manufacturer and the Society on a case by case basis.

4.2.3 Stage B - Type approval tests in the presence of the Surveyor

During the type test, the tests listed below are to be carried out in the presence of the Surveyor and the results are to be recorded in a report signed by both the turbine manufacturer and the Surveyor.

Any departures from this programme are to be agreed upon by the manufacturer and the Society.

a) Load points

The load points at which the turbine is to be operated according to the power/speed diagram are those listed below. The data to be measured and recorded when testing the turbine at various load points are to include all necessary parameters for turbine operation.

The operating time per load point depends on the turbine characteristics (achievement of steady-state condition) and the time for collection of the operating values.

Normally, an operating time of 0,5 hour per load point can be assumed.

At the maximum continuous power as per the following item (1) an operating time of two hours is required. Two sets of readings are to be taken at a minimum interval of one hour.

1) test at maximum continuous power P: i.e. 100% output at 100% torque and 100% speed.

2) test at maximum permissible torque (normally 110% of nominal torque T) at 100% speed; or test at maximum permissible power and speed according to the nominal propeller curve.

3) tests at partial loads, e.g. 75%, 50%, 25% of maximum continuous power P and speed according to the nominal propeller curve.

b) Additional tests
   - test at lowest turbine speed according to the nominal propeller curve
   - starting tests
   - governor tests
   - testing and rating of the safety systems.

4.2.4 Evaluation of test results

The results of the tests and checks required by [4.2.3] will be evaluated by the attending Surveyor. Normally the main operating data to be recorded during the tests are those listed in [4.3.4].

The values of temperatures and pressures of media, such as cooling media, lubricating oil, exhaust gases, etc., are to be within limits which, in the opinion of the Surveyor, are appropriate for the characteristics of the turbine tested.

4.2.5 Stage C - Inspection of turbine components

Immediately after the test run as per [4.2.3], a selected number of components agreed between the manufacturer and the Society are to be presented for inspection to the Surveyor.

4.3 Type tests of turbines admitted to an alternative inspection scheme

4.3.1 General

Turbines admitted to testing and inspections according to an alternative inspection scheme (see NR320, Sec 1, [3.2]) are to be type tested in the presence of the Surveyor in accordance with the following requirements.

The selection of the turbine to be tested from the production line is to be agreed upon with the Surveyor.

4.3.2 Type test

The programme of the type test is to be in general as specified below, P being the rated power and n the corresponding speed.

Any departures from this programme are to be agreed upon by the manufacturer and the Society.

a) 6 hours at full power

b) 10 hours shared at different partial loads (25%, 50%, 75% and 90% of power P);

c) 2 hours at intermittent loads

d) starting tests

e) testing of speed governor, overspeed device and lubricating oil system failure alarm device

f) testing of the minimum speed along the nominal (theoretical) propeller curve, for main propulsion turbines driving fixed pitch propellers, and of the minimum speed with no brake load, for main propulsion turbines driving controllable pitch propellers or for auxiliary turbines.

The tests at the above-mentioned outputs are to be combined together in working cycles which are to be repeated in succession for the entire duration within the limits indicated.

In particular, the full power test is to be carried out at the end of each cycle.

The partial load tests specified in (b) are to be carried out:

- along the nominal (theoretical) propeller curve and at constant speed, for propulsion turbines
- at constant speed, for turbines intended for generating sets.

In the case of prototype turbines, the duration and programme of the type test will be specially considered by the Society.

4.3.3 Alternatives

In cases of turbines for which the manufacturer submits documentary evidence proving successful service experience or results of previous bench tests, the Society may, at its discretion, allow a type test to be carried out, in the presence of the Surveyor according to a programme to be agreed upon in each instance.

4.3.4 Data to be recorded

During the type test, at least the following particulars are to be recorded:

a) ambient air temperature, pressure and atmospheric humidity in the test room

b) cooling medium temperature at the inlet of the turbine

c) characteristics of the fuel and lubricating oil used during the test

d) turbine speed

e) brake power

f) brake torque

g) intake and exhaust losses

h) lubricating oil pressure and temperature

i) exhaust gas temperature in locations of the flow gas path selected by the manufacturer

j) minimum starting air pressure and flow rate necessary to purge and start the turbine in cold condition, if applicable.

4.3.5 Inspection of main turbine components and evaluation of test results

The provisions of [4.2.4] and [4.2.5] are to be complied with, as far as applicable.

4.4 Material tests

4.4.1 The materials for the construction of the parts listed in Tab 3 are to be tested in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 3 and are to be effected by the Manufacturer in positions agreed upon by the Surveyor, where Manufacturer's experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there are grounds to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

Table 3 : Material and non-destructive tests

Turbine component	Material tests (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or X Ray examination
Rotating parts (compressors and turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	all
Stationary parts (castings for casings intended for a temperature exceeding 230°C and plates for casings intended for a temperature exceeding 370°C or pressure exceeding 4 Mpa)	all	spot as agreed between the Manufacturer and the Surveyor	–
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate Section of the Rules	as required in the appropriate Section of the Rules	as required in the appropriate Section of the Rules

4.5 Inspections and testing during construction

4.5.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of a Surveyor during the construction of all turbines which are indicated in [1.1.1]. For on-board trials see Ch 1, Sec 18, [3.8].

- Material tests as required (see Ch 1, Sec 4, [4.1])
- Welding fabrication (see [4.5.2])
- Hydrostatic tests (see [4.5.3])
- Rotor balancing and overspeed test (see [4.5.4] and [4.5.5])
- Shop trials (See [4.5.6]).

4.5.2 Welding fabrication

Welding fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.5.3 Hydrostatic tests

Finished casing parts and heat exchangers are to be subjected to hydrostatic testing at 1,5 times the maximum permissible working pressure. If it is demonstrated by other means that the strength of casing parts is sufficient, a tightness test at 1,1 times the maximum permissible working pressure may be accepted by the Society. Where the hydrostatic test cannot be performed, alternative methods for verifying the integrity of the casings may be agreed between the manufacturer and the Society on a case by case basis.

4.5.4 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.5.5 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above overspeed values and that rotors are free from defects, as verified by means of non-destructive tests.

4.5.6 Shop trials

For shop trials, see [4.2.3] and [4.3.2].

4.6 Certification

4.6.1 Type approval certificate and its validity

Subject to the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the engine manufacturer a "Type Approval Certificate" valid for all turbines of the same type.

4.6.2 Testing certification

a) Turbines admitted to an alternative inspection scheme

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 3 and tests and trials listed in [4.5.1]. However, the Society reserves the right to request that the shop trials be witnessed by a Surveyor on a case by case basis.

b) Engines not admitted to an alternative inspection scheme

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 3 and for works trials as per [4.5.3] and [4.5.4].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for the other items listed in Tab 3 and for trials described in [4.5.2], [4.5.5] and [4.5.6].

5 Additional requirements for dual fuel (DF) gas turbines

5.1 Design principles

5.1.1 DF gas turbines are to be designed so as to operate safely with any gas composition within the ship specification range, taking into account the possible variations of the gas composition during the voyage. Tests are to be carried out to demonstrate their ability in this respect.

5.1.2 DF gas turbines and associated gas treatment and gas supply systems as well as their control system are to be so designed and arranged as to allow the proper operation of the turbine taking into account the expected variations of the gas characteristics, in particular:

- lower heating value
- specific gravity
- gas temperature
- ambient temperature.

5.1.3 The fuel supply to DF gas turbines is to be capable of being switched over from gas fuel to oil fuel while the turbine is running, without significant fluctuation of the turbine output nor of the rotational speed.

5.1.4 Prior to a normal stop, a DF gas turbine is to be switched over from gas fuel to oil fuel.

5.1.5 After each gas operation of a DF gas turbine not followed by an oil fuel operation, the turbine including the exhaust system is to be purged during a sufficient time in order to discharge the gas which may be present.

5.1.6 DF gas turbines are to be fitted with a control system allowing a steady running with stable combustion, with any kind of gas as mentioned in [5.1.1] above, throughout the operating speed range of the turbine. Automatic switch over to oil fuel may however be accepted at low loads.

5.1.7 Gas fuel and oil fuel supply systems to DF gas turbines are to be so designed and controlled as to avoid any excessive gas delivery to the turbine, which may result in overspeed, in particular while the turbine is running with gas fuel and oil fuel at the same time.

5.1.8 Arrangements are to be made to avoid the condensation of heavy hydrocarbons or water in the turbine gas inlet system. Where this is achieved by heating the gas fuel, a superheat of at least 28°C above the dew point is to be observed to ensure that no liquid may appear in the gas system downstream of the heater. Where necessary, the gas piping system is to be heat traced to avoid any condensation, in particular during the turbine start-up.

5.2 Control, alarms and safety systems

5.2.1 Control systems of DF gas turbines are to be type-approved by the Society.

5.2.2 The alarm and safety systems are to be provided in accordance with Tab 4.

5.3 Type tests

5.3.1 DF gas turbines are to be subjected to specific type tests in gas mode and dual fuel mode, according to an approved program.

Table 4 : Dual fuel gas turbine alarm and safety systems

Parameter	Alarms	Automatic safety actions			
		Activation of the block-and-bleed valves	Activation of the master gas valve	Switch over to oil fuel mode	Engine shut down
Gas supply - abnormal pressure	L+H	X		X	
Gas supply - abnormal temperature	L+H	X		X	
Gas admission valve - failure	X	X		X	
Turbine stop from any cause	X	X			
Note 1: Symbol convention: H = High, L = Low, X = function is required					

Section 6 Gearing

1 General

1.1 Application

1.1.1 Unless otherwise specified, the requirements of this Section apply to:

- reduction and/or reverse enclosed gears intended for propulsion plants with a transmitted power of 220 kW and above
- other reduction and step-up enclosed gears with a transmitted power of 110 kW and above.

These requirements, however, may be applied to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above at the request of the Society.

The provisions of Article [2] apply only to cylindrical involute spur or helical gears with external or internal teeth.

The provisions of Article [3] apply only to bevel gears (straight or oblique teeth). Application of other specific methods for the design of bevel gears could be taken into consideration by the Society.

Additional requirements for gears fitted to ships having an **ICE** notation are given in Part F, Chapter 8.

1.2 Documentation to be submitted

1.2.1 Documents

Before starting construction, all plans, specifications and calculations listed in Tab 1 are to be submitted to the Society.

1.2.2 Data

The data listed in Tab 2 or Tab 3 and in Tab 4 are to be submitted with the documents required in [1.2.1].

Table 1 : Documents to be submitted for gearing

No.	A/I **(2)**	Description of the document **(1)**
1	A	Constructional drawings of shafts and flanges
2	A	Constructional drawings of pinions and wheels, including: a) specification and details of hardening procedure: • core and surface mechanical characteristics • diagram of the depth of the hardened layer as a function of hardness values b) specification and details of the finishing procedure: • finishing method of tooth flanks (hobbling, shaving, lapping, grinding, shot-peening) • surface roughness for tooth flank and root fillet • tooth flank corrections (helix modification, crowning, tip-relief, end-relief), if any • flank tolerance class according to ISO 1328-1:2013
3	A	Shrinkage calculation for shrunk-on pinions, wheels rims and/or hubs with indication of the minimum and maximum shrinkage allowances
4	I	Calculation of load capacity of the gears
5	A/I **(3)**	Constructional drawings of casings
6	A	Functional diagram of the lubricating system, with indication of the: • specified grade of lubricating oil • expected oil temperature in service • kinematic viscosity of the oil
7	A	Functional diagram of control, monitoring and safety systems
8	I	Longitudinal and transverse cross-sectional assembly of the gearing, with indication of the type of clutch
9	I	Data form for calculation of gears **(4)**
10	I	Detailed justification of material quality used for gearing calculation (ML, MQ, or ME according to ISO 6336-5)

(1) Constructional drawings are to be accompanied by the specification of the materials employed including the chemical composition, heat treatment and mechanical properties and, where applicable, the welding details, welding procedure and stress relieving procedure.

(2) Submission of the drawings may be requested:
- for approval, shown as "A" in the Table
- for information, shown as "I" in the Table.

(3) "A" for welded casing, "I" otherwise

(4) The forms are given in Tab 2, Tab 3 and Tab 4.

Table 2 : Data to be submitted for cylindrical gears

Symbol	Values		Unit	Description
	Pinion	Wheel		
a			mm	Operating centre distance
b_B			mm	Common face width (for double helix gear, width of one helix)
A			-	Flank tolerance class according to ISO 1328-1:2013
b_S			mm	Web thickness
s_R			mm	Rim thickness
$R_{m,rim}$			N/mm^2	Ultimate tensile strength of the rim material
B			mm	Total face width of double helix gears, including gap
d_s			mm	Shrinkage diameter
m_n			mm	Normal module
α_n			deg or rad	Normal pressure angle at reference cylinder
β			deg or rad	Helix angle at reference cylinder
x			-	Addendum modification coefficient
z			-	Number of teeth
P			kW	Transmitted power
n			rpm	Rotational speed
d_a			mm	Tip diameter
ρ_{a0}			mm	Tip radius of the tool
h_{fp}			mm	Basic rack dedendum
HRC			-	Rockwell hardness
R_{Zf}			µm	Mean peak-to-valley flank roughness of the gear pair
R_Z			µm	Mean peak-to-valley roughness of the gear pair
$R_{e,s}$			N/mm^2	Minimum yield strength of the shaft material
ν_{40}			mm^2/s	Nominal kinematic viscosity of oil at 40°C
pr			mm	Protuberance of the tool
q			mm	Material allowance for finish machining
d_{ext}			mm	External shaft diameter
d_{int}			mm	Internal shaft diameter
ℓ			mm	Bearing span
Z_E			N$^{1/2}$/mm	Elasticity factor

Table 3 : Data to be submitted for bevel gears

Symbol	Values		Unit	Description
	Pinion	Wheel		
A			-	Flank tolerance class according to ISO 1328-1:2013
s_R			mm	Rim thickness
d_s			mm	Shrinkage diameter
b			mm	Common face width (for double helix gear width of one helix)
m_{mn}			mm	Mean normal module
α_n			deg or rad	Normal pressure angle
β_m			deg or rad	Mean helix angle
z			-	Actual number of teeth
δ			deg or rad	Pitch angle
x_h			-	Addendum modification coefficient
x_s			-	Thickness modification coefficient
h_{aP}			mm	Addendum of the basic rack tooth profile
h_{fP}			mm	Dedendum of the basic rack tooth profile
ρ_{a0}			mm	Cutter edge radius

Symbol	Values		Unit	Description
	Pinion	Wheel		
r_{c0}			mm	Cutter radius
P			kW	Transmitted power
n			rpm	Rotational speed
HRC			-	Rockwell hardness
R_{Zf}			µm	Mean peak-to-valley flank roughness of the gear pair
R_Z			µm	Mean peak-to-valley roughness of the gear pair
$R_{e,s}$			N/mm^2	Minimum yield strength of the shaft material
ν_{40}			mm^2/s	Nominal kinematic viscosity of oil at 40°C
pr			mm	Protuberance of the tool
q			mm	Material allowance for finish machining
d_{ext}			mm	External shaft diameter
d_{int}			mm	Internal shaft diameter
ℓ			mm	Bearing span
Z_E			$N^{1/2}/mm$	Elasticity factor

Table 4 : General data to be submitted for bevel and cylindrical gears

Condition of use Tick the box

Main gears (propulsion)	Diesel engine	with hydraulic coupling	
		with elastic coupling	
		with other type of coupling	
	Turbine		
	Electric motor		
Gears intended for ahead running			
Gears intended for astern running only			
Other intermittent running			
Gears with occasional part load in reverse direction (main wheel in reverse gearbox)			
Idler gears			
Shrunk on pinions and wheel rims			
Otherwise			

Arrangement

Single gear		
Dual tandem gear	without quill shaft **(1)**	
	with quill shaft **(1)**	
Epicyclic gear	with 3 planetary gears and less	
	with 4 planetary gears	
	with 5 planetary gears	
	with 6 planetary gears and more	

Machining

No modification	
Central crowning fma	
Central crowning fma + fsh	
Helix correction	
Helix correction + crowning	
End relief	
Maximum base pitch deviation of the wheel	
With optimum profile correction	

(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.

Material			Pinion	Wheel
St	Normalized low carbon steels / cast steels	Wrought normalized low carbon steels		
St (Cast)		Cast steels		
GTS (Perl.)	Cast iron materials	Black malleable cast iron (perlitic structure)		
GGG (Perl.)		Nodular cast iron (perlitic structure)		
GGG (Bai.)		Nodular cast iron (bainitic structure)		
GGG (ferr.)		Nodular cast iron (ferritic structure)		
GG		Grey cast iron		
V	Through-hardened wrought steels	Carbon steels, alloy steels		
V (cast)	Through-hardened cast steels	Carbon steels, alloy steels		
Eh	Case-hardened wrought steels			
IF	Flame or induction hardened wrought or cast steels			
NT (nitr.)	Nitrided wrought steels/nitrided steels / nitrided through-hardening steels	Nitriding steels		
NV (nitr.)		Through-hardening steels		
NV (nitrocar.)	Wrought steels, nitrocarburized	Through-hardening steels		
(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.				

2 Design of gears - Determination of the load capacity of cylindrical gears

2.1 Symbols, units, definitions

2.1.1 Symbols and units

The meaning of the main symbols used in this Article is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate sub-articles.

A : Flank tolerance class according to ISO 1328-1:2013

a : Operating centre distance, in mm

b : Effective face width, in mm (for double helix gear, b = 2 b_B)

b_B : Common face width, in mm (for double helix gear, width of one helix)

b_S : Web thickness, in mm

B : Total face width of double helix gear, including gap, in mm

d : Reference diameter, in mm

d_a : Tip diameter, in mm

d_b : Base diameter, in mm

d_{ext} : External diameter of shaft, in mm

d_{int} : Internal diameter of shaft, in mm

d_f : Root diameter, in mm

d_s : Shrinkage diameter, in mm

d_w : Working pitch diameter, in mm

F_t : Nominal tangential load, in N

F_β : Total helix deviation, in µm

h : Tooth depth, in mmHB

h_{fp} : Basic rack dedendum, in mm

HB : Brinell hardness, in N/mm^2

HRC : Rockwell hardness

HV : Vickers hardness, in N/mm^2

k : Gear axial position on shaft with respect to the bearings

ℓ : Bearing span, in mm

m_n : Normal module, in mm

m_t : Transverse module, in mm

n : Rotational speed, in rpmP

P : Transmitted power, in kW

pr : Protuberance of the tool, in mm

q : Material allowance for finish machining, in mm

$R_{m,rim}$: Ultimate tensile strength of the rim material, in N/mm²
$R_{e,s}$: Minimum yield strength of the shaft material, in N/mm²
R_Z : Mean peak-to-valley roughness of the gear pair, in µm
R_{Zf} : Mean peak-to-valley flank roughness of the gear pair, in µm
s_R : Rim thickness, in mm
T : Transmitted torque, in kN.m
u : Reduction ratio
v : Linear velocity at pitch diameter, in m/s
x : Addendum modification coefficient
z : Number of teeth
z_n : Virtual number of teeth
α_a : Transverse profile angle at tooth tip
α_n : Normal pressure angle at reference cylinder
α_t : Transverse pressure angle at reference cylinder
α_{tw} : Transverse pressure angle at working pitch cylinder
β : Helix angle at reference cylinder
β_b : Base helix angle
ε_α : Transverse contact ratio
ε_β : Overlap ratio
ε_γ : Total contact ratio
ν_{40} : Nominal kinematic viscosity of oil at 40°C, in mm²/s
ρ_{a0} : Tip radius of the tool, in mm
σ_F : Tooth root bending stress, in N/mm²
σ_{FE} : Endurance limit for tooth root bending stress, in N/mm²
σ_{FP} : Permissible tooth root bending stress, in N/mm²
σ_H : Contact stress, in N/mm²
$\sigma_{H,lim}$: Endurance limit for contact stress, in N/mm²
σ_{HP} : Permissible contact stress, in N/mm²

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

2.1.2 Geometrical definitions

In the calculation of surface durability, b is the minimum face width on the pitch diameter between pinion and wheel.

In tooth strength calculations, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 or b_2 are not to be taken greater than b by more than one module m_n (in case of width of one gear much more important than the other).

For internal gear, z_2, a, d_2, d_{a2}, d_{b2}, x_2 and d_{w2} are to be taken negative.

$$u = \frac{z_2}{z_1}$$

Note 1: $u > 0$ for external gears, $u < 0$ for internal gears.

$$\tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta}$$

$$d_i = \frac{z_i \cdot m_n}{\cos\beta}$$

$$d_{bi} = d_i \cdot \cos\alpha_t$$

$$d_{w1} = \frac{2 \cdot a}{1 + u}$$

$$d_{w2} = \frac{2 \cdot a \cdot u}{1 + u}$$

$$d_{fi} = d_i + 2 \cdot m_n \cdot x_i - 2 \cdot h_{fPi}$$

$$h_i = 0{,}5\ (d_{ai} - d_{fi})$$

$$\cos\alpha_{tw} = \frac{d_{b1} + d_{b2}}{2a}$$

$$\sin\beta_b = \sin\beta \cdot \cos\alpha_n$$

$$z_{ni} = \frac{z_i}{\cos\beta \cdot (\cos\beta_b)^2}$$

$$\cos\alpha_{ai} = \frac{d_{bi}}{d_{ai}}$$

$$\varepsilon_\alpha = \frac{z_1}{2\pi}(\tan\alpha_{a1} - \tan\alpha_{wt}) + \frac{z_2}{2\pi}(\tan\alpha_{a2} - \tan\alpha_{wt})$$

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{\pi \cdot m_n}$$

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$F_{\beta i} = 2^{0,5 \cdot (Q_i - 5)} \cdot (0,1 \cdot |d_i|^{0,5} + 0,63 \cdot b_B{}^{0,5} + 4,2)$$

$$T_i = \frac{60}{2\pi} \cdot \frac{P}{n_i}$$

$$F_t = \frac{P}{n_1} \cdot \frac{60}{\pi \cdot d_1} \cdot 10^6$$

$$v_i = \frac{\pi \cdot n_i}{60} \cdot \frac{d_{wi}}{10^3}$$

2.2 Principle

2.2.1

a) The following requirements apply to cylindrical involute spur or helical gears with external or internal teeth, and provide a method for the calculation of the load capacity with regard to:

- the surface durability (contact stress)
- the tooth root bending stress.

The cylindrical gears for marine application are to comply with the following restrictions:

- $1,2 < \varepsilon_\alpha < 2,5$
- $\beta < 30°$
- $s_R > 3,5\ m_n$

The relevant formulae are provided in [2.4] and [2.5].

The influence factors common to the formulae are given in [2.3].

b) Gears, for which the conditions of validity of some factors or formulae are not satisfied, will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society. Any alternative calculations are to comply with the ISO 6336 series standard.

2.3 General influence factors

2.3.1 General

General influence factors are defined in [2.3.2], [2.3.3], [2.3.4], [2.3.5] and [2.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

2.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing (driven and driving machines).

The values of K_A are given in Tab 5.

2.3.3 Load sharing factor K_γ

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or tandem gears.

The values of K_γ are given in Tab 6.

Table 5 : Application factor K_A

Type of installation			K_A
Main gears (propulsion)	Diesel engine	with hydraulic coupling	1,05
		with elastic coupling	1,30
		with other type of coupling	1,50
	Turbine		1,05
	Electric motor		1,05
Auxiliary gears	Diesel engine	with hydraulic coupling	1,00
		with elastic coupling	1,20
		with other type of coupling	1,40
	Electric motor		1,00

Table 6 : Load sharing factor K_γ

Type of gear		K_γ
Dual tandem gear	without quill shaft **(1)**	1,15
	with quill shaft **(1)**	1,10
Epicyclic gear	with 3 planetary gears and less	1,00
	with 4 planetary gears	1,20
	with 5 planetary gears	1,30
	with 6 planetary gears and more	1,40
(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.		

2.3.4 Dynamic factor K_V (method B)

The dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of the pinion and the wheel.

The calculation of the dynamic factor K_V is defined in Tab 7, where:

N : Resonance ratio, i.e. ratio of the pinion speed to the resonance speed:

$N = n_1 / n_{E1}$, with:

n_{E1} : Resonance speed, in rpm, defined by the following formula:

$$n_{E1} = \frac{30000}{\pi z_1} \cdot \sqrt{\frac{c_{\gamma\alpha}}{m_{red}}}$$

where:

m_{red} : Reduced mass of gear pair, in kg/mm

In case of external gears, estimated calculation of m_{red} is given in Tab 8

$c_{\gamma\alpha}$: Mesh stiffness, in N/(mm·µm).

For gears with $\beta \leq 30°$, the calculation of $c_{\gamma\alpha}$ is detailed in Tab 9.

The value of N determines the range of vibrations:

- subcritical range, when $N \leq N_S$
- main resonance range, when $N_S < N < 1,15$

  This field is not permitted
- intermediate range, when $1,15 \leq N \leq 1,50$

  This field is normally to be avoided. Some alternative and more precise calculation could be accepted and special consideration will be given by the Society
- supercritical range, when $1,50 < N$.

The lower limit of resonance N_S is defined as follows:

- if $F_t K_A / b \geq 100$ N/mm:

  $N_s = 0,85$
- if $F_t K_A / b < 100$ N/mm:

$$N_s = 0,5 + 0,35 \sqrt{\frac{F_t K_A}{100b}}$$

Table 7 : Dynamic factor K_V

Resonance domain	Factor K_V
$N \le N_S$	$K_V = N\,(C_{v1}\,B_P + C_{v2}\,B_f + C_{v3}\,B_K) + 1$
$N > 1,50$	$K_V = C_{v5}\,B_P + C_{v6}\,B_F + C_{v7}$

Note 1:

B_P : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_P = \frac{c' \cdot f_{pb,eff}}{K_A \cdot (F_t/b)}$$

with:

c' : Single stiffness defined in Tab 9

$f_{pb,eff}$: Effective base pitch deviation, in µm, equal to: $f_{pb,eff} = f_{pb} - y_\alpha$ with f_{pb} defined in Tab 14 and y_α defined in Tab 15

B_f : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$B_f = B_P$

B_k : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_k = \left|1 - \frac{c' \cdot C_a}{K_A \cdot F_t/b}\right|$$

with:

$$C_a = \frac{1}{18} \cdot \left(\frac{\sigma_{Hlim}}{97} - (18,45\ )\right)^2 + 1,5$$

When material of the pinion is different from that of the wheel: $C_a = 0,5\,(C_{a1} + C_{a2})$

C_{v1} : Factor for pitch deviation effects: $C_{v1} = 0,32$

C_{v2} : Factor for tooth profile deviation effects:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v2} = 0,34$
- if $2 < \varepsilon_\gamma$: $C_{v2} = 0,57 / (\varepsilon_\gamma - 0,3)$

C_{v3} : Factor for cyclic variation effect in mesh stiffness:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v3} = 0,23$
- if $2 < \varepsilon_\gamma$: $C_{v3} = 0,096 / (\varepsilon_\gamma - 1,56)$

C_{v5} : Factor: $C_{v5} = 0,47$

C_{v6} : Factor:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v6} = 0,47$
- if $2 < \varepsilon_\gamma$: $C_{v6} = 0,12 / (\varepsilon_\gamma - 1,74)$

C_{v7} : Factor:

- if $1 < \varepsilon_\gamma \le 1,5$: $C_{v7} = 0,75$
- if $1,5 < \varepsilon_\gamma \le 2,5$: $C_{v7} = 0,125 \sin[\pi\,(\varepsilon_\gamma - 2)] + 0,875$
- if $2,5 < \varepsilon_\gamma$: $C_{v7} = 1$

Table 8 : Estimated calculation of reduced mass m_{red}

Gear rim	Rim ratio	m_{red}, in kg/mm
$s_{Ri} = 0$	$1 - q_i^4 = 1$	$m_{red} = \frac{\pi}{8} \cdot \left(\frac{d_{a1} + d_{f1}}{2\,d_{b1}}\right)^2 \cdot \frac{(d_{f1} + d_{a1})^2}{4 \cdot \left(\frac{1}{\rho_1} + \frac{1}{\rho_2 \cdot u^2}\right)}$
$s_{Ri} \ne 0$	$q_i = \frac{2 \cdot (d_{fi} - 2 \cdot s_{Ri})}{d_{fi} + d_{ai}}$	$m_{red} = \frac{\pi}{8} \cdot \left(\frac{d_{a1} + d_{f1}}{2\,d_{b1}}\right)^2 \cdot \frac{(d_{f1} + d_{a1})^2}{4 \cdot \left[\frac{1}{(1 - q_1^4) \cdot \rho_1} + \frac{1}{(1 - q_2^4) \cdot \rho_2 \cdot u^2}\right]}$

Note 1:

ρ_i is the density of gearing material ($\rho = 7,83 \cdot 10^{-6}$ for steel)

Table 9 : Mesh stiffness $c_{\gamma\alpha}$ (method B)

Specific load	$c_{\gamma\alpha}$, in N/(mm.µm) **(1)**
$F_t K_A / b \geq 100$ N/mm	$c_{\gamma\alpha} = c' (0,75\ \varepsilon_\alpha + 0,25) = c'_{th}\ C_M\ C_R\ C_B \cos\beta\ (0,75\ \varepsilon_\alpha + 0,25)$
$F_t K_A / b < 100$ N/mm	$c_{\gamma\alpha} = c'(0,75\ \varepsilon_\alpha + 0,25) = c'_{th}\ C_M C_R C_B \cos\beta \left(\frac{F_t K_A / b}{100}\right)^{0,25} (0,75\ \varepsilon_\alpha + 0,25)$

(1) When $\varepsilon_\alpha < 1,2$: $c_{\gamma\alpha}$ may be reduced up to 10% in case of spur gears.

Note 1:

c' : Single stiffness, in N/(mm.µm)

c'_{th} : Theoretical mesh stiffness, in N/(mm.µm), equal to:

$$c'_{th} = \frac{1}{0,04723 + \frac{0,15551}{z_{n1}} + \frac{0,25791}{z_{n2}} - 0,00635\ x_1 - 0,00193\ x_2 - \frac{0,11654\ x_1}{z_{n1}} - \frac{0,24188\ x_2}{z_{n2}} + 0,00529\ x_1^2 + 0,00182\ x_2^2}$$

where the following limitations are to be verified:

- $x_1 \geq x_2$, and
- $-0,5 \leq x_1 + x_2 \leq 2,0$

For internal gears, z_{n2} should be replaced by infinity

C_M : Measurements correction factor, equal to:

$C_M = 0,8$

C_R : Gear blank factor:

- for solid disc gears ($s_R = 0$):

  $C_R = 1,0$
- otherwise:

$$C_R = 1 + \frac{\ln(b_s / b)}{5 \cdot e^{s_R / 5 m_n}}$$

with the following limitations:

$0,2 \leq b_s / b \leq 1,2$ and $s_R / m_n \geq 1$

C_B : Basic rack factor, equal to:

$$C_B = 1 + 0,5 \cdot \left(1,2 - \frac{h_{fP}}{m_n}\right) \cdot [1,0 - 0,02 \cdot (20 - \alpha_n)]$$

When pinion basic rack dedendum is different from that of the wheel, $C_B = 0,5\ (C_{B1} + C_{B2})$.

2.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$ (method C)

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

a) The values of $K_{H\beta}$ are given in Tab 10. They apply only to gears with:

- wheel, case, wheel shaft and bearings of stiff construction
- pinion on a solid or hollow shaft with an inner diameter ratio not exceeding 0,5 and located symmetrically between the bearings
- no effect of clearances
- no external loads acting on the pinion shaft.

Note 1: Gears for which the above conditions are not satisfied will be given special consideration by the Society.

The calculation of the initial equivalent misalignment $F_{\beta x}$ is defined in Tab 11.

The calculations of the running-in allowance $y\beta$ and the running-in factor $\chi\beta$ are defined in Tab 12.

The calculation of the mesh misalignment due to deformations of shafts depends on the constant of the pinion K' and the distance s of the pinion. They are defined in Tab 13.

b) $K_{F\beta}$ is to be determined using the following formula:

$$K_{F\beta} = \sqrt[1 + h/b_B + (h/b_B)^2]{K_{H\beta}}$$

where b/h is the smaller of b_{B1}/h_1 and b_{B2}/h_2 but is not to be taken lower than 3.

2.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ (method B)

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are given in Tab 14.

Table 10 : Face load factor for contact stress $K_{H\beta}$

	Calculated face width	Factor $K_{H\beta}$
$\frac{F_{\beta y} c_{\gamma\beta}}{2F_m/b} \geq 1$	$\frac{b_{cal}}{b} = \sqrt{\frac{2F_m/b}{F_{\beta y} c_{\gamma\beta}}} \leq 1$	$K_{H\beta} = \sqrt{\frac{2F_{\beta y} c_{\gamma\beta}}{F_m/b}} \geq 2$
$\frac{F_{\beta y} c_{\gamma\beta}}{2F_m/b} < 1$	$\frac{b_{cal}}{b} = 0,5 + \frac{F_m/b}{F_{\beta y} c_{\gamma\beta}} > 1$	$K_{H\beta} = 1 + \frac{F_{\beta y} c_{\gamma\beta}}{2F_m/b} < 2$

Note 1:

b_{cal} : Calculated face width, in mm

F_m : Mean transverse tangential load, in N:

$F_m = F_t K_A K_V$

$F_{\beta y}$: Effective misalignment after running-in, in µm:

$F_{\beta y} = F_{\beta x} - y_\beta = F_{\beta x} \chi_\beta$

where:

$F_{\beta x}$: Initial equivalent misalignment. Estimated values are given in Tab 11

y_β, χ_β : Running-in allowance, in µm, and running-in factor, respectively, defined in Tab 12

$c_{\gamma\beta}$: Mesh stiffness, in N/(mm·µm):

$c_{\gamma\beta} = 0,85\ c_{\gamma\alpha}$

$c_{\gamma\alpha}$ being the mesh stiffness defined in Tab 9.

Table 11 : Initial equivalent misalignment $F_{\beta x}$

Helix modification	$F_{\beta x}$, in µm **(1)**	Default estimated values of f_{ma}
None	$F_{\beta x} = 1,33\ f_{sh} + f_{ma}$	$f_{ma} = F_\beta$
Central crowning with $C_\beta = 0,5\ f_{ma}$	$F_{\beta x} = 1,33\ f_{sh} + 0,5\ f_{ma}$	$f_{ma} = 0,5\ F_\beta$
Central crowning with $C_\beta = 0,5\ (f_{ma} + f_{sh})$	$F_{\beta x} = 0,665\ f_{sh} + 0,5\ f_{ma}$	$f_{ma} = 0,5\ F_\beta$
Helix correction	$F_{\beta x} = 0,133\ f_{sh} + f_{ma}$	$f_{ma} = 0,5\ F_\beta$
Helix correction plus central crowning	$F_{\beta x} = 0,133\ f_{sh} + 0,5\ f_{ma}$	$f_{ma} = 0,5\ F_\beta$
End relief	$F_{\beta x} = 0,931\ f_{sh} + 0,7\ f_{ma}$	$f_{ma} = 0,7\ F_\beta$

(1) The misalignment $F_{\beta x}$ is to be taken greater than $F_{\beta x,min} = 0,005\ F_m / b$

Note 1:

f_{sh} : Mesh misalignment due to deformations of shafts, in µm:

$$f_{sh} = \frac{F_m}{b} \cdot 0,023 \left(\left| B^* + K' \frac{\ell \cdot s \cdot d_1^{\,2}}{d_{ext}^{\,4}} - 0,3 \right| + 0,3 \right) \cdot \left(\frac{d_B}{d_1} \right)^2$$

where:

B* : Transmitted torque factor depending on k, percentage of input torque transmitted in one gear mesh:

- for spur and single helical gears: $B^* = 1 + 2\ (100 - k) / k$
- for double helical gears: $B^* = 0,5 + (200 - k) / k$

K′ : Constant of the pinion defined in Tab 13

s : Distance of the pinion, in mm, as shown in Tab 13

f_{ma} : Mesh misalignment due to manufacturing deviations, in µm.

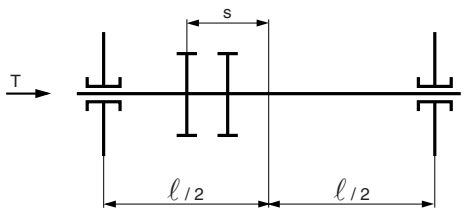
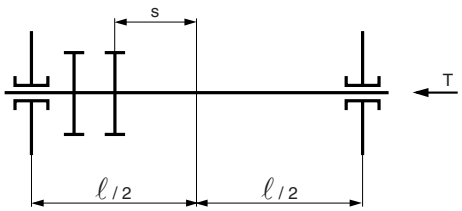
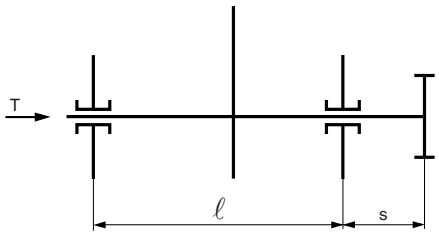
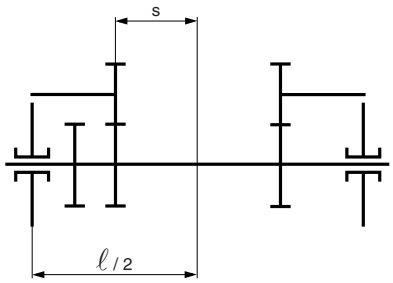
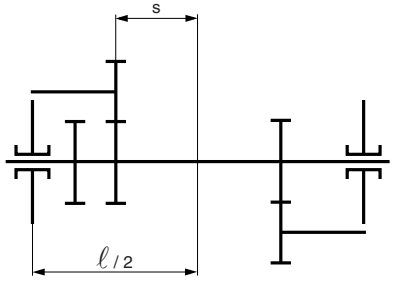
Table 12 : Running-in allowance y_β and running-in factor $\chi\beta$

Material	y_β, in µm	χ_β	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$y_\beta = \frac{320}{\sigma_{H,lim}} F_{\beta x}$	$\chi_\beta = 1 - \frac{320}{\sigma_{H,lim}}$	$y_\beta \leq F_{\beta x}$ and $\chi_\beta \geq 0$ • if 5 m/s < v ≤ 10 m/s: $y_\beta \leq 25600 / \sigma_{H,lim}$ • if 10 m/s < v: $y_\beta \leq 12800 / \sigma_{H,lim}$
GGG (ferr.), GG	$y_\beta = 0,55\ F_{\beta x}$	$\chi_\beta = 0,45$	• if 5 m/s < v ≤ 10 m/s: $y_\beta \leq 45$ • if 10 m/s < v: $y_\beta \leq 22$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$y_\beta = 0,15\ F_{\beta x}$	$\chi_\beta = 0,85$	$y_\beta \leq 6$

Note 1: $\sigma_{H,lim}$ is defined in [2.4.9].

Note 2: When material of the pinion differs from that of the wheel: $y_\beta = 0,5\ (y_{\beta 1} + y_{\beta 2})$ and $\chi_\beta = 0,5\ (\chi_{\beta 1} + \chi_{\beta 2})$

Table 13 : Constant of the pinion K' and distance of the pinion s

Arrangement **(1)**	Constant K' with stiffening	Constant K' without stiffening **(2)**
	0,48	0,8
	– 0,48	– 0,8
	1,33	1,33
	– 0,36	– 0,6
	– 0,6	– 1,0

(1) The following limitation is to be verified except when helix correction is applied:
$s / \ell < 0,3$

(2) No stiffening is assumed when $d_1 / d_{sh} < 1,15$ or when the pinion is keyed or shrinked to the shaft.

Table 14 : Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

	Factors $K_{H\alpha}$ and $K_{F\alpha}$	Limitations
$\varepsilon_\gamma \le 2$	$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_\gamma}{2}\left[0,9 + 0,4\,\frac{c_{\gamma\alpha}(f_{pb} - y_\alpha)}{F_{tH}/b}\right]$	$\frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2} \ge K_{H\alpha} \ge 1$
$\varepsilon_\gamma > 2$	$K_{H\alpha} = K_{F\alpha} = 0,9 + 0,4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\,\frac{c_{\gamma\alpha}(f_{pb} - y_\alpha)}{F_{tH}/b}$	$\frac{\varepsilon_\gamma}{0,25\,\varepsilon_\alpha + 0,75} \ge K_{F\alpha} \ge 1$

Note 1:

$c_{\gamma\alpha}$: Mesh stiffness, in N/mm.µm, defined in Tab 9

f_{pb} : Larger value of the base pitch deviation of pinion or wheel, in µm.

Default value: $f_{pb} = 0,3\,(m_n + 0,4\,|d_{bi}|^{0,5} + 4) \cdot 2^{0,5\,(Q_i - 5)}$

In case of optimum profile correction, f_{pb} is to be replaced by $f_{pb} / 2$

y_α : Running-in allowance, in µm, defined in Tab 15

F_{tH} : Determinant tangential load in transverse plane, in N:
$F_{tH} = F_t \cdot K_A \cdot K_V \cdot K_{H\beta}$

Table 15 : Running-in allowance y_α

Material	y_α, in µm	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$y_\alpha = \frac{160}{\sigma_{H,\,lim}} f_{pb}$	• if 5 m/s < v ≤ 10 m/s: $y_\alpha \le 12800 / \sigma_{H,lim}$ • if 10 m/s < v: $y_\alpha \le 6400 / \sigma_{H,lim}$
GGG (ferr.), GG	$y_\alpha = 0,275\, f_{pb}$	• if 5 m/s < v ≤ 10 m/s: $y_\alpha \le 22$ • if 10 m/s < v: $y_\alpha \le 11$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$y_\alpha = 0,075\, f_{pb}$	$y_\alpha \le 3$

Note 1: f_{pb} is defined in Tab 14 and $\sigma_{H,lim}$ is defined in [2.4.9].

Note 2: When material of the pinion differs from that of the wheel: $y_\alpha = 0,5\,(y_{\alpha 1} + y_{\alpha 2})$

2.4 Calculation of surface durability

2.4.1 General

The criterion for surface durability is based on the contact stress (hertzian pressure) σ_H on the pitch point or at the inner point of single pair contact.

The contact stress σ_H, defined in [2.4.2], is not to exceed the permissible contact stress σ_{HP} defined in [2.4.8].

2.4.2 Contact stress σ_H

The contact stress σ_H, in N/mm^2, is to be determined as follows.

- for the pinion:

$$\sigma_H = Z_B \cdot \sigma_{H0} \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

- for the wheel:

$$\sigma_H = Z_D \cdot \sigma_{H0} \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

Z_B, Z_D : Single pair mesh factors, respectively for pinion and for wheel, defined in [2.4.3]

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

K_V : Dynamic factor (see [2.3.4])

$K_{H\beta}$: Face load distribution factor (see [2.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [2.3.6])

$$\sigma_{H0} = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \cdot \frac{|u| + 1}{|u|}}$$

with:

Z_H : Zone factor, defined in [2.4.4]

Z_E : Elasticity factor, defined in [2.4.5]

Z_ε : Contact ratio factor, defined in [2.4.6]

Z_β : Helix angle factor, defined in [2.4.7].

2.4.3 Single pair mesh factors Z_B and Z_D

The single pair mesh factors Z_B for pinion and Z_D for wheel account for the influence on contact stresses of the tooth flank curvature at the inner point of single pair contact in relation to Z_H. These factors transform the contact stress determined at the pitch point to contact stresses, considering the flank curvature at the inner point of single pair contact.

Z_B and Z_D are to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

- $Z_B = M_1$ or 1, whichever is the greater, with:

$$M_1 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{z_1}\right] \cdot \left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_2}\right]}}$$

- $Z_D = M_2$ or 1, whichever is the greater, with:

$$M_2 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \frac{2\pi}{z_2}\right] \cdot \left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_1}\right]}}$$

b) for helical gears:

- if $\varepsilon_\beta \geq 1$:

  $Z_B = Z_D = 1$

- if $\varepsilon_\beta < 1$:

  $Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$ or 1, whichever is the greater

  $Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$ or 1, whichever is the greater.

Note 1: For gears with $\varepsilon_\alpha \leq 1$, a specific analysis of the decisive contact stress along the path of contact is necessary.

Note 2: For internal gears, $Z_D = 1$.

2.4.4 Zone factor Z_H

The zone factor Z_H accounts for the influence on the hertzian pressure of tooth flank curvature at the pitch point and transforms the tangential force at the reference cylinder to normal force at the pitch cylinder.

Z_H is to be determined as follows:

$$Z_H = \sqrt{\frac{2 \cdot \cos\beta_b \cdot \cos\alpha_{tw}}{(\cos\alpha_t)^2 \cdot \sin\alpha_{tw}}}$$

2.4.5 Elasticity factor Z_E

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the hertzian pressure.

For steel gears: $Z_E = 189{,}8\ N^{1/2}/mm$.

Note 1: Refer to ISO 6336-2 for other materials.

2.4.6 Contact ratio factor Z_ε

The contact ratio factor Z_ε accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

Z_ε is to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$$

b) for helical gears:

- for $\varepsilon_\beta \geq 1$:

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$$

- for $\varepsilon_\beta < 1$:

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3} \cdot (1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$$

2.4.7 Helix angle factor Z_β

The helix angle factor Z_β accounts for the influence of helix angle on the surface durability, allowing for such variables as the distribution of the load along the lines of contact.

Z_β is to be determined as follows:

$$Z_\beta = \frac{1}{\sqrt{\cos\beta}}$$

2.4.8 Permissible contact stress σ_{HP}

The permissible contact stress σ_{HP}, in N/mm^2, is to be determined separately for pinion and wheel, using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,lim}}{S_H} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$$

where:

$\sigma_{H,lim}$: Endurance limit for contact stress, defined in [2.4.9]

Z_{NT} : Life factor for contact stress, defined in [2.4.10]

Z_L, Z_V, Z_R: Lubrication, speed and roughness factors, respectively, defined in [2.4.11]

Z_W : Hardness ratio factor, defined in [2.4.12]

Z_X : Size factor for contact stress, defined in [2.4.13]

S_H : Safety factor for contact stress, defined in [2.4.14].

2.4.9 Endurance limit for contact stress $\sigma_{H,lim}$

The endurance limit for contact stress $\sigma_{H,lim}$ is the limit of repeated contact stress which can be permanently endured.

The values to be adopted for $\sigma_{H,lim}$ are given, in N/mm^2, with the following formula, in relation to the type of steel employed and the heat treatment performed:

$\sigma_{H,lim} = A\ x + B$

where:

A, B : Constants determined in Tab 16

x : Surface hardness HB or HV, in N/mm^2. The limitations x_{min} and x_{max} on surface hardness are indicated in Tab 16.

Special consideration will be given to other values of $\sigma_{H,lim}$, depending on the material category and specification of the steel employed.

Table 16 : Constants A and B and limitations on surface hardness HB or HV

	Quality **(1)**	A	B (N/mm^2)	Hardness	x_{min} (N/mm^2)	x_{max} (N/mm^2)
St	ML	1,000	190	HB	110	210
	MQ	1,000	190	HB	110	210
	ME	1,520	250	HB	110	210
St (cast)	ML	0,986	131	HB	140	210
	MQ	0,986	131	HB	140	210
	ME	1,143	237	HB	140	210
GTS (perl.)	ML	1,371	143	HB	135	250
	MQ	1,371	143	HB	135	250
	ME	1,333	267	HB	175	250
GGG	ML	1,434	211	HB	175	300
	MQ	1,434	211	HB	175	300
	ME	1,500	250	HB	200	300
GG	ML	1,033	132	HB	150	240
	MQ	1,033	132	HB	150	240
	ME	1,465	122	HB	175	275
V (carbon steels)	ML	0,963	283	HV	135	210
	MQ	0,925	360	HV	135	210
	ME	0,838	432	HV	135	210

(1) The requirements for each material quality are defined in ISO 6336-5.

	Quality **(1)**	A	B (N/mm²)	Hardness	x_{min} (N/mm²)	x_{max} (N/mm²)
V (alloy steels)	ML	1,313	188	HV	200	360
	MQ	1,313	373	HV	200	360
	ME	2,213	260	HV	200	390
V (cast, carbon steels)	ML	0,831	300	HV	130	215
	MQ	0,831	300	HV	130	215
	ME	0,951	345	HV	130	215
V (cast, alloy steels)	ML	1,276	298	HV	200	360
	MQ	1,276	298	HV	200	360
	ME	1,350	356	HV	200	360
Eh	ML	0,000	1300	HV	600	800
	MQ	0,000	1500	HV	660	800
	ME	0,000	1650	HV	660	800
IF	ML	0,740	602	HV	485	615
	MQ	0,541	882	HV	500	615
	ME	0,505	1013	HV	500	615
NT (nitr.)	ML	0,000	1125	HV	650	900
	MQ	0,000	1250	HV	650	900
	ME	0,000	1450	HV	650	900
NV (nitr.)	ML	0,000	788	HV	450	650
	MQ	0,000	998	HV	450	650
	ME	0,000	1217	HV	450	650
NV (nitrocar.)	ML	0,000	650	HV	300	650
	MQ	1,167	425	HV	300	450
	ME	1,167	425	HV	300	450
(1) The requirements for each material quality are defined in ISO 6336-5.						

2.4.10 Life factor for contact stress Z_{NT}

The life factor Z_{NT} accounts for the influence of limited service life on the permissible contact stress.

Some values of Z_{NT} are given for information in Tab 17.

The value of Z_{NT} to be used will be given special consideration by the Society, depending on the equipment's arrangement and use.

Table 17 : Life factor Z_{NT}

Material	Number of load cycles N_L	Z_{NT}
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast), Eh, IF	$N_L \leq 10^5$ or static	1,6
	$N_L = 5 \cdot 10^7$	1,0
	$N_L = 10^9$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
GGG (ferr.), GG, NT (nitr.), NV (nitr.)	$N_L \leq 10^5$ or static	1,3
	$N_L = 2 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
NV (nitrocar.)	$N_L \leq 10^5$ or static	1,1
	$N_L = 2 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0

2.4.11 Lubricant factor Z_L, speed factor Z_V and roughness factor Z_R

The lubricant factor Z_L accounts for the influence of the type of the lubricant and the influence of its viscosity, the speed factor Z_V accounts for the influence of the pitch line velocity, and the roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

These factors are to be determined as follows:

a) Lubricant factor Z_L

$$Z_L = C_{ZL} + \frac{4 \cdot (1,0 - C_{ZL})}{\left(1,2 + \frac{134}{\nu_{40}}\right)^2}$$

where:

C_{ZL} : Constant for lubricant factor, equal to:

- for $\sigma_{H,lim} < 850$ N/mm^2:
  $C_{ZL} = 0,83$
- if 850 N/mm^2 $\leq \sigma_{H,lim} \leq$ 1200 N/mm^2:

$$C_{ZL} = \frac{\sigma_{H,lim}}{4375} + 0,6357$$

- if $\sigma_{H,lim} >$ 1200 N/mm^2:
  $C_{ZL} = 0,91$

b) Speed factor Z_V

$$Z_V = C_{ZV} + \frac{2 \cdot (1,0 - C_{ZV})}{\sqrt{0,8 + \frac{32}{\nu}}}$$

where:

C_{ZV} : Constant for speed factor, equal to:
$C_{ZV} = C_{ZL} + 0,02$

c) Roughness factor Z_R

$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}}$$

where:

R_{Z10} : Mean relative peak-to-valley roughness for the gear pair, in µm, equal to:

$$R_{Z10} = R_{Zf}\left(\frac{10}{\rho_{red}}\right)^{1/3}$$

ρ_{red} : Relative radius of curvature, in mm, equal to:

$$\rho_{red} = \frac{0,5 \cdot d_{b1} \cdot d_{b2} \cdot \tan\alpha_{wt}}{d_{b1} + d_{b2}}$$

d_b being taken negative for internal gears

R_{Zf} : Mean peak-to-valley flank roughness for the gear pair, in µm, equal to:

$$R_{Zf} = \frac{R_{Zf1} + R_{Zf2}}{2}$$

C_{ZR} : Constant for roughness factor, equal to:

- if $\sigma_{H,lim} < 850$ N/mm^2:
  $C_{ZR} = 0,15$
- if 850 N/mm^2 $\leq \sigma_{H,lim} \leq$ 1200 N/mm^2:

$$C_{ZR} = 0,32 - \frac{\sigma_{H,lim}}{5000}$$

- if $\sigma_{H,lim} >$ 1200 N/mm^2:
  $C_{ZR} = 0,08$

2.4.12 Hardness ratio factor Z_W

The hardness ratio factor Z_W accounts for the increase of the surface durability in the following cases:

a) Surface-hardened with through-hardened wheel

- if HB < 130:

$$Z_W = 1,2 \cdot \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

- if $130 \leq HB \leq 470$:

$$Z_W = \left(1,2 - \frac{HB - 130}{1700}\right) \cdot \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

- if $HB > 470$:

$$Z_W = \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

where:

R_{ZH} : Equivalent roughness, in µm, equal to:

$$R_{ZH} = \frac{R_{Zf1}(10/\rho_{red})^{0,33} \cdot (R_{Zf1}/R_{Zf2})^{0,66}}{(\nu_{40} \cdot \nu/1500)^{0,33}}$$

ρ_{red} being the relative radius of curvature defined in [2.4.11].

b) Through-hardened pinion and wheel with pinion substantially harder than the wheel (in that case, the hardness factor is to be applied only to the wheel)

- if $HB_1 / HB_2 < 1,2$:

$Z_W = 1,0$

- if $1,2 \leq HB_1 / HB_2 \leq 1,7$:

$$Z_W = 1 + \left(0,00898 \frac{HB_1}{HB_2} - 0,00829\right) \cdot (u - 1,0)$$

- if $HB_1 / HB_2 > 1,7$:

$Z_W = 1,0 + 0,00698\ (u - 1,0)$

Note 1: In any cases, $Z_W \geq 1$

Note 2: If $u > 20$, $u = 20$ is to be taken.

2.4.13 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is in general equal to 1.

The value of Z_X to be used will be given special consideration by the Society depending on the material.

2.4.14 Safety factor for contact stress S_H

The values to be adopted for safety factor for contact stress S_H are given in Tab 18.

Table 18 : Safety factor for contact stress S_H

Type of installation		S_H
Main gears (propulsion)	single machinery	1,25
	duplicate machinery	1,20
Auxiliary gears		1,15

2.5 Calculation of tooth bending strength

2.5.1 General

The criterion for the tooth root bending strength is based on the local tensile stress at the tooth root in the direction of the tooth height.

The tooth root bending stress σ_F, defined in [2.5.2], is not to exceed the permissible tooth root bending stress σ_{FP} defined in [2.5.8].

2.5.2 Tooth root bending stress σ_F

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_t}{b \cdot m_n} Y_F \cdot Y_S \cdot Y_\beta \cdot Y_B \cdot Y_{DT} \cdot K_A \cdot K_\gamma \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha}$$

where:

Y_F : Tooth form factor, defined in [2.5.3]

Y_S : Stress correction factor, defined in [2.5.4]

Y_β : Helix angle factor, defined in [2.5.5]

Y_B : Rim thickness factor, defined in [2.5.6]

Y_{DT} : Deep tooth factor, defined in [2.5.7]

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

K_V : Dynamic factor (see [2.3.4])

$K_{F\beta}$: Face load distribution factor (see [2.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [2.3.6]).

When a shot peening treatment of the tooth root is applied according to a process agreed by the Society, a reduction of the bending stress σ_F (depending on the material category, but without being over 10%) could be taken in consideration only for carburized case-hardened steel gears.

2.5.3 Tooth form factor Y_F (method B)

The tooth form factor Y_F takes into account the effect of the tooth form on the nominal bending stress, assuming the load applied at the outer point of a single pair tooth contact.

In the case of helical gears, the form factors are to be determined in the normal section, i.e. for the virtual spur gear with the virtual number of teeth z_n.

Y_F is to be determined separately for the pinion and the wheel, using the following formula:

$$Y_F = \frac{6\frac{h_{Fe}}{m_n}\cos\alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where:

h_{Fe} : Bending moment arm, in mm:

- for external gears:

$$\frac{h_{Fe}}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{Fen})\frac{d_{en}}{m_n}\right] - \frac{1}{2}\left[z_n\cos\left(\frac{\pi}{3}-\theta\right) + \left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)\right]$$

- for internal gears:

$$\frac{h_{Fe}}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{Fen})\frac{d_{en}}{m_n}\right] - \frac{1}{2}\left[z_n\cos\left(\frac{\pi}{6}-\theta\right) - \sqrt{3}\left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)\right]$$

s_{Fn} : Tooth root chord at the critical section, in mm:

- for external gears:

$$\frac{s_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{3}-\theta\right) + \sqrt{3}\left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)$$

- for internal gears:

$$\frac{s_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{6}-\theta\right) + \left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)$$

ρ_{fPv} : Fillet radius at the basic rack, in mm:

- for external gears:

$$\rho_{fPv} = \rho_{a0}$$

- for internal gears:

$$\rho_{fPv} = \rho_{a0} + m_n\cdot\frac{(x_2 + h_{fP}/m_n - \rho_{a0}/m_n)^{1,95}}{3,156 - 1,036^{z_2}}$$

G : Parameter defined by the following formula:

$$G = \frac{\rho_{fPv}}{m_n} - \frac{h_{fP}}{m_n} + x$$

θ : Parameter defined by the following formula:

$$\theta = \frac{2G}{z_n}\tan\theta - H$$

This transcendental equation is to be calculated by iteration

H : Parameter defined by the following formulae:

- for external gears:

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

- for internal gears:

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{6}$$

E : Parameter defined by the following formula:

$$E = \frac{\pi}{4} m_n - h_{fP} \tan\alpha_n + \frac{s_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{a0}}{\cos\alpha_n}$$

s_{pr} : Residual fillet undercut, in mm:

$s_{pr} = pr - q$

The parameters of the virtual gears are defined as follows:

α_{Fen} : Load direction angle:

$\alpha_{Fen} = \alpha_{en} - \gamma_e$

γ_e : Parameter defined by the following formula:

$$\gamma_e = \frac{0{,}5\ \pi + 2 \cdot \tan\alpha_n \cdot x}{z_n} + inv\alpha_n - inv\alpha_{en}$$

with inv, involute function, equal to:

$inv\ \alpha = \tau\alpha v\ \alpha - \alpha$

α_{en} : Form factor pressure angle:

$$\cos\alpha_{en} = \frac{d_{bn}}{d_{en}}$$

d_{bn} : Virtual base diameter, in mm:

$d_{bn} = d_n \cos\alpha_n$

with:

d_n : Virtual reference diameter, in mm:

$$d_n = \frac{d}{(\cos\beta_b)^2} = m_n z_n$$

d_{en} : Parameter defined by the following formula:

$$d_{en} = \frac{2z}{|z|}\sqrt{\left[\frac{\sqrt{d_{an}^{\ 2} - d_{bn}^{\ 2}}}{2} - \frac{\pi d \cos\beta \cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \frac{d_{bn}^{\ 2}}{4}}$$

with:

d_{an} : Virtual tip diameter, in mm:

$d_{an} = d_n + d_a - d$

$\varepsilon_{\alpha n}$: Virtual transverse contact ratio:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{(\cos\beta_b)^2}$$

2.5.4 Stress correction factor Y_S (method B)

The stress correction factor Y_S is used to convert the nominal bending stress to local tooth root stress, assuming the load is applied at the outer point of a single pair tooth contact. It takes into account the influence of:

- the bending moment
- the proximity of the load application to the critical section.

Y_S is to be determined as follows:

$$Y_S = (1{,}2 + 0{,}13L)q_s^{\left(\frac{1}{1{,}21 + (2{,}3/L)}\right)}$$

where:

$$L = \frac{s_{Fn}}{h_{Fe}}$$

with s_{Fn} and h_{Fe} defined in [2.5.3]

q_s : Notch parameter:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

with s_{Fn} defined in [2.5.3]

Note 1: The notch parameter should be within the range: $1 \le q_s < 8$

ρ_F : Radius of root fillet, in mm:

$$\frac{\rho_F}{m_n} = \frac{\rho_{fPv}}{m_n} + \frac{2G^2}{\cos\theta \cdot (|z_n| \cdot \cos^2\theta - 2G)}$$

2.5.5 Helix angle factor Y_β

The helix angle factor Y_β converts the tooth root stress of a virtual spur gear to that of the corresponding helical gear, taking into account the oblique orientation of the lines of mesh contact.

Y_β is to be determined as follows:

if $\varepsilon_\beta \le 1$ and $\beta \le 30°$: $Y_\beta = 1 - \varepsilon_\beta \beta / 120$

if $\varepsilon_\beta \le 1$ and $\beta > 30°$: $Y_\beta = 1 - 0{,}25\,\varepsilon_\beta$

if $\varepsilon_\beta > 1$ and $\beta \le 30°$: $Y_\beta = 1 - \beta / 120$

if $\varepsilon_\beta > 1$ and $\beta > 30°$: $Y_\beta = 0{,}75$

2.5.6 Rim thickness factor Y_B

The rim thickness factor Y_B is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis.

Y_B is to be determined as follows:

- for external gears:
  - when $s_R / h \ge 1{,}2$:
    $Y_B = 1{,}0$
  - when $1{,}2 > s_R / h > 0{,}5$:

$$Y_B = 1{,}6 \ln\left(2{,}242 \frac{h}{s_R}\right)$$

Note 1: $s_R / h \le 0{,}5$ is to be avoided.

- for internal gears:
  - when $s_R / m_n \ge 3$:
    $Y_B = 1{,}0$
  - when $3 > s_R / m_n > 1{,}75$:

$$Y_B = 1{,}15 \ln\left(8{,}324 \frac{m_n}{s_R}\right)$$

Note 2: $s_R / h \le 1{,}75$ is to be avoided.

2.5.7 Deep tooth factor Y_{DT}

The deep tooth factor Y_{DT} adjusts the tooth root stress to take into account high precision gears and contact ratios within the range $2{,}05 < \varepsilon_{\alpha n} \le 2{,}5$ (where $\varepsilon_{\alpha n}$ is defined in [2.5.3]).

Y_{DT} is to be determined as follows:

- if $\varepsilon_{\alpha n} > 2{,}5$ and $A \le 4$: $Y_{DT} = 0{,}7$
- if $2{,}05 < \varepsilon_{\alpha n} \le 2{,}5$ and $A \le 4$: $Y_{DT} = -0{,}666\,\varepsilon_{\alpha n} + 2{,}366$
- otherwise: $Y_{DT} = 1{,}0$

2.5.8 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and for wheel, using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X$$

where:

σ_{FE} : Endurance limit for tooth root bending stress, defined in [2.5.9]

Y_d : Design factor, defined in [2.5.10]

Y_{NT} : Life factor for tooth root bending stress, defined in [2.5.11]

$Y_{\delta relT}$: Relative notch sensitive factor, defined in [2.5.12]

Y_{RrelT} : Relative surface factor, defined in [2.5.13]

Y_X : Size factor for tooth root bending stress, defined in [2.5.14]

S_F : Safety factor for tooth root bending stress, defined in [2.5.15].

2.5.9 Endurance limit for tooth root bending stress σ_{FE}

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root stress which can be permanently endured.

The values to be adopted for σ_{FE} are given, in N/mm^2, with the following formula, in relation to the type of steel employed and the heat treatment performed:

$\sigma_{FE} = A\ x + B$

where:

A, B : Constants determined in Tab 19

x : Surface hardness HB or HV, in N/mm^2. The limitations x_{min} and x_{max} on surface hardness are indicated in Tab 19.

Special consideration will be given to other values of σ_{FE}, depending on the material category and specification of the steel employed.

Table 19 : Constants A and B and limitations on surface hardness HB or HV

Material	Quality **(1)**	A	B (N/mm^2)	Hardness	x_{min} (N/mm^2)	x_{max} (N/mm^2)
St	ML	0,910	138	HB	110	210
	MQ	0,910	138	HB	110	210
	ME	0,772	294	HB	110	210
St (cast)	ML	0,626	124	HB	140	210
	MQ	0,626	124	HB	140	210
	ME	0,508	274	HB	140	210
GTS (perl.)	ML	0,700	154	HB	135	250
	MQ	0,700	154	HB	135	250
	ME	0,806	256	HB	175	250
GGG	ML	0,700	238	HB	175	300
	MQ	0,700	238	HB	175	300
	ME	0,760	268	HB	200	300
GG	ML	0,512	16	HB	150	240
	MQ	0,512	16	HB	150	240
	ME	0,400	106	HB	175	275
V (carbon steels)	ML	0,500	216	HV	115	215
	MQ	0,480	326	HV	115	215
	ME	0,566	404	HV	115	215
V (alloy steels)	ML	0,846	208	HV	200	360
	MQ	0,850	374	HV	200	360
	ME	0,716	462	HV	200	390
V (cast, carbon steels)	ML	0,448	234	HV	130	215
	MQ	0,448	234	HV	130	215
	ME	0,572	334	HV	130	215
V (cast, alloy steels)	ML	0,728	322	HV	200	360
	MQ	0,728	322	HV	200	360
	ME	0,712	372	HV	200	360
Eh	ML	0,000	624	HV	600	800
	MQ, > 25HRC lower	0,000	850	HV	660	800
	MQ, > 25HRC upper	0,000	922	HV	660	800
	MQ, > 35 HRC	0,000	1000	HV	660	800
	ME	0,000	1050	HV	660	800

(1) The requirements for each material quality are defined in ISO 6336-5.

Material	Quality **(1)**	A	B (N/mm²)	Hardness	x_{min} (N/mm²)	x_{max} (N/mm²)
IF	ML	0,610	152	HV	485	615
	MQ	0,276	580	HV	500	570
	ME	0,542	474	HV	500	615
NT (nitr.)	ML	0,000	540	HV	650	900
	MQ	0,000	840	HV	650	900
	ME	0,000	936	HV	650	900
NV (nitr.)	ML	0,000	516	HV	450	650
	MQ	0,000	726	HV	450	650
	ME	0,000	864	HV	450	650
NV (nitrocar.)	ML	0,000	448	HV	300	650
	MQ	1,306	188	HV	300	450
	ME	1,306	188	HV	300	450
(1) The requirements for each material quality are defined in ISO 6336-5.						

2.5.10 Design factor Y_d

The design factor Y_d takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength.

Y_d is to be determined as follows:

- for gears with occasional part load in reverse direction, such as main wheel in reverse gearboxes:

  $Y_d = 0,9$
- for idler gears (driven and driving tooth for each cycle i.e. alternating load):

  $Y_d = 0,7$
- for shrunk on pinions and wheel rims:

  $Y_d = 1 - \sigma_T / \sigma_{FE}$

  with:

  σ_{FE} : Endurance limit for tooth root bending stress (see [2.5.9])

  σ_T : Tangential stress induced by the shrinkage at the tooth root diameter.

  The maximum equivalent stress induced by the shrinkage in the inner diameter of the rim is not to exceed 80% of the yield strength of the rim material.
- otherwise:

  $Y_d = 1,0$

2.5.11 Life factor Y_{NT}

The life factor Y_{NT} accounts for the influence of limited service life on the permissible tooth root bending stress.

Some values of Y_{NT} are given in Tab 20 for information.

The value Y_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

Table 20 : Life factor Y_{NT}

Material	Number of load cycles N_L	Y_{NT}
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast), Eh, IF	$N_L \leq 10^3$ or static	2,5
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
GGG (ferr.), GG, NT (nitr.), NV (nitr.)	$N_L \leq 10^3$ or static	1,6
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
NV (nitrocar.)	$N_L \leq 10^3$ or static	1,1
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0

2.5.12 Relative notch sensitivity factor $Y_{\delta rel\,T}$

The relative notch sensitivity factor $Y_{\delta relT}$ indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

$Y_{\delta relT}$ is to be determined as follows:

$$Y_{\delta relT} = \frac{1 + \sqrt{\rho' \cdot 0,2 \cdot (1 + 2q_s)}}{1 + \sqrt{\rho' \cdot 1,2}}$$

where:

q_s : Notch parameter, as defined in [2.5.4]

ρ' : Slip-layer thickness, in mm, defined in Tab 21.

Table 21 : Slip-layer thickness ρ'

Material	ρ' (mm)
GG, R_m = 150 N/mm²	0,3124
GG, GGG (ferr.) R_m = 300 N/mm²	0,3095
NT, NV	0,1005
St, R_e = 300 N/mm²	0,0833
St, R_e = 400 N/mm²	0,0445
V, GTS, GGG (perl. bai.), R_e = 500 N/mm²	0,0281
V, GTS, GGG (perl. bai.), R_e = 600 N/mm²	0,0194
V, GTS, GGG (perl. bai.), R_e = 800 N/mm²	0,0064
V, GTS, GGG (perl. bai.), R_e = 1000 N/mm²	0,0014
Eh, IF	0,0030

2.5.13 Relative surface factor $Y_{Rrel\,T}$

The relative surface factor $Y_{Rrel\,T}$ takes into account the dependence of the root strength on the surface condition on the tooth root fillet (roughness).

The values to be adopted for $Y_{Rrel\,T}$ are given in Tab 22 in relation to the type of steel employed.

They are valid only when scratches or similar defects deeper than 12 R_a are not present.

Table 22 : Relative surface factor $Y_{Rrel\,T}$

Material	Y_{RrelT}	
	$R_z < 1$	$1 \le R_z \le 40$
V, V (cast), GGG (perl.), GGG (bai.), Eh, IF	1,120	$1,674 - 0,529\ (R_z + 1)^{0,1}$
St, St (cast)	1,070	$5,306 - 4,203\ (R_z + 1)^{0,01}$
GG, GGG (ferr.), NT, NV	1,025	$4,299 - 3,259\ (R_z + 1)^{0,0058}$
Note 1: R_z : Mean peak-to-valley roughness, in µm: $R_z = 6\ R_a$ with R_a : Arithmetic mean roughness.		

2.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 23 in relation to the type of steel employed and the value of the normal module m_n.

Table 23 : Size factor Y_X

Material	Normal module	Y_X
St, V, V (cast), GGG (perl.), GGG (bai.), GTS (perl.)	$m_n \leq 5$	1,00
	$5 < m_n < 30$	$1,03 - 0,006\ m_n$
	$m_n \geq 30$	0,85
Eh, IF, NT, NV	$m_n \leq 5$	1,00
	$5 < m_n < 25$	$1,05 - 0,01\ m_n$
	$m_n \geq 25$	0,80
GG, GGG (ferr.)	$m_n \leq 5$	1,00
	$5 < m_n < 25$	$1,075 - 0,015\ m_n$
	$m_n \geq 25$	0,70

2.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 24.

Table 24 : Safety factor for tooth root bending stress S_F

Type of installation		S_F
Main gears (propulsion)	single machinery	1,60
	duplicate machinery	1,55
Auxiliary gears	single machinery	1,45
	duplicate machinery	1,40

2.6 Calculation of scuffing resistance

2.6.1 General

The following calculations are requested for equipment running in supercritical domain, i.e. when $N > 1,5$ (see [2.3.4]).

The criterion for scuffing resistance is based on the calculation of the flash temperature method. According to this method, the risk of scuffing is assessed as a function of the properties of gear material, the lubricant characteristics, the surface roughness of tooth flanks, the sliding velocities and the load.

The interfacial contact temperatures are calculated as the sum of the interfacial bulk temperature of the moving interface and the fluctuating flash temperature of the moving faces in contact.

The maximum value of the interfacial contact temperature reduced by oil temperature is not to exceed 0,8 times the scuffing temperature reduced by oil temperature:

$$(\Theta_{B,Max} - \Theta_{oil}) \leq 0,8\ (\Theta_S - \Theta_{oil})$$

where:

$\Theta_{B,Max}$: Maximum contact temperature along the path of contact, in °C, defined in [2.6.2]

Θ_{oil} : Oil temperature, in °C

Θ_S : Scuffing temperature, in °C, defined in [2.6.11].

Additionally, the difference between the scuffing temperature and the contact temperature along the path is not to be below 30°C:

$$(\Theta_S - \Theta_{B,Max}) \geq 30°C$$

Other methods of determination of the scuffing resistance could be accepted by the Society.

2.6.2 Contact temperature Θ_B

The maximum contact temperature $\Theta_{B,Max}$ along the path of contact, in °C, is calculated as follows:

$$\Theta_{B,Max} = \Theta_{Mi} + \Theta_{fl,Max}$$

where:

Θ_{Mi} : Interfacial bulk temperature, in °C, defined in [2.6.10]

$\Theta_{fl,Max}$: Maximum flash temperature along the path of contact, in °C, defined in [2.6.3].

The flash temperature should be calculated on at least ten points along the path of contact and the maximum of these values has to be used for the calculation of maximum contact temperature.

2.6.3 Flash temperature Θ_{fl}

The flash temperature Θ_{fl} at any point along the path of contact, in °C, is calculated with the following formula:

$$\Theta_{fl} = \mu_m \cdot X_M \cdot X_J \cdot X_G \cdot (X_\Gamma \cdot w_{Bt})^{0,75} \cdot \frac{v^{0,5}}{a^{0,25}}$$

where:

μ_m : Mean coefficient of friction, defined in [2.6.4]

X_M : Thermo-elastic factor, in $K \cdot N^{-3/4} \cdot s^{-1/2} \cdot m^{-1/2} \cdot mm$, defined in [2.6.5]

X_J : Approach factor, defined in [2.6.6]

X_G : Geometry factor, defined in [2.6.7]

X_Γ : Load sharing factor, defined in [2.6.8]

w_{Bt} : Transverse unit load, in N/mm, defined in [2.6.9].

2.6.4 Mean coefficient of friction μ_m

An estimation of the mean coefficient of friction μ_m of common working conditions could be used with the following formula:

$$\mu_m = 0,06 \cdot \left(\frac{w_{Bt}}{v_{g\Sigma C} \cdot \rho_{relC}}\right)^{0,2} \cdot X_L \cdot X_R$$

where:

w_{Bt} : Transverse unit load, in N/mm, defined in [2.6.9]

$v_{g\Sigma C}$: Sum of tangential velocities in pitch point, in m/s:

$v_{g\Sigma C} = 2\, v \sin \alpha_{tw}$

with v not taken greater than 50 m/s

ρ_{relC} : Transverse relative radius of curvature, in mm:

$$\rho_{relC} = \frac{u}{(1+u)^2} \cdot a \cdot \sin\alpha_{tw}$$

X_L : Lubricant factor, given in Tab 25

X_R : Roughness factor, equal to:

$$X_R = \left(\frac{R_{zf1} + R_{zf2}}{2}\right)^{0,25}$$

Table 25 : Lubricant factor X_L

Type of lubricant	X_L **(1)**
Mineral oils	$X_L = 1,0\ \eta_{oil}^{-0,05}$
Water soluble polyglycols	$X_L = 0,6\ \eta_{oil}^{-0,05}$
Non water soluble polyglycols	$X_L = 0,7\ \eta_{oil}^{-0,05}$
Polyalfaolefins	$X_L = 0,8\ \eta_{oil}^{-0,05}$
Phosphate esters	$X_L = 1,3\ \eta_{oil}^{-0,05}$
Traction fluids	$X_L = 1,5\ \eta_{oil}^{-0,05}$
(1) η_{oil} is the dynamic viscosity at oil temperature Θ_{oil}.	

2.6.5 Thermo-elastic factor X_M

The thermo-elastic factor X_M accounts for the influence of the material properties of pinion and wheel:

$$X_M = 1000 \frac{E_r^{0,25}}{B_M}$$

where:

E_r : Reduced modulus of elasticity, in N/mm^2:

$$E_r = \frac{2}{(1-\nu_1)/E_1 + (1-\nu_2)/E_2}$$

E_1, E_2 : Moduli of elasticity of pinion and wheel material, in N/mm^2

ν_1, ν_2 : Poisson's ratios of pinion and wheel material

B_M : Mean thermal contact coefficient, in $N \cdot mm^{-1/2} \cdot m^{-1/2} \cdot s^{-1/2} \cdot K^{-1}$, equal to:

$B_M = (B_{M1} + B_{M2}) / 2$

B_{Mi} : Thermal contact coefficient of pinion material (i = 1) and wheel material (i = 2), given in $N \cdot mm^{-1/2} \cdot m^{-1/2} \cdot s^{-1/2} \cdot K^{-1}$ and equal to:

$B_{Mi} = (0{,}001\ \lambda_{Mi}\ \rho_{Mi}\ c_{Mi})^{0,5}$

An average value of 435 $N \cdot mm^{-1/2} \cdot m^{-1/2} \cdot s^{-1/2} \cdot K^{-1}$ for martensitic steels could be used when thermo-elastic coefficient is not known

λ_{Mi} : Heat conductivity of pinion material (i = 1) and wheel material (i = 2), in $N \cdot s^{-1} \cdot K^{-1}$

ρ_{Mi} : Density of pinion material (i = 1) and wheel material (i = 2), in $kg \cdot m^{-3}$

c_{Mi} : Specific heat per unit mass of pinion material (i = 1) and wheel material (i = 2), in $J \cdot kg^{-1} \cdot K^{-1}$.

2.6.6 Approach factor X_J

The approach factor X_J takes empirically into account an increased scuffing risk in the beginning of the approach path, due to mesh starting without any previously built up oil film. The approach factor at any point should be calculated according to the following formula:

- when pinion drives the wheel:
  - for $\Gamma \geq 0$:

    $X_J = 1$
  - for $\Gamma < 0$, provided that $X_J \geq 1$:

    $$X_J = 1 + \frac{C_{eff} - C_{a2}}{50}\left(\frac{-\Gamma}{\Gamma_E - \Gamma_A}\right)^3$$
- when wheel drives the pinion:
  - for $\Gamma \leq 0$:

    $X_J = 1$
  - for $\Gamma > 0$, provided that $X_J \geq 1$:

    $$X_J = 1 + \frac{C_{eff} - C_{a1}}{50}\left(\frac{\Gamma}{\Gamma_E - \Gamma_A}\right)^3$$

where:

C_{eff} : Optimal tip relief, in µm:

$$C_{eff} = \frac{K_A K_\gamma F_t}{b \cdot \cos\alpha_t \cdot c_\gamma}$$

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

$c_{\alpha\gamma}$: Mesh stiffness, in N/(mm.µm) (see Tab 9)

C_{ai} : Tip relief of pinion or wheel, in µm

Γ : Parameter of the point on the line of action, defined in Tab 26

Γ_A : Parameter of the lower end point of the path of contact, defined in Tab 26

Γ_E : Parameter of the upper end point of the path of contact, defined in Tab 26.

Table 26 : Parameter Γ on the line of action

Point		Γ
A :	Lower end point of the path of contact	$\Gamma_A = -\frac{z_2}{z_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{wt}} - 1\right)$
AU :	Lower end point of buttressing effect	$\Gamma_{AU} = \Gamma_A + 0{,}2 \sin\beta_b$
AB :	Intermediate point between A and B	$\Gamma_{AB} = 0{,}5\ (\Gamma_A + \Gamma_B)$
B :	Lower point of single pair tooth contact	$\Gamma_B = \frac{\tan\alpha_{a1}}{\tan\alpha_{wt}} - 1 - \frac{2\pi}{z_1 \tan\alpha_{wt}}$
C :	Point with parameter equal to 0	$\Gamma_C = 0$
M :	Intermediate point between A and E	$\Gamma_M = 0{,}5\ (\Gamma_A + \Gamma_E)$
D :	Upper point of single pair tooth contact	$\Gamma_D = -\frac{z_2}{z_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{wt}} - 1\right) + \frac{2\pi}{z_1 \tan\alpha_{wt}}$
DE :	Intermediate point between D and E	$\Gamma_{DE} = 0{,}5\ (\Gamma_D + \Gamma_E)$
EU :	Upper end point of buttressing effect	$\Gamma_{EU} = \Gamma_E - 0{,}2 \sin\beta_b$
E :	Upper end point of the path of contact	$\Gamma_E = \frac{\tan\alpha_{a1}}{\tan\alpha_{wt}} - 1$

2.6.7 Geometry factor X_G

The geometry factor X_G is calculated according to the following conditions:

- for external gear pair:

$$X_G = 0{,}51\, X_{\alpha\beta}(u+1)^{0,5}\, \frac{\left|(1+\Gamma)^{0,5} - (1-\Gamma/u)^{0,5}\right|}{(1+\Gamma)^{0,25}\,(u-\Gamma)^{0,25}}$$

- for internal gear pair:

$$X_G = 0{,}51\, X_{\alpha\beta}(u-1)^{0,5}\, \frac{\left|(1+\Gamma)^{0,5} - (1+\Gamma/u)^{0,5}\right|}{(1+\Gamma)^{0,25}\,(u+\Gamma)^{0,25}}$$

where:

$X_{\alpha\beta}$: Angle factor, equal to:

$X_{\alpha\beta} = 1{,}22\ (\sin \alpha_{wt})^{0,25}\ (\cos \alpha_{wt})^{-0,5}\ (\cos \beta_b)^{0,25}$

Γ : Parameter of the point on the line of action, defined in Tab 26.

2.6.8 Load sharing factor X_Γ

The load sharing factor X_Γ accounts for the load sharing of succeeding pairs of meshing teeth. It is defined as a function of the value of the parameter in the line of action, increasing at the approach path of transverse double contact.

- for narrow helical gears ($\varepsilon_\gamma < 2$) with unmodified profiles:

$X_\Gamma = X_{\Gamma,u}\, X_{but}$

- for narrow helical gears ($\varepsilon_\gamma < 2$) with profile modification:

$X_\Gamma = X_{\Gamma,m}\, X_{but}$

- for wide helical gears ($\varepsilon_\gamma \geq 2$) with unmodified profiles:

$$X_\Gamma = \frac{1}{\varepsilon_\alpha} X_{but}$$

- for wide helical gears ($\varepsilon_\gamma \geq 2$) with profile modification:

$X_\Gamma = X_{\Gamma,wm}\, X_{but}$

where:

X_{but} : Buttressing factor:

- for $\Gamma < \Gamma_{AU}$:

$$X_{but} = X_{butA} - \frac{\Gamma - \Gamma_A}{\Gamma_{AU} - \Gamma_A}(X_{butA} - 1)$$

- for $\Gamma_{AU} \leq \Gamma \leq \Gamma_{EU}$:

$X_{but} = 1$

- for $\Gamma_{EU} < \Gamma$:

$$X_{but} = X_{butE} - \frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_{EU}}(X_{butE} - 1)$$

Note 1: X_{but} is to be taken equal to 1 if $C_{ai} \geq C_{eff}$

X_{butA} , X_{butE} : Buttressing factors at, respectively, lower and upper end points of the path of contact:

$X_{butA} = X_{butE} = 1 + 0{,}3\ \varepsilon_\beta$, provided that

$X_{butA} = X_{butE} < 1{,}3$

$X_{\Gamma,u}$: Load sharing factor for unmodified profiles:

- for $\Gamma < \Gamma_B$:

$$X_{\Gamma,u} = \frac{A-3}{12} + \frac{1}{3}\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$

- for $\Gamma_B \leq \Gamma \leq \Gamma_D$:

$X_{\Gamma,u} = 1$

- for $\Gamma_D < \Gamma$:

$$X_{\Gamma,u} = \frac{A-3}{12} + \frac{1}{3}\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

Note 2: A is to be taken at least equal to 7.

$X_{\Gamma,m}$: Load sharing factor for profile modification:

- for $\Gamma < \Gamma_{AB}$, provided that $X_{\Gamma,m} \geq 0$:

$$X_{\Gamma,m} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a2}}{C_{eff}}\right)\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$

- for $\Gamma_{AB} \le \Gamma < \Gamma_B$, provided that $X_{\Gamma,m} \le 1$:

$$X_{\Gamma,m} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a1}}{C_{eff}}\right)\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$

- for $\Gamma_B \le \Gamma \le \Gamma_D$:

$X_{\Gamma,m} = 1$

- for $\Gamma_D < \Gamma \le \Gamma_{DE}$, provided that $X_{\Gamma,m} \le 1$:

$$X_{\Gamma,m} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a2}}{C_{eff}}\right)\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

- for $\Gamma_{DE} < \Gamma$, provided that $X_{\Gamma,m} \ge 0$:

$$X_{\Gamma,m} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a1}}{C_{eff}}\right)\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

$X_{\Gamma,wm}$: Load sharing factor for profile modification:

- for $\Gamma < \Gamma_{AB}$, provided that $X_{\Gamma,wm} \ge 0$:

$$X_{\Gamma,wm} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)C_{a1} + (3\varepsilon_\alpha + 1)C_{a2}}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}}\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$

- for $\Gamma_{AB} \le \Gamma \le \Gamma_{DE}$, provided that $X_{\Gamma,wm} \le 1$:

$$X_{\Gamma,wm} = \frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)(C_{a1} + C_{a2})}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}}$$

- for $\Gamma_{DE} < \Gamma$, provided that $X_{\Gamma,wm} \ge 0$:

$$X_{\Gamma,wm} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)C_{a2} + (3\varepsilon_\alpha + 1)C_{a1}}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}}\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_{DE}}$$

C_{eff} : Optimal tip relief, in µm (see [2.6.6])

C_{ai} : Tip relief of pinion or wheel, in µm

Γ_i : Parameter of any point on the line of action, given in Tab 26.

2.6.9 Transverse unit load w_{Bt}

The transverse unit load w_{Bt} is calculated according to the following formula:

$$w_{Bt} = K_A \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha} \cdot K_\gamma \cdot \frac{F_t}{b}$$

where:

K_A : Application factor (see [2.3.2])

K_V : Dynamic factor (see [2.3.4])

$K_{H\beta}$: Face load distribution factor (see [2.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [2.3.6])

K_γ : Load sharing factor (see [2.3.3]).

2.6.10 Interfacial bulk temperature Θ_{Mi}

The interfacial bulk temperature Θ_{Mi} may be suitably averaged from the two overall bulk temperatures of the teeth in contact, Θ_{M1} and Θ_{M2}. The following estimation could be used in general configurations:

$$\Theta_{Mi} = \Theta_{oil} + 0{,}47\ X_S\ X_{mp}\ \Theta_{fl,m}$$

where:

Θ_{oil} : Oil temperature, in °C

X_S : Lubrication system factor:

- for spray lubrication: $X_S = 1{,}2$
- for dip lubrication: $X_S = 1{,}0$
- for meshes with additional spray for cooling purpose: $X_S = 1{,}0$
- for gears submerged in oil, provided sufficient cooling: $X_S = 0{,}2$

X_{mp} : Multiple mating pinion factor:

$$X_{mp} = \frac{3 + n_p}{4}$$

n_p : Number of mesh in contact

$\Theta_{fl,m}$: Average flash temperature on the path of contact, in °C.
The average temperature should be calculated on at least ten equidistant points on the path line of contact between Γ_A and Γ_E.

2.6.11 Scuffing temperature Θ_S

The scuffing temperature Θ_S may be determined according to the following formula:

$\Theta_S = 80 + (0,85 + 1,4\ X_W)\ X_L\ (S_{FZG} - 1)^2$

where:

X_W : Structural factor given in Tab 27

X_L : Lubricant factor given in Tab 25

S_{FZG} : Load stage where scuffing occurs, according to gear tests, such as Ryder, FZG-Ryder, FZG L-42 or FZG A/8 3/90.

Table 27 : Structural factor X_W

Material	X_W
Through-hardened steel	1,00
Phosphated steel	1,25
Copper-plated steel	1,50
Bath or gas nitrided steel	1,50
Hardened carburized steel, with austenite content less than 10%	1,15
Hardened carburized steel, with austenite content between 10% and 20%	1,00
Hardened carburized steel, with austenite content above 20%	0,85
Austenite steel (stainless steel)	0,45

3 Design of gears - Determination of the load capacity of bevel gears

3.1 Symbols, units, definitions

3.1.1 Symbols and units

The meaning of the main symbols used in this Article is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate sub-articles.

A : Flank tolerance class according to ISO 1328-1:2013

a_v : Virtual operating centre distance, in mm

a_{vn} : Virtual operating centre distance, in mm

b : Effective face width, in mm

d_e : Outer pitch diameter, in mm

d_{ext} : External diameter of shaft, in mm

d_{int} : Internal diameter of shaft, in mm

d_m : Mean pitch diameter, in mm

d_s : Shrinkage diameter of the wheel, in mm

d_v : Virtual reference diameter, in mm

d_{va} : Virtual tip diameter, in mm

d_{van} : Virtual tip diameter, in mm

d_{vb} : Virtual base diameter, in mm

d_{vbn} : Virtual base diameter, in mm

d_{vf} : Virtual root diameter, in mm

d_{vn} : Virtual reference diameter, in mm

F_{mt} : Nominal tangential load, in N

F_β : Total helix deviation, in µm

$g_{v\alpha}$: Length of path of contact, in mm

$g_{v\alpha n}$: Length of path of contact, in mm

h_{aP} : Basic rack addendum, in mm

h_{fP} : Basic rack dedendum, in mm

h_v : Virtual tooth depth, in mm

HB : Brinell hardness, in N/mm²

HPX : Rockwell hardness

HV : Vickers hardness, in N/mm²

k : Gear axial position on shaft with respect to the bearings

ℓ : Bearing span, in mm

ℓ_{bm} : Length of the line of contact, in mm

ℓ'_{bm} : Length of the line of contact, in mm

m_{et} : Outer transverse module, in mm

m_{mn} : Mean normal module, in mm

m_{mt} : Mean transverse module, in mm

n : Rotational speed, in rpm

P : Transmitted power, in kW

p_{et} : Transverse base pitch, in mm

pr : Protuberance of the tool, in mm

q : Material allowance for finish machining, in mm

r_{c0} : Cutter radius, in mm

r_e : Outer cone distance, in mm

$R_{\varepsilon,\sigma}$: Minimum yield strength of the shaft material, in N/mm²

ρ_m : Mean cone distance, in mm

$R_{m,rim}$: Ultimate tensible strength of the rim material, in N/mm²

R_Z : Mean peak-to-valley roughness, in µm

R_{Zf} : Mean peak-to-valley flank roughness, in µm

s_R : Rim thickness, in mm

T : Transmitted torque, in kN·m

u : Reduction ratio

u_v : Virtual reduction ratio

v_{mt} : Linear speed at mean pitch diameter, in m/s

x_h : Addendum modification coefficient

x_S : Thickness modification coefficient

z : Number of teeth

z_v : Virtual number of teeth

z_{vn} : Virtual number of teeth

α_n : Normal pressure angle

α_{vt} : Virtual transverse pressure angle

β_m : Mean helix angle

β_{vb} : Virtual base helix angle

δ : Pitch angle

$\varepsilon_{v\alpha}$: Virtual transverse contact ratio

$\varepsilon_{v\alpha n}$: Virtual transverse contact ratio

$\varepsilon_{v\beta}$: Virtual overlap ratio

$\varepsilon_{v\gamma}$: Virtual total contact ratio

ν_{40} : Nominal kinematic viscosity of oil at 40°C, in mm²/s

ρ_{a0} : Tip radius of the tool, in mm

σ_F : Tooth root bending stress, in N/mm²

σ_{FE} : Endurance limit for tooth root bending stress, in N/mm²

σ_{FP} : Permissible tooth root bending stress, in N/mm²

σ_H : Contact stress, in N/mm²

$\sigma_{H,lim}$: Endurance limit for contact stress, in N/mm²

σ_{HP} : Permissible contact stress, in N/mm².

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

3.1.2 Geometrical definitions

In the calculation of surface durability, b is the minimum face width on the pitch diameter between pinion and wheel.

In tooth strength calculations, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 or b_2 are not to be taken greater than b by more than one module m_{mn} (in case of width of one gear much more important than the other).

a) General geometrical definitions

$$u = \frac{z_2}{z_1}$$

$$d_{ei} = \frac{z_i m_{mn}}{\cos\beta_m} + b_i \sin\delta_i$$

$$r_e = \frac{d_{e1}}{2\sin\delta_1} = \frac{d_{e2}}{2\sin\delta_2}$$

$$r_m = r_e - 0{,}5\ b$$

$$m_{et} = \frac{d_{e1}}{z_1} = \frac{d_{e2}}{z_2}$$

$$m_{mt} = \frac{r_m m_{et}}{r_e}$$

$$d_{mi} = \frac{z_i m_{mn}}{\cos\beta_m}$$

b) Geometrical definitions of virtual cylindrical gears in transverse section (suffix v)

$$z_{vi} = \frac{z_i}{\cos\delta_i}$$

$$u_v = \frac{z_{v2}}{z_{v1}}$$

$$\tan\alpha_{vt} = \frac{\tan\alpha_n}{\cos\beta_m}$$

$$\sin\beta_{vb} = \sin\beta_m \cdot \cos\alpha_n$$

$$d_{vi} = \frac{d_{mi}}{\cos\delta_i}$$

$$a_v = 0{,}5\ (d_{v1} + d_{v2})$$

$$d_{v\alpha t} = d_{vi} + 2\ h_{aPi}$$

$$d_{v\beta t} = d_{vi}\cos\alpha_{vt}$$

$$d_{v\phi t} = d_{vi} + 2\ m_{mn}\ x_{hi} - 2\ h_{fPi}$$

$$h_{vt} = 0{,}5\ (d_{vai} - d_{vfi})$$

$$p_{\varepsilon\tau} = m_{mt}\ \pi\cos\alpha_{vt}$$

$$(g_{v\alpha} = 0{,}5\ (\sqrt{d_{va1}^2 - d_{vb1}^2} + \sqrt{d_{va2}^2 - d_{vb2}^2}) - a_v \sin\alpha_{vt})$$

$$\left(\varepsilon_{v\alpha} = \frac{g_{v\alpha}}{p_{et}}\right)$$

$$\left(\varepsilon_{v\beta} = \frac{b\sin\beta_m}{\pi m_{mn}}\right)$$

$$(\varepsilon_{v\gamma} = \sqrt{\varepsilon_{v\alpha}^2 + \varepsilon_{v\beta}^2})$$

- if $\varepsilon_{v\beta} < 1$:

$$\ell_{bm} = \frac{b\varepsilon_{v\alpha}}{\cos\beta_{vb}\cdot\varepsilon_{v\gamma}^2}\cdot\sqrt{\varepsilon_{v\gamma}^2 - (2-\varepsilon_{v\alpha})^2\cdot(1-\varepsilon_{v\beta})^2}$$

- if $\varepsilon_{v\beta} \geq 1$:

$$\ell_{bm} = \frac{b\varepsilon_{v\alpha}}{\cos\beta_{vb}\cdot\varepsilon_{v\gamma}}$$

$$\ell'_{bm} = \ell_{\beta\mu}\cos\beta_{vb}$$

c) Geometrical definitions of virtual cylindrical gears in normal section (suffix vn)

$$z_{vni} = \frac{z_{vi}}{\cos\beta_m\cdot(\cos\beta_{vb})^2}$$

$$d_{vvt} = m_{mn}\ \zeta_{vvt}$$

$a_{vn} = 0,5\ (d_{vn1} + d_{vn2})$

$d_{v\alpha vt} = d_{vni} + 2\ h_{aPi}$

$d_{v\beta vt} = d_{vni} \cos \alpha_v$

$$g_{v\alpha n} = 0,5\ (\sqrt{d_{van1}^2 - d_{vbn1}^2} + \sqrt{d_{van2}^2 - d_{vbn2}^2}) - a_{vn} \sin \alpha_n$$

$$\varepsilon_{v\alpha n} = \frac{\varepsilon_{v\alpha}}{(\cos \beta_{vb})^2}$$

d) Definitions of transmissions characteristics

$$T_i = \frac{60}{2\pi} \cdot \frac{P}{n_i}$$

$$F_{mt} = \frac{P}{n_1} \cdot \frac{60}{\pi d_{m1}} \cdot 10^6$$

$$v_{mt} = \frac{\pi n_1}{60} \cdot \frac{d_{m1}}{10^3} = \frac{\pi n_2}{60} \cdot \frac{d_{m2}}{10^3}$$

$$F_{\beta i} = 2^{0,5 \cdot (Q_i - 5)} \cdot (0,1\ \cdot d_{vi}^{0,5} + 0,63\ \sqrt{b} + 4,2)$$

3.2 Principle

3.2.1

a) The following requirements apply to bevel spur or helical gears with external teeth, and provide a method for the calculation of the load capacity with regard to:
- the surface durability (contact stress)
- the tooth root bending stress.

The bevel gears for marine application are to comply with the following restrictions:
- $1,2 < \varepsilon_{v\alpha} < 2,5$
- $\beta_m < 30°$
- $s_R > 3,5\ m_{mn}$

The relevant formulae are provided in [3.4] and [3.5].

The influence factors common to the formulae are given in [3.3].

b) Gears, for which the conditions of validity of some factors or formulae are not satisfied, will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society. Any alternative calculations are to comply with ISO 6336 series standards.

3.3 General influence factors

3.3.1 General

General influence factors are defined in [3.3.2], [3.3.3], [3.3.4], [3.3.5] and [3.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

3.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing (driven and driving machines).

The values of K_A to be used are given in Tab 5.

3.3.3 Load sharing factor $K\gamma$

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or tandem gears.

The values of K_γ to be used are given in Tab 6.

3.3.4 Dynamic factor K_v

The dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of the pinion and wheel.

The calculation of the dynamic factor K_V is defined in Tab 28, where:

N : Resonance ratio, i.e. ratio of the pinion speed to the resonance speed:

$N = n_1 / n_{E1}$, with:

n_{E1} : Resonance speed, in rpm, defined by the following formula:

$$n_{E1} = \frac{30000}{\pi \cdot z_1} \cdot \sqrt{\frac{c_\gamma}{m_{red}}}$$

where:

m_{red} : Reduced mass of gear pair, in kg/mm. Estimated calculation of m_{red} is given by the following formula:

$$m_{red} = \frac{\rho \cdot 10^{-6} \cdot \pi}{8} \cdot \frac{d_{m1}^2}{(\cos\alpha_n)^2} \cdot \frac{u^2}{1+u^2}$$

ρ : Density of gearing material, equal to:

$\rho = 7,83$ for steel

c_γ : Mesh stiffness, in N/(mm.µm):

$c_\gamma = 20\ C_F\ C_b$

C_F and C_b being the correction factors for non average conditions defined in Tab 29.

The value of N determines the range of vibrations:

- subcritical range, when $N \leq 0,75$
- main resonance range, when $0,75 < N < 1,25$

  This field is not permitted
- intermediate range, when $1,25 \leq N \leq 1,50$

  This field is normally to be avoided. Some alternative and more precise calculation could be accepted and special consideration will be given by the Society
- supercritical range, when $1,50 < N$.

3.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root ending stress, account for the effects of non-uniform distribution of load across the face width.

a) The calculation of $K_{H\beta}$ is to be defined according to the mounting conditions of pinion and wheel:

- neither member cantilever mounted:

  $K_{H\beta} = 1,575 / C_b$
- one member cantilever mounted:

  $K_{H\beta} = 1,650 / C_b$
- both members cantilever mounted:

  $K_{H\beta} = 1,875 / C_b$

where C_b is the correction factor defined in Tab 29

b) $K_{F\beta}$ is to be determined using the following formula:

$K_{F\beta} = K_{H\beta} / K_{F0}$, with:

K_{F0} : Lengthwise curvature factor. It is to be taken above 1,0 and below 1,15 considering the following formula:

$$K_{F0} = 0,211 \cdot \left(\frac{r_{c0}}{r_m}\right)^{\frac{0,279}{\log(\sin\beta_m)}} + 0,789$$

3.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are given in Tab 30.

3.4 Calculation of surface durability

3.4.1 General

The criterion for surface durability is based on the contact stress (hertzian pressure) σ_H on the pitch point or at the inner point of single pair contact.

The contact stress σ_H, defined in [3.4.2], is not to exceed the permissible contact stress σ_{HP} defined in [3.4.9].

Table 28 : Dynamic factor K_V

Resonance domain	Factor K_V
$N \leq 0,75$	$K_V = N (C_{V1} B_p + C_{V2} B_f + C_{V3}) + 1$
$N > 1,50$	$K_V = C_{V5} B_p + C_{V6} B_f + C_{V7}$

Note 1:

B_p : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_p = \frac{c' f_{p,eff}}{K_A (F_{mt}/b)}$$

with:

c' : Single stiffness, in N/(mm·µm):
$c' = 14 C_F C_b$, with C_F and C_b defined in Tab 29

$f_{\pi,\varepsilon\phi\phi}$: Effective base pitch deviation, in µm:
$f_{\pi,\varepsilon\phi\phi} = f_{\pi\tau} - y_\alpha$
with f_{pt} defined in Tab 30 and y_α defined in Tab 31

B_f : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:
$B_f = B_p$

C_{V1} : Factor for pitch deviation effects:
$C_{v1} = 0,32$

C_{V2} : Factor for tooth profile deviation effects:

- if $1 < \varepsilon_{v\gamma} \leq 2$:
  $C_{V2} = 0,34$
- if $2 < \varepsilon_{v\gamma}$:

$$C_{V2} = \frac{0,57}{\varepsilon_{v\gamma} - 0,3}$$

C_{V3} : Factor for cyclic variation effect in mesh stiffness:

- if $1 < \varepsilon_{v\gamma} \leq 2$:
  $C_{V3} = 0,23$
- if $2 < \varepsilon_{v\gamma}$:

$$C_{V3} = \frac{0,096}{\varepsilon_{v\gamma} - 1,56}$$

C_{V5} : Factor equal to: $C_{V5} = 0,47$

C_{V6} : Factor:

- if $1 < \varepsilon_{v\gamma} \leq 2$:
  $C_{V6} = 0,47$
- if $2 < \varepsilon v_\gamma$:

$$C_{V6} = \frac{0,12}{\varepsilon_{v\gamma} - 1,74}$$

C_{V7} : Factor:

- if $1 < \varepsilon_{v\gamma} \leq 1,5$:
  $C_{V7} = 0,75$
- if $1,5 < \varepsilon v_\gamma \leq 2,5$:
  $C_{V7} = 0,125 \sin[\pi (\varepsilon_{v\gamma} - 2)] + 0,875$
- if $2,5 < \varepsilon v_\gamma$:
  $C_{V7} = 1$

Table 29 : Correction factors C_F and C_b

Conditions	Factors C_F and C_b
if $F_{mt} K_A / b_e \geq 100$ N/mm	$C_F = 1$
if $F_{mt} K_A / b_e < 100$ N/mm	$C_F = (F_{mt} K_A / b_e) / 100$
if $b_e / b \geq 0,85$	$C_b = 1$
if $b_e / b < 0,85$	$C_b = (b_e / b) / 0,85$

b_e : Effective face width, the real length of contact pattern. When b_e is not supplied, $b_e = 0,85$ b could be used.

Table 30 : Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

	Factors $K_{H\alpha}$ and $K_{F\alpha}$	Limitations
$\varepsilon_{v\gamma} \le 2$	$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_{v\gamma}}{2} \cdot \left(0,9 + 0,4 \cdot \frac{c_\gamma \cdot (f_{pt} - y_\alpha)}{F_{mtH}/b}\right)$	$\frac{\varepsilon_{v\gamma}}{\varepsilon_{v\alpha} \cdot Z_{LS}^2} \ge K_{H\alpha} \ge 1$ $\frac{\varepsilon_{v\gamma}}{\varepsilon_{v\alpha} \cdot Y_\varepsilon} \ge K_{F\alpha} \ge 1$
$\varepsilon_{v\gamma} > 2$	$K_{H\alpha} = K_{F\alpha} = 0,9 + 0,4 \cdot \sqrt{\frac{2 \cdot (\varepsilon_{v\gamma} - 1)}{\varepsilon_{v\gamma}}} \frac{c_\gamma \cdot (f_{pt} - y_\alpha)}{F_{mtH}/b}$	

Note 1:

c_γ : Mesh stiffness, in N/mm.µm, defined in [3.3.4]

f_{pt} : Larger value of the single pitch deviation of pinion or wheel, in µm.

Default value: $f_{pt} = 0,3\ (m_{mn} + 0,4\ |d_{vbi}|^{0,5} + 4) \cdot 2^{0,5\ (Q_i - 5)}$

In case of optimum profile correction, f_{pt} is to be replaced by $f_{pt} / 2$

y_α : Running-in allowance, in µm, defined in Tab 31

F_{mtH} : Determinant tangential load at mid-face width on the reference cone, in N:
$F_{mtH} = F_{mt} \cdot K_A \cdot K_V \cdot K_{H\beta}$

Table 31 : Running-in allowance y_α

Material	y_α, in µm	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$\frac{160}{\sigma_{H,lim}} f_{pt}$	• if 5 m/s < v_{mt} ≤ 10 m/s: $y_\alpha \le 12800 / \sigma_{H,lim}$ • if 10 m/s < v_{mt}: $y_\alpha \le 6400 / \sigma_{H,lim}$
GGG (ferr.), GG	0,275 f_{pt}	• if 5 m/s < v_{mt} ≤ 10 m/s: $y_\alpha \le 22$ • if 10 m/s < v_{mt}: $y_\alpha \le 11$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	0,075 f_{pt}	$y_\alpha \le 3$

Note 1: f_{pt} is defined in Tab 30 and $\sigma_{H,lim}$ is defined in [3.4.10].

Note 2: When material of the pinion differs from that of the wheel: $y_\alpha = 0,5\ (y_{\alpha 1} + y_{\alpha 2})$

3.4.2 Contact stress σ_H

The contact stress σ_H is to be determined as follows:

$$\sigma_H = \sigma_{H0} \cdot \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

K_A : Application factor (see [3.3.2])

K_γ : Load sharing factor (see [3.3.3])

K_ς : Dynamic factor (see [3.3.4])

$K_{H\beta}$: Face load distribution factor (see [3.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [3.3.6])

$$\sigma_{H0} = Z_{M-B} \cdot Z_H \cdot Z_E \cdot Z_{LS} \cdot Z_\beta \cdot Z_K \cdot \sqrt{\frac{F_{mt}}{d_{v1} \cdot \ell_{bm}} \cdot \frac{u_v + 1}{u_v}}$$

with:

Z_{M-B} : Mid-zone factor, defined in [3.4.3]

Z_H : Zone factor, defined in [3.4.4]

ZE : Elasticity factor, defined in [3.4.5]

$Z_{L\Sigma}$: Load-sharing factor, defined in [3.4.6]

Z_β : Helix angle factor, defined in [3.4.7]

Z_K : Bevel gear ratio factor, defined in [3.4.8].

3.4.3 Mid-zone factor Z_{M-B}

The mid-zone factor Z_{M-B} accounts for the difference of contact pressure between the pitch point and the determinant point of load application.

Z_{M-B} is to be determined as follows:

$$Z_{M-B} = \frac{\tan\alpha_{vt}}{\sqrt{\left[\sqrt{\frac{d_{va1}^2}{d_{vb1}^2} - 1} - \left(F_1 \cdot \frac{\pi}{z_{v1}}\right)\right] \cdot \left[\sqrt{\frac{d_{va2}^2}{d_{vb2}^2} - 1} - \left(F_2 \cdot \frac{\pi}{z_{v2}}\right)\right]}}$$

where F_1 and F_2 are defined according to the following conditions:

- if $0 \le \varepsilon_{v\beta} < 1$:
  $F_1 = 2 + (\varepsilon_{v\alpha} - 2) \cdot \varepsilon_{v\beta}$
  $F_2 = 2\,\varepsilon_{v\alpha} - 2 + (2 - \varepsilon_{v\alpha}) \cdot \varepsilon_{v\beta}$
- if $\varepsilon_{v\beta} \ge 1$:
  $F_1 = \varepsilon_{v\alpha}$
  $F_2 = \varepsilon_{v\alpha}$

3.4.4 Zone factor Z_H

The zone factor Z_H accounts for the influence on the hertzian pressure of tooth flank curvature at the pitch point.

Z_H is to be determined as follows:

$$Z_H = 2 \cdot \sqrt{\frac{\cos\beta_{vb}}{\sin(2 \cdot \alpha_{vt})}}$$

3.4.5 Elasticity factor Z_E

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the hertzian pressure.

The values of Z_E to be used are given in [2.4.5].

3.4.6 Load-sharing factor Z_{LS}

The load-sharing factor Z_{LS} accounts for load sharing between two or more pairs of teeth.

Z_{LS} is to be determined as follows:

- if $\varepsilon_{v\gamma} > 2$ and $\varepsilon_{v\beta} > 1$:

$$Z_{LS} = \left\{1 + 2\left[1 - \left(\frac{2}{\varepsilon_{v\gamma}}\right)^{1,5}\right] \cdot \sqrt{1 - \frac{4}{\varepsilon_{v\gamma}^2}}\right\}^{-0,5}$$

- if $\varepsilon_{v\gamma} \le 2$:
  $Z_{LS} = 1$
- otherwise, an alternative calculation should be supplied and will be given special consideration by the Society.

3.4.7 Helix angle factor Z_β

The helix angle factor Z_β accounts for the influence of helix angle on the surface durability, allowing for such variables as the distribution of the load along the lines of contact.

Z_β is to be determined as follows:

$$Z_\beta = \frac{1}{\sqrt{\cos\beta_m}}$$

3.4.8 Bevel gear factor Z_K

The bevel gear factor Z_K is an empirical factor which accounts for the difference between bevel and cylindrical gears loading.

Z_K is to be determined as follows:

$Z_K = 0,8$

3.4.9 Permissible contact stress σ_{HP}

The permissible contact stress σ_{HP}, in N/mm^2, is to be determined separately for pinion and wheel, using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,lim}}{S_H} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$$

where:

$\sigma_{H,lim}$: Endurance limit for contact stress, defined in [3.4.10]

Z_{NT} : Life factor for contact stress, defined in [3.4.11]

Z_L, Z_V, Z_R: Lubrication, speed and roughness factors, respectively, defined in [3.4.12]

Z_Ω : Hardness ratio factor, defined in [3.4.13]

Z_Ξ : Size factor for contact stress, defined in [3.4.14]

Σ_H : Safety factor for contact stress, defined in [3.4.15].

3.4.10 Endurance limit for contact stress $\sigma_{H,lim}$

The endurance limit for contact stress $\sigma_{H,lim}$, in N/mm^2, is the limit of repeated contact stress which can be permanently endured.

The values to be adopted for $\sigma_{H,lim}$ are given in [2.4.9] in relation to the type of steel employed and the heat treatment performed.

3.4.11 Life factor for contact stress Z_{NT}

The life factor Z_{NT} accounts for the influence of limited service life on the permissible contact stress.

Some values of Z_{NT} are given in Tab 17 for information.

The value of Z_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

3.4.12 Lubrication factor Z_L, speed factor Z_V and roughness factor Z_R

The lubricant factor Z_L accounts for the influence of the type of the lubricant and the influence of its viscosity, the speed factor Z_V accounts for the influence of the pitch line velocity, and the roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

These factors are to be determined according to the formulae of [2.4.11], using the following parameters:

ϖ_{mt} : Linear speed at mean pitch diameter, in m/s. It is to replace ϖ in the calculation of Z_V

ρ_{red} : Relative radius of curvature, in mm:

$$\rho_{red} = \frac{a_v \cdot \sin\alpha_{vt}}{\cos\beta_{vb}} \cdot \frac{u_v}{(1+u_v)^2}$$

3.4.13 Hardness ratio factor Z_W

The hardness ratio factor Z_W accounts for the increase of the surface durability. This factor is to be determined according to the formulae of [2.4.12], using the following parameters:

ϖ_{mt} : Linear speed at mean pitch diameter, in m/s. It is to replace ϖ in the calculations

ρ_{red} : Relative radius of curvature, in mm, as defined in [3.4.12]

υ_{ϖ} : Virtual reduction ratio. It is to replace u in the calculations.

3.4.14 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is in general equal to 1.

The value Z_X to be used will be given special consideration by the Society depending on the material.

3.4.15 Safety factor for contact stress S_H

The values to be adopted for the safety factor for contact stress S_H are given in Tab 18.

3.5 Calculation of tooth bending strength

3.5.1 General

The criterion for tooth root bending stress is based on the local tensile stress at the tooth root in the direction of the tooth height.

The tooth root bending stress σ_F, defined in [3.5.2], is not to exceed the permissible tooth root bending stress σ_{FP} defined in [3.5.8].

3.5.2 Tooth root bending stress σ_F

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_{mt}}{b \cdot m_{mn}} \cdot Y_{Fa} \cdot Y_{Sa} \cdot Y_{\varepsilon} \cdot Y_{LS} \cdot Y_K \cdot K_A \cdot K_{\gamma} \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha}$$

where:

Y_{Fa} : Tooth form factor, defined in [3.5.3]

Y_{Sa} : Stress correction factor, defined in [3.5.4]

Y_{ε} : Contact ratio factor, defined in [3.5.5]

Y_{LS} : Load sharing factor, defined in [3.5.6]

Y_K : Bevel gear factor, defined in [3.5.7]

K_A : Application factor (see [3.3.2])

K_{γ} : Load sharing factor (see [3.3.3])

K_V : Dynamic factor (see [3.3.4])

$K_{F\beta}$: Face load distribution factor (see [3.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [3.3.6]).

When a shot-peening treatment of the tooth root is applied according to a process agreed by the Society, a reduction of the bending stress σ_F (depending on the material category, but without being over 10%) could be taken in consideration only for carburized case-hardened steel gears.

3.5.3 Tooth form factor Y_{Fa}

The tooth form factor Y_{Fa} takes into account the effect of the tooth form on the nominal bending stress, assuming the load applied at the outer point of a single pair tooth contact of the virtual cylindrical gears in normal section.

Y_{Fa} is to be determined separately for the pinion and for the wheel, using the following formula:

$$Y_{Fa} = \frac{6 \cdot \frac{h_{Fa}}{m_{mn}} \cdot \cos\alpha_{Fan}}{\left(\frac{S_{Fn}}{m_{mn}}\right)^2 \cdot \cos\alpha_n}$$

where:

h_{Fa} : Bending moment arm, in mm:

$$\frac{h_{Fa}}{m_{mn}} = \frac{1}{2}\left[(\cos\gamma_a - \sin\gamma_a \cdot \tan\alpha_{Fan}) \cdot \frac{d_{van}}{m_{mn}} - z_{vn} \cdot \cos\left(\frac{\pi}{3} - \theta\right) - \left(\frac{G}{\cos\theta} - \frac{\rho_{a0}}{m_{mn}}\right)\right]$$

s_{Fn} : Tooth root chord at the critical section, in mm:

$$\frac{s_{Fn}}{m_{mn}} = z_{vn} \cdot \sin\left(\frac{\pi}{3} - \theta\right) + \sqrt{3} \cdot \left(\frac{G}{\cos\theta} - \frac{\rho_{a0}}{m_{mn}}\right)$$

G : Parameter defined by:

$$G = \frac{\rho_{a0}}{m_{mn}} - \frac{h_{fP}}{m_{mn}} + x_h$$

θ : Parameter defined by:

$$\theta = \frac{2 \cdot G}{z_{vn}} \cdot \tan\theta - H$$

This transcendental equation is to be calculated by iteration

H : Parameter defined by:

$$H = \frac{2}{z_{vn}} \cdot \left(\frac{\pi}{2} - \frac{E}{m_{mn}}\right) - \frac{\pi}{3}$$

E : Parameter defined by:

$$E = \left(\frac{\pi}{4} - x_s\right) m_{mn} - h_{fP} \tan\alpha_n + \frac{s_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{a0}}{\cos\alpha_n}$$

s_{pr} : Residual fillet undercut, in mm:

$s_{pr} = pr - q$

The parameters of the virtual gears are defined as follows:

α_{Fan} : Load direction angle:

$\alpha_{Fan} = \alpha_{an} - \gamma_a$

γ_a : Parameter defined by:

$$\gamma_a = \frac{o,5 \cdot \pi + 2(\tan\alpha_n \cdot x_h + x_s)}{z_{vn}} + inv\alpha_n - inv\alpha_{an}$$

with inv, involute function, equal to:

$inv\ \alpha = \tau\alpha v\ \alpha - \alpha$

α_{an} : Form factor pressure angle:

$$\cos\alpha_{an} = \frac{d_{vbn}}{d_{van}}$$

3.5.4 Stress correction factor Y_{Sa}

The stress correction factor Y_{Sa} is used to convert the nominal bending stress to local tooth root stress.

Y_{Sa} is to be determined as follows:

$$Y_{Sa} = (1,2 + 0,13L_a) \cdot q_s^{\frac{1}{1,21 + (2,3)/L_a}}$$

where:

$$L_a = \frac{s_{Fn}}{h_{Fa}}$$

with s_{Fn} and h_{Fa} defined in [3.5.3]

q_s : Notch parameter:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

with s_{Fn} defined in [3.5.3]

Note 1: The notch parameter should be within the range:

$1 \leq q_s < 8$

ρ_F : Fillet radius at contact point of 30° tangent, in mm:

$$\frac{\rho_F}{m_{mn}} = \frac{\rho_{a0}}{m_{mn}} + \frac{2G^2}{\cos\theta \cdot (z_{vn} \cdot \cos^2\theta - 2G)}$$

3.5.5 Contact ratio factor Y_ε

The contact ratio factor Y_ε converts the load application at the tooth tip to the decisive point of load application.

Y_ε is to be determined as follows:

- if $\varepsilon_{v\beta} \leq 1$:

$$Y_\varepsilon = 0,25 + \frac{0,75}{\varepsilon_{v\alpha}} - \varepsilon_{v\beta} \cdot \left(\frac{0,75}{\varepsilon_{v\alpha}} - 0,375\right)$$

- if $\varepsilon_{v\beta} > 1$:

$Y_\varepsilon = 0,625$

Note 1: A minimum of 0,625 should always be taken for Y_ε.

3.5.6 Load sharing factor Y_{LS}

The load sharing factor Y_{LS} accounts for load sharing between two or more pairs of teeth.

Y_{LS} is to be determined as follows:

$$Y_{LS} = Z_{LS}^2$$

3.5.7 Bevel gear factor Y_K

The bevel gear factor Y_K accounts for the difference between bevel and cylindrical gears loading.

Y_K is to be determined as follows:

$$Y_K = \left(\frac{1}{2} + \frac{\ell'_{bm}}{2b}\right)^2 \cdot \frac{b}{\ell'_{bm}}$$

3.5.8 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and for wheel, using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X$$

where:

σ_{FE} : Endurance limit for tooth root bending stress, defined in [3.5.9]

Ψ_δ : Design factor, defined in [3.5.10]

Ψ_{NT} : Life factor for tooth root bending stress, defined in [3.5.11]

$\Psi_{\delta relT}$: Relative notch sensitivity factor, defined in [3.5.12]

$\Psi_{P\rho\varepsilon IT}$: Relative surface factor, defined in [3.5.13]

Ψ_Ξ : Size factor for tooth root bending stress, defined in [3.5.14]

Σ_Φ : Safety factor for tooth root bending stress, defined in [3.5.15].

3.5.9 Endurance limit for tooth root bending stress σ_{FE}

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root stress which can be permanently endured.

The values to be adopted for σ_{FE} are given in [2.5.9]] in relation to the type of steel employed and the heat treatment performed.

3.5.10 Design factor Y_d

The design factor Y_d takes into account the influence of load reversing and shrink fit pre-stressing on the tooth root strength.

Y_d is defined in [2.5.10].

3.5.11 Life factor Y_{NT}

The life factor Y_{NT} accounts for the influence of limited service life on the permissible tooth root bending stress.

Some values of Y_{NT} are given in Tab 20 for information.

The value Y_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

3.5.12 Relative notch sensitivity factor $\Psi_{\delta relT}$

The relative notch sensitivity factor $\Psi_{\delta relT}$ indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

$\Psi_{\delta relT}$ is to be determined according to [2.5.12].

3.5.13 Relative surface factor $\Psi_{R\rho\varepsilon lT}$

The relative surface factor $\Psi_{R\rho\varepsilon lT}$ takes into account the dependence of the root strength on the surface condition on the tooth root fillet (roughness).

The values to be adopted for $\Psi_{R\rho\varepsilon lT}$ are given in Tab 22 in relation to the type of steel employed.

They are valid only when scratches or similar defects deeper than 12 R_a are not present.

3.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 23 in relation to the type of steel employed and the value of normal module m_{mn}.

3.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 24.

3.6 Calculation of scuffing resistance

3.6.1 General

The following calculations are requested for equipment running in supercritical domain i.e. when N > 1,5 (see [3.3.4]).

The criterion for scuffing resistance is based on the calculation of the flash temperature method. According to this method, the risk of scuffing is assessed as a function of the properties of gear material, the lubricant characteristics, the surface roughness of tooth flanks, the sliding velocities and the load.

The interfacial contact temperatures are calculated as the sum of the interfacial bulk temperature of the moving interface and the fluctuating flash temperature of the moving faces in contact.

The maximum value of the interfacial contact temperature reduced by oil temperature is not to exceed 0,8 times the scuffing temperature reduced by oil temperature:

$$(\Theta_{B,Max} - \Theta_{oil}) \leq 0,8\ (\Theta_{\sigma} - \Theta_{oil})$$

where:

$\Theta_{B,Max}$: Maximum contact temperature along the path of contact, in °C, defined in [3.6.2]

Θ_{oil} : Oil temperature, in °C

Θ_{Σ} : Scuffing temperature, in °C, defined in [3.6.11].

Additionally, the difference between the scuffing temperature and the contact temperature along the path is not to be below 30°C:

$$(\Theta_{\sigma} - \Theta_{B,Max}) \geq 30°C$$

Other methods of determination of the scuffing resistance could be accepted by the Society.

3.6.2 Contact temperature Θ_B

The maximum contact temperature $\Theta_{B,Max}$ along the path of contact, in °C, is calculated as follows:

$$\Theta_{B,Max} = \Theta_{Mi} + \Theta_{fl,Max}$$

where:

Θ_{Mi} : Interfacial bulk temperature, in °C, defined in [3.6.10]

$\Theta_{fl,Max}$: Maximum flash temperature along the path of contact, in °C, defined in [3.6.3].

The flash temperature is to be calculated on at least ten points along the path of contact and the maximum of these values has to be used for the calculation of maximum contact temperature.

3.6.3 Flash temperature Θ_{fl}

The flash temperature Θ_{fl} at any point along the path of contact, in °C, is calculated with the following formula:

$$\Theta_{fl} = \mu_m \cdot X_M \cdot X_J \cdot X_G (X_\Gamma \cdot w_{Bt})^{0,75} \cdot \frac{v_{mt}^{0,5}}{r_m^{0,25}}$$

where:

μ_m : Mean coefficient of friction, defined in [3.6.4]

Ξ_M : Thermo-elastic factor, in $K \cdot N^{-3/4} \cdot s^{-1/2} \cdot m^{-1/2} \cdot mm$, defined in [3.6.5]

Ξ_J : Approach factor, defined in [3.6.6]

Ξ_G : Geometry factor, defined in [3.6.7]

Ξ_Γ : Load sharing factor, defined in [3.6.8]]

ω_{Bt} : Transverse unit load, in N/mm, defined in [3.6.9].

3.6.4 Mean coefficient of friction μ_m

An estimation of the mean coefficient of friction μ_m of common working conditions could be used with the following formula:

$$\mu_m = 0,06 \cdot \left(\frac{w_{Bt}}{v_{g\Sigma C} \cdot \rho_{relC}} \right)^{0,2} \cdot X_L \cdot X_R$$

where:

w_{Bt} : Transverse unit load, in N/mm (see [3.6.9])

$v_{g\Sigma C}$: Sum of tangential velocities in pitch point, in m/s:

$v_{g\Sigma C} = 2\, v_{mt} \sin \alpha_{vt}$

with the maximum value of v_{mt} equal to 50 m/s

ρ_{relC} : Transverse relative radius of curvature, in mm:

$$\rho_{relC} = \frac{u \cdot \tan\delta_1 \cdot \tan\delta_2}{\tan\delta_1 + u \cdot \tan\delta_2} \cdot r_m \cdot \sin\alpha_{vt}$$

X_L : Lubricant factor, given in Tab 25

X_R : Roughness factor:

$$X_R = \left(\frac{R_{zf1} + R_{zf2}}{2} \right)^{0,25}$$

3.6.5 Thermo-elastic factor X_M

The thermo-elastic factor X_M accounts for the influence of the material properties of pinion and wheel.

The values to be adopted for X_M are given in [2.6.5] in relation to the gear material characteristics.

3.6.6 Approach factor X_J

The approach factor X_J takes empirically into account an increased scuffing risk in the beginning of the approach path, due to mesh starting without any previously built up oil film.

The values to be adopted for X_J are given in [2.6.6] in relation to the gear material characteristics.

3.6.7 Geometry factor X_G

The geometry factor X_G is calculated according to the following formula:

$$X_G = 0,51 X_{\alpha\beta} \left(\frac{1}{\tan\delta_1} + \frac{1}{\tan\delta_2} \right)^{0,25} \frac{\left| (1+\Gamma)^{0,5} - \left(1 + \Gamma \frac{\tan\delta_1}{\tan\delta_2}\right)^{0,5} \right|}{(1+\Gamma)^{0,25} \cdot \left(1 - \Gamma \frac{\tan\delta_1}{\tan\delta_2}\right)^{0,25}}$$

where:

$X_{\alpha\beta}$: Angle factor, equal to:

$X_{\alpha\beta} = 1,22\, (\sin\alpha_{vt})^{0,25} \cdot (\cos\alpha_{vt})^{-0,5} \cdot (\cos\beta_{vb})^{0,25}$

Γ : Parameter of the point on the line of action, defined in Tab 32.

3.6.8 Load sharing factor X_Γ

The load sharing factor X_Γ accounts for the load sharing of succeeding pairs of meshing teeth. It is defined as a function of the value of the parameter in the line of action, increasing at the approach path of transverse double contact.

The values to be adopted for X_Γ are given in [2.6.8].

The parameter of the line of action Γ to be used is given in Tab 32.

Table 32 : Parameter Γ on the line of action

Point			Γ
A	:	Lower end point of the path of contact	$\Gamma_A = -\frac{\tan\delta_2}{\tan\delta_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{vt}} - 1\right)$
AU	:	Lower end point of buttressing effect	$\Gamma_{AU} = \Gamma_A + 0,2 \sin\beta_{vb}$
AB	:	Intermediate point between A and B	$\Gamma_{AB} = 0,5\ (\Gamma_A + \Gamma_B)$
B	:	Lower point of single pair tooth contact	$\Gamma_B = \frac{\tan\alpha_{a1}}{\tan\alpha_{vt}} - 1 - \frac{2\pi \cdot \cos\delta_1}{z_1 \tan\alpha_{vt}}$
C	:	Point with parameter equal to 0	$\Gamma_C = 0$
M	:	Intermediate point between A and E	$\Gamma_M = 0,5\ (\Gamma_A + \Gamma_E)$
D	:	Upper point of single pair tooth contact	$\Gamma_D = -\frac{\tan\delta_2}{\tan\delta_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{vt}} - 1\right) + \frac{2\pi \cdot \cos\delta_1}{z_1 \tan\alpha_{vt}}$
DE	:	Intermediate point between D and E	$\Gamma_{DE} = 0,5\ (\Gamma_D + \Gamma_E)$
EU	:	Upper end point of buttressing effect	$\Gamma_{EU} = \Gamma_E - 0,2 \sin\beta_{vb}$
E	:	Upper end point of the path of contact	$\Gamma_E = \frac{\tan\alpha_{a1}}{\tan\alpha_{vt}} - 1$

Note 1:

$\alpha_{\alpha\alpha}$: Transverse tip pressure angle of pinion and wheel, in rad:

$$\cos\alpha_{ai} = \frac{\cos\alpha_{vt}}{1 + 2h_{fOi} \cdot (\cos\delta_i)/d_{mi}}$$

3.6.9 Transverse unit load w_{Bt}

The transverse unit load w_{Bt} is calculated according to the following formula:

$$w_{Bt} = K_A \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha} \cdot K_\gamma \cdot \frac{F_{mt}}{b}$$

where:

K_A : Application factor (see [3.3.2])

K_V : Dynamic factor (see [3.3.4])

$K_{H\beta}$: Face load distribution factor (see [3.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [3.3.6])

K_γ : Load sharing factor (see [3.3.3]).

3.6.10 Interfacial bulk temperature Θ_{Mi}

The interfacial bulk temperature Θ_{Mi} may be suitably averaged from the two overall bulk temperatures of the teeth in contact, Θ_{M1} and Θ_{M2}. An estimation of Θ_{Mi}, given in [2.6.10], could be used in general configurations.

3.6.11 Scuffing temperature Θ_σ

The scuffing temperature Θ_S may be determined according to the following formula:

$$\Theta_S = 80 + (0,85 + 1,4\ X_W) \cdot X_L \cdot (S_{FZG} - 1)^2$$

where:

X_W : Structural factor given in Tab 27

X_L : Lubricant factor given in Tab 25

S_{FZG} : Load stage where scuffing occurs, according to gear tests, such as Ryder, FZG-Ryder, FZG L-42 or FZG A/8 3/90.

4 Design and construction - except tooth load capacity

4.1 Materials

4.1.1 General

a) Forged, rolled and cast materials used in the manufacturing of shafts, couplings, pinions and wheels are to comply with the requirements of NR216 Materials and Welding.

b) Materials other than steels will be given special consideration by the Society.

Requirements mentioned in Ch 1, Sec 1, [3.7.2] are to be applied when other materials than steel are used for components in contact with flammable fluids.

4.1.2 Steels for pinions and wheel rims

a) Steels intended for pinions and wheels are to be selected considering their compatibility in service. In particular, for through-hardened pinion / wheel pairs, the hardness of the pinion teeth is to exceed that of the corresponding wheel. For this purpose, the minimum tensile strength of the pinion material is to exceed that of the wheel by at least 15%.

b) The minimum tensile strength of the core is not to be less than:

- 750 N/mm^2 for case-hardened teeth
- 800 N/mm^2 for induction-hardened or nitrided teeth.

4.2 Teeth

4.2.1 Manufacturing accuracy

a) Mean roughness (peak-to-valley) of shaved or ground teeth is not to exceed 4 µm.

b) Wheels are to be cut by cutters with a method suitable for the expected type and quality. Whenever necessary, the cutting is to be carried out in a temperature-controlled environment.

4.2.2 Tooth root

Teeth are to be well faired and rounded at the root. The fillet radius at the root of the teeth, within a plane normal to the teeth, is to be not less than 0,25 m_n.

Profile-grinding of gear teeth is to be performed in such a way that no notches are left in the fillet.

4.2.3 Tooth tips and ends

a) All sharp edges on the tips and ends of gear teeth are to be removed after cutting and finishing of teeth.

b) Where the ratio b/d exceeds 0,3, the ends of pinion and wheel are to be chamfered to an angle between 45 and 60 degrees. The chamfering depth is to be at least equal to 1,5 m_n.

4.2.4 Surface treatment

a) The hardened layer on surface-hardened gear teeth is to be uniform and extended over the whole tooth flank and fillet.

b) Where the pinions and the toothed portions of the wheels are case-hardened and tempered, the teeth flanks are to be ground while the bottom lands of the teeth remain only case-hardened. The superficial hardness of the case-hardened zone is to be at least equal to 56 C Rockwell units.

c) Where the pinions and the toothed portions of the wheels are nitrided, the hardened layer is to comply with Tab 33.

d) The use of other processes of superficial hardening of the teeth, such as flame hardening, will be given special consideration, in particular as regards the values to be adopted for $\sigma_{H,lim}$ and σ_{FE}.

Table 33 : Characteristics of the hardened layer for nitrided gears

Type of steel	Minimum thickness of hardened layer, in mm **(1)**	Minimum hardness (HV)
Nitrided steel	0,6	500 (at 0,25 mm depth)
Other steels	0,3	450 (surface)

(1) Depth of the hardened layer where the hardness is reduced to the core hardness. When the grinding of nitrided teeth is performed, the depth of the hardened layer to be taken into account is the depth after grinding.

4.3 Wheels and pinions

4.3.1 General

Wheel bodies are to be so designed that radial deflexions and distortions under load are prevented, so as to ensure a satisfactory meshing of teeth.

4.3.2 Welding

a) Where welding is employed for the construction of wheels, the welding procedure is to be submitted to the Society for approval. Welding processes and their qualification are to comply with NR216 Materials and Welding.

b) Stress relieving treatment is to be performed after welding.

c) Examination of the welded joints is to be performed by means of magnetic particle or dye penetrant tests to the satisfaction of the Surveyor. Suitable arrangements are to be made to permit the examination of the internal side of the welded joints.

4.3.3 Shrink-fits

a) The shrink-fit assembly of:

- rim and wheel body, and
- wheel body and shaft

is to be designed with a safety factor against slippage of not less than 2,8 c where c is a coefficient having the following values:

- c = 1 for gears driven by turbines or electric motors
- c = 1 for gears driven by diesel engines through a hydraulic, electromagnetic or high elasticity coupling
- c = 1,2 in the other cases.

Note 1: The manufacturer is to ensure that the maximum torque transmitted during the clutch engagement does not exceed the nominal torque by more than 20%.

b) The shrink-fit assembly is to take into account the thermal expansion differential between the shrunk-on parts in the service conditions.

4.3.4 Bolting

Where rims and hubs are joined together through bolted side plates or flanges, the assembly is to be secured:

- by tight fit bolts, or
- by bolts and tight fit pins.

The nuts are to be suitably locked by means other than welding.

4.4 Shafts and bearings

4.4.1 General

Shafts and their connections, in particular flange couplings and shrink-fits connections, are to comply with the provisions of Ch 1, Sec 7.

4.4.2 Pinion and wheel shafts

The minimum diameter of pinion and gear wheel shafts is not to be less than the value d_S, in mm, given by the following formula:

$$d_S = \left\{ \left[\left(10,2 + \frac{28000}{R_{S,min}} \right) T \right]^2 + \left[\frac{170000}{412 + R_{s,min}} M \right]^2 \right\}^{\frac{1}{6}} \left(\frac{1}{1 - K_d^4} \right)^{\frac{1}{3}}$$

where:

$R_{S,min}$: Minimum yield strength of the shaft material, in N/mm^2

T : Nominal torque transmitted by the shaft, in Nm

M : Bending moment on the shaft, in Nm

K_d : Coefficient having the following values:

- for solid shafts: $K_d = 0$
- for hollow shafts, K_d is equal to the ratio of the hole diameter to the outer shaft diameter.

  Where $K_d \leq 0,3$: $K_d = 0$ may be taken.

Note 1: The values of d_S, T and M refer to the cross-section of the shaft concerned.

As an alternative to the above formula, the Society may accept direct strength calculations considering static and fatigue stresses occurring simultaneously and assuming safety factors for the material employed of at least:

- 1,5 in respect of the yield strength
- 2,0 in respect of the alternating bending fatigue limit.

4.4.3 Quill shafts

The minimum diameter of quill shafts subject to torque only is not to be less than the value d_{QS}, in mm, given by the following formula:

$$d_{QS} = \left[\left(7,65 + \frac{27000}{R_{S,min}} \right) \cdot \frac{T}{1 - K_d^4} \right]^{\frac{1}{3}}$$

$R_{S,min}$ and K_d being defined in [4.4.2].

4.4.4 Bearings

a) Thrust bearings and their supports are to be so designed as to avoid detrimental deflexions under load.

b) Life duration of bearings is not to be less than 40 000 hours. Shorter durations may be accepted on the basis of the actual load time distribution, and subject to the agreement of the owner.

4.5 Casings

4.5.1 General

Manufacturers are to build gear casings of sufficient stiffness such that misalignment, external loads and thermal effects in all service conditions do not adversely affect the overall tooth contact.

4.5.2 Welded casings

a) Carbon content of steels used for the construction of welded casings is to comply with the provisions of NR216 Materials and Welding.

b) The welded joints are to be so arranged that welding and inspection can be performed satisfactorily. They are to be of the full penetration type.

c) Welded casings are to be stress-relieved after welding.

4.5.3 Openings

Access or inspection openings of sufficient size are to be provided to permit the examination of the teeth and the structure of the wheels.

4.6 Lubrication

4.6.1 General

a) Manufacturers are to take care of the following points:
- reliable lubrication of gear meshes and bearings is ensured:
  - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
  - for all angles stated in Ch 1, Sec 1, [2.4]
- in multi-propellers plants not fitted with shaft brakes, provision is to be made to ensure lubrication of gears likely to be affected by windmilling.

b) Lubrication by means other than oil circulation under pressure will be given special consideration.

4.6.2 Pumps

a) Gears intended for propulsion or other essential services are to be provided with:
- one main lubricating pump, capable of maintaining a sufficient lubrication of the gearbox in the whole speed range
- and one standby pump independently driven of at least the same capacity.

b) In the case of:
- gears having a transmitted power not exceeding 375 kW
- or multi-engines plants

one of the pumps mentioned in a) may be a spare pump ready to be connected to the reduction gear lubricating oil system, provided disassembling and reassembling operations can be carried out on board in a short time.

4.6.3 Filtration

a) Forced lubrication systems are to be fitted with a device which efficiently filters the oil in the circuit.

b) When fitted to gears intended for propulsion machinery or machinery driving electric propulsion generators, such filters are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

4.7 Control and monitoring

4.7.1 Gears are to be provided with the alarms and safeguards listed in Tab 34.

Table 34 : Indications, alarms and safeguards for gears

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Lubricating oil temperature at the oil cooler outlet		local					
Lubricating oil pressure		local					
	L **(1)**			X			
Oil tank level		local					
(1) May be omitted in case of restricted navigation notation.							

5 Installation

5.1 General

5.1.1 Manufacturers and shipyards are to take care directly that stiffness of gear seating and alignment conditions of gears are such as not to adversely affect the overall tooth contact and the bearing loads under all operating conditions of the ship.

5.2 Fitting of gears

5.2.1 Means such as stoppers or fitted bolts are to be arranged in the case of gears subject to propeller thrust. However, where the thrust is transmitted by friction and the relevant safety factor is not less than 2, such means may be omitted.

6 Certification, inspection and testing

6.1 General

6.1.1

a) Inspection and testing of shafts and their connections (flange couplings, hubs, bolts, pins) are to be carried out in accordance with the provisions of Ch 1, Sec 7.

b) For inspection of welded joints of wheels, refer to [4.3.2].

6.2 Workshop inspection and testing

6.2.1 Testing of materials

Chemical composition and mechanical properties are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Chapter 5 for the following items:

- pinions and wheel bodies
- rims
- plates and other elements intended for propulsion gear casings of welded construction.

6.2.2 Testing of pinion and wheel forgings

a) Mechanical tests of pinions and wheels are to be carried out in accordance with:
   - NR216 Materials and Welding, Ch 5, Sec 5, [1.6] for normalised and tempered or quenched and tempered forgings
   - NR216 Materials and Welding, Ch 5, Sec 5, [1.7] for surface-hardened forgings.

b) Non-destructive examination of pinion and wheel forgings is to be performed in accordance with NR216 Materials and Welding, Ch 5, Sec 5, [1.8].

6.2.3 Balancing test

Rotating components, in particular gear wheel and pinion shaft assemblies with the coupling part attached, are to undergo a static balancing test.

Where $n^2.d \geq 1{,}5.10^9$, gear wheel and pinion shaft assemblies are also to undergo a dynamic balancing test.

6.2.4 Verification of cutting accuracy

Examination of the accuracy of tooth cutting is to be performed in the presence of the Surveyor. Records of measurements of errors, tolerances and clearances of teeth are to be submitted at the request of the Surveyor.

6.2.5 Meshing test

a) A tooth meshing test is to be performed in the presence of the Surveyor. This test is to be carried out at a load sufficient to ensure tooth contact, with the journals located in the bearings according to the normal running conditions. Before the test, the tooth surface is to be coated with a thin layer of suitable coloured compound.

b) The results of such test are to demonstrate that the tooth contact is adequately distributed on the length of the teeth. Strong contact marks at the end of the teeth are not acceptable.

c) A permanent record of the tooth contact is to be made for the purpose of subsequent checking of alignment following installation on board.

d) For type approved cylindrical gears, with a power not greater than 375 kW and a cast casing, the above required workshop meshing test could be waived at the Surveyor satisfaction.

6.2.6 Hydrostatic tests

a) Hydraulic or pneumatic clutches are to be hydrostatically tested before assembly to 1,5 times the maximum working pressure of the pumps.

b) Pressure piping, pumps casings, valves and other fittings are to be hydrostatically tested in accordance with the requirements of Ch 1, Sec 10, [20].

Section 7 Main Propulsion Shafting

1 General

1.1 Application

1.1.1 This Section applies to shafts, couplings, clutches and other shafting components transmitting power for main propulsion. In addition, main propulsion machinery components are to comply with the requirements listed in Tab 1.

Table 1 : Rule requirements for main propulsion components

Item		Reference
Power transmission equipment	Diesel engines	Ch 1, Sec 2
	Turbines	Ch 1, Sec 4, Ch 1, Sec 5
	Gear	Ch 1, Sec 6
	Propellers	Ch 1, Sec 8
	Thrusters	Ch 1, Sec 15
Shaft line analysis	Shaft alignment	Ch 1, Sec 7
	Torsional vibration	Ch 1, Sec 9
Additional requirements	Navigation in ice	Pt F, Ch 8, Sec 3

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 2 for approval.

Plans of power transmitting parts and shaft liners listed in Tab 2 are to include the relevant material specifications.

Table 2 : Documentation to be submitted

No.	Document (drawings, calculations, etc.)
1	Shafting arrangement **(1)**
2	Thrust shaft
3	Intermediate shafts
4	Propeller shaft
5	Shaft liners, relevant manufacture and welding procedures, if any
6	Couplings and coupling bolts
7	Flexible couplings **(2)**
8	Sterntube
9	Details of sterntube glands
10	Oil piping diagram for oil lubricated propeller shaft bearings
11	Shaft alignment calculation report, see also [3.3.2], item a)
12	Procedure of shaft alignment, see also [3.3.3]
13	Sea trials program, see Ch 1, Sec 18, [3.11.3] and Ch 1, Sec 18, [3.11.4]

(1) This drawing is to show the entire shafting, from the main engine coupling flange to the propeller. The location of the thrust block, and the location and number of shafting bearings (type of material and length) are also to be shown.

(2) The Manufacturer of the elastic coupling is also to submit the following data:

- allowable mean transmitted torque (static) for continuous operation
- maximum allowable shock torque
- maximum allowable speed of rotation
- maximum allowable values for radial, axial and angular misalignment

In addition, when the torsional vibration calculation of main propulsion system is required (see Ch 1, Sec 9), the following data are also to be submitted:

- allowable alternating torque amplitude and power loss for continuous operation, as a function of frequency and/or mean transmitted torque
- static and dynamic stiffness, as a function of frequency and/or mean transmitted torque
- moments of inertia of the primary and secondary halves of the coupling
- damping coefficient or damping capability
- properties of rubber components
- for steel springs of couplings: chemical composition and mechanical properties of steel employed.

2 Design and construction

2.1 Materials

2.1.1 General

The use of other materials or steels having values of tensile strength exceeding the limits given in [2.1.2], [2.1.3] and [2.1.4] will be considered by the Society in each case.

2.1.2 Shaft materials

Where shafts may experience vibratory stresses close permissible stresses for transient operation (see Ch 1, Sec 9), the materials are to have a specified minimum ultimate tensile strength R_m of 500 N/mm^2. Otherwise materials having a specified minimum ultimate tensile strength R_m of 400 N/mm^2 may be used.

For use in the following formulae in this Section, R_m is limited as follows:

- For carbon and carbon manganese steels, R_m is not exceed 760 N/mm^2
- For alloy steels, R_m is not to exceed 800 N/mm^2
- For propeller shafts, R_m is not to exceed 600 N/mm^2 (for carbon, carbon manganese and alloy steels).

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions are not acceptable when derived from the formulae given in this Section unless the Society verifies that the materials exhibit similar fatigue life as conventional steels (see Ch 1, App 6).

2.1.3 Couplings, flexible couplings, hydraulic couplings

Non-solid forged couplings and stiff parts of elastic couplings subjected to torque are to be of forged or cast steel, or nodular cast iron.

Rotating parts of hydraulic couplings may be of grey cast iron, provided that the peripheral speed does not exceed 40m/s.

2.1.4 Coupling bolts

Coupling bolts are to be of forged, rolled or drawn steel.

In general, the value of the tensile strength of the bolt material R_{mB} is to comply with the following requirements:

- $R_m \leq R_{mB} \leq 1,7\ R_m$
- $R_{mB} \leq 1000$ N/mm^2.

2.1.5 Shaft liners

Liners are to be of metallic corrosion resistant material complying with the applicable requirements of NR216 Materials and Welding and with the approved specification, if any; in the case of liners fabricated in welded lengths, the material is to be recognised as suitable for welding.

In general, they are to be manufactured from castings.

For small shafts, the use of liners manufactured from pipes instead of castings may be considered.

Where shafts are protected against contact with seawater not by metal liners but by other protective coatings, the coating procedure is to be approved by the Society.

2.1.6 Sterntubes

Sterntubes are to comply with the requirements of Pt B, Ch 11, Sec 3, [4.5].

2.2 Shafts - Scantling

2.2.1 General

The provisions of this sub-article apply to propulsion shafts such as an intermediate and propeller shafts of traditional straight forged design and which are driven by rotating machines such as diesel engines, turbines or electric motors.

For shafts that are integral to equipment, such as for gear boxes, podded drives, electrical motors and/or generators, thrusters, turbines and which in general incorporate particular design features, additional criteria in relation to acceptable dimensions have to be taken into account. For the shafts in such equipment, the provisions of this sub-article apply only to shafts subject mainly to torsion and having traditional design features. Other shafts will be given special consideration by the Society.

2.2.2 Alternative calculation methods

Alternative calculation methods may be considered by the Society. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions

2.2.3 Shafts diameters

The diameter of intermediate shafts, thrust shafts and propellers shafts is not to be less than that determined from the following formula:

$$d = F \cdot k \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160} \right]^{1/3}$$

where:

d : Minimum required diameter in mm

Q : Factor equal to d_i / d_o , where:

- d_i : Actual diameter of the shaft bore, in mm (to be taken as 0 for solid shafts)
- d_o : Outside diameter of the shaft, in mm.

Note 1: Where $d_i \leq 0,4\ d_o$, Q may be taken as 0.

F : Factor for type of propulsion installation equal to:

- 95 for intermediate and thrusts shafts in turbine installations, diesel installations with hydraulic (slip type) couplings and electric propulsion installations
- 100 for all other diesel installation and all propeller shafts.

k : Factor for the particular shaft design features, see Tab 3

n : Speed of rotation of the shaft, in revolution per minute, corresponding to power P

P : Maximum continuous power of the propulsion machinery for which the classification is requested, in kW

R_m : Specified minimum tensile strength of the shaft material, in N/mm^2, see [2.1.2].

The diameter of the propeller shaft located forward of the inboard stern tube seal may be gradually reduced to the corresponding diameter required for the intermediate shaft using the minimum specified tensile strength of the propeller shaft in the formula and recognising any limitations given in [2.1.2].

Note 2: Transitions of diameters are to be designed with either a smooth taper or a blending radius equal to the change in diameter.

Table 3 : Values of factor k

For intermediate shafts with						For thrust shafts external to engines		propeller shafts		
straight sections and integral coupling flange **(1)**	shrink fit coupling **(2)**	keyway, tapered connection **(3) (4)**	keyway, cylindrical connection **(3) (4)**	radial hole **(5)**	longitudinal slots **(6)**	on both sides of thrust collar **(1)**	in way of bearing when a roller bearing is used	flange mounted or keyless taper fitted propellers **(7)**	key fitted propellers **(7)**	between forward end of aft most bearing and forward stern tube seal
1,00	1,00	1,10	1,10	1,10	1,20	1,10	1,10	1,22	1,26	1,15

(1) The fillet radius is to be in accordance with the provisions of [2.5.1].

(2) k values refer to the plain shaft section only. Where shafts may experience vibratory stresses close to permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in [2.2.3] Note 2.

(3) At a distance of not less than $0,2\ d_o$ from the end of the keyway the shaft diameter may be reduced to the diameter calculated with k = 1,0.

(4) Keyways are to be in accordance with the provisions of [2.5.5].

(5) Diameter of the radial bore is not to exceed $0,3\ d_o$.

(6) Subject to limitations as $\ell/d_o < 0,8$ and $d_i/d_o < 0,7$ and $e/d_o > 0,15$, where:

- ℓ : slot length in mm
- e : slot width in mm

The end rounding of the slot is not to be less than e/2. an edge rounding should preferably be avoided as this increases the stress concentration slightly.

The k value is valid for 1, 2, 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(7) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2,5 times the required diameter.

2.3 Liners

2.3.1 General

Metal liners or other protective coatings approved by the Society are required where propeller shafts are not made of corrosion-resistant material.

Metal liners are generally to be continuous; however, discontinuous liners, i.e. liners consisting of two or more separate lengths, may be accepted by the Society on a case by case basis, provided that:

- they are fitted in way of all supports
- the shaft portion between liners, likely to come into contact with sea water, is protected with a coating of suitable material with characteristics, fitting method and thickness approved by the Society.

2.3.2 Scantling

The thickness of metal liners fitted on propeller shafts or on intermediate shafts inside sterntubes is to be not less than the value t, in mm, given by the following formula:

$$t = \frac{d + 230}{32}$$

where:

d : Actual diameter of the shaft, in mm.

Between the sternbushes, the above thickness t may be reduced by 25%.

2.4 Stern tube bearings

2.4.1 Oil lubricated aft bearings of antifriction metal

a) The length of bearings lined with white metal or other antifriction metal is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above, provided the nominal bearing pressure is not more than 0,8 N/mm^2, as determined by static bearing reaction calculations taking into account shaft and propeller weight, as exerting solely on the aft bearing, divided by the projected area of the shaft.

However, the minimum bearing length is to be not less than 1,5 times its actual inner diameter.

2.4.2 Oil lubricated aft bearings of synthetic rubber, reinforced resin or plastics material

a) For bearings of synthetic rubber, reinforced resin or plastics material which are approved by the Society for use as oil lubricated sternbush bearings, the length of the bearing is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above provided the nominal bearing pressure is not more than 0,6 N/mm^2, as determined according to [2.4.1] b).

However, the minimum length of the bearing is to be not less than 1,5 times its actual inner diameter.

Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

c) Synthetic materials for application as oil lubricated stern tube bearings are to be of an approved type.

2.4.3 Water lubricated aft bearings

a) The length of the bearing is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

b) For a bearing of synthetic material, consideration may be given to a bearing length less than 4 times, but in no case less than 2 times, the rule diameter of the shaft in way of the bearing, provided the bearing design and material is substantiated by experiments to the satisfaction of the Society.

c) Synthetic materials for application as water lubricated stern tube bearings are to be Type Approved by the Society.

2.4.4 Grease lubricated bearings

The length of grease lubricated bearings is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

2.4.5 Oil or grease lubrication system

a) For oil lubricated bearings, provision for oil cooling is to be made.

A gravity tank is to be fitted to supply lubricating oil to the sterntube; the tank is to be located above the full load waterline.

Oil sealing glands are to be suitable for the various sea water temperatures which may be encountered in service.

b) Grease lubricated bearings will be specially considered by the Society.

2.4.6 Water circulation system

For water lubricated bearings, means are to be provided to ensure efficient water circulation. In case of open loop systems, the sea water suction is normally to be from a sea chest.

The water grooves on the bearings are to be of ample section such as to ensure efficient water circulation and be scarcely affected by wear, particularly for bearings of the plastic type.

The shut-off valve or cock controlling the water supply is to be fitted direct to the stuffing box bulkhead or in way of the water inlet to the sterntube, when this is fitted forward of such bulkhead.

2.5 Couplings

2.5.1 Flange couplings

a) Flange couplings of intermediate and thrust shafts and the flange of the forward coupling of the propeller shaft are to have a thickness not less than 0,2 times the rule diameter of the solid intermediate shaft and not less than the coupling bolt diameter calculated for a tensile strength equal to that of the corresponding shaft.

The fillet radius at the base of solid forged flanges is to be not less than 0,08 times the actual shaft diameter.

The fillet may be formed of multi-radii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 0,08 times the actual shaft diameter.

For non-solid forged flange couplings, the above fillet radius is not to cause a stress in the fillet higher than that caused in the solid forged flange as above.

Fillets are to have a smooth finish and are not to be recessed in way of nuts and bolt heads.

b) Where the propeller is connected to an integral propeller shaft flange, the thickness of the flange is to be not less than 0,25 times the rule diameter of the aft part of the propeller shaft. The fillet radius at the base of the flange is to be not less than 0,125 times the actual diameter.

The strength of coupling bolts of the propeller boss to the flange is to be equivalent to that of the aft part of the propeller shaft.

c) Non-solid forged flange couplings and associated keys are to be of a strength equivalent to that of the shaft.

They are to be carefully fitted and shrunk on to the shafts, and the connection is to be such as to reliably resist the vibratory torque and astern pull.

d) For couplings of intermediate and thrust shafts and for the forward coupling of the propeller shaft having all fitted coupling bolts, the coupling bolt diameter in way of the joining faces of flanges is not to be less than the value d_B, in mm, given by the following formula:

$$d_B = 0,65 \cdot \left[\frac{d^3 \cdot (R_m + 160)}{n_B \cdot D_C \cdot R_{mB}}\right]^{0,5}$$

where:

d : Rule diameter of solid intermediate shaft, in mm, taking into account the ice strengthening requirements of Pt F, Ch 8, Sec 3, where applicable

n_B : Number of fitted coupling bolts

D_C : Pitch circle diameter of coupling bolts, in mm

R_m : Value of the minimum tensile strength of intermediate shaft material taken for calculation of d, in N/mm^2

R_{mB} : Value of the minimum tensile strength of coupling bolt material, in N/mm^2. Where, in compliance with [2.1.1], the use of a steel having R_{mB} in excess of the limits specified in [2.1.4] is allowed for coupling bolts, the value of R_{mB} to be introduced in the formula is not exceed the above limits.

e) Flange couplings with non-fitted coupling bolts may be accepted on the basis of the calculation of bolt tightening, bolt stress due to tightening, and assembly instructions.

To this end, the torque based on friction between the mating surfaces of flanges is not to be less than 2,8 times the transmitted torque, assuming a friction coefficient for steel on steel of 0,18. In addition, the bolt stress due to tightening in way of the minimum cross-section is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2 proof stress ($R_{p\,0,2}$), of the bolt material.

Transmitted torque has the following meanings:

- For main propulsion systems powered by diesel engines fitted with slip type or high elasticity couplings, by turbines or by electric motors: the mean transmitted torque corresponding to the maximum continuous power P and the relevant speed of rotation n, as defined under [2.2.3].
- For main propulsion systems powered by diesel engines fitted with couplings other than those mentioned in (a): the mean torque above increased by 20% or by the torque due to torsional vibrations, whichever is the greater.

The value 2,8 above may be reduced to 2,5 in the following cases:

- Ships having two or more main propulsion shafts
- When the transmitted torque is obtained, for the whole functioning rotational speed range, as the sum of the nominal torque and the alternate torque due to the torsional vibrations, calculated as required in Ch 1, Sec 9.

2.5.2 Shrunk couplings

Non-integral couplings which are shrunk on the shaft by means of the oil pressure injection method or by other means may be accepted on the basis of the calculation of shrinking and induced stresses, and assembly instructions.

To this end, the force due to friction between the mating surfaces is not to be less than 2,8 times the total force due to the transmitted torque and thrust.

The value 2,8 above may be reduced to 2,5 in the cases specified under item e) of [2.5.1].

The values of 0,14 and 0,18 will be taken for the friction coefficient in the case of shrinking under oil pressure and dry shrink fitting, respectively.

In addition, the equivalent stress due to shrinkage determined by means of the von Mises-Hencky criterion in the points of maximum stress of the coupling is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the material of the part concerned.

The transmitted torque is that defined under item e) of [2.5.1].

For the determination of the thrust, see Ch 1, Sec 8, [3.1.2].

2.5.3 Other couplings

Types of couplings other than those mentioned in [2.5.1] and [2.5.2] will be specially considered by the Society.

2.5.4 Flexible couplings

a) The scantlings of stiff parts of flexible couplings subjected to torque are to be in compliance with the requirements of Article [2].

b) For flexible components, the limits specified by the Manufacturer relevant to static and dynamic torque, speed of rotation and dissipated power are not to be exceeded.

c) Where all the engine power is transmitted through one flexible component only (ships with one propulsion engine and one shafting only), the flexible coupling is to be fitted with a torsional limit device or other suitable means to lock the coupling should the flexible component break.

In stiff transmission conditions with the above locking device, a sufficiently wide speed range is to be provided, free from excessive torsional vibrations, such as to enable safe navigation and steering of the ship. As an alternative, a spare flexible element is to be provided on board.

2.5.5 Propeller shaft keys and keyways

a) Keyed connections are in general not to be used in installations with a barred speed range.

b) Keyways

Keyways on the propeller shaft cone are to comply with the following requirements (see Fig 1).

Keyways are to have well rounded corners, with the forward end faired and preferably spooned, so as to minimize notch effects and stress concentrations.

The fillet radius at the bottom of the keyway is to be not less than 1,25% of the actual propeller shaft diameter at the large end of the cone.

The distance from the large end of the propeller shaft cone to the forward end of the key is to be not less than 20% of the actual propeller shaft diameter in way of the large end of the cone.

Key securing screws are not to be located within the first one-third of the cone length from its large end; the edges of the holes are to be carefully faired.

Note 1: Different scantlings may be accepted, provided that at least the same reduction in stress concentration is ensured.

c) Keys

The sectional area of the key subject to shear stress is to be not less than the value A, in mm^2, given by the following formula:

$$A = 0{,}4\frac{d^3}{d_{PM}} \cdot \frac{R_{e\cdot shaft}}{R_{e\cdot key}}$$

where:

d : Rule diameter, in mm, of the shaftline calculated in accordance with [2.2.3] for intermediate shaft, assuming:

Q = 0

Rm: Specified yield strength of the propeller shaft material, see also [2.1.2].

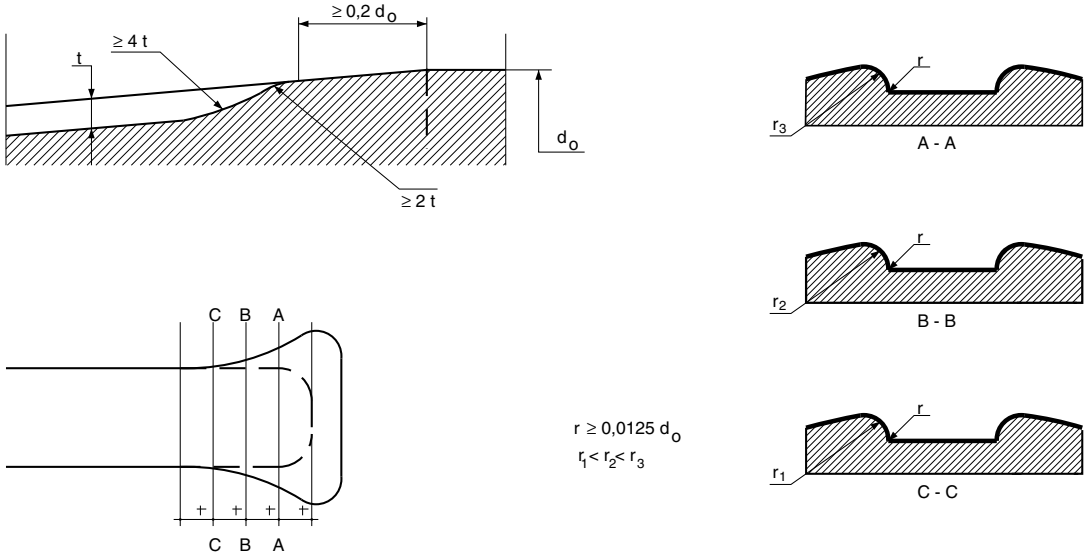
d_{PM} : Actual diameter of propeller shaft at mid-length of the key, in mm.

$R_{e.shaft}$: Minimum specified yield strength of the shaft's material.

$R_{e.key}$: Minimum specified yield strength of the key's material. The material yield strength of the key is to be higher or equal to the material yield strength of the shaft.

The edges of the key are to be rounded.

Figure 1 : Details of forward end of propeller shaft keyway



2.6 Design of oil control systems for clutches

2.6.1 Separate oil systems intended for the control of clutches are to include at least two power pumps, of such a capacity as to maintain normal control with any one pump out of action.

2.6.2 In the case of propulsion plants comprising:

- more than one shaft line with the clutches fitted with their own control system, or
- one engine with an output not exceeding 220 kW.

One of the pumps mentioned in [2.6.1] may be a spare pump ready to be connected to the oil control system, provided disassembling and reassembling operations can be carried out on board in a short time.

2.6.3 However, when the propulsion plant comprises one or more engines, each with an output not exceeding 220 kW, the standby or spare pump may be omitted for the clutches provided that they are so designed as to be fixed mechanically in the "clutched" position and that the capacity of the starting means ensures the number of starts required in such conditions.

2.7 Monitoring

2.7.1 General

In addition to those given in this item, the requirements of Part C, Chapter 3 apply.

2.7.2 Propeller shaft monitoring

For the assignment of the propeller shaft monitoring system notation, see Pt F, Ch 5, Sec 2.

2.7.3 Indicators

The local indicators for main propulsion shafting to be installed on ships of 500 gross tonnage and upwards without automation notations are given in Tab 4. For monitoring of engines, gears, controllable pitch propellers and thrusters, see Ch 1, Sec 2, Ch 1, Sec 6, Ch 1, Sec 8 and Ch 1, Sec 15, respectively. For monitoring of turbines, see Ch 1, Sec 4 or Ch 1, Sec 5, as applicable.

The indicators listed in Tab 4 are to be fitted at a normally attended position.

Table 4 : Shafting and clutches of propulsion machinery

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Temperature of each shaft thrust bearing (non applicable for ball or roller bearings)	H		X				
Stern tube bush oil gravity tank level	L						
Clutches lubricating oil temperature	H		X				
Clutches oil tank level	L						

3 Arrangement, installation and shaft alignment

3.1 General

3.1.1 The installation is to be carried out according to the instructions of the component Manufacturer or approved documents, when required.

3.1.2 The installation of sterntubes and/or associated non-shrunk bearings is subject to approval of procedures and materials used.

3.1.3 The joints between liner parts are not to be located in way of supports and sealing glands.

Metal liners are to be shrunk on to the shafts by pre-heating or forced on by hydraulic pressure with adequate interference; dowels, screws or other means of securing the liners to the shafts are not acceptable.

3.2 Protection of propeller shaft against corrosion

3.2.1 The propeller shaft surface between the propeller and the sterntube, and in way of propeller nut, is to be suitably protected in order to prevent any entry of sea water, unless the shaft is made of austenitic stainless steel.

3.3 Shaft alignment

3.3.1 General

Shaft alignment calculations report and shaft alignment procedures are to be submitted for review in the following cases, and excluding PODs and azimuth thrusters:

- Propulsion plants with a shaft diameter of 300 mm or greater in way of the aftermost bearing, whether or not they comprise a gearbox.
- Geared propulsion plants with power take-in (PTI) or power take-off (PTO), where the shaft diameter in way of the aftermost bearing is 150 mm or greater.

For ships to which the additional class notation **MON SHAFT** is assigned and with a water lubricated shaft, the shaft alignment calculations are to be performed for both initial conditions (new bearings) and conditions of maximum permissible wear according to the bearing manufacturer's recommendations and deemed satisfactory by the Society (see Pt F, Ch 5, Sec 2, [3.1.6]).

3.3.2 Shaft alignment calculations

a) Shaft alignment calculations report

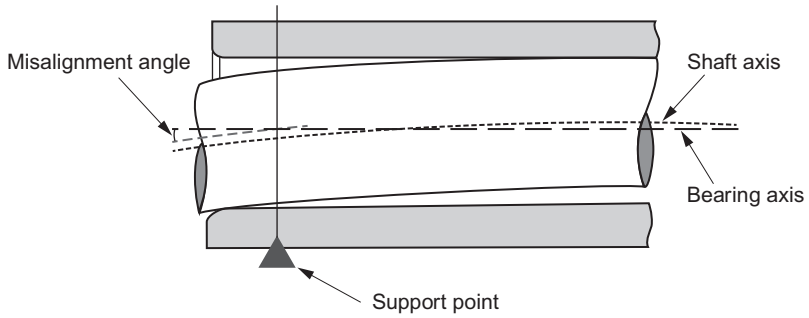
The shaft alignment calculations report is to include:

- Description of the line shafting system such as shaft diameter, bearing length, bearing liner material, bearing axial position, bearing clearance, propulsion system specifications (e.g. rated power of main engine and propeller shaft rpm), and relevant equipment list, such as prime mover, reduction gear, and shaft generator
- Stern tube lubricant specifications (type and viscosity)
- Propeller dimensional data, weight and buoyancy effect, including propeller cap, bonnet and pertinent energy-saving devices
- Hydrodynamic propeller loads in running conditions including vessel turning condition, where known
- For geared installations, gear forces and moments should be included
- External forces acting on crankshaft
- Axial positions of the bearings' points of support
- Bearing Stiffness values for all bearings in the shaftline
- Definition of a reference line
- Bearing offsets from reference line
- Thermal displacement of the bearings between cold and hot machinery conditions
- Effect of predicted hull deflections over the range of the ship's operating drafts, where required (see item b))
- Calculated bearing loads and shaftline deflection at the conditions as defined in item f)
- Relative Slope between tail shaft and aft stern tube bearing for all conditions, as defined in item f) at supporting point (see Fig 2) or the alternative information as per item g) 4)

Note 1: The relative slope for each segment of the effective bearing length is defined as the angle between the bearing segment slope and the tangent line to the shaft at the equivalent point of support.

- Details of aft stern tube bearing geometry including slope bore, where applied
- Bending moment and shear force diagrams along the line shafting for static and running conditions, as defined in item f)
- Bearing Reaction Influence coefficients' table.

Figure 2 : Relative slope for bearing with single point of support



b) Line shafting modelling:

1) For direct drive, line shafting is to be modelled up to the engine main bearing located towards the free end of the engine/motor extending the main engine maker's equivalent crankshaft model or by Finite Element modelling of the crankshaft.

2) For geared installation, the line shaft is to be modelled up to the fore end of the gearbox output shaft.

3) For shaft having a diameter of 300mm or greater in way of the aftermost bearing, line shafting is to be modelled, taking into account hull deflections (see item e)).

4) Where hull deflections are not available and expected to have an influence, for direct drives, line shafting is to be modelled at least up to the five aft-most engine main bearings and in accordance with the main engine maker's equivalent crankshaft model. Higher safety margins are to be applied and justified.

c) Bearing modelling:

1) For aftmost bearing:

The number of support points and their axial position is to be justified by the designer for each shaft alignment condition presented.

2) For other bearings:

Location of support point are to be at the mid-length of bearing.

d) Hydrodynamic propeller loads:

Transverse and vertical hydrodynamic propeller loads should be used. These can be estimated by calculations such as, lifting surface method, boundary panel method, CFD or based on empirical/database formulae duly justified.

In case hydrodynamic propeller loads are not available, then duly validated empirical formulae may be used for the running condition calculations. Tab 5 shows moments acting in a longitudinal/vertical plane obtained from regression of calculated and measured data, which may be used in the absence of other validated values. Bending moments in transverse/horizontal plane should be considered in extreme cases where the shaft might be running in or close to the side oil grooves.

A turning condition is hereby defined as the condition in which the vessel is performing a steady state full rudder turn to port or starboard, commencing from a straight course at a ballast or full scantling draft at MCR condition, considering a clockwise turning propeller.

e) Hull deflections

Hull deflections may be estimated by finite element calculations, by measurements from similar vessels or other recognized or benchmarked calculation methodologies.

Similar vessels are defined as being of the same ship type and having similar vessel size, double bottom height in the area of the engine room, sterntube and stern arrangement, subject to agreement by the Society.

f) Shaft alignment calculations conditions:

1) If hull deflections are available, shaft alignment calculations are to be performed for the following conditions:

- Cold, static, afloat conditions corresponding to line shafting installation with a specified range of propeller immersion
- Hot, static, afloat condition at minimum navigating draft with corresponding propeller immersion (normally 100% immersion)
- Hot, running condition at MCR at minimum navigating draft with corresponding propeller immersion (normally 100% immersion) including vessel turning condition with propeller hydrodynamic forces as defined in section item d)
- Hot, static at fully loaded condition
- Hot, running MCR at fully loaded condition, including vessel turning condition with propeller hydrodynamic forces as defined in section item d).

2) If hull deflections are not available, then shaft alignment calculations are to be performed for the following conditions:

- Cold, static, afloat conditions with a specified range of propeller immersion
- Hot, static, afloat condition with propeller 100% immersed
- Hot, running condition at MCR with propeller 100% immersed including vessel turning condition with propeller hydrodynamic forces as defined in section item d).

g) Calculation Acceptance Criteria:

1) Bearing loads

Shaftline bearing loads in all conditions, except turning conditions, should be positive (supporting the shaft) and within manufacturer's limits. In addition, if hull deflections are not considered in the calculations, calculated intermediate bearing loads should not exceed 80% of the manufacturer's upper limit.

In case of multi-point supports used to model a bearing, the total load of the bearing should be considered.

For aft stern tube bearing, refer to [2.4] regarding the maximum static load.

Prime mover bearing loads should be within the manufacturer's limits.

The main gear wheel bearing reaction loads including differential loads' criteria should be within the manufacturer's limits, as applicable.

In the MCR straight ahead condition, if any shaftline bearing load is lower than 5% of manufacturer's maximum limits, bending vibrations should be investigated (see Ch 1, Sec 9, [4]), with the bearing in question considered as unloaded.

2) Bending moments and shear forces

Bending moment and shear force values should be within manufacturer's limits at the thrust shaft flange of the gearbox/ prime mover, as applicable

3) Aftmost bearing slope

Single slope/no-slope bearings under all static conditions:

- If a single point of support is utilized for the bearing model, the relative slope between the propeller shaft and the aftmost bearing bush, (stern tube or strut), should not exceed 0.3 mm/m or 0.3 mrad. In case 0.3 mrad is exceeded, slope boring should be applied.
- For the single slope bearing having multiple points of support, alternative methods (See item 4), in accepting the alignment condition may be considered by the Society on a case-by-case basis.

Multi-slope bearings should be assessed using alternative modelling techniques.

4) Alternative modelling techniques

When alternative recognized modelling techniques are used, such as 3D Finite Element Modelling with Fluid Structure Interaction between the bearing oil film and the rotating shaft, the relevant assumptions and practices should be detailed in the submitted calculation report.

If a 3D Finite Element Modelling with Fluid Structure Interaction between the bearing oil film and the rotating shaft is used, the relative slope criterion should be replaced by an oil film thickness criterion so that the oil film thickness is within an acceptable range under all analyzed running conditions; 30 µm is normally considered as a safe value for oil lubricated bearings, and 10µm for water lubricated bearings.

Other modelling techniques and acceptance criteria may be considered by the Society on a case by case basis.

Table 5 : Moments acting on the propeller in a longitudinal/vertical plane

	Straight ahead condition	Turning condition
For single screw vessel	–5% of Q +30% of Q **(1)**	–30% of Q **(1)**
For twin screw vessel	±20% of Q **(1)**	–40% of Q **(1)**

(1) Q: Torque at MCR
Positive sign (+) implies upward moment about the transverse axis
Negative sign (–) implies downward moment about the transverse axis.

3.3.3 Shaft alignment procedure

a) General

The shaft alignment procedure is to be submitted for review and is to be consistent with the approved shaft alignment calculations report.

Procedure of shaft alignment is to include, at least:

- Definition of a reference line
- Bearing locations (including temporary supports); offsets in respect of the reference line and loads
- Bearing offset tolerances
- Position and value of the jack down force, if any
- Gap and Sag calculated values between shaft coupling flanges with tolerances
- Jack-up positions, loads with tolerances and correction factors
- Crankshaft deflection measurements, if not include in Engine installation procedure.

b) Verification of the alignment procedure

The purpose of the verification procedure is to ensure that the alignment measurements comply with the calculated values.

The shaft alignment verification procedure is described in Ch 1, Sec 18, [3.11.1].

The shaft alignment verification is to be carried out by the shipyard in presence of the Surveyor and submitted to the Society.

The criteria for acceptability of the alignment conditions include the following:

- The measured installed slope of the aft sterntube bearing should be within a +/- 0.1 mm/m. The resulting relative slope between shaft and bearing is not to be above 0.3 mm/m.
- The shaftline bearings' offsets (vertical and horizontal) in respect of the reference line is to correspond to those in the calculation with a tolerance of +/-0.1 mm if doing a full sighting as described in Ch 1, Sec 18, [3.11.1], item d) 2).
- Gap and sag tolerances are normally ±0.05 mm, the effect of larger tolerances should be duly considered if applied.
- When the jack-up load measurements are carried out in a draft condition as considered in the calculations for cold and hot conditions, the jack-up loads is to stay within a +/- 20% tolerance range from the calculated bearing loads, except for the main engine bearings, where the engine designer tolerances is to be applied. In case a bearing load is calculated to be less than 5% of the maximum allowable, then the above-mentioned +/- 20% correlation tolerance range is not applicable, and it should be dealt with on a case-by-case basis.

4 Material tests, workshop inspection and testing, certification

4.1 Material and non-destructive tests, workshop inspections and testing

4.1.1 Material tests

Shafting components are to be tested by the Manufacturer in accordance with Tab 6 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 6 and are to be effected in positions agreed upon by the Surveyor, where Manufacturer's experience shows defects are most likely to occur.

Ultrasonic testing requires the Manufacturer's signed certificate.

4.1.2 Hydrostatic tests

Parts of hydraulic couplings, clutches of hydraulic reverse gears and control units, hubs and hydraulic cylinders of controllable pitch propellers, including piping systems and associated fittings, are to be hydrostatically tested to1,5 times the maximum working pressure.

Sterntubes, when machine-finished, and propeller shaft liners, when machine-finished on the inside and with an overthickness not exceeding 3 mm on the outside, are to be hydrostatically tested to 0,2 N/mm^2.

4.2 Certification

4.2.1 Testing certification

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in items 1 to 5 of Tab 6.

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for hydrostatic tests of components indicated in [4.1.2] and for material and non-destructive tests of components in items of Tab 6 other than those for which Society's certificates (C) are required.

Table 6 : Material and non-destructive tests

Shafting component	Material tests (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Coupling (separate from shafts)	all	if diameter ≥ 100 mm **(1)**	if diameter ≥ 200 mm **(1)**
2) Propeller shafts	all	if diameter ≥ 100 mm **(1)**	if diameter ≥ 200 mm **(1)**
3) Intermediate shafts	all	if diameter ≥ 100 mm **(1)**	if diameter ≥ 200 mm **(1)**
4) Thrust shafts	all	if diameter ≥ 100 mm **(1)**	if diameter ≥ 200 mm **(1)**
5) Cardan shafts (flanges, crosses, shafts, yokes)	all	if diameter ≥ 100 mm **(1)**	if diameter ≥ 200 mm **(1)**
6) Sterntubes	all	–	–
7) Sterntube bushes and other shaft bearings	all	–	–
8) Propeller shaft liners	all	–	–
9) Coupling bolts or studs	all	–	–
10) Flexible couplings (metallic parts only)	all	–	–
11) Thrust sliding-blocks (frame only)	all	–	–
(1) 150 mm in case of a rolled bar used in place of a forging			

Section 8 Propellers

1 General

1.1 Application

1.1.1 Propulsion propellers

The requirements of this Section apply to propellers of any size and type intended for propulsion. They include fixed and controllable pitch propellers, including those ducted in fixed nozzles.

1.1.2 Exclusions

The requirements of this Section do not apply to propellers and impellers in bow and stern thrusters, which are covered in Ch 1, Sec 15, or to propellers for ships with ice strengthening, which are covered in Pt F, Ch 8, Sec 3.

1.2 Definitions

1.2.1 Solid propeller

A solid propeller is a propeller (including hub and blades) cast in one piece.

1.2.2 Built-up propeller

A built-up propeller is a propeller cast in more than one piece. In general, built up propellers have the blades cast separately and fixed to the hub by a system of bolts and studs.

1.2.3 Controllable pitch propellers

Controllable pitch propellers are built-up propellers which include in the hub a mechanism to rotate the blades in order to have the possibility of controlling the propeller pitch in different service conditions.

1.2.4 Nozzle

A nozzle is a circular structural casing enclosing the propeller.

1.2.5 Ducted propeller

A ducted propeller is a propeller installed in a nozzle.

1.2.6 Geometry of propeller

For all geometrical definitions (see Fig 1):

a) Blade area and area ratio

A_P : Projected blade area, i.e. projection of the blade area in the direction of the propeller shaft

A_D : Developed blade area, i.e. area enclosed by the connection line between the end points of the cylindrical profile sections turned in the propeller plane

A_E : Expanded blade area, i.e. area enclosed by the connection line between the end points of the developed and additionally straightened sections

A_O : Disc area calculated by means of the propeller diameter

B : Developed area ratio with $B = A_D / A_O$

b) Rake and rake angle

h : Rake is the horizontal distance between the line connecting the blade tip to the blade root and the vertical line crossing the propeller axis in the same point where the prolongation of the first line crosses it, taken in correspondence of the blade tip. Aft rakes are considered positive, fore rakes are considered negative.

Rake angle is the angle at any point between the tangent to the generating line of the blade at that point and a vertical line passing at the same point. If the blade generating line is straight, there is only one rake angle; if it is curved there are an infinite number of rake angles.

c) Skew angle at tip of blade

ϑ : Skew angle at the tip of blade, i.e. the angle on the projected blade plane between a line starting at the centre of the propeller axis and tangent to the blade midchord line and a line also starting at the centre of the propeller axis and passing at the outer end of this midchord line as measured.

d) Skewed propellers

Skewed propellers are propellers whose blades have a skew angle other than 0.

e) Leading and trailing edges

LE : Leading edge of a propeller blade, i.e. the edge of the blade at side entering the water while the propeller rotates

TE : Trailing edge of a propeller blade, i.e. the edge of the blade opposite to the leading edge.

1.2.7 Rake angle

Rake angle is the angle at any point between the tangent to the generating line of the blade at that point and a vertical line passing at the same point. If the blade generating line is straight, there is only one rake angle; if it is curved there are an infinite number of rake angles (see Fig 1).

1.2.8 Skew angle

Skew angle is the angle between a ray starting at the centre of the propeller axis and tangent to the blade midchord line and a ray also starting at the centre of the propeller axis and passing at the blade tip (see Fig 1).

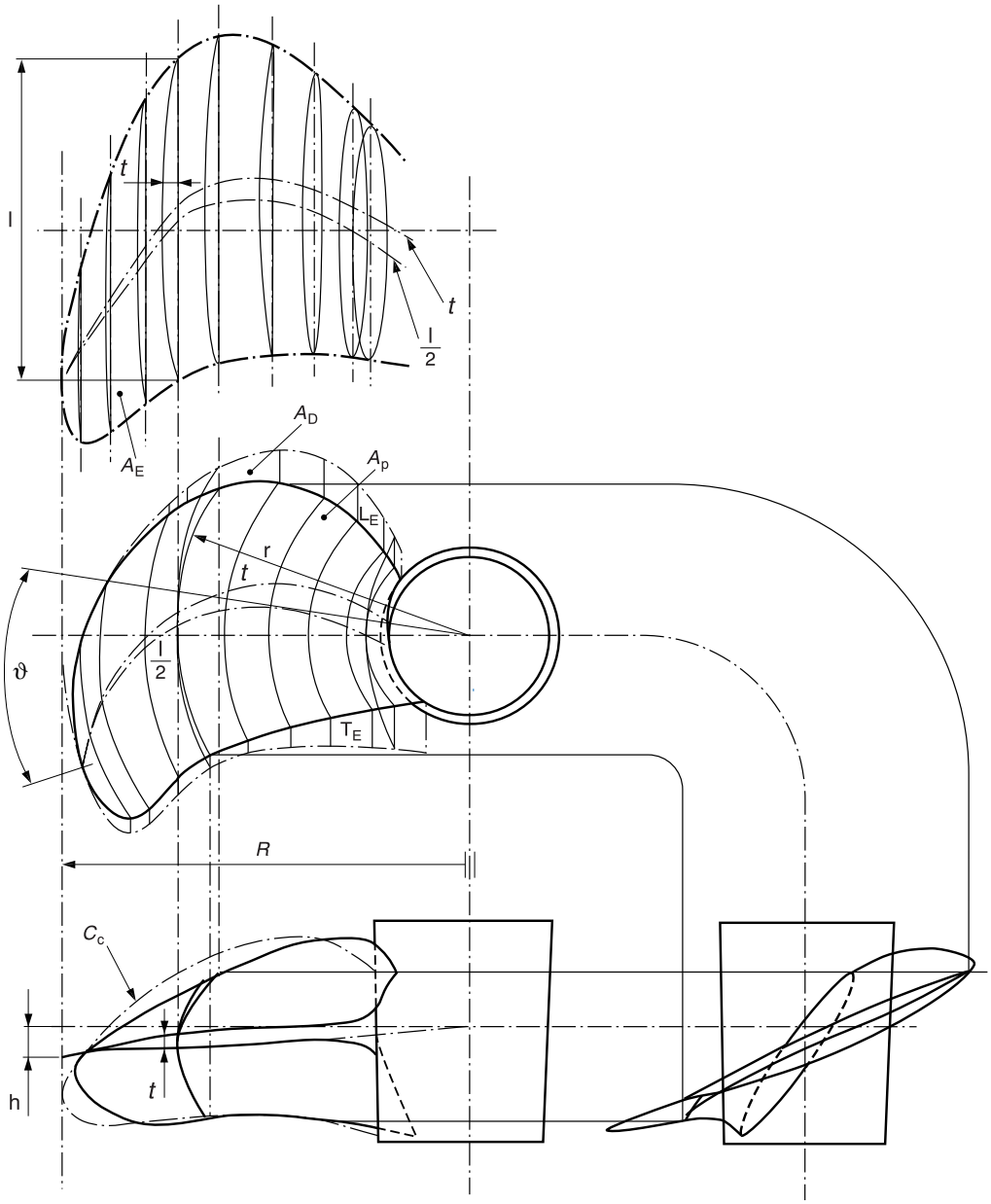
1.2.9 Skewed propellers

Skewed propellers are propellers whose blades have a skew angle other than 0.

1.2.10 Highly skewed propellers and very highly skewed propellers

Highly skewed propellers are propellers having blades with skew angle exceeding 25°. Very highly skewed propellers are propellers having blades with skew angle exceeding 50°.

Figure 1 : Description of propeller



1.2.11 Leading edge

The leading edge of a propeller blade is the edge of the blade at side entering the water while the propeller rotates (see Fig 1).

1.2.12 Trailing edge

The trailing edge of a propeller blade is the edge of the blade opposite the leading edge (see Fig 1).

1.2.13 Blade developed area

Blade developed area is the area of the blade surface expanded in one plane.

1.2.14 Developed area ratio

Developed area ratio is the ratio of the total blade developed area to the area of the ring included between the propeller diameter and the hub diameter.

1.3 Documentation to be submitted

1.3.1 Solid propellers

The documents listed in Tab 1 are to be submitted for solid propellers intended for propulsion.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

Table 1 : Documents to be submitted for solid propellers

No.	A/I **(1)**	ITEM
1	A	Sectional assembly
2	A	Blade and hub details
3	I	Rating (power, rpm, etc.)
4	A	Data and procedures for fitting propeller to the shaft
(1) A = to be submitted for approval ; I = to be submitted for information		

1.3.2 Built-up and controllable pitch propellers

The documents listed in Tab 2, as applicable, are to be submitted for built-up and controllable pitch propellers intended for propulsion.

Table 2 : Documents to be submitted for built-up and controllable pitch propellers

No.	A/I **(1)**	ITEM
1	A/I	Same documents requested for solid propellers
2	A	Blade bolts and pre-tensioning procedures
3	I	Pitch corresponding to maximum propeller thrust and to normal service condition
4	A	Pitch control mechanism
5	A	Pitch control hydraulic system
(1) A = to be submitted for approval ; I = to be submitted for information		

1.3.3 Very highly skewed propellers and propellers of unusual design

For very highly skewed propellers and propellers of unusual design, in addition to the documents listed in Tab 1 and Tab 2, as applicable, a detailed hydrodynamic load and stress analysis is to be submitted (see [2.4.3]).

2 Design and construction

2.1 Materials

2.1.1 Normally used materials for propeller hubs and blades

a) Tab 3 indicates the minimum tensile strength R_m (in N/mm^2), the density δ (in kg/dm^3) and the material factor f of normally used materials.

b) Common bronze, special types of bronze and cast steel used for the construction of propeller hubs and blades are to have a minimum tensile strength of 400 N/mm^2.

c) Other materials are subject of special consideration by the Society following submission of full material specification.

Table 3 : Normally used materials for propeller blades and hub

Material	R_m	δ	f
Common bronze	400	8,3	7,6
Manganese bronze	440	8,3	7,6
Nickel-manganese bronze	440	8,3	7,9
Aluminium bronze	590	7,6	8,3
Steel	440	7,9	9,0

2.1.2 Materials for studs

In general, steel (preferably nickel-steel) is to be used for manufacturing the studs connecting steel blades to the hub of built-up or controllable pitch propellers, and high tensile brass or stainless steel is to be used for studs connecting bronze blades.

2.2 Solid propellers - Blade thickness

2.2.1

a) The maximum thickness $t_{0.25}$, in mm, of the solid propeller blade at the section at 0,25 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,25} = 3,2\left[f \cdot \frac{1,5.10^6.\rho.M_T + 51.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l \cdot z \cdot R_m}\right]^{0,5}$$

where:

f : Material factor as indicated in Tab 3

ρ : $\rho = D/H$

H : Mean pitch of propeller, in m. When H is not known, the pitch at 0,7 radius from the propeller axis $H_{0,7}$ may be used instead of H

D : Propeller diameter, in m

M_T : Continuous transmitted torque, in kN.m; where not indicated, the value given by the following formula may be assumed for M_T:

$$M_T = 9,55 \cdot \left(\frac{P}{N}\right)$$

P : Maximum continuous power of propulsion machinery, in kW

N : Rotational speed of the propeller, in rev/min

δ : Density of blade material, in kg/dm³, as indicated in Tab 3

B : Developed area ratio

h : Rake, in mm

l : Expanded width of blade section at 0,25 radius from propeller axis, in mm

z : Number of blades

R_m : Minimum tensile strength of blade material, in N/mm².

b) The maximum thickness $t_{0.6}$, in mm, of the solid propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,6} = 1,9\left[f \frac{1,5.10^6.\rho_{0,6}.M_T + 18,4.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l_{0,6} \cdot z \cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,6}$: $D/H_{0.6}$

$H_{0.6}$: Pitch at 0,6 radius from the propeller axis, in m

$l_{0.6}$: Expanded width of blade section at 0,6 radius from propeller axis, in mm.

c) The radius at the blade root is to be at least 3/4 of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account. If the propeller hub extends over 0,25 radius, the thickness calculated by the formula in a) is to be compared with the thickness obtained by linear interpolation of the actual blade thickness up to 0,25 radius.

d) As an alternative to the above formulae, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society, on a case by case basis. The safety factor to be used in this analysis is not to be less than 8 with respect to the ultimate tensile strength of the propeller material R_m.

2.3 Built-up propellers and controllable pitch propellers

2.3.1 Blade thickness

a) The maximum thickness $t_{0.35}$, in mm, of the blade at the section at 0,35 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,35} = 2,7\left[f\,\frac{1,5.10^6.\rho_{0,7}.M_T + 41.\delta\left(\frac{D}{100}\right)^3 B.l_{0,35}.N^2h}{l_{0,35}\cdot z\cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,7} = D / H_{0.7}$

$H_{0.7}$: Pitch at 0,7 radius from the propeller axis, in m. The pitch to be used in the formula is the actual pitch of the propeller when the propeller develops the maximum thrust

$l_{0.35}$: Expanded width of blade section at 0,35 radius from propeller axis, in mm.

b) The maximum thickness $t_{0.6}$, in mm, of the propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the formula in [2.2.1] b), using the value of $l_{0,35}$ in lieu of l.

c) The radius at the blade root is to be at least ¾ of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account.

d) As an alternative to the above formulae, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society, on a case by case basis. The safety factor to be used in this analysis is not to be less than 8 with respect to the ultimate tensile strength of the propeller blade material R_m.

2.3.2 Flanges for connection of blades to hubs

a) The diameter D_F, in mm, of the flange for connection to the propeller hub is not to be less than that obtained from the following formula:

$$D_F = D_C + 1,8d_{PR}$$

where:

D_C : Stud pitch circle diameter, in mm

d_{PR} : Diameter of studs.

b) The thickness of the flange is not to be less than 1/10 of the diameter D_F.

2.3.3 Connecting studs

a) The diameter d_{PR}, in mm, at the bottom of the thread of the studs is not to be less than obtained from the following formula:

$$d_{PR} = \left(\frac{4,6.10^7.\rho_{0,7}.M_T + 0,88.\delta.\left(\frac{D}{10}\right)^3.B.l_{0,35}.N^2.h_1}{n_{PR}\cdot z\cdot D_C\cdot R_{m,PR}}\right)^{0,5}$$

where:

h_1 : $h_1 = h + 1,125\ D_C$

n_{PR} : Total number of studs in each blade

$R_{m,PR}$: Minimum tensile strength of stud material, in N/mm^2.

b) The studs are to be tightened in a controlled manner such that the tension on the studs is approximately 60-70% of their yield strength.

c) The shank of studs may be designed with a minimum diameter equal to 0,9 times the root diameter of the thread.

d) The studs are to be properly secured against unintentional loosening.

2.4 Skewed propellers

2.4.1 Skewed propellers

The thickness of skewed propeller blades may be obtained by the formulae in [2.2] and [2.3.1], as applicable, provided the skew angle is less than 25°.

2.4.2 Highly skewed propellers

a) For solid and controllable pitch propellers having skew angles between 25° and 50°, the blade thickness, in mm, is not to be less than that obtained from the following formulae:

1) For solid propellers

$$t_{S-0,25} = t_{0,25} \cdot (0,92 + 0,0032\vartheta)$$

2) For built-up and controllable pitch propellers

$$t_{S-0,35} = t_{0,35} \cdot (0,9 + 0,004\vartheta)$$

3) For all propellers

$$t_{S-0,6} = t_{0,6} \cdot (0,74 + 0,0129\vartheta - 0,0001\vartheta^2)$$

$$t_{S-0,9} = t_{0,6} \cdot (0,35 + 0,0015\vartheta)$$

where:

$t_{S-0,25}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,25 radius from the propeller axis

$t_{0,25}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,25 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,35}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,35 radius from the propeller axis

$t_{0,35}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,35 radius from the propeller axis, obtained by the formula in [2.3.1]

$t_{S-0,6}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,6 radius from the propeller axis

$t_{0,6}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,6 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,9}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,9 radius from the propeller axis

ϑ : Skew angle.

b) As an alternative, highly skewed propellers may be accepted on the basis of a stress analysis, as stated in [2.4.3] for very highly skewed propellers.

2.4.3 Very highly skewed propellers

For very highly skewed propellers, the blade thickness is to be obtained by the Manufacturer, using a stress analysis according to a calculation criteria accepted by the Society. The safety factor to be used in this direct analysis is not to be less than 9 with respect to the ultimate tensile strength of the propeller blade material, R_m.

2.5 Ducted propellers

2.5.1 The minimum blade thickness of propellers with wide tip blades running in nozzles is not to be less than the values obtained by the applicable formula in [2.2] or [2.3.1], increased by 10%.

2.6 Features

2.6.1 Blades and hubs

a) All parts of propellers are to be free of defects and are to be built and installed with clearances and tolerances in accordance with sound marine practice.

b) Particular care is to be taken with the surface finish of the blades.

2.6.2 Controllable pitch propellers pitch control system

a) Where the pitch control mechanism is operated hydraulically, two independent, power-driven pump sets are to be fitted. For propulsion plants up to 220 kW, one power-driven pump set is sufficient provided that, in addition, a hand-operated pump is fitted for controlling the blade pitch.

b) Pitch control systems are to be provided with an engine room indicator showing the actual setting of the blades. Further blade position indicators are to be mounted on the bridge and in the engine control room, if any.

c) Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

d) Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades

- does not change, or
- assumes a final position slowly enough to allow the emergency control system to be put into operation.

e) Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to operate when the remote control system fails. This requirement may be complied with by means of a device which locks the propeller blades in the “ahead” setting.

f) Tab 4 indicates the monitoring requirements to be displayed at the control console.

Table 4 : Controllable pitch propeller

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Oil tank level	L						

3 Arrangement and installation

3.1 Fitting of propeller on the propeller shaft

3.1.1 General

a) Screw propeller hubs are to be properly adjusted and fitted on the propeller shaft cone.

b) The forward end of the hole in the hub is to have the edge rounded to a radius of approximately 6 mm.

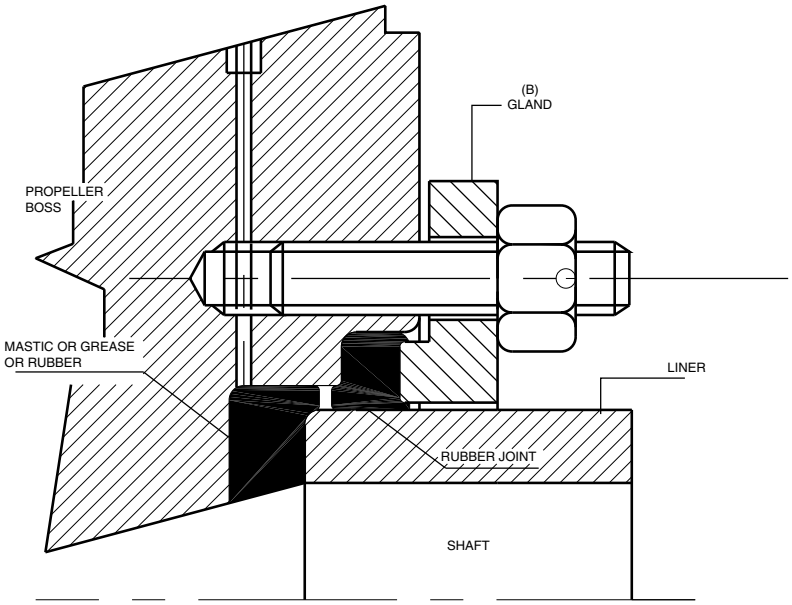
c) In order to prevent any entry of sea water under the liner and onto the end of the propeller shaft, the arrangement of Fig 2 is generally to be adopted for assembling the liner and propeller boss.

d) The external stuffing gland is to be provided with a seawater resistant rubber ring preferably without joints. The clearance between the liner and the internal air space of the boss is to be as small as possible. The internal air space is to be filled with an appropriate protective material which is insoluble in sea water and non-corrodible or fitted with a rubber ring.

e) All free spaces between the propeller shaft cone, propeller boss, nut and propeller cap are to be filled with a material which is insoluble in sea water and non-corrodible. Arrangements are to be made to allow any air present in these spaces to withdraw at the moment of filling. It is recommended that these spaces be tested under a pressure at least equal to that corresponding to the immersion of the propeller in order to check the tightness obtained after filling.

f) For propeller keys and key area, see Ch 1, Sec 7, [2.5.5].

Figure 2 : Example of sealing arrangement



3.1.2 Shrinkage of keyless propellers

In the case of keyless shrinking of propellers, the following requirements apply:

a) The meaning of the symbols used in the subparagraphs below is as follows:

A : 100% theoretical contact area between propeller boss and shaft, as read from plans and disregarding oil grooves (i.e. oil grooves do not need to be subtracted), in mm^2

C :
- C = 1 for turbines, geared diesel engines, electrical drives and direct-drive reciprocating internal combustion engines with a hydraulic, electromagnetic or high elasticity coupling
- C = 1,2 for diesel engines having couplings other than those specified above.

The Society reserves the right to increase the value of C if the shrinkage needs to absorb an extremely high pulsating torque

d_{PM} : Diameter of propeller shaft at the mid-point of the taper in the axial direction, in mm

d_H : Mean outer diameter of propeller hub at the axial position corresponding to d_{PM}, in mm

d_{35} : Push-up length, in mm, at 35°C

d_T : Push-up length, in mm, at temperature T

d_{MAX} : Maximum permissible pull-up length, in mm, at 0°C

E_P : Value of the modulus of elasticity of shaft material, in N/ mm^2

E_M : Value of the modulus of elasticity of boss material, in N/ mm^2

F : Tangential force at interface, in N

K : $K = d_H/d_{PM}$

M_T : Continuous torque transmitted, in N.m; where not indicated, M_T may be assumed as indicated in [2.2.1]

p_{35} : Surface pressure between mating surfaces, in N/mm^2, at 35°C

p_T : Surface pressure, in N/mm^2, between mating surfaces at temperature T

p_0 : Surface pressure between mating surfaces, in N/mm^2, at 0°C

p_{MAX} : Maximum permissible surface pressure, in N/mm^2, at 0°C

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of propeller boss material, in N/mm^2

$R_{m,B}$: Value of the minimum tensile strength of the propeller boss material, in N/mm^2

S : Continuous thrust developed for free running ship, in N

s_F : Safety factor against friction slip at 35°C

T : Temperature of hub and propeller shaft material, in °C, assumed for calculation of pull-up length and push-up load

V : Ship speed at P power, in knots

W_T : Push-up load, in N, at temperature T

θ : Half taper of propeller shaft (for instance: taper = 1/15, θ =1/30)

μ : Coefficient of friction between mating surfaces

σ_{ID} : Equivalent uni-axial stress in the boss according to the von Mises-Hencky criterion, in N/mm^2

α_P : Coefficient of linear expansion of shaft material, in mm/(mm°C)

α_M : Coefficient of linear expansion of boss material, in mm/(mm°C)

ν_P : Poisson's ratio for shaft material

ν_M : Poisson's ratio for boss material.

For other symbols not defined above, see [2.2].

b) The manufacturer is to submit together with the required constructional plans specifications containing all elements necessary for verifying the shrinkage. Tests and checks deemed necessary for verifying the characteristics and integrity of the propeller material are also to be specified.

c) Moreover, the manufacturer is to submit an instruction handbook, in which all operations and any precautions necessary for assembling and disassembling the propeller, as well as the values of all relevant parameters, are to be specified. A copy, endorsed by the Society, is to be kept on board each ship where the propeller is installed.

d) The formulae and other provisions below do not apply to propellers where a sleeve is introduced between shaft and boss or in the case of hollow propeller shafts. In such cases, a direct shrinkage calculation is to be submitted to the Society.

e) The taper of the propeller shaft cone is not to exceed 1/15.

f) Prior to final pull-up, the contact area between the mating surfaces is to be checked and is not to be less than 70% of the theoretical contact area (100%). Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable.

g) After final push-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

h) The safety factor s_F against friction slip at 35°C is not to be less than 2,8, under the combined action of torque and propeller thrust, based on the maximum continuous power P for which classification is requested at the corresponding speed of rotation N of the propeller, plus pulsating torque due to torsionals.

i) For the oil injection method, the coefficient of friction μ is to be 0,13 in the case of bosses made of bronze, brass or steel. For other methods, the coefficient of friction will be considered in each case by the Society.

j) The maximum equivalent uni-axial stress in the boss at 0°C, based on the von Mises-Hencky criterion, is not to exceed 70% of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the propeller material, based on the test piece value. For cast iron, the value of the above stress is not to exceed 30% of the nominal tensile strength.

k) For the formulae given below, the material properties indicated in the following items are to be assumed:

- Modulus of elasticity, in N/mm^2:

  Cast and forged steel: E = 206000

  Cast iron: E = 98000

Type Cu_1 and Cu_2 brass: E = 108000

Type Cu_3 and Cu_4 brass: E = 118000

- Poisson's ratio:

  Cast and forged steel: $\nu = 0,29$

  Cast iron: $\nu = 0,26$

  All copper based alloys: $\nu = 0,33$

- Coefficient of linear expansion in mm/(mm.°C)

  Cast and forged steel and cast iron: $\alpha = 12,0\ 10^{-6}$

  All copper based alloys: $\alpha = 17,5\ 10^{-6}$.

l) For shrinkage calculation the formulae in the following items, which are valid for the ahead condition, are to be applied. They will also provide a sufficient margin of safety in the astern condition.

- Minimum required surface pressure at 35°C:

$$p_{35} = \frac{s_F S}{AB} \cdot \left[-s_F\theta + \left(\mu^2 + B \cdot \frac{F^2}{S^2} \right)^{0,5} \right]$$

  where:

  $B = \mu^2 - s_F^2\theta^2$

- Corresponding minimum pull-up length at 35°C:

$$d_{35} = \frac{p_{35} d_{PM}}{2\theta} \cdot \left[\frac{1}{E_M} \cdot \left(\frac{K^2+1}{K^2-1} + \nu_M \right) + \frac{1-\nu_P}{E_P} \right]$$

- Minimum pull-up length at temperature T (T<35°C):

$$d_T = d_{35} + \frac{d_{PM}}{2\theta} \cdot (\alpha_M - \alpha_P) \cdot (35 - T)$$

- Corresponding minimum surface pressure at temperature T:

$$p_T = p_{35} \cdot \frac{d_T}{d_{35}}$$

- Minimum push-up load at temperature T:

$$W_T = Ap_T \cdot (\mu + \theta)$$

- Maximum permissible surface pressure at 0°C:

  when the propeller boss is made of cast iron:

$$p_{MAX} = \frac{0,3 R_{m,B} \cdot (K^2 - 1)}{(3K^4 + 1)^{0,5}}$$

  when the propeller boss is made of other materials:

$$p_{MAX} = \frac{0,7 R_{S,MIN} \cdot (K^2 - 1)}{(3K^4 + 1)^{0,5}}$$

- Corresponding maximum permissible pull-up length at 0°C:

$$d_{MAX} = d_{35} \cdot \frac{p_{MAX}}{p_{35}}$$

- Tangential force at interface:

$$F = \frac{2000 C M_T}{d_{PM}}$$

- Continuous thrust developed for free running ship; if the actual value is not given, the value, in N, calculated by one of the following formulae may be considered:

$$S = 1760 \cdot \frac{P}{V}$$

$$S = 57,3 \cdot 10^3 \cdot \frac{P}{H \cdot N}$$

3.1.3 Circulating currents

Means are to be provided to prevent circulating electric currents from developing between the propeller and the hull. A description of the type of protection provided and its maintenance is to be kept on board.

4 Testing and certification

4.1 Material tests

4.1.1 Solid propellers

Material used for the construction of solid propellers is to be tested in accordance with the requirements of NR216 Materials and Welding in the presence of the Surveyor.

4.1.2 Built-up propellers and controllable pitch propellers

In addition to the requirement in [4.1.1], materials for studs and for all other parts of the mechanism transmitting torque are to be tested in the presence of the Surveyor.

4.2 Testing and inspection

4.2.1 Controllable pitch propellers

The complete hydraulic system for the control of the controllable pitch propeller mechanism is to be hydrotested at a pressure equal to 1,5 times the design pressure. The proper operation of the safety valve is to be tested in the presence of the Surveyor.

4.2.2 Balancing

Finished propellers are to be statically balanced in accordance with the specified ISO 484 tolerance class. However, for built-up and controllable pitch propellers, the required static balancing of the complete propeller may be replaced by an individual check of blade weight and gravity centre position.

Refer also to:

- NR216 Materials and Welding, Ch 6, Sec 8, [1.9.3] for stainless steel propeller blades, and
- NR216 Materials and Welding, Ch 8, Sec 3, [1.9.4] for copper alloy propeller blades.

4.3 Certification

4.3.1 Certification of propellers

Propellers having the characteristics indicated in [1.1.1] are to be individually tested and certified by the Society.

4.3.2 Mass produced propellers

Mass produced propellers of a type as mentioned in [1.1] may be accepted within the framework of the type approval program of the Society.

Section 9 Shaft Vibrations

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the shafting of the following installations:

- propulsion systems with prime movers developing 220 kW or more
- other systems with internal combustion engines developing 110 kW or more and driving auxiliary machinery intended for essential services.

1.1.2 Exemptions

The requirements of this Section may be waived in cases where satisfactory service operation of similar installations is demonstrated.

2 Design of systems in respect of vibrations

2.1 Principle

2.1.1 General

a) Special consideration shall be given by Manufacturers *to the design, construction and installation of propulsion machinery systems so that any mode of their vibrations shall not cause undue stresses in these systems in the normal operating ranges.*

b) Calculations are to be carried out for the configurations of the system likely to have influence on the torsional vibrations.

c) Additionally, where deemed necessary by the Manufacturer, axial and/or bending vibrations are to be further investigated.

2.1.2 Vibration levels

Systems are to have torsional, bending and axial vibrations both in continuous and in transient running acceptable to the Manufacturers, and in accordance with the requirements of this Section.

Where vibrations are found to exceed the limits stated in this Section, the builder of the plant is to propose corrective actions, such as:

- operating restrictions, provided that the owner is informed, or
- modification of the plant.

2.1.3 Condition of components

Systems are to be designed considering the following conditions, as deemed necessary by the Manufacturer:

- engine: cylinder malfunction
- flexible coupling: possible variation of the stiffness or damping characteristics due to heating or ageing
- vibration damper: possible variation of the damping coefficient.

2.2 Modifications of existing plants

2.2.1 Where substantial modifications of existing plants, such as:

- change of the running speed or power of the engine
- replacement of an important component of the system (propeller, flexible coupling, damper) by one of different characteristics, or
- connection of a new component

are carried out, new vibration analysis is to be submitted for approval.

3 Torsional vibrations

3.1 Documentation to be submitted

3.1.1 Calculations

Torsional vibration calculations are to be submitted for the various configurations of the plants, showing:

- the equivalent dynamic system used for the modelling of the plant, with indication of:
  - inertia and stiffness values for all the components of the system
  - outer and inner diameters and material properties of the shafts

- the natural frequencies
- the values of the vibratory torques or stresses in the components of the system for the most significant critical speeds and their analysis in respect of the Rules and other acceptance criteria
- the possible restrictions of operation of the plant.

3.1.2 Particulars to be submitted

The following particulars are to be submitted with the torsional vibration calculations:

a) for turbines, multi-engine installations or installations with power take-off systems:
   - description of the operating configurations
   - load sharing law between the various components for each configuration

b) for installations with controllable pitch propellers, the power/rotational speed values resulting from the combinator operation

c) for prime movers, the service speed range and the minimum speed at no load

d) for internal combustion engines:
   - manufacturer and type
   - nominal output and rotational speed
   - mean indicated pressure
   - number of cylinders
   - "V" angle
   - firing angles
   - bore and stroke
   - excitation data, such as the polynomial law of harmonic components of excitations
   - nominal alternating torsional stress considered for crankpin and journal

Note 1: The nominal alternating torsional stress is part of the basic data to be considered for the assessment of the crankshaft. It is defined in Ch 1, App 1.

e) for turbines:
   - nominal output and rotational speed
   - power/speed curve and range of operation
   - number of stages, and load sharing between the stages
   - main excitation orders for each rotating disc
   - structural damping of shafts
   - external damping on discs (due to the fluid)

f) for reduction or step-up gears, the speed ratio for each step

g) for flexible couplings:
   - the maximum torque
   - the nominal torque
   - the permissible vibratory torque
   - the permissible heat dissipation
   - the relative damping
   - the torsional dynamic stiffness / transmitted torque relation where relevant

h) for torsional vibration dampers:
   - the manufacturer and type
   - the permissible heat dissipation
   - the damping coefficient
   - the inertial and stiffness properties, as applicable

i) for propellers:
   - the type of propeller: ducted or not ducted
   - the number of propellers of the ship
   - the number of blades
   - the excitation and damping data, if available

j) for electric motors, generators and pumps, the drawing of the rotating parts, with their mass moment of inertia and main dimensions.

3.2 Definitions, symbols and units

3.2.1 Definitions

a) Torsional vibration stresses referred to in this Article are the stresses resulting from the alternating torque corresponding to the synthesis of the harmonic orders concerned.

b) The misfiring condition of an engine is the malfunction of one cylinder due to the absence of fuel injection (which results in a pure compression or expansion in the cylinder).

3.2.2 Symbols, units

The main symbols used in this Article are defined as follows:

τ : Torsional vibration stress, as defined in [3.2.1], in N/mm^2

τ_1 : Permissible stress due to torsional vibrations for continuous operation, in N/mm^2

τ_2 : Permissible stress due to torsional vibrations for transient running, in N/mm^2

R_m : Tensile strength of the shaft material, as defined in Ch 1, Sec 7, [2.1.2], in N/mm^2

C_R : Material factor, equal to:

$$\frac{R_m + 160}{18}$$

d : Minimum diameter of the shaft, in mm

C_D : Size factor of the shaft, equal to:

$0,35 + 0,93\ d^{-0,2}$

N : Speed of the shaft for which the check is carried out, in rev/min

N_n : Nominal speed of the shaft, in rev/min

N_c : Critical speed, in rev/min

λ : Speed ratio, equal to N/N_n

C_λ : Speed ratio factor, equal to:

- $3 - 2\ \lambda^2$ for $\lambda < 0,9$
- 1,38 for $0,9 \le \lambda < 1,05$

C_k : Factor depending on the stress concentration factor of the shaft design features given in Tab 1.

Table 1 : Values of C_k factors

Intermediate shafts with							Thrust shafts external to engines		Propeller shafts		
straight sections and integral coupling flanges	shrink-fit couplings **(1)**	keyways, tapered connection **(2)**	keyways, cylindrical connection **(2)**	radial hole	longitudinal slot **(3)**	splined shafts	on both sides of thrust collar	in way of axial bearing where a roller bearing is used as a thrust bearing	flange mounted or keyless fitted propellers **(4)**	key fitted propellers **(4)**	between forward end of aft most bearing and forward stern tube seal
1,00	1,00	0,60	0.45	0.50	0.30	0,80	0,85	0,85	0,55	0,55	0.80

(1) C_k values refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in Ch 1, Sec 7, [2.5.1]

(2) Keyways are to be in accordance with the provisions of Ch 1, Sec 7, [2.5.1].

(3) Subject to limitations as $\ell/d_o < 0,8$ and $d_i/d_o < 0,7$ and $e/d_o > 0,15$, where:

ℓ : Slot length in mm

e : Slot width in mm

d_i, d_o : As per Sec 7, [2.2.3]

The C_k value is valid for 1, 2 and 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(4) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2.5 times the required diameter.

Note 1: Higher values of C_k factors based on direct calculations may also be considered.

Note 2: The determination of C_k factors for shafts other than those given in this table will be given special consideration by the Society.

3.3 Calculation principles

3.3.1 Method

a) Torsional vibration calculations are to be carried out using a recognised method.

b) Where the calculation method does not include harmonic synthesis, attention is to be paid to the possible superimposition of two or more harmonic orders of different vibration modes which may be present in some restricted ranges.

3.3.2 Scope of the calculations

a) Torsional vibration calculations are to be carried out considering:
- normal firing of all cylinders, and
- misfiring of one cylinder.

b) Where the torsional dynamic stiffness of the coupling depends on the transmitted torque, two calculations are to be carried out:
- one at full load
- one at the minimum load expected in service.

c) For installations with controllable pitch propellers, two calculations are to be carried out:
- one for full pitch condition
- one for zero pitch condition.

d) The calculations are to take into account other possible sources of excitation, as deemed necessary by the Manufacturer. Electrical sources of excitations, such as static frequency converters, are to be detailed. The same applies to transient conditions such as engine start up, reversing, clutching in, as necessary.

e) The natural frequencies are to be considered up to a value corresponding to 15 times the maximum service speed. Therefore, the excitations are to include harmonic orders up to the fifteenth.

3.3.3 Criteria for acceptance of the torsional vibration loads under normal firing conditions

a) Torsional vibration stresses in the various shafts are not to exceed the limits defined in [3.4]. Higher limits calculated by an alternative method may be considered, subject to special examination by the Society.

The limit for continuous running τ_1 may be exceeded only in the case of transient running in restricted speed ranges, which are defined in [3.4.5]. In no case are the torsional vibration stresses to exceed the limit for transient running τ_2.

Propulsion systems are to be capable of running continuously without restrictions at least within the speed range between 0,8 N_n and 1,05 N_n. Transient running may be considered only in restricted speed ranges for speed ratios $\lambda \leq 0,8$.

Auxiliary machinery is to be capable of running continuously without restrictions at least within the range between 0,95 N_n and 1,1 N_n. Transient running may be considered only in restricted speed ranges for speed ratios $\lambda \leq 0,95$.

b) Torsional vibration levels in other components are to comply with the provisions of [3.5].

c) The generating set is to show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

3.3.4 Criteria for acceptance of torsional vibration loads under misfiring conditions

a) The provisions of [3.3.3] related to normal firing conditions also apply to misfiring conditions.

Note 1: For propulsion systems operated at constant speed, restricted speed ranges related to misfiring conditions may be accepted for speed ratios $\lambda > 0,8$.

b) Where calculations show that the limits imposed for certain components may be exceeded under misfiring conditions, a suitable device is to be fitted to indicate the occurrence of such conditions.

3.4 Permissible limits for torsional vibration stresses in crankshaft, propulsion shafting and other transmission shafting

3.4.1 General

a) The limits provided below apply to steel shafts. For shafts made of other material, the permissible limits for torsional vibration stresses will be determined by the Society after examination of the results of fatigue tests carried out on the material concerned.

b) These limits apply to the torsional vibration stresses as defined in [3.2.1]. They relate to the shaft minimum section, without taking account of the possible stress concentrations.

3.4.2 Crankshaft

a) Where the crankshaft has been designed in accordance with Ch 1, App 1, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:
- $\tau_1 = \tau_N$ for continuous running
- $\tau_2 = 1,7\ \tau_N$ for transient running,

where τ_N is the nominal alternating torsional stress on which the crankshaft scantling is based (see Note 1 in [3.1.2]).

b) Where the crankshaft has not been designed in accordance with Ch 1, App 1, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:

- $\tau_1 = 0,55 \cdot C_R \cdot C_D \cdot C_\lambda$ for continuous running
- $\tau_2 = 2,3\ \tau_1$ for transient running.

3.4.3 Intermediate shafts, thrust shafts and propeller shafts

The torsional vibration stresses in any intermediate, thrust and propeller shafts are not to exceed the following limits:

- $\tau_1 = C_R \cdot C_k \cdot C_D \cdot C_\lambda$ for continuous running
- $\tau_2 = 1,7\ \tau_1 \cdot C_k^{-0,5}$ for transient running.

3.4.4 Transmission shafting for generating sets and other auxiliary machinery

The torsional vibration stresses in the transmission shafting for generating sets and other auxiliary machinery, such as pumps or compressors, are not to exceed the following limits:

- $\tau_1 = 0,90 \cdot C_R \cdot C_D$ for continuous running
- $\tau_2 = 5,4\ \tau_1$ for transient running.

3.4.5 Restricted speed ranges

a) Where the torsional vibration stresses exceed the limit τ_1 for continuous running, restricted speed ranges are to be imposed which are to be passed through rapidly.

b) The limits of the restricted speed range related to a critical speed N_c are to be calculated in accordance with the following formula:

$$\frac{16 \cdot N_c}{18 - \lambda} \leq N \leq \frac{(18 - \lambda) \cdot N_c}{16}$$

c) Where the resonance curve of a critical speed is obtained from torsional vibration measurements, the restricted speed range may be established considering the speeds for which the stress limit for continuous running τ_1 is exceeded.

d) Where restricted speed ranges are imposed, they are to be crossed out on the tachometers and an instruction plate is to be fitted at the control stations indicating that:

- the continuous operation of the engine within the considered speed range is not permitted
- this speed range is to be passed through rapidly.

e) When restricted speed ranges are imposed, the accuracy of the tachometers is to be checked in such ranges as well as in their vicinity.

f) Restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation.

3.5 Permissible vibration levels in components other than shafts

3.5.1 Gears

a) The torsional vibration torque in any gear step is not to exceed 30% of the torque corresponding to the approved rating throughout the service speed range.

Where the torque transmitted at nominal speed is less than that corresponding to the approved rating, higher torsional vibration torques may be accepted, subject to special consideration by the Society.

b) Gear hammering induced by torsional vibration torque reversal is not permitted throughout the service speed range, except during transient running at speed ratios $\lambda \leq 0,3$.

Where calculations show the existence of torsional vibration torque reversals for speed ratios $\lambda > 0,3$, the corresponding speed ranges are to be identified by appropriate investigations during sea trials and considered as restricted speed ranges in accordance with [3.4.5].

3.5.2 Generators

a) In the case of alternating current generators, the torsional vibration amplitude at the rotor is not to exceed ± 2,5 electrical degrees at service rotational speed under full load working conditions.

b) Vibratory inertia torques due to torsional vibrations and imposed on the rotating parts of the generator are not to exceed the values M_A, in N.m, calculated by the following formulae, as appropriate:

- for $0,95 \leq \lambda \leq 1,1$: $M_A = \pm 2,5\ M_T$
- for $\lambda \leq 0,95$: $M_A = \pm 6\ M_T$

where:

M_T : Mean torque transmitted by the engine under full load running conditions, in N.m

Note 1: In the case of two or more generators driven by the same engine, the portion of M_T transmitted to each generator is to be considered.

λ : Speed ratio defined in [3.2.2].

3.5.3 Flexible couplings

a) Flexible couplings are to be capable of withstanding the mean transmitted torque and the torsional vibration torque throughout the service speed range, without exceeding the limits for continuous operation imposed by the manufacturer (permissible vibratory torque and power loss).

Where such limits are exceeded under misfiring conditions, appropriate restrictions of power or speed are to be established.

b) The coupling selection for the generating set is to take into account the stresses and torques imposed on it by the torsional vibration of the system.

c) Flexible couplings fitted in generating sets are also to be capable of withstanding the torques and twist angles arising from transient criticals and short-circuit currents. Start up conditions are also to be checked.

3.5.4 Dampers

a) Torsional vibration dampers are to be such that the permissible power loss recommended by the manufacturer is not exceeded throughout the service speed range.

b) Dampers for which a failure may lead to a significant vibration overload of the installation will be the subject of special consideration.

3.6 Torsional vibration measurements

3.6.1 General

a) The Society may require torsional vibration measurements to be carried out under its attendance in the following cases:

- where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
- where doubts arise as to the actual stress amplitudes or critical speed location, or
- where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

3.6.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

4 Bending vibrations

4.1 Application

4.1.1 The provisions of this Article apply to ships covered by a) or b):

a) Ships fitted with propulsion systems having a transmitted power in excess of 1000 kW and one of the following arrangements:

- Ratio ℓ/D exceeding the following value:

$$\frac{\ell}{D} = 10\left(\frac{\ln 2}{D}\right) + D^2$$

where:

ℓ : Span between the aft bearings of the propeller shaft, in m

D : Diameter of the propeller shaft, in m

- bearings located outboard the hull (brackets)
- cardan shafts.

b) Ships required to submit shaft alignment calculations (as per Ch 1, Sec 7, [3.3.1]) and falling into one of the following cases:,

- Ships with shafting systems whose bearing span exceeds:

$$450\sqrt{d}$$

where:

d : Actual shaft diameter, in mm, of the tail shaft or intermediate shaft, whichever is the lesser.

- Ships for which the shaft alignment calculation report shows that at least one bearing load is lower than 5% of manufacturer's limits. In this case, the bearing in question is to be considered as unloaded (refer to Ch 1, Sec 7, [3.3.2]item g) 1)).

4.2 Documentation to be submitted

4.2.1 Particulars to be submitted

The following particulars are to be submitted with the bending vibration calculations:

- shafting arrangement with indication of:
  - the diameter and length of the shafts
  - the position of the bearings
  - the mounting characteristics of the cardan shafts
  - detailed drawings of the bearings and their seating
  - details of the bearing lubrication, including the oil viscosity
  - the diametrical and polar moments of inertia of the propeller in air and water
  - propeller mass entrained water
- where vibratory amplitudes and bending moment calculations are required (see [4.2.2] item b)):
  - excitations values (bending moments and bending forces)
  - damping values.

4.2.2 Calculations

a) Bending vibration calculations are to show:
   - the equivalent dynamic system used for the modelling of the plant, with indication of the mass of the shafts, propeller and other rotating components, and the lateral stiffness of the bearings, including that of the oil film and that of the seating
   - the natural bending frequencies and associated mode shapes
   - the possible restrictions of operation of the plant.

b) Where bending vibration calculations show a risk of vibration resonance, restrictions of operations of the plant are identified, or where deemed necessary by the Society or the manufacturer, additional calculations are to be provided showing the values of the vibratory amplitudes, bending moments and stresses in the shafting for the most significant critical speeds.

4.3 Calculation principles

4.3.1 Scope of the calculations

Bending vibration calculations are to take into account:

- the stiffness of the bearings and their seatings and, where applicable, that of the lubricating oil film
- the excitations due to the propeller and cardan shafts.

Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy, parametric studies are to be carried out.

4.3.2 Criteria for acceptance of the bending vibration levels

a) The first shafting vibration mode is not to be excited by the first propeller blade excitation order, in the speed range between 80% and 110% of nominal speed.

b) Where bending vibration calculations show a risk of vibration resonance, vibration induced stresses are not to exceed 1,5 times the one indicated in [3.4.3] in the whole speed range. In case the shafting is checked by means of direct calculation the allowable stresses will be established on a case-by-case basis.

   Additionally, vibratory amplitudes in way of aft stern tube bearing should not exceed bearing clearance value.

4.4 Bending vibration measurements

4.4.1 General

The Society may require bending vibration measurements in the following cases:

- where the calculations indicate the possibility of dangerous critical speeds in or near the operating speed range
- where the accuracy of some data is not deemed sufficient
- where restricted speed ranges need to be verified.

Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

4.4.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

5 Axial vibrations

5.1 General

5.1.1 The provisions of this Article apply to the axial vibrations of propulsion systems fitted with:

- an internal combustion engine having a power exceeding 2000 kW and a running speed of less than 200 RPM, or
- a shaft line where the power transmitted exceeds 375 kW and the L/D ratio exceeds 50

  where:

  L : Total length of the shaft line between the propeller and the thrust bearing

  D : Minimum diameter of the shaft line.

5.2 Documentation to be submitted

5.2.1 Calculations

Axial vibration calculations are to show:

- the equivalent dynamic system used for the modelling of the plant, with indication of the masses and axial stiffnesses for all the components of the system
- the natural frequencies
- the axial vibration amplitude in way of the sterntube sealing gland for the most significant critical speeds
- for engines directly connected to the shaftline, the axial vibration amplitude at the free end of the crankshaft for the most significant critical speeds
- the possible restrictions of operation of the plant.

5.2.2 Particulars to be submitted

The following particulars are to be submitted with the axial vibration calculations:

- detailed drawing of the thrust bearing and its supporting structure with indication of their flexibility
- for the propeller:
  - the thrust
  - the excitations (axial forces)
  - the damping characteristics
- for the engine:
  - the axial excitations
  - the permissible axial amplitude at the free end of the crankshaft
  - the characteristics of the axial vibration damper or detuner.

5.3 Calculation principles

5.3.1 Scope of the calculations

Axial vibration calculations are to take into account:

- the flexibility of the thrust bearing and its supporting structure
- the excitations due to the engine and to the propeller.

Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy (e.g. the flexibility of the thrust bearing and its supporting structure), parametric studies are to be carried out.

Where the plant includes an axial vibration damper or detuner, a calculation is to be carried out assuming a malfunction of the damper or detuner.

5.3.2 Criteria for acceptance of the axial vibration levels

The axial vibration force acting on the thrust bearing is not to exceed 30% of the nominal thrust.

The axial vibration amplitude is not to exceed:

- at the free end of the crankshaft, the limit recommended by the engine manufacturer
- in way of the sterntube sealing gland, the limit recommended by the sealing gland manufacturer, if any.

Where the calculations show that in the continuous operation speed range the above limits may be exceeded in the event of malfunction of the axial vibration damper or detuner, a suitable device is to be fitted to indicate the occurrence of such conditions.

Note 1: When detuners or dampers of satisfactorily proven design are used, this requirement may be waived.

5.4 Axial vibration measurements

5.4.1 General

The Society may require axial vibration measurements in the following cases:

- where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
- where the accuracy of some data is not deemed sufficient
- where restricted speed ranges need to be verified.

Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

5.4.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

Section 10 Piping Systems

1 General

1.1 Application

1.1.1

a) General requirements applying to all piping systems are contained in Articles:
- Article [2] for their design and construction
- Article [3] for the welding of steel pipes
- Article [4] for the bending of pipes
- Article [5] for their arrangement and installation
- Article [20] for their certification, inspection and testing.

b) Specific requirements for ship piping systems and machinery piping systems are given in Articles [6] to [19].

1.2 Documentation to be submitted

1.2.1 Documents

The documents listed in Tab 1 are to be submitted.

1.2.2 Additional information

The information listed in Tab 2 is also to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Drawing showing the arrangement of the sea chests and ship side valves
2	A	Diagram of the bilge system (in and outside machinery spaces), including calculation for the bilge main, bilge branch lines and bilge pumps capacity as per Rule requirements
3	A	Specification of the central priming system intended for bilge pumps, when provided
4	A	Diagram of the ballast system (in and outside machinery spaces). See also Ch 1, Sec 13, [1.4] for the installation of ballast water treatment (BWTS) on board
5	A	Diagram of the scuppers and sanitary discharge systems
6	A	Diagram of the air, sounding and overflow systems
7	A	Diagram of cooling systems (sea water and fresh water)
8	A	Diagram of fuel oil system
9	A	Drawings of the fuel oil tanks not forming part of the ship's structure
10	A	Diagram of the lubricating oil system
11	A	Diagram of the thermal oil system
12	A	Diagram of the hydraulic systems intended for essential services or located in machinery spaces
13	A	Diagram of steam system, including safety valve exhaust and drain pipes
14	A I	For high temperature steam pipes: • stress calculation note • drawing showing the actual arrangement of the piping in three dimensions
15	A	Diagram of the boiler feed water and condensate system
16	A	Diagram of the compressed air system, including: • starting air calculation as per Rule requirements • procedure and preliminary calculation showing that after "dead ship conditions" the propulsion may be restored within 30 min
17	A	Diagram of the hydraulic and pneumatic remote control systems

(1) A = to be submitted for approval
I = to be submitted for information.

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

No.	I/A **(1)**	Document **(2)**
18	A	Diagram of the remote level gauging system
19	A	Diagram of the exhaust gas system
20	A	Diagram of drip trays and gutterway draining system
21	A	Arrangement of the ventilation system
22	A	Diagram of the oxyacetylene welding system
23	A	Drawings and specification of valves and accessories, where required in [2.7]

(1) A = to be submitted for approval
I = to be submitted for information.
(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

Table 2 : Information to be submitted

No.	I/A **(1)**	Document
1	I	Nature, service temperature and pressure of the fluids
2	A	Material, external diameter and wall thickness of the pipes
3	A	Type of the connections between pipe lengths, including details of the welding, where provided
4	A	Material, type and size of the accessories
5	A	Capacity, prime mover and, when requested, location of the pumps
6	A	For plastic pipes: • the chemical composition • the physical and mechanical characteristics in function of temperature • the characteristics of inflammability and fire resistance • the resistance to the products intended to be conveyed

(1) A = to be submitted for approval
I = to be submitted for information.

1.3 Definitions

1.3.1 Piping and piping systems

a) Piping includes pipes and their connections, flexible hoses and expansion joints, valves and their actuating systems, other accessories (filters, level gauges, etc.) and pump casings.

b) Piping systems include piping and all the interfacing equipment such as tanks, pressure vessels, heat exchangers, pumps and centrifugal purifiers, but do not include boilers, turbines, internal combustion engines and reduction gears.

Note 1: The equipment other than piping is to be designed in accordance with the relevant Sections of Part C, Chapter 1.

1.3.2 Design pressure

a) The design pressure of a piping system is the pressure considered by the manufacturer to determine the scantling of the system components. It is not to be taken less than the maximum working pressure expected in this system or the highest setting pressure of any safety valve or relief device, whichever is the greater.

b) The design pressure of a boiler feed system is not to be less than 1,25 times the design pressure of the boiler or the maximum pressure expected in the feed piping, whichever is the greater.

c) The design pressure of steam piping located upstream of pressure reducing valves (high pressure side) is not to be less than the setting pressure of the boiler or superheater safety valves.

d) The design pressure of a piping system located on the low pressure side of a pressure reducing valve where no safety valve is provided is not to be less than the maximum pressure on the high pressure side of the pressure reducing valve.

e) The design pressure of a piping system located on the delivery side of a pump or a compressor is not to be less than the setting pressure of the safety valve for displacement pumps or the maximum pressure resulting from the operating (head-capacity) curve for centrifugal pumps, whichever is the greater.

1.3.3 Design temperature

The design temperature of a piping system is the maximum temperature of the medium inside the system.

1.3.4 Flammable oils

Flammable oils include fuel oils, lubricating oils, thermal oils and hydraulic oils.

1.4 Symbols and units

1.4.1 The following symbols and related units are commonly used in this Section. Additional symbols, related to some formulae indicated in this Section, are listed wherever it is necessary.

p : Design pressure, in MPa

T : Design temperature, in °C

t : Rule required minimum thickness, in mm

D : Pipe external diameter, in mm.

1.5 Class of piping systems

1.5.1 Purpose of the classes of piping systems

Piping systems are subdivided into three classes, denoted as class I, class II and class III, for the purpose of acceptance of materials, selection of joints, heat treatment, welding, pressure testing and the certification of fittings.

1.5.2 Definitions of the classes of piping systems

a) Classes I, II and III are defined in Tab 3

b) The following systems are not covered by Tab 3:

- cargo piping for oil tankers, gas tankers and chemical tankers, and
- fluids for refrigerating plants.

Table 3 : Class of piping systems

Media conveyed by the piping system	Class I	Class II **(1)** **(4)**	Class III **(7)**
Toxic media	without special safeguards **(3)**	not applicable	not applicable
Corrosive media	without special safeguards **(3)**	with special safeguards **(3)**	not applicable
Flammable media: • heated above flashpoint, or • having flashpoint < 60°C Liquefied gas	without special safeguards **(3)**	with special safeguards **(3)**	not applicable
Oxyacetylene	irrespective of p	not applicable	not applicable
Steam	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 170
Thermal oil	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 150
Fuel oil **(8)** Lubricating oil Flammable hydraulic oil **(5)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Other media **(5)** **(6)**	p > 4 or T > 300	other **(2)**	p ≤ 1,6 and T ≤ 200

(1) Valves under static pressure on oil fuel tanks or lubricating oil tanks belong to class II.

(2) Pressure and temperature conditions other than those required for class I and class III.

(3) Safeguards for reducing leakage possibility and limiting its consequences:
e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening etc.

(4) Valves and fittings fitted on the ship side and collision bulkhead belong to class II. See also [20.5.3] b).

(5) Steering gear hydraulic piping system belongs to class I irrespective of p and T.

(6) Including water, air, gases, non-flammable hydraulic oil, urea for SCR systems, when piping materials selected according to ISO 18611-3:2014 for urea in SCR .

(7) The open ended pipes, irrespective of T, generally belong to class III (as drains, overflows, vents, exhaust gas lines, boiler escape pipes, etc.).

(8) Design pressure for fuel oil systems is to be determined in accordance with Tab 4.

Note 1: p : Design pressure, as defined in [1.3.2], in MPa.

Note 2: T : Design temperature, as defined in [1.3.3], in °C.

Note 3: Flammable media generally include the flammable liquids as oil fuel, lubricating oil, thermal oil and flammable hydraulic oil.

Table 4 : Definition of the design pressure for fuel oil systems

Working pressure P, in bar	Working temperature T, in °C	
	T ≤ 60	T > 60
P ≤ 7	3 bar or max. working pressure, whichever is the greater	3 bar or max. working pressure, whichever is the greater
P > 7	max. working pressure	14 bar or max. working pressure, whichever is the greater

2 General requirements for design and construction

2.1 Materials

2.1.1 General

Materials to be used in piping systems are to be suitable for the medium and the service for which the piping is intended.

For piping systems included in engine, turbine or gearbox installation in contact with flammable fluids, requirements mentioned in Ch 1, Sec 1, [3.7.2] are to be applied when other materials than steel are used.

2.1.2 Use of metallic materials

a) Metallic materials are to be used in accordance with Tab 5.

b) Materials for class I and class II piping systems are to be manufactured and tested in accordance with the appropriate requirements of NR216 Materials and Welding.

c) Materials for class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national or international standards or specifications.

d) Mechanical characteristics required for metallic materials are specified in NR216 Materials and Welding.

2.1.3 Use of plastics

a) Plastics may be used for piping systems belonging to class III in accordance with Ch 1, App 3. The use of plastics for other systems or in other conditions will be given special consideration.

b) Plastics intended for piping systems dealt with in this Section are to be of a type approved by the Society.

2.2 Thickness of pressure piping

2.2.1 Calculation of the thickness of pressure pipes

a) The thickness t, in mm, of pressure pipes is to be determined by the following formula but, in any case, is not to be less than the minimum thickness given in Tab 6 to Tab 9.

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}}$$

where:

t_0 : Coefficient, in mm, equal to:

$$t_0 = \frac{p \cdot D}{2Ke + p}$$

with:

p and D : as defined in [1.4.1],

K : Permissible stress defined in [2.2.2]

e : Weld efficiency factor to be:

- equal to 1 for seamless pipes and pipes fabricated according to a welding procedure approved by the Society,
- specially considered by the Society for other welded pipes, depending on the service and the manufacture procedure.

b : Thickness reduction due to bending defined in [2.2.3], in mm

c : Corrosion allowance defined in [2.2.4], in mm

a : Negative manufacturing tolerance percentage:

- equal to 10 for copper and copper alloy pipes, cold drawn seamless steel pipes and steel pipes fabricated according to a welding procedure approved by the Society
- equal to 12,5 for hot laminated seamless steel pipes
- subject to special consideration by the Society in other cases.

b) The thickness thus determined does not take into account the particular loads to which pipes may be subjected. Attention is to be drawn in particular to the case of high temperature and low temperature pipes.

Table 5 : Conditions of use of metallic materials in piping systems

Material	Allowable classes	Maximum design temperature **(1)**	Particular conditions of use
Carbon and carbon-manganese steels	III, II, I	400 **(2)**	Class I and II pipes are to be seamless drawn pipes **(3)**
Copper and aluminium brass	III, II, I	200	• Not to be used in fuel oil systems, except for class III pipes of a diameter not exceeding 25 mm not passing through fuel oil tanks • Not to be used for boiler blow-down valves nor for associated pieces for connection to the shell plating **(4)**
Copper-nickel	III, II, I	300	
Special high temperature resistant bronze	III, II, I	260	
Stainless steel	III, II, I	300	In general, austenitic stainless steel is not to be used for sea water systems (see Note **(6)**)
Spheroidal graphite cast iron/Nodular cast iron	III, II **(5)**	350	• Minimum elongation is not to be less than 12% on a gauge length of $5{,}65.S^{0,5}$, where S is the actual cross-sectional area of the test piece • Not to be used for boiler blow-down valves nor for associated pieces for connection to the shell plating
Grey cast iron/ Ordinary cast iron	III, II	220	Grey cast iron/ordinary cast iron is not to be used for the following systems: • boiler blow-down systems and other piping systems subject to shocks, high stresses and vibrations • bilge lines in tanks • parts of scuppers and sanitary discharge systems located next to the hull below the freeboard deck or for passengers ships below the bulkhead deck • ship side valves and fittings • valves fitted on the collision bulkhead • valves fitted to fuel oil and lubricating oil tanks under static pressure head • class II fuel oil systems and thermal oil systems
Aluminium and aluminium alloys	III, II	200	Aluminium and aluminium alloys are not to be used on the following systems: • flammable oil systems • sounding and air pipes of fuel oil tanks • fire-extinguishing systems • bilge system in boiler or machinery spaces or in spaces containing fuel oil tanks or pumping units • scuppers and overboard discharges except for pipes led to the bottoms or to the shell above the freeboard deck or fitted at their upper end with closing means operated from a position above the freeboard deck • boiler blow-down valves and pieces for connection to the shell plating

(1) Maximum design temperature is not to exceed that assigned to the class of piping.

(2) Higher temperatures may be accepted if metallurgical behaviour and time dependent strength (ultimate tensile strength after 100 000 hours) are in accordance with national or international standards or specifications and if such values are guaranteed by the steel manufacturer.

(3) Pipes fabricated by a welding procedure approved by the Society may also be used.

(4) Pipes made of copper and copper alloys are to be seamless.

(5) Use of spheroidal cast iron / nodular cast iron for class I piping systems will be given special consideration by the Society.

(6) Austenitic stainless steels including grades 304, 304L, 316 and 316L are not considered suitable for use in seawater piping systems. Other types of stainless steel with higher contents of chromium, molybdenum and nitrogen may be considered if a technical justification considering critical factors (e.g. chemical composition, stagnant sea water, or low flow sea water piping, operational consideration, etc.) is provided. This includes austenitic stainless steels with at least 3% molybdenum and duplex ferritic-austenitic stainless steels such as grades UNS S31803 or UNS S2550.

Table 6 : Minimum wall thickness for steel pipes

External diameter (mm)	Minimum nominal wall thickness (mm)			Minimum reinforced wall thickness (mm) **(2)**	Minimum extra-reinforced wall thickness (mm) **(3)**
	Pipes in general **(1)**	Vent, overflow and sounding pipes for integral tanks **(1) (5)**	Sea water pipes, bilge and ballast systems **(1) (4)**		
10,2 - 12,0	1,6	–	–	–	–
13,5 - 19,3	1,8	–	–	–	–
20,0	2,0	–	–	–	–
21,3 - 25,0	2,0	–	3,2	–	–
26,9 - 33,7	2,0	–	3,2	–	–
38,0 - 44,5	2,0	4,5	3,6	6,3	7,6
48,3	2,3	4,5	3,6	6,3	7,6
51,0 - 63,5	2,3	4,5	4,0	6,3	7,6
70,0	2,6	4,5	4,0	6,3	7,6
76,1 - 82,5	2,6	4,5	4,5	6,3	7,6
88,9 - 108,0	2,9	4,5	4,5	7,1	7,8
114,3 - 127,0	3,2	4,5	4,5	8,0	8,8
133,0 - 139,7	3,6	4,5	4,5	8,0	9,5
152,4 - 168,3	4,0	4,5	4,5	8,8	11,0
177,8	4,5	5,0	5,0	8,8	12,7
193,7	4,5	5,4	5,4	8,8	12,7
219,1	4,5	5,9	5,9	8,8	12,7
244,5 - 273,0	5,0	6,3	6,3	8,8	12,7
298,5 - 368,0	5,6	6,3	6,3	8,8	12,7
406,4 - 457,2	6,3	6,3	6,3	8,8	12,7

(1) Attention is drawn to the special requirements regarding:

- bilge and ballast systems
- scupper and discharge pipes
- sounding, air and overflow pipes
- ventilation systems
- oxyacetylene welding systems
- CO_2 fire-extinguishing systems (see Ch 4, Sec 15)
- cargo lines (see Pt D, Ch 10, Sec 3). The wall thickness is to be subject to special consideration by the Society.

(2) Reinforced wall thickness applies to pipes passing through tanks containing a fluid distinct from that conveyed by the pipe and to pipe connections fitted to the tanks.

(3) Extra-reinforced wall thickness applies to pipes connected to the shell below the freeboard deck, excluding scupper and discharge pipes.

(4) The minimum wall thickness for bilge lines and ballast lines through deep tanks is to be subject to special consideration by the Society. The ballast lines within oil cargo tanks (where permitted) is to be subject to special consideration by the Society (see Pt D, Ch 7, Sec 4, [2.1.3]).

(5) For sounding pipes, except those for flammable cargoes, the minimum wall thickness is intended to apply only to the part outside the tank.

Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognised standards.

Note 2: For pipes efficiently protected against corrosion, the thickness may be reduced by an amount up to 1 mm.

Note 3: The thickness of threaded pipes is to be measured at the bottom of the thread.

Note 4: The minimum thickness listed in this table is the nominal wall thickness and no allowance is required for negative tolerance and reduction in thickness due to bending.

Note 5: For nominal diameters ND > 450 mm, the minimum wall thickness is to be in accordance with a national or an international standard, but is not to be less than the minimum wall thickness of the appropriate column indicated for 450 mm pipe size.

Note 6: Exhaust gas pipe minimum wall thickness is to be subject to special consideration by the Society.

Table 7 : Minimum wall thickness for copper and copper alloy pipes

External diameter (mm)	Minimum wall thickness (mm)	
	Copper	Copper alloy
8 - 10	1,0	0,8
12 - 20	1,2	1,0
25 - 44,5	1,5	1,2
50 - 76,1	2,0	1,5
88,9 - 108	2,5	2,0
133 - 159	3,0	2,5
193,7 - 267	3,5	3,0
273 - 457,2	4,0	3,5
470	4,0	3,5
508	4,5	4,0
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognised standards.		

Table 8 : Minimum wall thickness for austenitic stainless steel pipes

External diameter (mm)	Minimum wall thickness (mm)
10,2 to 17,2	1,0
21,3 to 48,3	1,6
60,3 to 88,9	2,0
114,3 to 168,3	2,3
219,1	2,6
273,0	2,9
323,9 to 406,4	3,6
over 406,4	4,0
Note 1: Diameters and thicknesses according to national or international standards may be accepted.	

Table 9 : Minimum wall thickness for aluminium and aluminium alloy pipes

External diameter (mm)	Minimum wall thickness (mm)
0 - 10	1,5
12 - 38	2,0
43 - 57	2,5
76 - 89	3,0
108 - 133	4,0
159 - 194	4,5
219 - 273	5,0
above 273	5,5
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognised standards. **Note 2:** For sea water pipes, the minimum thickness is not to be less than 5 mm.	

2.2.2 Permissible stress

a) The permissible stress K is given:

- in Tab 10 for carbon and carbon-manganese steel pipes
- in Tab 11 for alloy steel pipes, and
- in Tab 12 for copper and copper alloy pipes,

as a function of the temperature. Intermediate values may be obtained by interpolation.

b) Where, for carbon steel and alloy steel pipes, the value of the permissible stress K is not given in Tab 10 or Tab 11, it is to be taken equal to the lowest of the following values:

$$\frac{R_{m,20}}{2,7} \qquad \frac{R_e}{A} \qquad \frac{S_R}{A} \qquad S$$

where:

$R_{m,20}$: Minimum tensile strength of the material at ambient temperature (20°C), in N/mm²

R_e : Minimum yield strength or 0,2% proof stress at the design temperature, in N/mm²

S_R : Average stress to produce rupture in 100000 h at design temperature, in N/mm²

S : Average stress to produce 1% creep in 100000 h at design temperature, in N/mm²

A : Safety factor to be taken equal to:

- 1,6 when R_e and S_R values result from tests attended by the Society
- 1,8 otherwise.

c) The permissible stress values adopted for materials other than carbon steel, alloy steel, copper and copper alloy will be specially considered by the Society.

Table 10 : Permissible stresses for carbon and carbon-manganese steel pipes

Specified minimum tensile strength (N/mm²)	Design temperature (°C)												
	≤50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

Table 11 : Permissible stresses for alloy steel pipes

Type of steel	Specified minimum tensile strength (N/mm²)	Design temperature (°C)									
		≤50	100	200	300	350	400	440	450	460	470
1Cr1/2Mo	440	159	150	137	114	106	102	101	101	100	99
2 1/4Cr1Mo annealed	410	76	67	57	50	47	45	44	43	43	44
2 1/4Cr1Mo normalised and tempered below 750°C	490	167	163	153	144	140	136	130	128	127	116
2 1/4Cr1Mo normalised and tempered above 750°C	490	167	163	153	144	140	136	130	122	114	105
1/2Cr 1/2Mo 1/4V	460	166	162	147	120	115	111	106	105	103	102

Type of steel	Specified minimum tensile strength (N/mm²)	Design temperature (°C)									
		480	490	500	510	520	530	540	550	560	570
1Cr1/2Mo	440	98	97	91	76	62	51	42	34	27	22
2 1/4Cr1Mo annealed	410	42	42	41	41	41	40	40	40	37	32
2 1/4Cr1Mo normalised and tempered below 750°C	490	106	96	86	79	67	58	49	43	37	32
2 1/4Cr1Mo normalised and tempered above 750°C	490	96	88	79	72	64	56	49	43	37	32
1/2Cr 1/2Mo 1/4V	460	101	99	97	94	82	72	62	53	45	37

Table 12 : Permissible stresses for copper and copper alloy pipes

Material (annealed)	Specified minimum tensile strength (N/mm²)	Design temperature (°C)										
		≤50	75	100	125	150	175	200	225	250	275	300
Copper	215	41	41	40	40	34	27,5	18,5				
Aluminium brass	325	78	78	78	78	78	51	24,5				
Copper-nickel 95/5 and 90/10	275	68	68	67	65,5	64	62	59	56	52	48	44
Copper-nickel 70/30	365	81	79	77	75	73	71	69	67	65,5	64	62

2.2.3 Thickness reduction due to bending

a) Unless otherwise justified, the thickness reduction b due to bending is to be determined by the following formula:

$$b = \frac{Dt_0}{2{,}5\rho}$$

where:

ρ : Bending radius measured on the centre line of the pipe, in mm

D : as defined in [1.4.1]

t_0 : as defined in [2.2.1].

b) When the bending radius is not given, the thickness reduction is to be taken equal to:

$$\frac{t_0}{10}$$

c) For straight pipes, the thickness reduction is to be taken equal to 0.

2.2.4 Corrosion allowance

The values of corrosion allowance c are given for steel pipes in Tab 13 and for non-ferrous metallic pipes in Tab 14.

Table 13 : Corrosion allowance for steel pipes

Piping system	Corrosion allowance (mm)
Superheated steam	0,3
Saturated steam	0,8
Steam coils in cargo tanks and liquid fuel tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow-down systems for boilers	1,5
Compressed air	1,0
Hydraulic oil	0,3
Lubricating oil	0,3
Fuel oil	1,0
Thermal oil	1,0
Fresh water	0,8
Sea water	3,0
Refrigerants referred to in Ch 1, Sec 16	0,3
Cargo systems for oil tankers	2,0
Cargo systems for ships carrying liquefied gases	0,3
Note 1: For pipes passing through tanks, an additional corrosion allowance is to be considered in order to account for the external corrosion. **Note 2:** The corrosion allowance of pipes efficiently protected against corrosion may be reduced by no more than 50%. **Note 3:** When the corrosion resistance of alloy steels is adequately demonstrated, the corrosion allowance may be disregarded.	

Table 14 : Corrosion allowance for non-ferrous metal pipes

Piping material **(1)**	Corrosion allowance (mm) **(2)**
Copper	0,8
Brass	0,8
Copper-tin alloys	0,8
Copper-nickel alloys with less than 10% of Ni	0,8
Copper-nickel alloys with at least 10% of Ni	0,5
Aluminium and aluminium alloys	0,5

(1) The corrosion allowance for other materials will be specially considered by the Society. Where their resistance to corrosion is adequately demonstrated, the corrosion allowance may be disregarded.

(2) In cases of media with high corrosive action, a higher corrosion allowance may be required by the Society.

2.2.5 Tees

As well as complying with the provisions of [2.2.1] to [2.2.4], the thickness t_T of pipes on which a branch is welded to form a Tee is not to be less than that given by the following formula:

$$t_T = \left(1 + \frac{D_1}{D}\right) \cdot t_0$$

where:

D_1 : External diameter of the branch pipe

D : As defined in [1.4.1]

t_0 : As defined in [2.2.1].

Note 1: This requirement may be dispensed with for Tees provided with a reinforcement or extruded.

2.3 Calculation of high temperature pipes

2.3.1 General

For main steam piping having a design temperature exceeding 400°C, calculations are to be submitted to the Society concerning the stresses due to internal pressure, piping weight and any other external load, and to thermal expansion, for all cases of actual operation and for all lengths of piping.

The calculations are to include, in particular:

- the components, along the three principal axes, of the forces and moments acting on each branch of piping
- the components of the displacements and rotations causing the above forces and moments
- all parameters necessary for the computation of forces, moments and stresses.

In way of bends, the calculations are to be carried out taking into account, where necessary, the pipe ovalisation and its effects on flexibility and stress increase.

A certain amount of cold springing, calculated on the basis of expected thermal expansion, is to be applied to the piping during installation. Such springing is to be neglected in stress calculations; it may, however, be taken into account in terms of its effect on thrusts on turbines and other parts.

2.3.2 Thermal stress

The combined stress σ_{ID}, in N/mm^2, due to thermal expansion, calculated by the following formula:

$$\sigma_{ID} = (\sigma^2 + 4\,\tau^2)^{0,5}$$

is to be such as to satisfy the following equation:

$$\sigma_{ID} \leq 0,75\,K_{20} + 0,25\,K_T$$

where:

σ : Value of the longitudinal stress due to bending moments caused by thermal expansion, increased, if necessary, by adequate factors for bends, in N/mm^2; in general it is not necessary to take account of the effect of axial force

τ : Value of the tangential stress due to torque caused by thermal expansion, in N/mm^2; in general it is not necessary to take account of the effect of shear force

K_{20} : Value of the permissible stress for the material employed, calculated according to [2.2.2], for a temperature of 20°C, in N/mm^2

K_T : Value of the permissible stress for the material employed, calculated according to [2.2.2], for the design temperature T, in N/mm^2.

2.3.3 Longitudinal stresses

The sum of longitudinal stresses σ_L, in N/mm^2, due to pressure, piping weight and any other external loads is to be such as to satisfy the following equation:

$\sigma_L \leq K_T$

where K_T is defined in [2.3.2].

2.3.4 Alternative limits for permissible stresses

Alternative limits for permissible stresses may be considered by the Society in special cases or when calculations have been carried out following a procedure based on hypotheses other than those considered above.

2.4 Junction of pipes

2.4.1 General

a) The junctions between metallic pipe lengths or between metallic pipe lengths and fittings are to be made by:
   - direct welding (butt-weld, socket-weld)
   - bolted flanges (welded-on or screwed-on)
   - threaded sleeve joints, or
   - mechanical joints (see [2.4.5]).

   The joints are to comply with a recognised standard or to be of a design proven to be suitable for the intended purpose and acceptable to the Society. See also [2.1.2].

   The expression “mechanical joints” means devices intended for direct connection of pipe lengths other than by welding, flanges or threaded joints described in [2.4.2], [2.4.3], [2.4.4].

b) The number of joints in flammable oil piping systems is to be kept to the minimum necessary for mounting and dismantling purposes.

c) The gaskets and packings used for the joints are to suit the design pressure, the design temperature and the nature of the fluids conveyed.

d) The junction between plastic pipes is to comply with Ch 1, App 3.

2.4.2 Welded metallic joints

a) Welded joints are to be used in accordance with Tab 15. Welding and non destructive testing of welds are to be carried out in accordance with Article [3].

b) Butt-welded joints are to be of full penetration type, with or without special provision for a high quality of root side.

   The expression "special provision for a high quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by the Society.

c) Slip-on sleeve and socket welded joints are to have sleeves, sockets and weldments of adequate dimensions in compliance with a standard recognised by the Society.

Table 15 : Use of welded and threaded metallic joints in piping systems

Joints	Permitted classes of piping	Restrictions of use
Butt-welded, with special provision for a high quality of root side **(1)**	III, II, I	no restrictions
Butt-welded, without special provision for a high quality of root side **(1)**	III, II	no restrictions
Slip-on sleeve and socket welded **(2)**	III	no restrictions
Threaded sleeve joints with tapered thread **(3)**	I	not allowed for: • pipes with outside diameter of more than 33,7 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur **(4)**.
	III, II	not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur **(4)**.

Joints	Permitted classes of piping	Restrictions of use
Threaded sleeve joints with parallel thread and tightening suitable for intended design conditions **(3)**	III	not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur **(4)**.

(1) For expression "special provision for a high quality of root side" see [2.4.2] b).

(2) Particular cases may be allowed by the Society for piping systems of Class I and II having outside diameter ≤ 88,9 mm except for piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

(3) In particular cases, sizes in excess of those mentioned above may be accepted by the Society if found in compliance with a recognised national and/or international standard.

(4) Threaded sleeve joints may be accepted for connecting instrumentation lines equipment (e.g., pressure/temperature sensors) to piping conveying flammable media if such connections comply with a recognized national and/or international standard, such as ASME B31.1 and ASME B31.3. The use of threaded sleeve joints is limited to external diameters up to 25 mm.

Note 1: Other applications will be specially considered by the Society.

2.4.3 Metallic flange connections

a) In general, the metallic flange connections used for piping systems are to be in compliance with a standard recognised by the Society.

b) The material used for flanges and gaskets is to be suitable for the nature and temperature of the fluid, as well as pipes on which the flanges are to be fitted.

c) The dimensions and configuration of flanges and bolts are to be chosen in accordance with recognised standard intended for design pressure and design temperature of the piping system. Otherwise, the flange connections are subject to special consideration.

d) Flanges are to be attached to the pipes by welding or screwing. Examples of acceptable metallic flange connections are shown in Fig 1. However, other types of flange connections may be also considered by the Society in each particular case, provided that they are in accordance with national or international standards applicable to the piping system and recognise the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

e) Permitted applications are indicated in Tab 16.

Table 16 : Use of metallic flange connections in piping systems (types as shown in Fig 1)

Type of media conveyed	Class of piping (see Tab 3)		
	I	II	III
Toxic or corrosive media Flammable liquids (where heated above flashpoint or having flashpoint < 60°C) Liquefied gases	A1, A2, B1, B2, B3 **(1) (2) (4)**	A1, A2, B1, B2, B3, C1, C2, C3 **(1) (4)**	not applicable
Fuel oil Lubricating oil	A1, A2, B1, B2, B3	A1, A2, B1, B2, B3, C1, C2, C3	A1, A2, B1, B2, B3, C1, C2, C3, E2
Steam Thermal oil	A1, A2, B1, B2, B3 **(2) (3)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2 **(6)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2
Other media as water, air, gases (refrigerants), non-flammable hydraulic oil, etc.	A1, A2, B1, B2, B3 **(3)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2 **(6)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E1, E2 **(5) (6) (7)**

(1) When design pressure p (see [1.3.2]) exceeds 1 MPa, types A1 and A2 only.

(2) For nominal diameter ND ≥ 150 mm, types A1 and A2 only.

(3) When design temperature T (see [1.3.3] exceeds 400°C, types A1 and A2 only.

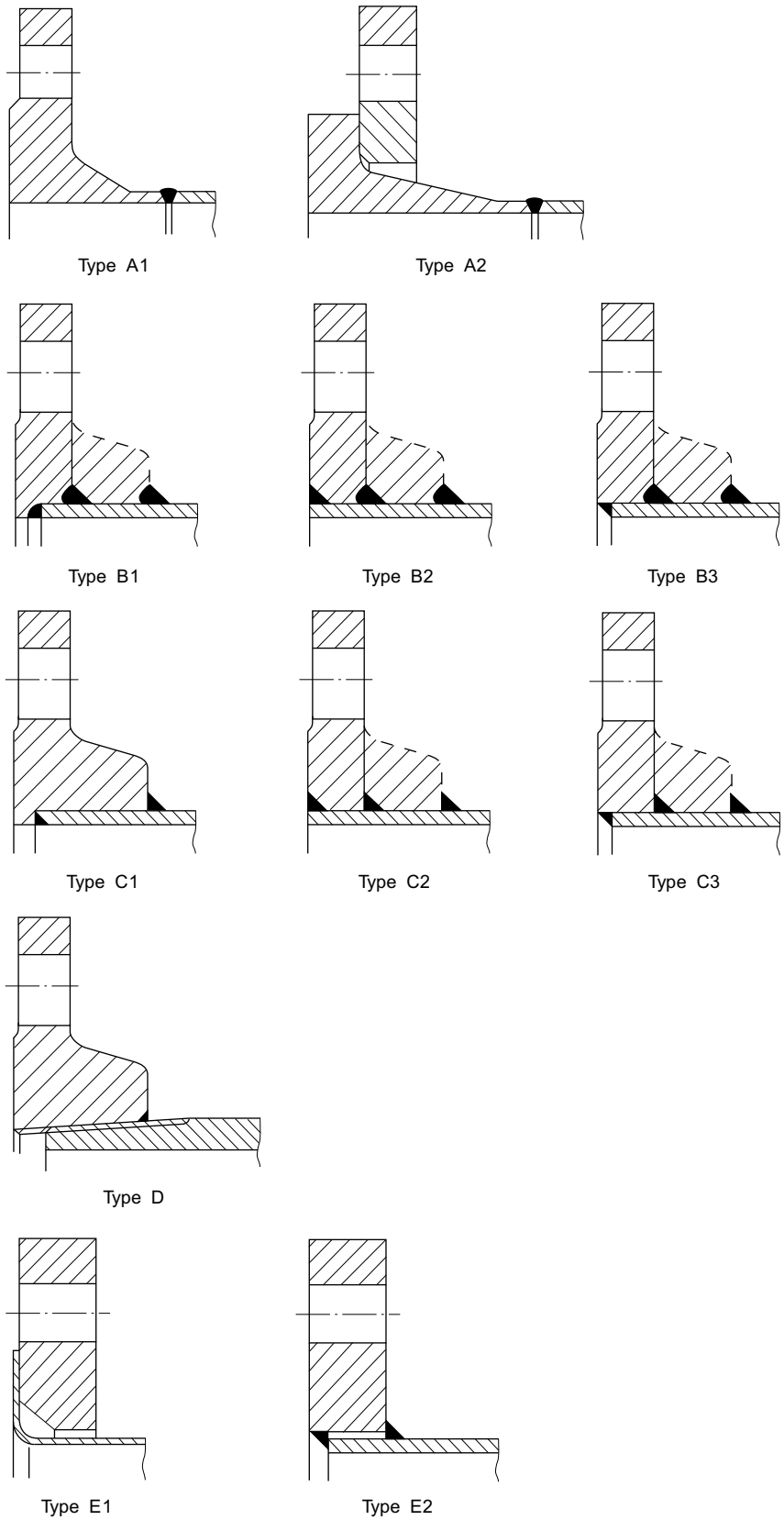
(4) For cargo piping of ships having the service notation **chemical tanker**, IBC Code Ch. 5, 5.3 and Pt D, Ch 8, Sec 5, [3.1.4] are to be applied. For cargo piping of ships having the service notation **liquefied gas carrier**, Pt D, Ch 9, Sec 5, [8.3] is to be applied.

(5) Type E2: only for design pressure p ≤ 1,6 MPa and design temperature T ≤ 150°C.

(6) Types D and E2: only for design temperature T ≤ 250°C.

(7) Type E1: only for water pipelines and for open ended lines (e.g. drain, overflow, air vent piping, etc.).

Figure 1 : Examples of metallic flange connections



Note 1: For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. For certain types of thread, after the flange has been screwed hard home, the pipe is to be expanded into the flange.

Note 2: The leg length of the fillet weld, as well as the dimension of the groove penetration in the flange, is to be in general equal to 1,5 times the pipe thickness but not less than 5 mm.

2.4.4 Slip-on threaded joints

a) Slip-on threaded joints having pipe threads where pressure-tight joints are made on the threads with parallel or tapered threads are to comply with requirements of a recognised national and / or international standard and are to be acceptable to the Society.

b) Slip-on threaded joints may be used for piping systems in accordance with Tab 15.

c) Threaded joints may be accepted also in CO_2 piping systems, provided that they are used only inside protected spaces and in CO_2 cylinder rooms.

2.4.5 Mechanical joints

Due to the great variations in design and configuration of mechanical joints, specific recommendation regarding calculation method for theoretical strength calculations is not specified. The Type Approval is to be based on the results of testing of the actual joints.

Below specified requirements are applicable to pipe unions, compression couplings, slip-on joints as shown in Fig 2. Similar joints complying with these requirements may be acceptable.

a) The application and pressure ratings of different mechanical joints are to be approved by the Society. The approval is to be based on the Type Approval procedure provided in Ch 1, App 5. Mechanical joints including pipe unions, compression couplings, slip-on joints and similar joints are to be of approved type for the service conditions and the intended application.

b) Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

c) Material of mechanical joints is to be compatible with the piping material and internal and external media.

d) As far as applicable, the mechanical joints are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure is to be specially considered by the Society.

e) Where appropriate, mechanical joints are to be of fire resistant type as required by Tab 17.

f) Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the ship's side below the bulkhead deck of passenger ships and freeboard deck of cargo ships or tanks containing flammable fluids.

g) The number of mechanical joints in flammable liquid systems is to be kept to a minimum. In general, flanged joints conforming to recognised standards are to be used.

h) Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

i) Slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces which are not easily accessible (refer to IMO MSC/Circ.734), except that these joints may be permitted in tanks that contain the same media as the pipe where the joint is fitted. Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

j) Application of mechanical joints and their acceptable use for each service is indicated in Tab 17; dependence upon the class of piping, pipe dimensions, working pressure and temperature is indicated in Tab 18.

k) In some particular cases, sizes in excess of those mentioned above may be accepted by the Society if they are in compliance with a recognised national and/or international standard.

l) Application of various mechanical joints may be accepted as indicated by Tab 17. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

m) Mechanical joints are to be tested in accordance with a program approved by the Society, which is to include at least the following:

   1) leakage test
   2) vacuum test (where necessary)
   3) vibration (fatigue) test
   4) fire endurance test (where necessary)
   5) burst pressure test
   6) pressure pulsation test (mandatory for piping systems classes I and II, where necessary for piping system class III)
   7) assembly test (where necessary)
   8) pull out test (where necessary).

n) The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.

Figure 2 : Examples of mechanical joints

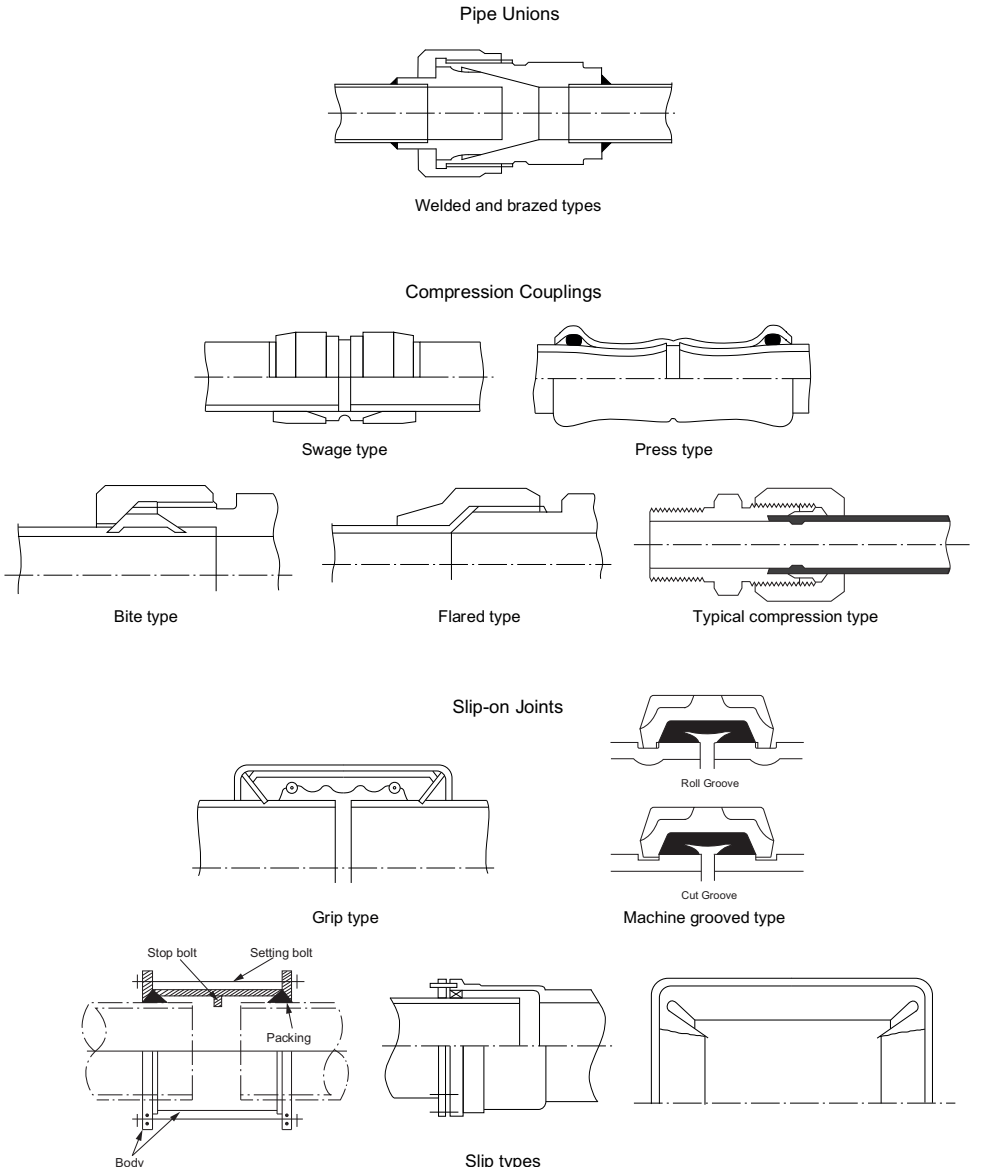


Table 17 : Application of mechanical joints

Systems		Kind of connections			Classification of pipe system	Fire endurance test condition **(7)**
		Pipe unions	Compression couplings	Slip-on joints		
FLAMMABLE FLUIDS (FLASHPOINT ≤ 60°C)						
1	Cargo oil lines **(1)**	+	+	+	dry	30 min dry (*)
2	Crude oil washing lines **(1)**	+	+	+	dry	30 min dry (*)
3	Vent lines **(3)**	+	+	+	dry	30 min dry (*)
INERT GAS						
4	Water seal effluent lines	+	+	+	wet	30 min wet (*)
5	Scrubber effluent lines	+	+	+	wet	30 min wet (*)
6	Main lines **(1)** **(2)**	+	+	+	dry	30 min dry (*)
7	Distribution lines **(1)**	+	+	+	dry	30 min dry (*)
FLAMMABLE FLUIDS (FLASHPOINT > 60°C)						
8	Cargo oil lines **(1)**	+	+	+	dry	30 min dry (*)
9	Fuel oil lines **(2)** **(3)**	+	+	+	wet	30 min wet (*)
10	Lubricating oil lines **(2)** **(3)**	+	+	+	wet	30 min wet (*)
11	Hydraulic oil **(2)** **(3)**	+	+	+	wet	30 min wet (*)
12	Thermal oil **(2)** **(3)**	+	+	+	wet	30 min wet (*)

	Systems	Kind of connections			Classification of pipe system	Fire endurance test condition **(7)**
		Pipe unions	Compression couplings	Slip-on joints		
	SEA WATER					
13	Bilge lines **(4)**	+	+	+	dry / wet	8 min dry + 22 min wet (*)
14	Permanent water filled fire extinguishing systems, e.g. fire main, sprinkler systems **(3)**	+	+	+	wet	30 min wet (*)
15	Non-permanent water filled fire extinguishing systems, e.g. foam, drencher systems and fire main **(3)**	+	+	+	dry / wet	8 min dry + 22 min wet (*) For foam systems, Ch 4, Sec 15, [5] to be observed
16	Ballast system **(4)**	+	+	+	wet	30 min wet (*)
17	Cooling water system **(4)**	+	+	+	wet	30 min wet (*)
18	Tank cleaning services	+	+	+	dry	Fire endurance test not required
19	Non-essential systems	+	+	+	dry dry / wet wet	Fire endurance test not required
	FRESH WATER					
20	Cooling water system **(4)**	+	+	+	wet	30 min wet (*)
21	Condensate return **(4)**	+	+	+	wet	30 min wet (*)
22	Non-essential systems	+	+	+	dry dry / wet wet	Fire endurance test not required
	SANITARY / DRAINS / SCUPPERS					
23	Deck drains (internal) **(5)**	+	+	+	dry	Fire endurance test not required
24	Sanitary drains	+	+	+	dry	
25	Scuppers and discharge (overboard)	+	+	–	dry	
	SOUNDING / VENT					
26	Water tanks / Dry spaces	+	+	+	dry / wet	Fire endurance test not required
27	Oil tanks (flashpoint > 60°C) **(2) (3)**	+	+	+	dry	
	MISCELLANEOUS					
28	Starting/Control air **(4)**	+	+	–	dry	30 min dry (*)
29	Service air (non-essential)	+	+	+	dry	Fire endurance test not required
30	Brine	+	+	+	wet	
31	CO_2 system (outside protected space)	+	+	–	dry	30 min dry (*)
32	CO_2 system (inside protected space)	+	+	–	dry	Mechanical joints are to be constructed of materials with melting point above 925°C Refer to Ch 4, Sec 15, [4]
33	Steam	+	+	+ **(6)**	wet	Fire endurance test not required

Note 1: + : Application is allowed ; – : Application is not allowed.

(*) Fire test as specified in Ch 1, App 5, [2.7.6].

Footnotes - Fire resistance capability

If mechanical joints include any components which readily deteriorate in case of fire, the following footnotes are to be observed:

(1) Fire endurance test is to be applied when mechanical joints are installed in pump rooms and open decks.

(2) Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions (refer to IMO Circular MSC/Circ.734).

(3) Approved fire-resistant types except in cases where such mechanical joints are installed on open decks, as defined in Ch 4, Sec 5, [1.4.3] item b) 2) (10), and not used for fuel oil lines.

(4) Fire endurance test is to be applied when mechanical joints are installed inside machinery spaces of category A.

Footnotes - General

(5) Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.

(6) Slip type slip-on joints as shown in Fig 2. May be used for pipes on deck with a design pressure of 10 bar or less.

(7) In cases exposure time (t_T) is greater than 30 minutes the dry-wet test conditions are 8 minutes dry and, accordingly, the wet period t_T – 8 min

If a connection has passed the "30 min dry" test, it is considered suitable also for applications for which the "8 min dry+22 min wet" and/or "30 min wet " tests are required. If a connection has passed the "8 min dry+22 min wet" test, it is considered suitable also for applications for which the "30 min wet" test is required.

Table 18 : Application of mechanical joints depending upon the class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe Unions			
Welded and brazed types	+ (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm)	+
Compression Couplings			
Swage type	+	+	+
Bite type	+	+	+
Typical compression type	+	+	+
Flared type	+	+	+
Press type	–	–	+
Slip-on Joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
Note 1: + : Application is allowed ; – : Application is not allowed.			

2.5 Protection against overpressure

2.5.1 General

a) These requirements deal with the protection of piping systems against overpressure, with the exception of heat exchangers and pressure vessels, which are dealt with in Ch 1, Sec 3, [3.5.1].

b) Safety valves are to be sealed after setting.

2.5.2 Protection of flammable oil systems

Provisions shall be made to prevent overpressure in any flammable oil tank or in any part of the flammable oil systems, including the filling lines served by pumps on board.

2.5.3 Protection of pump and compressor discharges

a) Provisions are to be made so that the discharge pressure of pumps and compressors cannot exceed the pressure for which the pipes located on the discharge of these pumps and compressors are designed.

b) When provided on the pump discharge for this purpose, safety valves are to lead back to the pump suction or to any other suitable place.

c) The discharge capacity of the safety valves installed on pumps and compressors is to be such that the pressure at the discharge side cannot exceed by more than 10% the design pressure of the discharge pipe in the event of operation with closed discharge.

2.5.4 Protection of pipes

a) Pipes likely to be subjected to a pressure exceeding their normal working pressure are to be provided with safety valves or equivalent overpressure protecting devices.

b) In particular, pipes located on the low pressure side of pressure reducing valves are to be provided with safety valves unless they are designed for the maximum pressure on the high pressure side of the pressure reducing valve. See also [1.3.2] and [2.9.1].

c) The discharge capacity of the devices fitted on pipes for preventing overpressure is to be such that the pressure in these pipes cannot exceed the design pressure by more than 10%.

2.6 Flexible hoses and expansion joints

2.6.1 General

a) Definitions:

- Flexible hose assembly: short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation
- Expansion joint: an assembly designed to safely absorb the heat-induced expansion and contraction, mainly to allow axial relative movement between pipes and the ship's structure as required in [5.6].

b) Flexible hoses and expansion joints are to be of a type approved by the Society. Unless otherwise specified, they are to comply with the requirements of this sub-article.

c) The requirements of this sub-article apply to flexible hoses and expansion joints of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporarily connected flexible hoses or hoses of portable equipment.

d) Unless otherwise specified, the requirements of this sub-article do not apply for flexible hose assemblies and expansion joints intended to be used in fire extinguishing systems.

e) Flexible hose assemblies and expansion joints intended for piping systems with a design temperature below the ambient temperature are subject to special consideration by the Society.

f) Specific requirements for flexible hoses and expansion joints intended for cargo pipe lines are given in:

- Part D, Chapter 7 for oil tankers
- Part D, Chapter 8 for chemical tankers
- Part D, Chapter 9 for liquefied gas carriers
- NR 620 for flexible hoses intended for LNG bunkering.

2.6.2 General conditions of use applicable to flexible hoses and expansion joints

a) Unless otherwise specified, the Society may permit the use of flexible hoses and expansion joints, made of both metallic and non-metallic materials, provided they are approved for the intended service. They may be accepted for use in oil fuel, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, Class III steam systems and exhaust gas systems where they comply with the requirements of this sub-article.

b) For steam systems, the flexible hose assemblies and expansion joints are to be of metallic construction.

c) The position of flexible hose assemblies and expansion joints is to be clearly shown on the drawings listed in [1.2.1] and [1.2.2] when submitted to the Society.

d) Flexible hose assembly or an expansion joint is to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any requirements of the Society.

e) The arrangement and installation of the flexible hose assemblies and expansion joints are also to comply with [5.9.3].

2.6.3 Specific conditions of use applicable to flexible hoses

a) Flexible hose assembly is not accepted in high pressure fuel oil injection systems.

b) Flexible hose assemblies for essential services or containing either flammable or toxic media are not to exceed 1,5 m in length.

2.6.4 General requirements for the design of flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be designed and constructed in accordance with recognised National or International standards acceptable to the Society.

b) Acceptance of a flexible hose assembly or an expansion joint is subject to satisfactory prototype testing in accordance with the provisions of [20.2].

c) The material, design and construction are to be at least suitable for:

- marine environment and external contact with hydrocarbons
- internal contact and resistance to the fluid they are to convey
- maximal pressure and temperature of fluid they are to convey
- maximum expected forces due to vibrations
- maximum expected impulse peak pressure.

The metallic materials are to comply with [2.1.2].

d) Where rubber materials are intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems, the construction is to incorporate a single, double or more, closely woven integral wire braid or other suitable material reinforcement acceptable to the Society.

Flexible hoses and expansion joints of plastic materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid, are to have suitable material reinforcement, as far as practicable.

Rubber or plastic material hoses and expansion joints used in oil supply lines to burners are to have external wire braid protection in addition to the reinforcement mentioned above.

e) Flexible hose assemblies and expansion joints constructed of non-metallic materials, which are intended for installation in piping systems for flammable media or in sea water systems where failure may result in flooding, are to be of fire-resistant type except in cases where such hoses are installed on open decks as defined in Ch 4, Sec 5, [1.5.2], item b), (10) and not used for fuel oil lines.

Fire resistance is to be demonstrated by testing in accordance with the standards specified in Tab 36 and Tab 38.

f) Flexible hoses and expansion joints are to be complete with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with [2.4.5] as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose or expansion joint with particular reference to pressure and impulse tests.

2.6.5 Specific requirements for the design of flexible hoses

The hose clamps and similar types of end attachments are not acceptable for use in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0,5 MPa and provided that there are double clamps at each end connection.

2.6.6 Marking

Flexible hoses or expansion joints are to be permanently marked by the manufacturer with the following details:

- manufacturer's name or trademark
- date of manufacture (month/year)
- designation type reference
- nominal diameter
- pressure rating
- temperature rating.

Where a flexible hose assembly or an expansion joint is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

2.7 Valves and accessories

2.7.1 General

a) Valves and accessories are normally to be built in accordance with a recognised standard. Otherwise, they are subject to special consideration for approval by the Society.

Valves and fittings in piping systems are to be compatible with the pipes to which they are attached in respect of their strength (see [1.3.2] for design pressure) and are to be suitable for effective operation at the maximum working pressure they will experience in service.

Valves and accessories which are fitted:

- in a class I piping system, or
- in a class II piping system, or
- on the ship side, on the collision bulkhead, on fuel oil tanks or on lubricating oil tanks under static pressure,

are to be subject to the applicable testing and inspection required by the Rules. See [20.7.1].

b) Shut-off valves are to be provided where necessary to isolate pumps, heat exchangers, pressure vessels, etc., from the rest of the piping system when necessary, and in particular:

- to allow the isolation of duplicate components without interrupting the fluid circulation
- for survey or repair purposes.

2.7.2 Design of valves and accessories

a) Materials of valve and accessory bodies are to comply with the provisions of [2.1].

b) Connections of valves and accessories with pipes are to comply with the provisions of [2.4].

c) All valves and accessories are to be so designed as to prevent the loosening of covers and glands when they are operated.

d) Valves are to be so designed as to shut with a right-hand (clockwise) motion of the wheels.

e) Valves are to be provided with local indicators showing whether they are open or shut, unless this is readily apparent.

2.7.3 Valves with remote control

a) Unless otherwise specified, the valves and cocks which can not be fitted in places where they are at all times readily accessible are to be provided with remote control.

All valves which are provided with remote control are also to be designed for local manual operation.

b) The remote control system and means of local operation are to be independent. For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached.

c) For submerged valves in ballast, cargo, or other tanks where accepted by the Society, local manual operation may be by extended spindle or portable hand pump.

The manual operation by hand pump is to have the control lines to each submerged valve provided with the quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump. For shipside valves and valves on the collision bulkhead, the hand pump is to be permanently attached and fitted to the quick coupling connection. For other valves, not less than two portable hand pumps are to be provided.

d) In the case of valves which are to be provided with remote control in accordance with the Rules, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

e) Power failure of the remote control system is not to cause an undesired change of the valve position.

f) Unless otherwise specified, indicators are to be provided on the remote controls to show whether the valves are open or closed.

The indicators for local manual control are to comply with [2.7.2], item e).

2.8 Sea inlets and overboard discharges

2.8.1 General

a) Except where expressly stated in Article [8], the requirements of this sub-article do not apply to scuppers and sanitary discharges.

b) Unless otherwise specified, the number of sea inlets is to be as stated in [10.7].

c) The sea inlets are to comply also with the requirements specified for particular service notations or additional class notations, such as:

- Pt D, Ch 7, Sec 4, [2.3.6] for oil tankers and FLS tankers
- Pt E, Ch 4, Sec 3, [3.3.2] for fire fighting ships
- Pt D, Ch 15, Sec 4, [1.8] for fishing vessels
- Pt F, Ch 8, Sec 3, [3.2] for navigation in ice
- Pt F, Ch 8, Sec 4, [6.3.2] for navigation in cold weather conditions.

2.8.2 Design of sea inlets and overboard discharges

a) All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

b) Sea inlets and overboard discharges are to be fitted with valves complying with [2.7] and [2.8.3].

c) Machinery space main and auxiliary sea inlets and discharges in connection with the operation of machinery are to be fitted with readily accessible valves between the pipes and the shell plating or between the pipes and fabricated boxes attached to the shell plating. The valves may be controlled locally and are to be provided with indicators showing whether they are open or closed.

d) Sea inlets are to be so designed and arranged as to limit turbulence and to avoid the admission of air due to motion of the ship.

e) Sea inlets are to be fitted with gratings complying with [2.8.4].

f) Provisions are to be made for clearing sea inlet gratings.

g) Sea chests are to be suitably protected against corrosion.

h) Sea water suction lines are to be fitted with strainers having a free passage area of at least twice that of the sea suction valve.

2.8.3 Valves

a) Sea inlet and overboard discharge valves are to be secured:

- directly on the shell plating, or
- on sea chests built on the shell plating, with scantlings in compliance with Part B of the Rules, or
- on extra-reinforced and short distance pieces attached to the shell (see Tab 6).

b) The bodies of the valves and distance pieces are to have a spigot passing through the plating without projecting beyond the external surface of such plating or of the doubling plates and stiffening rings, if any.

c) Valves are to be secured by means of:

- bolts screwed through the plating with a countersunk head, or
- studs screwed in heavy pads themselves secured to the hull or chest plating, without penetration of the plating by the stud holes.

d) The use of butterfly valves will be specially considered by the Society. In any event, butterfly valves not fitted with flanges are not to be used for water inlets or overboard discharges unless provisions are made to allow disassembling at sea of the pipes served by these valves without any risk of flooding.

e) The materials of the valve bodies and connecting pieces are to comply with Tab 5.

f) Ship side valves serving piping systems made of plastics are to comply with following requirements:

- the ship side valves required in [2.8.2] and, where provided, the connecting pipes to the shell are to be made of metal in accordance with [2.1], and
- Ship side valves are to be provided with remote control from outside the space concerned. See Ch 1, App 3, Tab 1

g) In manned machinery spaces, the valves may be controlled locally and shall be provided with indicators showing whether they are open or closed. Location of controls shall comply with [5.5.4].

2.8.4 Gratings

a) Gratings are to have a free flow area not less than twice the total section of the pipes connected to the inlet.

b) When gratings are secured by means of screws with a countersunk head, the tapped holes provided for such screws are not to pass through the plating or doubling plates outside distance pieces or chests.

c) Screws used for fixing gratings are not to be located in the corners of openings in the hull or of doubling plates.

d) In the case of large sea inlets, the screws used for fixing the gratings are to be locked and protected from corrosion.

e) When gratings are cleared by use of compressed air or steam devices, the chests, distance pieces and valves of sea inlets and outlets thus arranged are to be so constructed as to withstand the maximum pressure to which they may be subjected when such devices are operating.

f) For additional class notation **INWATERSURVEY**, see Pt F, Ch 15, Sec 3.

2.8.5 Ship side connections for blow-down of boilers

a) Blow-down pipes of boilers are to be provided with cocks or valves placed as near the end of the pipes as possible, while remaining readily accessible and located above the engine room floor.

b) Blow-down valves are to be so designed that it is easy to ascertain whether they are open or shut. Where cocks are used, the control keys are to be such that they cannot be taken off unless the cocks are shut. Where valves are used, the control-wheels are to be permanently fixed to the spindle.

c) A protection ring is to be fitted on the shell plating, outside, at the end of the blow-down pipes. The spigot of the valve referred to in [2.8.3], item b), is to pass through this ring.

2.9 Control and monitoring

2.9.1 General

a) Local indicators are to be provided for at least the following parameters:

- pressure, in pressure vessels, at pump or compressor discharge, at the inlet of the equipment served, on the low pressure side of pressure reducing valves
- temperatures, in tanks and vessels, at heat exchanger inlet and outlet
- levels, in tanks and vessels containing liquids.

b) Safeguards are to be provided where an automatic action is necessary to restore acceptable values for a faulty parameter.

c) Automatic controls are to be provided where it is necessary to maintain parameters related to piping systems at a pre-set value.

2.9.2 Level gauges

Level gauges used in flammable oil systems are to be of a type approved by the Society and are subject to the following conditions:

- in passenger ships, they are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of flammable oil
- in cargo ships, their failure or overfilling of the tank is not to permit release of flammable oil into the space. The use of cylindrical gauges is prohibited. The Society may permit the use of oil-level gauges with flat glasses and self-closing valves between the gauges and flammable oil tanks.
- their glasses are to be made of heat-resistant material and efficiently protected against shocks.

On cargo ships of less than 500 gross tonnage and non-propelled ships:

- cylindrical gauges may be used provided they are fitted with self-closing valves at their lower end as well as at their upper end if the latter is below the maximum liquid level
- in the case of tanks not subject to filling by power pumps, with the exception of fuel oil service tanks, the valves need not be of the self-closing type. Such valves are, however, to be readily accessible and instruction plates are to be fitted adjacent to them specifying that they are to be kept closed.

3 Welding of steel piping

3.1 Application

3.1.1

a) The following requirements apply to welded joints belonging to class I or II piping systems.

They may also be applied to class III piping systems, at the discretion of the Society.

b) This article does not apply to refrigerated cargo installation piping systems operating at temperatures lower than minus 40°C.

c) The requirements for qualification of welding procedures are given in NR216 Materials and Welding.

3.2 General

3.2.1 Welding processes

a) Welded joints of pipes are to be made by means of electric arc or oxyacetylene welding, or any other previously approved process.

b) When the design pressure exceeds 0,7 MPa, oxyacetylene welding is not permitted for pipes with an external diameter greater than 100 mm or a thickness exceeding 6 mm.

3.2.2 Location of joints

The location of welded joints is to be such that as many as possible can be made in a workshop. The location of welded joints to be made on board is to be so determined as to permit their joining and inspection in satisfactory conditions.

3.3 Design of welded joints

3.3.1 Types of joints

a) Except for the fixing of flanges on pipes in the cases mentioned in Fig 1 and for the fixing of branch pipes, joints between pipes and between pipes and fittings are to be of the butt-welded type. Other type of connections might be accepted by the Society according to Tab 15.

b) For butt-welded joints between pipes or between pipes and flanges or other fittings, correctly adjusted backing rings may be used; such rings are to be either of the same grade of steel as the elements to be welded or of such a grade as not to adversely influence the weld; if the backing ring cannot be removed after welding, it is to be correctly profiled.

3.3.2 Assembly of pipes of unequal thickness

If the difference of thickness between pipes to be butt-welded exceeds 10% of the thickness of the thinner pipe plus 1 mm, subject to a maximum of 4 mm, the thicker pipe is to be thinned down to the thickness of the thinner pipe on a length at least equal to 4 times the offset, including the width of the weld if so desired.

3.3.3 Accessories

a) When accessories such as valves are connected by welding to pipes, they are to be provided with necks of sufficient length to prevent abnormal deformations during the execution of welding or heat treatment.

b) For the fixing by welding of branch pipes on pipes, it is necessary to provide either a thickness increase as indicated in [2.2.5] or a reinforcement by doubling plate or equivalent.

3.4 Preparation of elements to be welded and execution of welding

3.4.1 General

Attention is drawn to the provisions of Ch 1, Sec 3, which apply to the welding of pressure pipes.

3.4.2 Edge preparation for welded joints

The preparation of the edges is preferably to be carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching, grinding or chipping back to sound metal.

3.4.3 Abutting of parts to be welded

a) The elements to be welded are to be so abutted that surface misalignments are as small as possible.

b) As a general rule, for elements which are butt-welded without a backing ring the misalignment between internal walls is not to exceed the lesser of:

- the value given in Tab 19 as a function of thickness t and internal diameter d of these elements, and
- t/4.

Where necessary, the pipe ends are to be bored or slightly expanded so as to comply with these values; the thickness obtained is not to be less than the Rule thickness.

c) In the case of welding with a backing ring, smaller values of misalignment are to be obtained so that the space between the backing ring and the internal walls of the two elements to be assembled is as small as possible; normally this space is not to exceed 0,5 mm.

d) The elements to be welded are to be adequately secured so as to prevent modifications of their relative position and deformations during welding.

Table 19 : Maximum value of misalignment

d (mm)	t (mm)		
	t ≤ 6	6 < t ≤ 10	10 < t
d < 150	1,0	1,0	1,0
150 ≤ d < 300	1,0	1,5	1,5
300 ≤ d	1,0	1,5	2,0

3.4.4 Protection against adverse weather conditions

a) Pressure pipes are to be welded, both on board and in the shop, away from draughts and sudden temperature variations.

b) Unless special justification is given, no welding is to be performed if the temperature of the base metal is lower than 0°C.

3.4.5 Preheating

a) Preheating is to be performed as indicated in Tab 20, depending on the type of steel, the chemical composition and the pipe thickness.

b) The temperatures given in Tab 20 are based on the use of low hydrogen processes. Where low hydrogen processes are not used, the Society reserves the right to require higher preheating temperatures.

Table 20 : Preheating temperature

Type of steel		Thickness of thicker part (mm)	Minimum preheating temperature (°C)
C and C-Mn steels	$C + \frac{Mn}{6} \leq 0,40$	t ≥ 20 **(2)**	50
	$C + \frac{Mn}{6} > 0,40$	t ≥ 20 **(2)**	100
0,3 Mo		t ≥ 13 **(2)**	100
1 Cr 0,5 Mo		t < 13	100
		t ≥ 13	150
2,25 Cr 1 Mo **(1)**		t < 13	150
		t ≥ 13	200
0,5 Cr 0,5 Mo V **(1)**		t < 13	150
		t ≥ 13	200

(1) For 2,25 Cr 1 Mo and 0,5 Cr 0,5 Mo V grades with thicknesses up to 6 mm, preheating may be omitted if the results of hardness tests carried out on welding procedure qualification are considered acceptable by the Society.

(2) For welding in ambient temperature below 0°C, the minimum preheating temperature is required independent of the thickness unless specially approved by the Society.

3.5 Post-weld heat treatment

3.5.1 General

a) As far as practicable, the heat treatment is to be carried out in a furnace. Where this is impracticable, and more particularly in the case of welding on board, the treatment is to be performed locally by heating uniformly a circular strip, extending on at least 75 mm on both sides of the welded joint; all precautions are to be taken to permit accurate checking of the temperature and slow cooling after treatment.

b) For austenitic and austenitic ferritic steels, post-weld head treatment is generally not required.

3.5.2 Heat treatment after welding other than oxyacetylene welding

a) Stress relieving heat treatment after welding other than oxyacetylene welding is to be performed as indicated in Tab 21, depending on the type of steel and thickness of the pipes.

b) The stress relieving heat treatment is to consist in heating slowly and uniformly to a temperature within the range indicated in Tab 21, soaking at this temperature for a suitable period, normally one hour per 25 mm of thickness with a minimum of half an hour, cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C and subsequently cooling in still atmosphere.

c) In any event, the heat treatment temperature is not to be higher than $(T_T - 20)$°C, where T_T is the temperature of the final tempering treatment of the material.

3.5.3 Heat treatment after oxyacetylene welding

Stress relieving heat treatment after oxyacetylene welding is to be performed as indicated in Tab 22, depending on the type of steel.

Table 21 : Heat treatment temperature

Type of steel	Thickness of thicker part (mm)	Stress relief treatment temperature (°C)
C and C-Mn steels	t ≥ 15 **(1) (3)**	550 to 620
0,3 Mo	t ≥ 15 **(1)**	580 to 640
1 Cr 0,5 Mo	t ≥ 8	620 to 680
2,25 Cr 1 Mo 0,5 Cr 0,5 Mo V	any **(2)**	650 to 720

(1) Where steels with specified Charpy V notch impact properties at low temperature are used, the thickness above which post-weld heat treatment is to be applied may be increased, subject to the special agreement of the Society.

(2) For 2,25Cr 1Mo and 0,5Cr 0,5Mo V grade steels, heat treatment may be omitted for pipes having thickness lower than 8 mm, diameter not exceeding 100 mm and service temperature not exceeding 450°C.

(3) For C and C-Mn steels, stress relieving heat treatment may be omitted up to 30 mm thickness, subject to the special agreement of the Society.

Table 22 : Heat treatment after oxyacetylene welding

Type of steel	Heat treatment and temperature (°C)
C and C-Mn	Normalising 880 to 940
0,3 Mo	Normalising 900 to 940
1Cr-0,5Mo	Normalising 900 to 960 Tempering 640 to 720
2,25Cr-1Mo	Normalising 900 to 960 Tempering 650 to 780
0,5Cr-0,5Mo-0,25V	Normalising 930 to 980 Tempering 670 to 720

3.6 Inspection of welded joints

3.6.1 General

a) The inspection of pressure pipe welded joints is to be performed at the various stages of the fabrication further to the qualifications defined in [3.1.1], item c).

b) The examination mainly concerns those parts to be welded further to their preparation, the welded joints once they have been made and the conditions for carrying out possible heat treatments.

c) The required examinations are to be carried out by qualified operators in accordance with procedures and techniques to the Surveyor's satisfaction.

3.6.2 Visual examination

Welded joints, including the inside wherever possible, are to be visually examined.

3.6.3 Non-destructive examinations

Non-destructive tests required are given in:

- Tab 23 for class I pipes
- Tab 24 for class II pipes.

Table 23 : Class I pipe - Type of welded joints

Class I pipe outer diameter D	Butt welded joint	Fillet weld for flange connection	Other welded joint which cannot be radiographed
Frequency of testing	every weld for D > 75 mm minimum 10% of welds selected in agreement with the Surveyor for D ≤ 75 mm	every weld for D > 75 mm minimum 10% of welds selected in agreement with the Surveyor for D ≤ 75 mm	every weld for D > 75 mm minimum 10% of welds selected in agreement with the Surveyor for D ≤ 75 mm
Extent of testing	full length	full length	full length
Type of testing	radiographic or equivalent accepted by the Society	magnetic particle or liquid penetrant	magnetic particle or liquid penetrant

Table 24 : Class II pipe - Type of welded joints

Class II pipe outer diameter D	Butt welded joint	Fillet weld for flange connection	Other welded joint which cannot be radiographed
Frequency of testing	minimum 10% of welds selected in agreement with the Surveyor for D > 100 mm	minimum 10% of welds selected in agreement with the Surveyor for D > 100 mm	minimum 10% of welds selected in agreement with the Surveyor for D > 100 mm
Extent of testing	full length	full length	full length
Type of testing	radiographic or equivalent accepted by the Society	magnetic particle or liquid penetrant	magnetic particle or liquid penetrant

3.6.4 Defects and acceptance criteria

a) Joints for which non-destructive examinations reveal unacceptable defects are to be re-welded and subsequently to undergo a new non-destructive examination. The Surveyor may require that the number of joints to be subjected to non-destructive examination is larger than that resulting from the provisions of [3.6.3].

b) Acceptance criteria and repairs

- Indications evaluated to be crack, lack of fusion or lack of penetration for class I pipes are not acceptable. Indications evaluated to be crack or lack of fusion in welds for class II pipes are not acceptable. Other types of imperfection are to be assessed in accordance with a recognised standard accepted by the Society.
- Unacceptable indications are to be eliminated and repaired where necessary. The repair welds are to be examined on their full length using magnetic particle or liquid penetrant test and ultrasonic or radiographic testing.

  When unacceptable indications are found, additional area of the same weld length are to be examined unless the indication is judged isolated without any doubt. In case of automatic welded joints, additional NDE is to be extended to all areas of the same weld length.

  The extent of examination can be increased at the surveyor's discretion when repeated non-acceptable indications are found.

4 Bending of pipes

4.1 Application

4.1.1 This Article applies to pipes made of:

- alloy or non-alloy steels,
- copper and copper alloys.

4.2 Bending process

4.2.1 General

The bending process is to be such as not to have a detrimental influence on the characteristics of the materials or on the strength of the pipes.

4.2.2 Bending radius

Unless otherwise justified, the bending radius measured on the centreline of the pipe is not to be less than:

- twice the external diameter for copper and copper alloy pipes,
- 3 times the external diameter for cold bent steel pipes.

4.2.3 Acceptance criteria

a) The pipes are to be bent in such a way that, in each transverse section, the difference between the maximum and minimum diameters after bending does not exceed 10% of the mean diameter; higher values, but not exceeding 15%, may be allowed in the case of pipes which are not subjected in service to appreciable bending stresses due to thermal expansion or contraction.

b) The bending is to be such that the depth of the corrugations is as small as possible and does not exceed 5% of their length.

4.2.4 Hot bending

a) In the case of hot bending, all arrangements are to be made to permit careful checking of the metal temperature and to prevent rapid cooling, especially for alloy steels.

b) Hot bending is to be generally carried out in the temperature range 850°C - 1000°C for all steel grades; however, a decreased temperature down to 750°C may be accepted during the forming process.

4.3 Heat treatment after bending

4.3.1 Copper and copper alloy

Copper and copper alloy pipes are to be suitably annealed after cold bending if their external diameter exceeds 50 mm.

4.3.2 Steel

a) After hot bending carried out within the temperature range specified in [4.2.4], the following applies:
   - for C, C-Mn and C-Mo steels, no subsequent heat treatment is required,
   - for Cr-Mo and C-Mo-V steels, a subsequent stress relieving heat treatment in accordance with Tab 21 is required.

b) After hot bending performed outside the temperature range specified in [4.2.4], a subsequent new heat treatment in accordance with Tab 22 is required for all grades.

c) After cold bending at a radius lower than 4 times the external diameter of the pipe, a heat treatment in accordance with Tab 22 is required.

5 Arrangement and installation of piping systems

5.1 General

5.1.1 Unless otherwise specified, piping and pumping systems covered by the Rules are to be permanently fixed on board ship.

5.2 Location of tanks and piping system components

5.2.1 Flammable oil systems

Location of tanks and piping system components conveying flammable fluids under pressure is to comply with [5.10].

5.2.2 Piping systems with open ends

Attention is to be paid to the requirements for the location of open-ended pipes on board ships having to comply with the provisions of [5.5].

5.2.3 Pipe lines located inside tanks

a) The passage of pipes through tanks, when permitted, normally requires special arrangements such as reinforced thickness or tunnels, in particular for:
   - bilge pipes
   - ballast pipes
   - scuppers and sanitary discharges
   - air, sounding and overflow pipes
   - fuel oil pipes.

b) Junctions of pipes inside tanks are to be made by welding or flange connections. See also [2.4.3].

5.2.4 Overboard discharges

a) All discharges in the shell plating below the freeboard deck shall be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

b) In manned machinery spaces, the valves may be controlled locally and shall be provided with indicators showing whether they are open or closed. For control of discharge valves fitted below the waterline, see [5.5.4].

c) Overboard discharges are to be so located as to prevent any discharge of water into the lifeboats while they are being lowered.

5.2.5 Piping and electrical apparatus

As far as possible, pipes are not to pass near switchboards or other electrical apparatus. If this requirement is impossible to satisfy, gutterways or masks are to be provided wherever deemed necessary to prevent projections of liquid or steam on live parts.

5.3 Passage through bulkheads or decks

5.3.1 General

For ships other than cargo ships, see also the additional requirements for the relevant service notations.

5.3.2 Penetration of watertight bulkheads or decks and fire divisions

a) Where penetrations of watertight bulkheads or decks and fire divisions are necessary for piping and ventilation, arrangements are to be made to maintain the watertight integrity and fire integrity. See also Ch 4, Sec 5, [2].

b) In cargo ships, the Society may permit relaxation in the watertightness of opening above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

c) In passenger ships, lead or other heat sensitive materials are not to be used in piping systems which penetrate watertight subdivision bulkheads or decks, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkhead or decks.

This applies in particular to the following systems:

- bilge system
- ballast system
- scuppers and sanitary discharge systems.

It is not applicable to cable penetrations in watertight bulkheads and decks.

Any penetration used for the passage of heat-sensitive piping systems through a watertight bulkhead or deck in passenger ships is to be tested with the heat sensitive piping and is to be type approved for watertight integrity as per paragraphs 4 and 5 of the explanatory notes to regulation II-1/13.2.3 contained in the annex of resolution MSC.429(98)/ Rev.2, as applicable, after the fire test.

d) Where bolted connections are used when passing through watertight bulkheads or decks, the bolts are not to be screwed through the plating. Where welded connections are used, they are to be welded on both sides of the bulkhead or deck.

e) Penetrations of watertight bulkheads or decks and fire divisions by plastic pipes are to comply with Ch 1, App 3, [4.7.2].

5.3.3 Passage through the collision bulkhead

a) Except as provided in b), the collision bulkhead may be pierced below the bulkhead deck of passenger ships and the freeboard deck of cargo ships by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a remotely controlled valve capable of being operated from above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The valve shall be normally closed. If the remote control system should fail during operation of the valve, the valve shall close automatically or be capable of being closed manually from a position above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The valve shall be located at the collision bulkhead on either the forward or aft side, provided the space on the aft side is not a cargo space. The valve shall be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

b) If the forepeak is divided to hold two different kinds of liquids the Society may allow the collision bulkhead to be pierced below the bulkhead deck of passenger ships and the freeboard deck of cargo ships by two pipes, each of which is fitted as required by a), provided the Society is satisfied that there is no practical alternative to the fitting of such a second pipe and that, having regard to the additional subdivision provided in the forepeak, the safety of the ship is maintained

c) The remote operation device of the valve referred to in a) is to include an indicator to show whether the valve is open or shut.

5.4 Independence of lines

5.4.1 Independence between bilge and ballast lines

These lines are to be independent. This requirement does not need to be fulfilled for:

- pipes located between collecting boxes and pump suctions
- pipes located between pumps and overboard discharges

5.4.2 Liquid cargo, lubricating oil and fuel oil

These lines are not to be connected to bilge and ballast lines.

5.4.3 Pipe lines connected to tanks used alternatively as ballast, fuel oil, liquid or dry cargo when permitted

Such pipes shall be fitted with blind flanges or other appropriate change over-devices in order to avoid any mishandling.

5.5 Prevention of progressive flooding

5.5.1 Principle

a) In order to comply with the subdivision and damage stability requirements of Pt B, Ch 3, Sec 3, provision is to be made to prevent any progressive flooding of a dry compartment served by any open-ended pipe, in the event that such pipe is damaged or broken in any other compartment by collision or grounding.

b) For this purpose, if pipes are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired. Refer to Pt B, Ch 3, Sec 3.

5.5.2 Extent of damage

For the definition of the assumed transverse extent of damage, reference is to be made to Pt B, Ch 3, Sec 3.

5.5.3 Piping arrangement

a) The assumed transverse extent of damage is not to contain any pipe with an open end in a compartment located outside this extent, except where the section of such pipe does not exceed 710 mm^2.

Note 1: Where several pipes are considered, the limit of 710 mm^2 applies to their total section.

b) Where the provisions of item a) cannot be fulfilled, and after special examination by the Society, pipes may be situated within the assumed transverse extent of damage penetration provided that:
   - either a closable valve operable from above the bulkhead deck is fitted at each penetration of a watertight subdivision and secured directly on the bulkhead, or
   - a closable valve operable from above the bulkhead deck is fitted at each end of the pipe concerned, the valves and their control system being inboard of the assumed extent of damage, or
   - the tanks to which the pipe concerned leads are regarded in the damage stability calculations as being flooded when damage occurs in a compartment through which the pipe passes.

c) Valves required to be operable from above the bulkhead deck are to be fitted with an indicator to show whether the valve is open or shut.

   Where the valve is remote controlled by other than mechanical means, and where the remote control system is located, even partly, within the assumed extent of damage penetration, this system is to be such that the valve is automatically closed by loss of power.

d) Air and overflow pipes are to be so arranged as to prevent the possibility of flooding of other tanks in other watertight compartments in the event of any one tank being flooded.

   This arrangement is to be such that in the range of positive residual righting levers beyond the angle of equilibrium stage of flooding, the progressive flooding of tanks or watertight compartments other than that flooded does not occur.

5.5.4 Suction and discharge valves below the waterline

a) The location of the controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system shall be so sited as to allow adequate time for operation in case of influx of water to the space, having regard to the time likely to be required in order to reach and operate such controls. If the level to which the space could become flooded with the ship in the fully loaded condition so requires, arrangements shall be made to operate the controls from a position above such level.

A calculation is to be carried out to show that the time taken from alarm activation plus the time to reach and fully close manually operated or powered valves is less than the time taken for the influx of water to reach the control without submergence of the platform on which the person is operating the valves. If necessary a remote control device is to be fitted above the level.

Note 1: The time it takes for the influx of water to reach the control of valves should be based on a breach in the largest diameter seawater line in the lowest location in the engine room when the ship is fully loaded.

Note 2: The time it takes to reach the sea valves should be determined based on the distance between the navigation bridge and the platform from where the valves associated with the aforementioned seawater line are manually operated (or the actuator for valves controlled by stored mechanical energy).

Note 3: In the event calculations are not available, 10 minutes shall be regarded as adequate time for operation unless other requirements are specified by the flag Administration.

b) When the Administration of the State whose flag the ship is entitled to fly has issued specific rules covering flooding protection, the Society may accept such rules for classification purposes in lieu of those given in item a).

5.6 Provision for expansion

5.6.1 General

Piping systems are to be so designed and pipes so fixed as to allow for relative movement between pipes and the ship's structure, having due regard to the:

- temperature of the fluid conveyed
- coefficient of thermal expansion of the pipes material
- deformation of the ship's hull.

5.6.2 Fitting of expansion devices

All pipes subject to thermal expansion and those which, due to their length, may be affected by deformation of the hull, are to be fitted with expansion pieces or loops.

5.7 Supporting of the pipes

5.7.1 General

Unless otherwise specified, the fluid lines referred to in this Section are to consist of pipes connected to the ship's structure by means of collars or similar devices.

5.7.2 Arrangement of supports

Shipyards are to take care that:

a) The arrangement of supports and collars is to be such that pipes and flanges are not subjected to abnormal bending stresses, taking into account their own mass, the metal they are made of, and the nature and characteristics of the fluid they convey, as well as the contractions and expansions to which they are subjected.

b) Heavy components in the piping system, such as valves, are to be independently supported.

5.8 Protection of pipes

5.8.1 Protection against shocks

Pipes passing through cargo holds and 'tweendecks are to be protected against shocks by means of strong casings.

5.8.2 Protection of sea water pipes from mechanical damage

Seawater pipes in cargo holds for dry cargoes, including cargo spaces of ships assigned the service notation **ro-ro passenger ship**, **PCTC, PCC**, **ro-ro cargo ship**, **container ship** or of ships assigned the additional service feature **equipped for carriage of containers**, are to be protected from impact of cargo where they are liable to be damaged.

5.8.3 Protection against corrosion and erosion

a) Pipes are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment.

b) The layout and arrangement of sea water pipes are to be such as to prevent sharp bends and abrupt changes in section as well as zones where water may stagnate. The inner surface of pipes is to be as smooth as possible, especially in way of joints. Where pipes are protected against corrosion by means of galvanising or other inner coating, arrangements are to be made so that this coating is continuous, as far as possible, in particular in way of joints.

c) If galvanised steel pipes are used for sea water systems, the water velocity is not to exceed 3 m/s.

d) If copper pipes are used for sea water systems, the water velocity is not to exceed 2 m/s.

e) Arrangements are to be made to avoid galvanic corrosion.

f) If aluminium bras pipes are used for sea water systems, the water velocity is not to exceed 3 m/s

g) If 90/10 copper-nickel-iron pipes are used for sea water systems, the water velocity is not to exceed 3,5 m/s

h) If 70/30 copper-nickel pipes are used for sea water systems, the water velocity is not to exceed 5 m/s

i) If GRP pipes are used for sea water systems, the water velocity is not to exceed 5 m/s.

Note 1: For the seawater velocity limits above, a tolerance of 10% is acceptable.

5.8.4 Protection against frosting

Pipes are to be adequately insulated against cold wherever deemed necessary to prevent frost.

This applies specifically to pipes passing through refrigerated spaces and which are not intended to ensure the refrigeration of such spaces.

5.8.5 Protection of high temperature pipes and components

a) All pipes and other components where the temperature may exceed 220°C are to be efficiently insulated. Where necessary, precautions are to be taken to protect the insulation from being impregnated with flammable oils.

b) Particular attention is to be paid to lagging in way of flanges.

5.9 Valves, accessories and fittings

5.9.1 General

Cocks, valves and other accessories are generally to be arranged so that they are easily visible and accessible for manoeuvring, control and maintenance. They are to be installed in such a way as to operate properly.

5.9.2 Valves and accessories

a) In machinery spaces and tunnels, the cocks, valves and other accessories of the fluid lines referred to in this Section are to be placed:

- above the floor, or
- when this is not possible, immediately under the floor, provided provision is made for their easy access and control in service.

b) Control-wheels of low inlet valves are to rise at least 0,45 m above the lowest floor.

5.9.3 Flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be in compliance with [2.6]. They are to be installed in clearly visible and readily accessible locations.

b) The number of flexible hoses and expansion joints is to be kept to minimum and limited for the purpose stated in [2.6.1], item c).

c) In general, flexible hoses and expansion joints are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

d) The installation of a flexible hose assembly or an expansion joint is to be in accordance with the manufacturer's instructions and use limitations, with particular attention to the following:

- orientation
- end connection support (where necessary)
- avoidance of hose contact that could cause rubbing and abrasion
- minimum bend radii.

e) Flexible hose assemblies or expansion joints are not to be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.

f) Where flexible hoses or an expansion joint are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated, as far as practicable, by the use of screens or other similar protection, to the satisfaction of the Society.

g) The adjoining pipes are to be suitably aligned, supported, guided and anchored.

h) Isolating valves are to be provided permitting the isolation of flexible hoses intended to convey flammable oil or compressed air.

i) Expansion joints are to be protected against over extension or over compression.

j) Where they are likely to suffer external damage, flexible hoses and expansion joints are to be provided with adequate protection.

5.9.4 Thermometers

Thermometers and other temperature-detecting elements in fluid systems under pressure are to be provided with pockets built and secured so that the thermometers and detecting elements can be removed while keeping the piping under pressure.

5.9.5 Pressure gauges

Pressure gauges and other similar instruments are to be fitted with an isolating valve or cock at the connection with the main pipe.

5.9.6 Nameplates

a) Accessories such as cocks and valves on the fluid lines referred to in this Section are to be provided with nameplates indicating the apparatus and lines they serve except where, due to their location on board, there is no doubt as to their purpose.

b) Nameplates are to be fitted at the upper part of air and sounding pipes.

5.10 Additional arrangements for flammable fluids

5.10.1 General

All necessary precautions are to be taken to reduce fire risks from flammable liquids, such as:

- drips
- leaks under pressure
- overflow
- hydrocarbon accumulation in particular under lower floors
- discharges of oil vapours during heating
- soot or unburnt residue in smoke stacks or exhaust pipes.

Unless otherwise specified, the requirements in [5.10.3] apply to:

- fuel oil systems, in all spaces
- lubricating oil systems, in machinery spaces
- other flammable oil systems, in locations where means of ignition are present.

5.10.2 Prohibition of carriage of flammable oils in forepeak tanks

In cargo ships of more than 400 gross tonnage and in passenger ships, fuel oil, lubricating oil and other flammable oils are not to be carried in forepeak tanks or tanks forward of the collision bulkhead.

5.10.3 Prevention of flammable oil leakage ignition

a) As far as practicable, the piping arrangement in the flammable oil systems shall comply generally with the following:
   - The conveying of flammable oils through accommodation and service spaces is to be avoided. Where it is not possible, the arrangement may be subject to special consideration by the Society, provided that the pipes are of a material approved having regard to the fire risk.
   - The pipes are not to be located immediately above or close to the hot surfaces (exhaust manifolds, silencers, steam pipelines, boilers, etc.), electrical installations or other sources of ignition. Otherwise, suitably protection (screening and effective drainage to the safe position) is to be provided to prevent of spraying or leakage onto the sources of ignition.
   - Parts of the piping systems conveying heated flammable oils under pressure exceeding 0,18 MPa are to be placed above the platform or in any other position where defects and leakage can readily be observed. The machinery spaces in way of such parts are to be adequately illuminated.

b) No flammable oil tanks are to be situated where spillage or leakage therefrom can constitute a hazard by falling on:
   - hot surfaces, including those of boilers, heaters, steam pipes, exhaust manifolds and silencers
   - electrical equipment
   - air intakes
   - other sources of ignition.

c) Parts of flammable oil systems under pressure exceeding 0,18 MPa such as pumps, filters and heaters are to comply with the provisions of b) above.

d) Pipe connections, expansion joints and flexible parts of flammable oil lines are to be screened or otherwise suitably protected to avoid, as far as practicable, oil spray or oil leakages onto hot surfaces, into machinery air intakes, or on other sources of ignition. In case of additional class notation **AUT-IMS**, see also Pt F, Ch 3, Sec 4, [3.1.2]. The fastening of connections (nuts, screws, etc.) of lubricating oil or fuel oil pipes above 1,8 bar pressure is to be locked.

e) Any relief valve or air vent cock fitted within the flammable liquid systems is to discharge to a safe position, such as an appropriate tank.

f) Appropriate means are to be provided to prevent undue opening (due to vibrations) of air venting cocks fitted on equipment or piping containing flammable liquid under pressure.

5.10.4 Provisions for flammable oil leakage containment

a) Tanks used for the storage of flammable oils together with their fittings are to be so arranged as to prevent spillages due to leakage or overfilling.

b) Drip trays with adequate drainage to contain possible leakage from flammable fluid systems are to be fitted:
   - under independent tanks
   - under burners
   - under purifiers and any other oil processing equipment
   - under pumps, heat exchangers and filters
   - under valves and all accessories subject to oil leakage
   - surrounding internal combustion engines.

c) The coaming height of drip trays is to be appropriate for the service and not less than 75 mm. In case of additional class notation **AUT-IMS**, see also Pt F, Ch 3, Sec 4, [3.1.1].

d) Where boilers are located in machinery spaces on ‘tweendecks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the ‘tweendecks are to be provided with oil-tight coamings at least 200 mm in height.

e) Where drain pipes are provided for collecting leakages, they are to be led to an appropriate drain tank.

f) The draining system of the room where thermal fluid heaters are fitted, as well as the save all of the latter, are not to allow any fire extension outside this room. See also [13.3.2].

5.10.5 Drain tank

a) The drain tank is not to form part of an overflow system and is to be fitted with an overflow alarm device.

b) In ships required to be fitted with a double bottom, appropriate precautions are to be taken when the drain tank is constructed in the double bottom, in order to avoid flooding of the machinery space where drip trays are located, in the event of accidentally running aground.

5.10.6 Valves

All valves and cocks forming part of flammable oil systems are to be capable of being operated from readily accessible positions and, in machinery spaces, from above the working platform.

5.10.7 Level switches

Level switches fitted to flammable oil tanks are to be contained in a steel or other fire-resisting enclosure.

6 Bilge systems

6.1 Application

6.1.1 This Article does not apply to bilge systems of non-propelled ships. See Part D, Chapter 14.

6.1.2 Ships assigned the additional service feature SPxxx or SPxxx-capable

Ships assigned the additional service feature **SPxxx** or **SPxxx-capable** are to comply, in addition to the applicable requirements of this Article, with the requirements of Pt D, Ch 11, Sec 4, [1], considering special personnel as passengers.

6.1.3 Ships assigned the additional service feature IPxxx or IPxxx-capable

Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** are to comply, in addition to the applicable requirements of this Article, with the requirements of Pt D, Ch 11, Sec 4, [1], considering industrial personnel as passengers.

6.2 Principle

6.2.1 General

An efficient bilge pumping system shall be provided, capable of pumping from and draining any watertight compartment other than a space permanently appropriated for the carriage of fresh water, water ballast, fuel oil or liquid cargo and for which other efficient means of pumping are provided, under all practical conditions. Efficient means shall be provided for draining water from insulated holds.

Bilge pumping system is not intended at coping with water ingress resulting from structural or main sea water piping damage.

6.2.2 Availability of the bilge system

The bilge system is to be able to work while the other essential installations of the ship, especially the fire-fighting installations, are in service.

6.2.3 Bilge and ballast systems

The arrangement of the bilge and ballast pumping system shall be such as to prevent the possibility of water passing from the sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another.

Provisions shall be made to prevent any deep tank having bilge and ballast connections being inadvertently flooded from the sea when containing cargo, or being discharged through a bilge pump when containing water ballast.

6.3 Design of bilge systems

6.3.1 General

a) The bilge pumping system is to consist of pumps connected to a bilge main line so arranged as to allow the draining of all spaces mentioned in [6.2.1] through bilge branches, distribution boxes and bilge suctions, except for some small spaces where individual suctions by means of hand pumps may be accepted as stated in [6.6.3] and [6.6.4].

b) If deemed acceptable by the Society, bilge pumping arrangements may be dispensed with in specific compartments provided the safety of the ship is not impaired.

6.3.2 Number and distribution of bilge suctions

a) Draining of watertight spaces is to be possible, when the ship is on an even keel and either is upright or has a list of up to 5°, by means of at least:

- two suctions in machinery spaces, including one branch bilge suction and one direct suction and, in addition, for spaces containing propulsion machinery, one emergency bilge suction
- one suction in other spaces.

See also [6.5.5].

b) Bilge suctions are to be arranged as follows:

- wing suctions are generally to be provided except in the case of short and narrow compartments when a single suction ensures effective draining in the above conditions
- in the case of compartments of unusual form, additional suctions may be required to ensure effective draining under the conditions mentioned in item a).

c) In all cases, arrangements are to be made such as to allow a free and easy flow of water to bilge suctions.

6.3.3 Prevention of communication between spaces Independence of the lines

a) Bilge lines are to be so arranged as to avoid inadvertent flooding of any dry compartment.

b) Bilge lines are to be entirely independent and distinct from other lines except where permitted in [5.4].

c) In ships designed for the carriage of flammable or toxic liquids in enclosed cargo spaces, the bilge pumping system is to be designed to prevent the inadvertent pumping of such liquids through machinery space piping or pumps. See also Ch 4, Sec 12, [2.6].

6.4 Draining of cargo spaces

6.4.1 General

a) Cargo holds are to be fitted with bilge suctions connected to the bilge main.

b) Drainage arrangements for cargo holds likely to be used alternatively for ballast, fuel oil or liquid or dry cargoes are to comply with [7.1].

c) Drainage of enclosed cargo spaces situated on the freeboard deck of a cargo ship and on the bulkhead deck of a passenger ship shall comply with [8.5].

d) Drainage of enclosed cargo spaces intended to carry dangerous goods (see Ch 4, Sec 12) shall be provided in accordance with Ch 4, Sec 12, [2.6].

6.4.2 Ships without double bottom

a) In ships without double bottom, bilge suctions are to be provided in the holds:

- at the aft end in the centreline where the rise of floor exceeds 5°
- at the aft end on each side in other cases.

b) Additional suctions may be required if, due to the particular shape of the floor, the water within the compartment cannot be entirely drained by means of the suctions mentioned in a) above.

6.4.3 Ships with double bottom

a) In ships with double bottom, bilge suctions are to be provided in the holds on each side aft. Where the double bottom plating extends from side to side, the bilge suctions are to be led to wells located at the wings. Where the double bottom plating slopes down to the centreline by more than 5°, a centreline well with a suction is also to be provided.

b) If the inner bottom is of a particular design, shows discontinuity or is provided with longitudinal wells, the number and position of bilge suctions will be given special consideration by the Society.

6.4.4 Locations of suctions according to the length of the hold

In holds with length greater than L_{RB}, bilge suctions are to be provided in the fore and aft ends.

$L_{RB} = 0,2L$

where:

L : Rule length as defined in Pt B, Ch 1, Sec 3, [2.1.1], but is not to be taken greater than 45m or lower than 35m.

6.4.5 Additional suctions

Additional suctions may be required in the forward part of holds in ships which are likely to navigate normally with a trim by the head.

6.4.6 Drainage of cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion

In cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion and fitted with a fixed pressure water-spraying fire-extinguishing system, the pumping arrangement is to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effect upon stability of the added weight and free surface of water is to be taken into account to the extent deemed necessary by the Society in its approval of the stability information. See Part B, Chapter 3.

See also [8.7].

6.4.7 Drainage of cargo spaces intended for the carriage of flammable or toxic liquids

In ships designed for the carriage of flammable or toxic liquids in enclosed cargo spaces, and where large quantities of such liquids are carried, consideration is to be given to the provision of additional means of draining such spaces. See also Ch 4, Sec 12, [2.6].

6.5 Draining of machinery spaces

6.5.1 General

Where all the propulsion machinery, boilers and main auxiliaries are located in a single watertight space, the bilge suctions are to be distributed and arranged in accordance with the provisions of [6.5.5].

6.5.2 Branch bilge suction

The branch bilge suction is to be connected to the bilge main.

6.5.3 Direct suction

The direct suction is to be led direct to an independent power bilge pump and so arranged that it can be used independently of the main bilge line.

The use of ejectors for pumping through the direct suction will be given special consideration.

6.5.4 Emergency bilge suction

a) The emergency bilge suction is to be led directly from the drainage level of the machinery space to a main circulating (or cooling) pump and fitted with a non-return valve.

b) In ships where, in the opinion of the Society, the main circulating (or cooling) pump is not suitable for this purpose, the emergency bilge suction is to be led from the largest available independent power driven pump to the drainage level of the machinery space. Such a pump is not to be a bilge pump. Its capacity when the emergency suction is operating is to be at least equal to the required capacity of each bilge pump as determined in [6.7.4].

c) The emergency bilge suction is to be located at the lowest possible level in the machinery spaces.

6.5.5 Number and distribution of suctions in propulsion machinery spaces

a) In propulsion machinery spaces, bilge suctions are to include:

- where the bottom of the space, bottom plating or top of the double bottom slope down to the centreline by more than 5°, at least two centreline suctions, i.e. one branch bilge suction and one direct suction, or
- where the bottom of the space is horizontal or slopes down to the sides and in all passenger ships, at least two suctions, i.e. one branch bilge suction and one direct suction, on each side, and
- one emergency bilge suction.

Note 1: In cargo ships, if an emergency bilge suction is arranged in accordance with [6.8.5] and connected to a self-priming pump, the direct bilge suction may be omitted on the side where the emergency suction is fitted.

b) If the tank top is of a particular design or shows discontinuity, additional suctions may be required.

c) Where the propulsion machinery space is located aft, suctions are normally to be provided on each side at the fore end and, except where not practicable due to the shape of the space, on each side at the aft end of the space.

d) In electrically propelled ships, provision is to be made to prevent accumulation of water under electric generators and motors.

6.5.6 Number and distribution of suctions in boiler and auxiliary machinery spaces

In boiler and auxiliary compartments, bilge suctions are to include:

- bilge branch suctions distributed as required in [6.4.2] to [6.4.5] for cargo holds
- one direct suction.

6.6 Draining of dry spaces other than cargo holds and machinery spaces

6.6.1 General

a) Except where otherwise specified, bilge suctions are to be branch bilge suctions, i.e. suctions connected to a bilge main.

b) Draining arrangements of tanks are to comply with the provisions of [7].

6.6.2 Draining of cofferdams

a) All cofferdams are to be provided with suction pipes led to the bilge main.

b) Where cofferdams are divided by longitudinal watertight bulkheads or girders into two or more parts, a single suction pipe led to the aft end of each part is acceptable.

6.6.3 Draining of fore and aft peaks

a) Where the peaks are not used as tanks and bilge suctions are not fitted, drainage of both peaks may be effected by hand pump suction provided that the suction lift is well within the capacity of the pump and in no case exceeds 7,3 m.

b) Except where permitted in [5.3.3], the collision bulkhead is not to be pierced below the freeboard deck.

c) For tankers, see Pt D, Ch 7, Sec 4, [2.1.4].

d) For ships intended primarily to carry dry cargo in bulk, see [6.6.7].

6.6.4 Draining of spaces above fore and aft peaks

a) Provision is to be made for the drainage of the chain lockers and watertight compartments above the fore peak tank by hand or power pump suctions.

b) Steering gear compartments or other small enclosed spaces situated above the aft peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions. However, in the case of rudder stock glands located below the summer load line, the bilge suctions of the steering gear compartment are to be connected to the main bilge system.

c) If the compartments referred to in b) are adequately isolated from the adjacent ‘tweendecks, they may be drained by scuppers discharging to the tunnel (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks situated in well-lighted and visible positions.

Note 1: This arrangement is not applicable to ships required to comply with [5.5], and in particular to passenger ships, unless they are specially approved in relation to subdivision.

d) For ships intended primarily to carry dry cargo in bulk, see [6.6.7].

6.6.5 Draining of tunnels

a) Tunnels are to be drained by means of suctions connected to the main bilge system. Such suctions are generally to be located in wells at the aft end of the tunnels.

b) Where the top of the double bottom, in the tunnel, slopes down from aft to forward, an additional suction is to be provided at the forward end of this space.

6.6.6 Draining of refrigerated spaces

Provision is to be made for the continuous drainage of condensate in refrigerated and air cooler spaces. To this end, valves capable of blanking off the water draining lines of such spaces are not to be fitted, unless they are operable from an easily accessible place located above the load waterline.

6.6.7 Specific requirements for drainage of forward spaces of bulk, ore and combination carriers ("dewatering system")

Unless otherwise specified, this requirement applies to ships with service notation **bulk carrier**, **bulk carrier ESP**, **ore carrier ESP**, **combination carrier /OBO ESP**, **combination carrier /OOC ESP**, **self-unloading bulk carrier ESP** as described in Pt A, Ch 1, Sec 2, [4.3].

a) The bilge of dry spaces any part of which extends forward of the foremost cargo hold, as well as the means for draining and pumping ballast tanks forward of the collision bulkhead, is to be capable of being brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. The following criteria are to govern the application of the requirement:

- a position which is accessible via an under deck passage, a pipe trunk or other similar means of access is not to be taken as being in the accessible enclosed space.
- the requirement does not apply to the enclosed spaces the volume of which does not exceed 0,1% of the ship maximum displacement volume and to the chain locker.

b) The water level detectors, giving an audible and visual alarm located on the navigation bridge, are to be fitted:

- in any ballast tank forward of the collision bulkhead, indicating when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.
- in any dry or void space which is to comply with the requirements in item a), giving the alarm at a water level of 0,1 m above the deck.

c) The capacity of the dewatering system is to be designed to remove water from the forward spaces at a rate of not less than $(320 \cdot A)$ m^3/h, where A is the cross-sectional area, in m^2, of the largest air pipe or ventilator pipe connected from the exposed deck to a closed forward space that is required to be dewatered by these arrangements.

d) When dewatering systems are in operation, the following is to be fulfilled:

- other systems essential for the safety of the ship, including fire-fighting and bilge systems, are to remain available and ready for immediate use
- it is to be possible to start fire pumps immediately and to have a ready available supply of fire-fighting water
- the systems for normal operation of electric power supplies, propulsion and steering are not to be affected by this operation.

e) The drainage arrangements are to be such that:

- any accumulated water can be drained directly by a pump or an eductor
- it may be possible to configure and use bilge system for any compartment when the drainage system is in operation
- remotely operated valves within the system comply with [2.7.3]
- bilge wells are protected by gratings or strainers to prevent blockage of the drainage system with debris.

f) Where pipes serving such tanks or bilge pierce the collision bulkhead, valve operation by means of remotely operated actuators may be accepted as an alternative to the valve control required in [5.3.3], provided that the location of such valve controls complies with [5.3.3]. For that purpose, the following is to be fulfilled:

- the valve required in [5.3.3] is to be capable of being controlled from the position as required in item a)
- the valve is not to move from the demanded position in the case of failure of the control system power or actuator power
- positive indication is to be provided at the remote control station to show that the valve is fully open or closed
- in addition, the local hand powered valve operation from above the freeboard deck is also to be provided.

g) The piping arrangements for drainage of closed dry spaces may be connected to the piping arrangements for drainage of water ballast tanks, provided that:

- two non-return valves are provided to prevent the ingress of water into dry spaces from those intended for the carriage of water ballast
- the non-return valves are located in readily accessible positions
- one of these non-return valves is fitted with shut-off isolation arrangement
- the shut-off isolation arrangement is capable of being controlled from the position as required in item a).

h) The enclosures of electrical equipment for the dewatering system installed in any of the forward dry spaces are to be in accordance with requirements given in Ch 2, Sec 3, [4.1.5].

6.7 Bilge pumps

6.7.1 Number and arrangement of pumps

a) For cargo ships, at least two power pumps connected to the main bilge system are to be provided, one of which may be driven by the propulsion machinery.

b) Additional requirements for passenger ships are given in Part D.

c) Each pump may be replaced by a group of pumps connected to the bilge main, provided their total capacity meets the requirements specified in [6.7.4].

d) Alternative arrangements, such as the use of a hand pump in lieu of a power pump, will be given special consideration by the Society.

6.7.2 Use of ejectors

One of the pumps may be replaced by a hydraulic ejector connected to a high pressure water pump and capable of ensuring the drainage under similar conditions to those obtained with the other pump.

On passenger ships, the pump supplying the ejector is not to be used for other services.

6.7.3 Use of other pumps for bilge duties

a) Other pumps may be used for bilge duties, such as fire, general service, sanitary service or ballast pumps, provided that:

- they meet the capacity requirements
- suitable piping arrangements are made
- pumps are available for bilge duty when necessary.

b) The use of bilge pumps for fire duty is to comply with the provisions of Ch 4, Sec 6.

6.7.4 Capacity of the pumps

a) Each power bilge pump is to be capable of pumping water through the required main bilge pipe at a speed of not less than 2 m/s.

b) The capacity of each pump or group of pumps is not to be less than:

$$Q = 0{,}00565\ d^2$$

where:

Q : Minimum capacity of each pump or group of pumps, in m^3/h

d : Internal diameter, in mm, of the bilge main as defined in [6.8.1].

Note 1: For cargo ships of less than 35 m in length:

- the speed of water to be considered for calculating the capacity may be reduced to 1,22 m/s
- the capacity of each pump or group of pumps is not to be less than $Q = 0{,}00345\ d^2$.

c) If the capacity of one of the pumps or one of the groups of pumps is less than the Rule capacity, the deficiency may be compensated by an excess capacity of the other pump or group of pumps; as a rule, such deficiency is not permitted to exceed 30% of the Rule capacity.

Note 2: This provision does not apply to passenger ships.

d) The capacity of hand pumps is to be based on one movement once a second.

e) Where an ejector is used in lieu of a driven pump, its suction capacity is not to be less than the required capacity of the pump it replaces.

6.7.5 Choice of the pumps

a) Bilge pumps are to be of the self-priming type. Centrifugal pumps are to be fitted with efficient priming means, unless an approved priming system is provided to ensure the priming of pumps under normal operating conditions.

b) Circulating or cooling water pumps connected to an emergency bilge suction need not be of the self-priming type.

c) Sanitary, ballast and general service pumps may be accepted as independent power bilge pumps if fitted with the necessary connections to the bilge pumping system.

d) Hand pumps are to have a maximum suction height not exceeding 7,30 m and to be operable from a position located above the load waterline.

6.7.6 Connection of power pumps

a) Bilge pumps and other power pumps serving essential services which have common suction or discharge are to be connected to the pipes in such a way that:

- compartments and piping lines remain segregated in order to prevent possible intercommunication
- the operation of any pump is not affected by the simultaneous operation of other pumps.

b) The isolation of any bilge pump for examination, repair or maintenance is to be made possible without impeding the operation of the remaining bilge pumps.

6.7.7 Electrical supply of submersible pump motors

a) Where submersible bilge pumps are provided, arrangements are to be made to start their motors from a convenient position above the bulkhead deck.

b) Where an additional local-starting device is provided at the motor of a permanently installed submersible bilge pump, the circuit is to be arranged to provide for the disconnection of all control wires therefrom at a position adjacent to the starter installed on the deck.

6.8 Size of bilge pipes

6.8.1 Bilge main line

a) The diameter of the bilge main is to be calculated according to the following formula:

$$d = 25 + 1{,}68\sqrt{L(B + D)}$$

where:

d : Internal diameter of the bilge main, in mm

L and B : Length and breadth of the ship as defined in Pt B, Ch 1, Sec 3, in m

D : Moulded depth of the ship to the bulkhead deck, in m, provided that, in a ship having an enclosed cargo space on the bulkhead deck which is internally drained in accordance with the requirements of [8.5.3] and which extends for the full length of the ship, D is measured to the next deck above the bulkhead deck. Where the enclosed cargo spaces cover a lesser length, D is to be taken as the moulded depth to the bulkhead deck plus l·h/L where l and h are the aggregate length and height, respectively, of the enclosed cargo spaces, in m.

Note 1: In cargo ships fitted with side ballast tanks forming a double hull on the whole length of the holds, the diameter of the bilge main may be determined by introducing the actual breadth of the holds amidships as B in the above formula. For the part of bilge main serving the suctions to machinery spaces, the cross-section is not to be less than twice the cross-sections resulting from [6.8.3], item a) for branch bilge suctions to those machinery spaces and need not exceed that of the bilge main resulting from the above formula.

b) In no case is the actual internal diameter to be:

- more than 5 mm smaller than that obtained from the formula given in a), or
- less than 60 mm, or
- less than that obtained from the formula given in [6.8.3] for branch bilge suctions.

c) For tankers, the internal diameter d of the bilge main in engine room shall be determined in accordance with Pt D, Ch 7, Sec 4, [2.2.2].

d) For cargo ships where L < 20 m and assigned with a restricted navigation notation, as well as for sailing ships with or without auxiliary engine, the bilge system will be specially considered by the Society in each particular case.

6.8.2 Distribution box branch pipes

The cross-section of any branch pipe connecting the bilge main to a bilge distribution box is not to be less than the sum of the cross-sections required for the two largest branch suctions connected to this box. However, this cross-section need not exceed that of the bilge main.

6.8.3 Branch bilge suction pipes

a) The internal diameter, in mm, of pipes situated between distribution boxes and suctions in holds and machinery spaces is not to be less than the diameter given by the following formula:

$$d_1 = 25 + 2{,}16\sqrt{L_1(B + D)}$$

where:

B and D : as defined in [6.8.1]

L_1 : Length of the compartment, in m.

d_1 is not to be less than 50 mm and need not exceed 100 mm.

b) For ships other than passenger ships, which have side ballast tanks forming a double hull, the diameter of suction pipes in holds may be determined by introducing as B the actual breadth of the holds amidships.

6.8.4 Direct suctions other than emergency suctions

a) Direct suctions are to be suitably arranged and those in a machinery space are to be of a diameter not less than that required for the bilge main.

b) In cargo ships having separate machinery spaces of small dimensions, the size of the direct suctions need not exceed that given in [6.8.3] for branch bilge suctions.

6.8.5 Emergency suctions in machinery spaces

a) The diameter of emergency bilge suction pipes is to be:

- at least two thirds of the diameter of the pump inlet in the case of steamships
- the same as the diameter of the pump inlet in the case of motorships.

b) Where the emergency suction is connected to a pump other than a main circulating or cooling pump, the suction is to be the same diameter as the main inlet of the pump.

6.8.6 Bilge suctions from tunnels

Bilge suction pipes to tunnel wells are not to be less than 65 mm in diameter. In ships up to 60 metres in length, this diameter may be reduced to 50 mm.

6.8.7 Scuppers in aft spaces

Any scupper provided for draining aft spaces and discharging to the tunnel is to have an internal diameter not less than 35 mm.

6.8.8 Bilge for small ships

For cargo ships of a length L, as defined in [6.8.1], less than 20 m and assigned with a restricted navigation notation, as well as for sailing ships with or without auxiliary engine, the bilge system will be specially considered by the Society in each single case.

6.8.9 Bilge main for tankers

In tankers and other ships where the bilge pumps are designed to pump from the machinery space only, the internal diameter d, in mm, of the bilge main may be less than that required by the formula in [6.8.1] above, but it is to be not less than that obtained from the formula specified in Pt D, Ch 7, Sec 4.

6.9 Bilge accessories

6.9.1 Drain valves on watertight bulkheads

a) The fitting of drain valves or similar devices is not allowed on the collision bulkhead.

b) On other watertight bulkheads, the fitting of drain valves or similar devices is allowed unless practical alternative draining means exist. Such valves are to be easily accessible at all times and operable from above the freeboard deck. Means indicating whether the valves are open or closed are to be provided.

6.9.2 Screw-down non-return valves

a) Accessories are to be provided to prevent intercommunication of compartments or lines which are to remain segregated from one another. For this purpose, non-return devices are to be fitted:

- on the pipe connections to bilge distribution boxes or to the alternative valves, if any
- on direct and emergency suctions in machinery spaces
- on the suctions of pumps which also have connections from the sea or from compartments normally intended to contain liquid
- on flexible bilge hose connections
- on the suctions of water bilge ejectors
- at the open end of bilge pipes passing through deep tanks
- in compliance with the provisions for the prevention of progressive flooding, if applicable.

b) Screw-down and other non-return valves are to be of a recognised type which does not offer undue obstruction to the flow of water.

6.9.3 Mud boxes

In machinery spaces and shaft tunnels, termination pipes of bilge suctions are to be straight and vertical and are to be led to mud boxes so arranged as to be easily inspected and cleaned.

The lower end of the termination pipe is not to be fitted with a strum box.

6.9.4 Strum boxes

a) In compartments other than machinery spaces and shaft tunnels, the open ends of bilge suction pipes are to be fitted with strum boxes or strainers having holes not more than 10 mm in diameter. The total area of such holes is to be not less than twice the required cross-sectional area of the suction pipe.

b) Strum boxes are to be so designed that they can be cleaned without having to remove any joint of the suction pipe.

6.9.5 Bilge wells

a) The wells provided for draining the various compartments are to be of a capacity not less than 0,15 m^3. In small compartments, smaller cylindrical wells may be fitted.

b) Bilge wells are to comply with the relevant provisions of Part B.

6.9.6 Liquid sealed traps

a) The bilge line of refrigerated spaces is to be provided with liquid sealed traps of adequate size arranged for easy cleaning and refilling with brine. These traps are to be fitted with removable grids intended to hold back waste products when defrosting.

b) Where drain pipes from separate refrigerated rooms join a common main, each of these pipes is to be provided with a liquid sealed trap.

c) As a general rule, liquid sealed traps are to be fitted with non-return valves. However, for refrigerated spaces not situated in the ship bottom, non-return valves may be omitted, provided this arrangement does not impair the integrity of the watertight subdivision.

6.10 Materials

6.10.1 *All bilge pipes used in or under coal bunkers or fuel storage tanks or in boiler or machinery spaces, including spaces in which oil-settling tanks or fuel oil pumping units are situated, shall be of steel or other suitable material non-sensitive to heat.*

6.11 Bilge piping arrangement

6.11.1 Passage through double bottom compartments

Bilge pipes are not to pass through double bottom compartments. If such arrangement is unavoidable, the parts of bilge pipes passing through double bottom compartments are to have reinforced thickness, as per Tab 6 for steel pipes.

6.11.2 Passage through deep tanks

The parts of bilge pipes passing through deep tanks intended to contain water ballast, fresh water, liquid cargo or fuel oil are normally to be contained within pipe tunnels. Alternatively, such parts are to have reinforced thickness, as per Tab 6 for steel pipes, and are to be made either of one piece or several pieces assembled by welding, by reinforced flanges or by devices deemed equivalent for the application considered; the number of joints is to be as small as possible. These pipes are to be provided at their ends in the holds with non-return valves.

6.11.3 Provision for expansion

Where necessary, bilge pipes inside tanks are to be fitted with expansion bends. Sliding joints are not permitted for this purpose.

6.11.4 Connections

Connections used for bilge pipes passing through tanks are to be welded joints or reinforced flange connections.

6.11.5 Access to valves and distribution boxes

All distribution boxes and manually operated valves in connection with the bilge pumping arrangement shall be in positions which are accessible under ordinary circumstances

Hand-wheels of valves controlling emergency bilge suctions are to rise at least 0,45 m above the manoeuvring floor.

6.12 Water ingress detection

6.12.1 Specific requirements for bulk, ore and combination carriers

Unless otherwise specified, the provisions of [6.12.1] apply to ships having one of the following service notations:

- **bulk carrier ESP**, **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP**, **bulk carrier**, **self-unloading bulk carrier ESP**
- **ore carrier ESP**
- **combination carrier/OBO ESP** or **combination carrier/OOC ESP**.

a) Each cargo hold is to be fitted with the water level detectors, giving audible and visual alarms located on the navigation bridge, one when the water level above the inner bottom in any hold reaches a height of 0,5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m.

b) The water level detectors (see Note 1) are to be fitted in the aft end of the cargo holds. For cargo holds which are used for water ballast, an alarm overriding device may be installed. The visual alarms are to clearly discriminate between the two different water levels detected in each hold.

Note 1: Refer to the Performance standards for water level detectors on bulk carriers and single hold cargo ships other than bulk carriers (IMO Resolution MSC.188(79) Rev.2).

c) Relevant documentation and drawings are to be submitted for review, including at least:

- type approval of Water Ingress Detection System, i.e. sensors/detectors wiring and control panel
- general arrangement of sensors and cables
- power supply electrical diagram
- detailed installation drawing of a sensor
- copy of the DOC of compliance for the carriage of dangerous goods and BC Code attestation, if any.

6.12.2 Specific requirements for single hold cargo ships other than bulk carriers

Unless otherwise specified, the provisions of [6.12.2] apply to ships having a length L of less than 80 m and 500 GT and over, with the service notation **general cargo ship** (see Note 1), **cement carrier**, **container ship**, **ro-ro cargo ship**, **PCTC** (see Note 2), **PCC** (see Note 2), **refrigerated cargo ship**, **livestock carrier**, **deck ship** (see Note 2), **liquefied gas carrier** (with independent tanks) (see Note 2) or **supply** (see Note 2).

a) Ships with a single cargo hold below the freeboard deck, or with cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to the freeboard deck, are to be fitted with water level detectors, giving audible and visual alarms located on the navigation bridge, one when the water level above the inner bottom reaches a height of not less than 0,3 m and another at a height not more than 15% of the mean depth of the cargo hold.

b) The water level detectors (see [6.12.1], Note 1) are to be fitted in the aft end of the cargo hold or above its lowest part where the inner bottom is not parallel to the designed waterline. Where webs or partial watertight bulkheads are fitted above the inner bottom, the Society may require the fitting of additional detectors. The visual alarms are to clearly discriminate between the two different water level detectors in hold.

c) The water level detectors need not to be fitted in ships complying with the requirements in [6.12.1] or in ships having watertight side compartments each side of the cargo hold length extending vertically at least from the inner bottom to the freeboard deck.

d) Relevant documentation and drawings are to be submitted for review, including at least:

- type approval of Water Ingress Detection System, i.e. sensors/detectors wiring and control panel
- general arrangement of sensors and cables
- power supply electrical diagram
- detailed installation drawing of a sensor
- copy of the DOC of compliance for the carriage of dangerous goods and BC Code attestation, if any.

Note 1: The requirements also apply to dedicated forest product carriers, dedicated woodchip carriers, timber and log carriers, with the same conditions.

Note 2: The scope of application for this type of ships is subject to special consideration.

6.12.3 Specific requirements for multiple hold cargo ships other than bulk carriers and tankers

Unless otherwise specified, the provisions of [6.12.3] apply to multiple hold cargo ships of 500 GT and over having the service notation **general cargo ship** (see Note 1), **cement carrier**, **container ship**, **ro-ro cargo ship**, **PCTC** (see Note 2), **PCC** (see Note 2), **refrigerated cargo ship**, **livestock carrier**, **deck ship** (see Note 2) or **supply** (see Note 2).

a) Water level detectors (see [6.12.1], Note 1) are to be fitted in each cargo hold intended for dry cargoes. Water level detectors are not required for cargo holds located entirely above the freeboard deck.

b) The water level detectors required by item a) are to:

1) give audible and visual alarms at the navigation bridge, one when the water level above the bottom of the cargo hold reaches a height of not less than 0,3 m, and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m; and

2) be fitted at the aft end of the cargo holds. For cargo holds which are occasionally used for water ballast, an alarm overriding device may be installed. The visual alarms shall clearly discriminate between the two different water levels detected in each hold.

c) As an alternative to the water level detector at a height of not less than 0,3 m as per item b)1), a bilge level sensor (see [6.12.1], Note 1) serving the bilge pumping arrangements required by [6.2] to [6.11] and installed in the cargo hold bilge wells or other suitable location is considered acceptable, subject to:

1) the fitting of the bilge level sensor at a height of not less than 0,3 m at the aft end of the cargo hold; and

2) the bilge level sensor giving audible and visual alarm at the navigation bridge which is clearly distinctive from the alarm given by the other water level detector fitted in the cargo hold.

d) Relevant documentation and drawings are to be submitted for review, including at least:

- type approval of water detectors, including sensor wiring and control panel
- general arrangement of sensors and cables
- power supply electrical diagram
- detailed installation drawing of sensors
- copy of the document of compliance for the carriage of dangerous goods (DoC) and BC Code attestation, if any.

Note 1: The requirements also apply to dedicated forest product carriers, dedicated woodchip carriers, timber and log carriers, with the same conditions.

Note 2: The scope of application for this type of ships is subject to special consideration.

7 Ballast systems

7.1 Principles

7.1.1 Independence of ballast lines

Ballast lines are to be entirely independent and distinct from other lines except where permitted in [5.4].

7.1.2 Prevention of undesirable communication between spaces or with the sea

Ballast systems in connection with bilge systems are to be so designed as to avoid any risk of undesirable communication between spaces or with the sea. See [6.2.3].

7.1.3 Alternative carriage of ballast water or other liquids and dry cargo

Holds and deep tanks designed for the alternative carriage of water ballast, fuel oil or dry cargo are to have their filling and suction lines provided with blind flanges or appropriate change-over devices to prevent any mishandling.

7.1.4 Ballast water management systems

In addition to the requirements contained in BWM Convention (2004) and the Code for Approval of Ballast Water Management Systems (BWMS Code), ballast water management systems (BWMS), where fitted, are to comply with the requirements of Ch 1, Sec 13.

7.2 Ballast pumping arrangement

7.2.1 Filling and suction pipes

a) All tanks including aft and fore peak and double bottom tanks intended for ballast water are to be provided with suitable filling and suction pipes connected to special power driven pumps of adequate capacity.

b) Small tanks used for the carriage of domestic fresh water may be served by hand pumps.

c) Suctions are to be so positioned that the transfer of sea water can be suitably carried out in the normal operating conditions of the ship. In particular, two suctions may be required in long compartments.

d) On bulk carriers, the means for draining and pumping ballast tanks forward of the collision bulkhead are to comply with [6.6.7].

7.2.2 Pumps

At least two power driven ballast pumps are to be provided, one of which may be driven by the propulsion unit. Sanitary and general service pumps may be accepted as independent power ballast pumps.

Bilge pumps may be used for ballast water transfer provided the provisions of [6.7.3] are fulfilled.

Alternative means of deballasting, such as an eductor, may be accepted in lieu of a second ballast pump, subject to special consideration in each particular case.

7.2.3 Passage of ballast pipes through tanks

If not contained in pipe tunnels, the ballast steel pipes passing through tanks intended to contain fresh water, fuel oil or liquid cargo are:

- to have reinforced thickness, as per Tab 6
- to consist either of a single piece or of several pieces assembled by welding, by reinforced flanges or by devices deemed equivalent for the application considered
- to have a minimal number of joints in these lines
- to have expansion bends in these lines within the tank, where needed
- not to have slip joints.

For ballast lines passing through oil cargo tanks, where permitted, see Pt D, Ch 7, Sec 4, [2.1.3].

7.2.4 Ballast valves and piping arrangements

a) Ballast tank valves

Valves controlling flow to ballast tanks are to be arranged so that they remain closed at all times except when ballasting. Where butterfly valves are used, they are to be of a type able to prevent movement of the valve position due to vibration or flow of fluids.

b) Remote control valves

Remote control valves, where fitted, are to be arranged so that they close and remain closed in the event of loss of control power. The valves may remain in the last ordered position upon loss of power, provided that there is a readily accessible manual means to close the valves upon loss of power.

Remote control valves are to be clearly identified as to the tanks they serve and are to be provided with position indicators at the ballast control station.

c) Ballast piping arrangements

For ships which are subject to damage stability, the piping arrangements are to comply with the requirements of [5.5] concerning the prevention of progressive flooding. The pipes, if damaged, which are located within the extent of assumed damage, are not to affect damage stability considerations.

7.2.5 Temporary storage of treated sewage or grey water in ballast water tanks

The temporary storage of treated sewage and grey water in ballast water tanks is allowed under the following conditions:

a) Mixing ballast water and treated sewage or grey water is not permitted.

b) Ballast water tanks intended for temporary the storage of treated sewage or grey water are to be adequately protected against corrosion considering the fluids to be stored.

c) Hull strength and stability are to be assessed in regards of ships operation while the BW are used for temporary storage of grey water or treated sewage: see Pt B, Ch 5, Sec 8, [3.2.1], item d).

d) Appropriate measures to prevent the contamination of the ballast system by treated sewage or grey water are to be provided, such as valves, blanks, spectacle flanges blinds, or using isolating pumps and pipelines.

e) The ballast water tanks to be used for temporary storage of treated sewage or grey water are to be clearly identified.

f) The procedure for temporary storage of treated sewage or grey water in ballast water tanks shall be approved by the Administration in accordance with BWM.2/Circ.82."

7.3 Ballast water exchange at sea

7.3.1 General

Unless otherwise specified, this sub-article applies to ships assigned with additional class notation **BWE**.

7.3.2 Definitions

a) A Ballast Water Exchange (BWE) plan contains procedures and advice to safely and efficiently exchange of ballast water in accordance with applicable structural and stability requirements and taking into account the precautions contained in Appendix 2 of IMO Res. A. 868(20).

b) Sequential method - a process by which a ballast tank or hold intended for the carriage of water ballast is emptied of at least 95% or more of its volume and then refilled with replacement ballast water.

c) Flow-through method - a process by which replacement ballast water is pumped into a ballast tank or hold intended for the carriage of water ballast allowing water to flow through overflow or other arrangements. At least three times the tank or hold volume is to be pumped through the tank or hold.

d) Dilution method - a process by which replacement ballast water is filled through the top of the ballast tank or hold intended for the carriage of water ballast with simultaneous discharge from the bottom at the same flow rate and maintaining a constant level in the tank or hold. At least three times the tank or hold volume is to be pumped through the tank or hold.

7.3.3 Ballast water pumping and piping arrangement

a) Ballast water pumping and piping arrangements are to be capable of filling and pumping out any ballast tank and hold intended for the carriage of water ballast under any environmental conditions permitted by the Ballast Water Exchange (BWE) plan.

b) Where the flow-through method of water ballast exchange is used, the design of water ballast exit arrangements is to be such that, when the tank or hold is overflowing at the maximum pumping capacity available to the tank or hold, it is not subject to a pressure greater than that for which it has been designed.

c) Every ballast tank and hold intended for the carriage of water ballast is to be provided with isolating valves for filling and /or emptying purposes.

d) On ships classed for navigation in ice, ship side ballast discharge valves placed above the assigned lightest load line are to be arranged with adequate heating arrangements.

7.3.4 Sea chests and shipside openings intended for ballast water exchange

The relative positions of ballast water intake and discharge openings are to be such as to preclude as far as practicable the possibility of contamination of replacement ballast water by water which is being pumped out.

7.3.5 Pumps

a) The ballast system is to be served by at least two pumps.

b) The complete ballast water exchange of cargo holds, where used for the carriage of water ballast, is to be possible by one pump within not more than twenty four hours.

7.3.6 System arrangement

a) The design of ballast water systems is to allow the ballast water exchange operations with the minimum number of operational procedures.

b) The internal arrangements of ballast tanks, as well as ballast water piping inlet and outlet arrangements, are to allow, as far as practical, the complete ballast water exchange and the clearing of any sediments.

c) The design of sea suction line strainers is to be such as to permit cleaning of strainers without interrupting ballast water exchange procedures.

7.3.7 Control features

a) Remote control, local control, emergency control

- Remote control - ballast pumps, and all valves which may be operated during ballast water exchange are to be provided with a means of remote control from a central ballast control station.
- Local control - a means of local control is to be provided at each ballast pump operated during ballast water exchange.
- Emergency control - a readily accessible manual means for control of any valve required for ballast water exchange is to be also provided to enable the emergency operation in the event of main control system failure (see also [7.2.4], item b)).

b) The central ballast control station is to include the following:

- a valve position indicating system,
- a tank level indicating system,
- a draft indicating system,
- a means of communication between the central ballast control station and those spaces containing the means of local control for the ballast pumps and the manually operated independent means of control for the valves.

c) The ballast pump and ballast valve control systems are to be so arranged that the failure of any component within the control system is not to cause the loss of operation to the pumps or valves of other systems.

7.3.8 Tanks

a) For ships with an **ICE** or **COLD** class notation (as defined in Pt A, Ch 1, Sec 2, [6.10]) and, generally, where a risk of water ballast freezing exists, water ballast tanks are to be provided with means to prevent the water from freezing. See Pt F, Ch 8, Sec 1, [2.2.2] and Pt F, Ch 8, Sec 4, [6.3.3].

b) The design of ballast tanks is to allow ready sampling of ballast water and sediments, as far as practical. Providing safe access to the tanks by the fitting of tank hatches as an alternative to manholes is recommended. The area immediately below any tank opening is to be free in order to enable the use of sampling equipment or free access.

7.3.9 Special provisions depending on the method of ballast water exchange

a) Flow-through method

- The capability of the ballast water system to provide ballast water exchange by the flow-through method without the risk of the tank being subject to a pressure greater than that for which it has been designed is to be demonstrated by water flow calculations and by testing on board. Subject to consideration in each particular case, the calculation may be omitted where justified that total cross-sectional area of all vent pipes fitted to the tank is not less than twice the sectional area of the related filling pipes.
- The flow-through method with water flowing over the deck is not permitted. The use of collecting pipes, internal overflow pipes or interconnecting pipe/trunk arrangements between tanks may be accepted to avoid water flowing over the deck.

b) Dilution method

- Where the dilution method is accepted, arrangements are to be made to automatically maintain the ballast water level in the tanks at a constant level. These arrangements are to include the provision of a manual emergency stop for any operating ballast pump, in case of valve malfunction or incorrect control actions.
- High and low water level alarms are to be provided where maintaining a constant level in a tank is essential to the safety of the ship during ballast water exchange.

8 Scuppers and sanitary discharges

8.1 Application

8.1.1

a) This Article applies to:
- scuppers and sanitary discharge systems, and
- discharges from sewage tanks.

b) Discharges in connection with machinery operation are dealt with in [2.8].

Note 1: Arrangements not in compliance with the provisions of this Article may be considered for the following ships:
- ships of less than 24 m in length
- cargo ships of less than 500 gross tonnage
- ships to be assigned restricted navigation notations
- non-propelled units.

8.2 Principle

8.2.1

a) Scuppers, sufficient in number and suitable in size, are to be provided to permit the drainage of water likely to accumulate in the spaces which are not located in the ship's bottom.

b) The number of scuppers and sanitary discharge openings in the shell plating is to be reduced to a minimum either by making each discharge serve as many as possible of the sanitary and other pipes, or in any other satisfactory manner.

c) Except otherwise specified, the design of scuppers and sanitary discharges shall generally comply with the 2004 edition of ISO 15749-1 to -5. Other recognised national or international standard acceptable to the Society may be studied on a case by case basis.

8.3 Drainage from spaces below the freeboard deck or within enclosed superstructures and deckhouses on the freeboard deck

8.3.1 Normal arrangement

Scuppers and sanitary discharges from spaces below the freeboard deck or from within superstructures and deckhouses on the freeboard deck fitted with doors complying with the provisions of Pt B, Ch 11, Sec 7 are to be led to:
- the bilge in the case of scuppers, or
- suitable sanitary tanks in the case of sanitary discharges.

8.3.2 Alternative arrangement

The scuppers and sanitary discharges may be led overboard provided that:
- the spaces drained are located above the load waterline formed by a 5° heel, to port or starboard, at a draft corresponding to the assigned summer freeboard, and
- the pipes are fitted with efficient means of preventing water from passing inboard in accordance with [8.8]

8.4 Drainage of superstructures or deckhouses not fitted with efficient weathertight doors

8.4.1 Scuppers leading from superstructures or deckhouses not fitted with doors complying with the requirements of Pt B, Ch 11, Sec 7 are to be led overboard.

8.5 Drainage of enclosed cargo spaces situated on the bulkhead deck or on the freeboard deck

8.5.1 General

Means of drainage are to be provided for enclosed cargo spaces situated on the bulkhead deck of a passenger ship and on the freeboard deck of a cargo ship. The Society may permit the means of drainage to be dispensed with in any particular compartment if it is satisfied that, by reason of size or internal subdivision of such space, the safety of the ship is not impaired.

8.5.2 Cases of spaces located above the waterline resulting from a 5° heel

a) Scuppers led through the shell from enclosed superstructures used for the carriage of cargo are permitted, provided the spaces drained are located above the waterline resulting from a 5° heel to port or starboard at a draught corresponding to the assigned summer freeboard. Such scuppers are to be fitted in accordance with the requirements stated in [8.8].

b) In other cases, the drainage is to be led inboard in accordance with the provisions of [8.5.3].

8.5.3 Cases where the bulkhead or freeboard deck edge is immersed when the ship heels 5° or less

Where the freeboard is such that the edge of the bulkhead deck or the edge of the freeboard deck, respectively, is immersed when the ship heels 5° or less, the drainage of the enclosed cargo spaces on the bulkhead deck or on the freeboard deck,

respectively, is to be led to a suitable space, or spaces, of appropriate capacity, having a high water level alarm and provided with suitable arrangements for discharge overboard.

In addition, it is to be ensured that:

- the number, size and arrangement of the scuppers are such as to prevent unreasonable accumulation of free water - see also [8.7]
- the pumping arrangements take account of the requirements for any fixed pressure water-spraying fire-extinguishing system - see also [8.7]
- water contaminated with petrol or other dangerous substances is not drained to machinery spaces or other spaces where sources of ignition may be present, and
- where the enclosed cargo space is protected by a carbon dioxide fire-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

8.6 Drainage of cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion

8.6.1 Prevention of build-up of free surfaces

In cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion and fitted with a fixed pressure water-spraying fire-extinguishing system, the drainage arrangement is to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effect upon stability of the added weight and free surface of water are to be taken into account to the extent deemed necessary by the Society in its approval of the stability information. Refer to Pt B, Ch 3, Sec 3.

8.6.2 Scupper draining

Scuppers from cargo spaces, other than ro-ro spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion are not to be led to machinery spaces or other places where sources of ignition may be present.

8.7 Drainage and pumping arrangements for vehicle, special category and ro-ro spaces protected by fixed pressure water-spraying systems

8.7.1 When fixed pressure water-spraying fire-extinguishing systems are fitted, in view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks during the operation of the fixed pressure water-spraying system, the following arrangements shall be provided.

8.7.2 In cargo ships, the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces. In such case, the drainage system shall be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles, taking into account IMO Circular MSC.1/Circ.1320. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible, the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Society in its approval of the stability information. Such information shall be included in the stability information supplied to the master as required in Pt B, Ch 3, Sec 2, [1.1.1].

8.7.3 For passenger ships, refer to Pt D, Ch 11, Sec 4, [1.6].

8.7.4 For closed vehicles and ro-ro spaces and special category spaces, where fixed pressure water-spraying systems are fitted, means shall be provided to prevent the blockage of drainage arrangements, taking into account IMO Circular MSC.1/Circ.1320.

8.8 Arrangement of discharges led overboard

8.8.1 Arrangements for discharges led from spaces below the bulkhead or freeboard deck

a) Normal arrangement:

Each separate discharge led though the shell plating from spaces below the bulkhead or freeboard deck is to be provided with one automatic non-return valve fitted with positive means of closing it from above the bulkhead or freeboard deck or.

b) Alternative arrangement when the inboard end of the discharge pipe is above the summer waterline by more than 0,01 L:

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that the inboard valve is:

- above the deepest subdivision load line, and
- always accessible for examination under service conditions.

c) For SOLAS ships, no other alternative arrangement as those described above is accepted except for discharges led from the shell plating from spaces above the bulkhead or freeboard deck and those as provided in e).

d) For NON SOLAS ships:

1) The provisions of this sub-article are applicable only to those discharges which remain open during the normal operation of a ship. For discharges which must necessarily be closed at sea, such as gravity drains from topside ballast tanks, a single screw-down valve operated from the deck may be accepted.

2) The position of the inboard end of discharges is related to the timber summer load waterline when a timber freeboard is assigned.

3) Alternative arrangement when the inboard end of the discharge pipe is above the summer waterline by more than 0,01 L:

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that:

- the inboard valve is above the level of the tropical load waterline so as to always be accessible for examination under service conditions, or
- where this is not practicable, a locally controlled sluice valve is interposed between the two automatic non-return valves.

4) Alternative arrangement when the inboard end of the discharge pipe is above the summer waterline by more than 0,02 L:

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02 L, a single automatic non-return valve without positive means of closing may be accepted subject to the approval of the Society.

e) Arrangement of discharges through manned machinery spaces:

Where sanitary discharges and scuppers lead overboard through the shell in way of machinery spaces, the fitting at the shell of a locally operated positive closing valve together with a non-return valve inboard may be accepted. The operating position of the valve will be given special consideration by the Society.

8.8.2 Arrangements for discharges led from other spaces

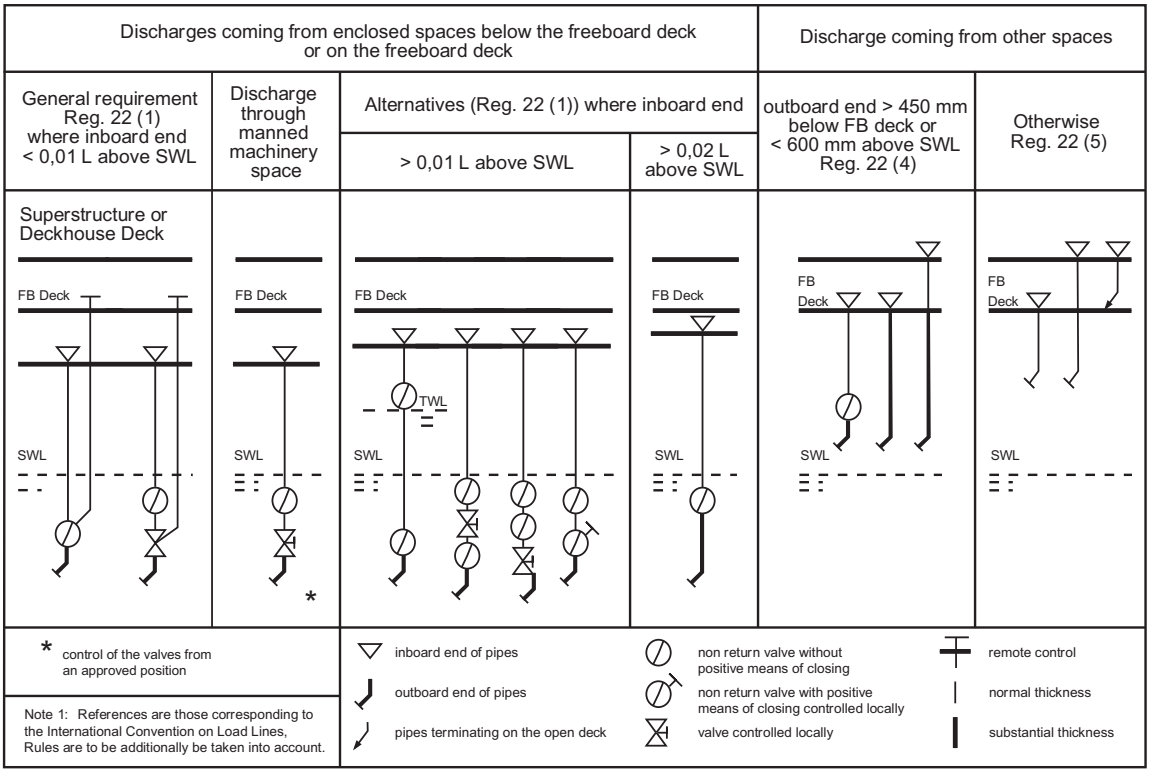
a) Scupper and discharge pipes originating at any level and penetrating the shell either more than 450 millimetres below the freeboard deck or less than 600 millimetres above the summer load waterline are to be provided with a non-return valve at the shell. Unless required by [8.8.1], this valve may be omitted if the piping is of substantial thickness, as per Tab 25.

b) Scupper and discharge pipes penetrating the shell less than 450 millimetres below the freeboard deck and more than 600 millimetres above the summer load waterline are not required to be provided with a non-return valve at the shell.

8.9 Summary table of overboard discharge arrangements

8.9.1 The various arrangements acceptable for scuppers and sanitary overboard discharges are summarised in Fig 3.

Figure 3 : Overboard discharge arrangement



8.10 Valves and pipes

8.10.1 Materials

a) All shell fittings and valves are to be of steel, bronze or other ductile material. Valves of ordinary cast iron or similar material are not acceptable. All scupper and discharge pipes are to be of steel or other ductile material. Refer to [2.1].

b) Plastic is not to be used for the portion of discharge line from the shell to the first valve.

8.10.2 Thickness of pipes

a) The thickness of scupper and discharge pipes led to the bilge or to draining tanks is not to be less than that required in [2.2].

b) The thickness of scupper and discharge pipes led to the shell is not to be less than the minimum thickness given in Fig 3 and Tab 25.

8.10.3 Operation of the valves

a) Where valves are required to have positive means of closing, such means is to be readily accessible and provided with an indicator showing whether the valve is open or closed.

b) Where plastic pipes are used for sanitary discharges and scuppers, the valve at the shell is to be operated from outside the space in which the valve is located.

Where such plastic pipes are located below the summer waterline (timber summer load waterline), the valve is to be operated from a position above the freeboard deck.

Refer also to Ch 1, App 3.

Table 25 : Minimum thickness of scupper and discharge pipes led to the shell

External diameter of the pipe d, in mm	Substantial thickness, in mm	Normal thickness, in mm
d ≤ 80,0	7,00	4,50
155	9,25	4,50
180	10,00	5,00
220	12,50	5,80
230 ≤ d	12,50	6,00
Note 1: Intermediate sizes may be determined by interpolation.		

8.11 Arrangement of scuppers and sanitary discharge piping

8.11.1 Overboard discharges and valve connections

a) Overboard discharges are to have pipe spigots extending through the shell plate and welded to it, and are to be provided at the internal end with a flange for connection to the valve or pipe flange.

b) Valves may also be connected to the hull plating in accordance with the provisions of [2.8.3], item c).

8.11.2 Passage through cargo spaces

Where scupper and sanitary discharge pipes are led through cargo spaces, the pipes and the valves with their controls are to be adequately protected by strong casings or guards.

8.11.3 Passage through tanks

a) As a rule, scupper and sanitary discharge pipes are not to pass through fuel oil tanks.

b) Where scupper and discharge pipes pass unavoidably through fuel oil tanks and are led through the shell within the tanks, the thickness of the piping is not to be less than that given in Tab 25, column 1 (substantial thickness). It need not, however, exceed the thickness of the adjacent Rule shell plating.

c) Scupper and sanitary discharge pipes are normally not to pass through fresh and drinking water tanks.

d) For passage through cargo oil tanks, see Pt D, Ch 7, Sec 4.

8.11.4 Passage through watertight bulkheads or decks

a) The intactness of machinery space bulkheads and of tunnel plating required to be of watertight construction is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments which are situated below the freeboard deck.

b) Such scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but close to the above-mentioned adjacent compartments and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

8.11.5 Discharge in refrigerated spaces

No scupper pipe from non-refrigerated spaces is to discharge in refrigerated spaces.

8.11.6 Discharge from galleys and their stores

Discharges from galleys and their stores are to be kept separate from other discharges and be drained overboard or in separate drainage tanks; alternatively, discharges are to be provided with adequate devices against odours and overflow.

8.11.7 Discharge from aft spaces

Where spaces located aft of the aft peak bulkhead not intended to be used as tanks are drained by means of scuppers discharging to the shaft tunnel, the provisions of [6.6.4] item c) are to be complied with.

8.11.8 Scupper tank

a) The scupper tank air pipe is to be led to above the freeboard deck.

b) Provision is to be made to ascertain the level of water in the scupper tank.

8.11.9 Drains from the funnels

Drain line from the funnel or stack top should not terminate on an exposed deck owing to the soot that may be contained in the wastewater. Except otherwise specified, this line may be connected to other lines draining exposed decks and leading directly overboard, taking into consideration the quantity of wastewater occurring.

8.11.10 Sewage and grey water discharges

The requirements specified below are general and should apply to any ship fitted with sewage and grey water piping systems. They are not sufficient for the compliance with MARPOL Annex IV and for additional class notation **CLEANSHIP**. Furthermore, the National Authority of the country in which the ship is to be registered may also have additional requirements.

a) Except otherwise specified, the sewage (or black water) means:

- drainage and other wastes from any form of toilets and urinals
- drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises
- drainage from spaces containing living animals; or
- other waste waters when mixed with the drainages defined above.

b) Grey water means other sanitary discharges which are not sewage.

c) In general, sewage systems should be of a design which will avoid the possible generation of toxic and flammable gases (such as hydrogen sulphide, methane, ammonia) during the sewage collection and treatment. Additional means of protection is to be suitable ventilation of the pipework and tanks.

d) Drain lines from the hospital area should be, as far as practicable, separated from other discharges and fitted to the drain collector at the lowest level.

e) Sewage and grey water may be collected into storage tanks together or separately, either for holding prior to transfer to a treatment unit, or for later discharge. Any tank used for holding sewage shall comply with the following:

- suitable air pipes shall be fitted, leading to the open deck
- design and configuration of those tanks should be such as to facilitate the effective drainage and flushing of the tanks
- suitable means for flushing of the tanks shall be provided
- such tanks are to be efficiently protected against corrosion
- tanks shall have a means to indicate visually the amount of its content
- suitable means for emptying sewage tanks through the standard discharge connection to reception facilities shall be provided. Ballast and bilge pumps are not be used for that purpose.

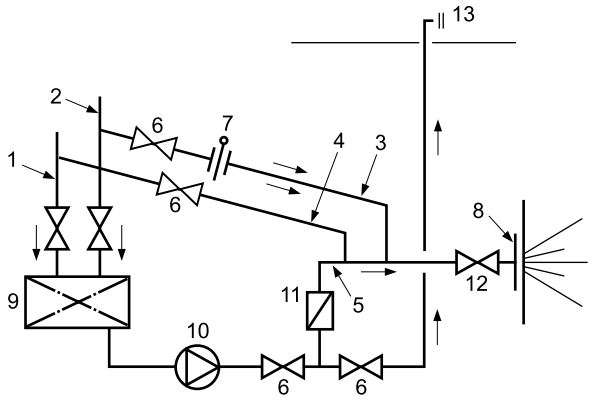
f) Air pipes from the sewage and grey water systems are to be independent of all other air pipes and to be led to the outside of the ship, away from any air intake. Sewage pipes should not terminate in areas to which personnel have frequent access and should be clear of any sources of ignition.

g) The overboard discharges shall be located as far from seawater inlets as possible, seen in the direction of travel. In general, the sewage outlets should be located below the summer loadline.

h) The sewage and grey water discharge lines are to be fitted at the ships' side with screw-down valve and non-return valve. Possible characteristically arrangement is shown on Fig 4.

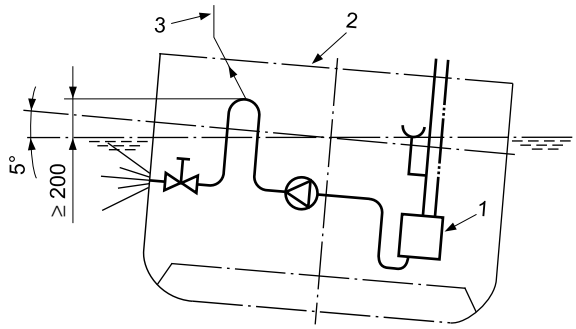
The non-return valve may be omitted where a pipe loop is fitting on discharge line, provided that the lowest part of the loop is at least 200 mm above the waterline with the ship on summer loadline draft and when the ship has a 5° list (see Fig 5).

Figure 4 : Sewage and grey water overboarddischarge typical arrangement



1 grey water drain line
2 sewage water drain line
3 bypass line for sewage
4 bypass line for grey water
5 sewage disposal line
6 shutoff gate valve
7 spectacle flange, optional
8 overboard discharge
9 collector tank or treatment unit
10 pump
11 non-return valve
12 screw-down overboard valve
13 standard discharge connection

Figure 5 : Typical overboard discharge arrangement without non-return valve



1 collector tank or treatment unit
2 freeboard deck
3 vent (leading on top of funnel).

9 Air, sounding and overflow pipes

9.1 Air pipes

9.1.1 Principle

Air pipes are to be fitted to all tanks, double bottoms, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements, in order to allow the passage of air or liquid so as to prevent excessive pressure or vacuum in the tanks or compartments, in particular in those which are fitted with piping installations. Their open ends are to be so arranged as to prevent the free entry of sea water in the compartments.

9.1.2 Number and position of air pipes

a) Air pipes are to be so arranged and the upper part of compartments so designed that air or gas likely to accumulate at any point in the compartments can freely evacuate.

b) Air pipes are to be fitted opposite the filling pipes and/or at the highest parts of the compartments, the ship being assumed to be on an even keel.

c) In general, two air pipes are to be fitted for each compartment, except in small compartments, where only one air pipe may be accepted. When the top of the compartment is of irregular form, the position of air pipes will be given special consideration by the Society.

Note 1: Two air vents are normally required for long tanks e.g. a ballast tank in a double hull ship.

In machinery spaces, two air vents are not normally required.

d) Where only one air pipe is provided, it is not to be used as a filling pipe.

9.1.3 Location of open ends of air pipes

a) Air pipes of double bottom compartments, tunnels, deep tanks and other compartments which can come into contact with the sea or be flooded in the event of hull damage are to be led to above the bulkhead deck or the freeboard deck.

Note 1: In ships not provided with a double bottom, air pipes of small cofferdams or tanks not containing fuel oil or lubricating oil may discharge within the space concerned.

b) Air pipes of tanks intended to be pumped up are to be led to the open above the bulkhead deck or the freeboard deck.

c) Air pipes other than those of flammable oil tanks may be led to enclosed cargo spaces situated above the freeboard deck, provided that:

- overflow pipes are fitted in accordance with [9.3.4], where the tanks may be filled by pumping
- enclosed cargo spaces are fitted with scuppers discharging overboard and being capable of draining all the water which may enter through the air pipes without giving rise to any water accumulation
- suitable drainage arrangement is to be fitted below the air pipe outlet, leading to the nearest scupper
- such arrangement is not to impair integrity of fire divisions or watertight decks and bulkheads subject to the damage stability requirements.

d) In passenger ships, air pipes terminating within a superstructure which are not fitted with watertight means of closure shall be considered as unprotected openings when applying Pt B, Ch 3, App 3, [1.6.11].

e) The air pipe of the scupper tank is to be led to above freeboard deck.

f) The location of air pipes for flammable oil tanks is also to comply with [9.1.7].

9.1.4 Height of air pipes

a) The height of air pipes extending above the freeboard deck or superstructure deck from the deck to the point where water may have access below is to be at least:

- 760 mm on the freeboard deck, and
- 450 mm on the superstructure deck.

This height is to be measured from the upper face of the deck, including sheathing or any other covering, up to the point where water may penetrate inboard.

b) Where these heights may interfere with the working of the ship, a lower height may be approved, provided the Society is satisfied that this is justified by the closing arrangements and other circumstances. Satisfactory means which are permanently attached are to be provided for closing the openings of the air pipes.

c) The height of air pipes may be required to be increased on ships subject to damage stability requirements since the air pipe outlets are to be above final waterline at any damaged condition assumed by the Damage stability examination as defined in Pt B, Ch 3, App 4, [3.5.2].

d) The height of air pipes discharging through the side of the superstructure is to be at least 2,3 m above the summer load waterline.

9.1.5 Fitting of closing appliances

a) Satisfactory appliances which are permanently attached are to be provided for closing the openings of air pipes in order to prevent the free entry of water into the spaces concerned, except for pipes of tanks fitted with cross-flooding connections.

b) Automatic closing appliances are to be fitted in the following cases:

- where air pipes to ballast and other tanks extend above the freeboard or superstructure decks
- where, with the ship at its summer load waterline, the openings are immersed at an angle of heel of 40° or, at the angle of down-flooding if the latter is less than 40°
- where, as per [9.1.3] item c), air pipes terminate in enclosed spaces
- where, as per [9.1.4] item b), air pipes have a height lower than that required in [9.1.4] item a)
- and for ships assigned timber freeboard.

See also Pt B, Ch 3, Sec 2, [2.1.2] and Pt B, Ch 3, Sec 3, [3.3.2].

c) Automatic closing appliances are to be of a type approved by the Society. Requirements for type tests are given in [20.3.1].

d) For ships subject to specific buoyancy or stability requirements, the fitting of closing appliances to air pipes will be given special consideration.

e) Pressure/vacuum valves installed on cargo tanks, as per Part D, Chapter 7 and Part D, Chapter 8, can be accepted as closing appliances.

9.1.6 Design of closing appliances

a) When air pipes are required to be fitted with automatic closing devices, they are to comply with the following:

1) Air pipe automatic closing devices are to be so designed that they will withstand both ambient and working conditions, and be suitable for use at inclinations up to and including ± 40°.

2) Air pipe automatic closing devices are to be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

3) Efficient ball or float seating arrangements are to be provided for the closures. Bars, cage or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state and made in such a way that the ball or float is not damaged when subjected to water impact due to a tank being overfilled.

4) Air pipe automatic closing devices are to be self-draining.

5) The clear area through an air pipe closing device in the open position is to be at least equal to the area of the inlet.

6) An automatic closing device is to:

- prevent the free entry of water into the tanks
- allow the passage of air or liquid to prevent excessive pressure or vacuum coming on the tank.

7) In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim. Where side covers are provided and their function is integral to providing functions of the closing device as outlined in [9.1.6]item a) 6), they shall have a minimum wall thickness of 6 mm. If the air pipe head can meet the tightness test in [20.3.1], item a) without the side covers attached, then the side covers are not considered to be integral to the closing device, in which case a wall less than 6 mm can be acceptable for side covers.

8) The maximum allowable tolerances for wall thickness of floats is not to exceed ± 10% of thickness.

9) The inner and the outer chambers of an automatic air pipe head is to be of a minimum thickness of 6 mm.

10) Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

11) For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

12) For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side), an additional harder coating is to be applied. This is to be an aluminium bearing epoxy, or other equivalent, coating, applied over the zinc.

13) Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and to seawater and suitable for operating at ambient temperatures between –25°C and +85°C.

b) Where closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out. For this purpose, a hole of approximately 10 mm in diameter may be provided in the bend of the air pipe or at any other suitable position in the closing appliance.

c) Wooden plugs and trailing canvas are not permitted in position 1 or position 2, as defined in Pt B, Ch 3, Sec 2.

9.1.7 Special arrangements for air pipes of flammable oil tanks

a) Air pipes from fuel oil tanks and from thermal oil heating plants expansion tanks and thermal oil storage tanks, are to discharge to a safe position on the open deck where no danger will be incurred from issuing oil or gases.

Where fitted, wire gauze diaphragms are to be of corrosion resistant material and readily removable for cleaning and replacement. The clear area of such diaphragms is not to be less than the cross-sectional area of the pipe.

b) Air pipes of lubricating or hydraulic oil storage tanks, which are neither heated nor subject to flooding in the event of hull damage, may be led to machinery spaces, provided that in the case of overflowing the oil cannot come into contact with electrical equipment, hot surfaces or other sources of ignition.

c) The location and arrangement of vent pipes for fuel oil service, settling and lubrication oil tanks are to be such that in the event of a broken vent pipe there is no risk of ingress of seawater or rainwater.

d) Air pipes of fuel oil service, settling and lubrication oil tanks likely to be damaged by impact forces are to be adequately reinforced.

e) Where seawater or rainwater may enter fuel oil service, settling and lubrication oil tanks through broken air pipes, arrangements such as water traps with:

- automatic draining, or
- alarm for water accumulation

are to be provided.

9.1.8 Construction of air pipes

a) Where air pipes to ballast and other tanks extend above the freeboard deck or superstructure deck, the exposed parts of the pipes are to be of substantial construction, with a minimum wall thickness of at least:

- 6,0 mm for pipes of 80 mm or smaller external diameter
- 8,5 mm for pipes of 165 mm or greater external diameter,

Intermediate minimum thicknesses may be determined by linear interpolation.

b) Air pipes with height exceeding 900 mm are to be additionally supported.

c) In each compartment likely to be pumped up, and where no overflow pipe is provided, the total cross-sectional area of air pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

d) The internal diameter of air pipes is not to be less than 50 mm, except for tanks of less than 2 m^3.

e) Air pipes from several tanks or spaces may be led into a common main line, provided that:

- the tanks or spaces are not intended for liquids which are not compatible and that the arrangement could not effect unacceptable condition for the ship
- the cross-sectional area of the air pipes main is generally not less than the aggregate cross-sectional area of the two largest pipes discharging into the main. However, a reduced value may be considered for acceptance in each particular case on the basis of back pressure calculation submitted for all normal working conditions
- as far as practical, each separate air pipe is fitted to the common air pipe from the top side
- where no overflow pipes are provided, the cross-sectional area of a common air pipe from several tanks is not less than 1,25 times the area of the common filling pipeline for these tanks
- where the tanks or spaces are situated at the shell side, the connections to the air pipes main are to be above the freeboard deck. Where it is not practical, different position proposed as far as possible above the deepest load waterline may be considered for acceptance. For vessels subject to damage stability requirements these connections are to be above final waterline at any damaged condition assumed by the Damage stability examination as defined in Pt B, Ch 3, App 4, [3.5.2].

f) Vents acting also as overflows may be accepted provided all the requirements applicable to both vents and overflows are complied with.

g) Where tanks are fitted with cross flooding connections, the air pipes are to be of adequate area for these connections.

9.1.9 Strength requirements to resist green sea forces for the air pipes, ventilator pipes and their closing devices located within the forward quarter length

a) In addition to all other requirements specified before, the following shall apply on the exposed deck over the forward 0,25 L, applicable to:

- All ship types of sea going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1 L or 22 m above the summer load waterline, whichever is the lesser.
- For application to existing ships (that are contracted for construction prior to 1 January 2004), see Part A, Chapter 6.

The rule length "L" is the distance, in m, taken as defined in Pt B, Ch 1, Sec 3, [2.1.1].

The requirements do not apply to the cargo tank venting systems and the inert gas systems of tankers.

b) Generally, the bending moments and stresses in air and ventilator pipes are to be calculated at following critical positions:

- at penetration pieces
- at weld or flange connections
- at toes of supporting brackets.

Bending stresses in the net section are not to exceed 0,8 of the specified minimum yield stress or 0,2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2,0 mm is then to be applied.

Relevant drawing and calculation shall be submitted.

c) For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thickness and bracket heights are specified in Tab 26. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Tab 27 but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

d) For other configurations, loads according to item i) are to be applied, and means of support determined in order to comply with the requirements of item b). Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in [9.1.8].

e) For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thickness and bracket heights are specified in Tab 27. Brackets, where required are to be as specified in item c). See also Pt B, Ch 11, Sec 12, [9].

f) For ventilators of height greater than 900 mm, brackets or alternative means of support shall be fitted according to the arrangement acceptable to the Society. See also Pt B, Ch 11, Sec 12, [9]. Pipe thickness is not to be taken less than as indicated in [9.1.8].

g) All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in item i).

h) Rotating type mushroom ventilator heads are not suitable for application in the areas where these requirements are applied.

i) Applied loading may be calculated:

- The pressures p, in kN/m^2, acting on air pipes, ventilator pipes and their closing devices may be calculated from:

  $p = 0,5\ \rho\ V^2\ C_d\ C_s\ C_p$

  where:

  ρ : Density of sea water, equal to 1,025 t/m^3

  V : Velocity of water over the fore deck, in m/s, to be taken equal to:

  - 13,5 if $d \leq 0,5\ d_1$
  - $13,5\sqrt{2\left(1-\frac{d}{d_1}\right)}$

    if $0,5\ d_1 < d < d_1$

  d : Distance, in m, from the summer load line to the exposed deck

  d_1 : 0,1 L or 22 m, whichever is the lesser

  C_d : Shape coefficient, equal to:

  - 0,5 for pipes
  - 1,3 for air pipe or ventilator heads in general
  - 0,8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction

  C_s : Slamming coefficient, equal to 3,2

  C_p : Protection coefficient, equal to:

  - 0,7 for pipes and ventilator heads located immediately behind a breakwater or a forecastle
  - 1,0 elsewhere and immediately behind a bulwark.

- Forces acting in the horizontal direction on the pipe and its closing device may be calculated from formula above, using the largest projected area of each component.

Table 26 : 760 mm air pipe thickness and bracket standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm^2)	Height of brackets **(1)** (mm)
40A **(3)**	6,0	–	520
50A **(3)**	6,0	–	520
65A	6,0	–	480
80A	6,3	–	460
100A	7,0	–	380
125A	7,8	–	300
150A	8,5	–	300
175A	8,5	–	300
200A	8,5 **(2)**	1900	300 **(2)**
250A	8,5 **(2)**	2500	300 **(2)**
300A	8,5 **(2)**	3200	300 **(2)**
350A	8,5 **(2)**	3800	300 **(2)**
400A	8,5 **(2)**	4500	300 **(2)**

(1) Brackets (see [9.1.9] items b) to h)) need not extend over the joint flange for the head.

(2) Brackets are required where the as fitted (gross) thickness is less than 10,5 mm, or where the tabulated projected head area is exceeded.

(3) Not permitted for new ships - see Tab 6.

Note 1: For other air pipe heights, the relevant requirements of [9.1.9] are to be applied.

Table 27 : 900 mm ventilator pipe thickness and bracket standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness, (mm)	Maximum projected area of head (cm^2)	Height of brackets (mm)
80A	6,3	–	460
100A	7,0	–	380
150A	8,5	–	300
200A	8,5	550	–
250A	8,5	880	–
300A	8,5	1200	–
350A	8,5	2000	–
400A	8,5	2700	–
450A	8,5	3300	–
500A	8,5	4000	–
Note 1: For other ventilator heights, the relevant requirements of [9.1.9], items b) to h), are to be applied.			

9.2 Sounding pipes

9.2.1 Principle

a) Sounding devices are to be fitted to tanks intended to contain liquids as well as to all compartments which are not readily accessible at all times.

b) For compartments normally intended to contain liquids, the following systems may be accepted in lieu of sounding pipes:
- a level gauge of an approved type efficiently protected against shocks, or
- a remote level gauging system of an approved type, provided an emergency means of sounding is available in the event of failure affecting such system.

9.2.2 Position of sounding pipes

Sounding pipes are to be located as close as possible to suction pipes.

9.2.3 Termination of sounding pipes

a) As a general rule, sounding pipes are to end above the bulkhead deck or the freeboard deck in easily accessible places and are to be fitted with efficient, permanently attached, metallic closing appliances.

b) In machinery spaces and tunnels, where the provisions of item a) cannot be satisfied, short sounding pipes led to readily accessible positions above the floor and fitted with efficient closing appliances may be accepted.

In ships required to be fitted with a double bottom, such closing appliances are to be of the self-closing type.

9.2.4 Special arrangements for sounding pipes of flammable oil tanks

a) Where sounding pipes are used in flammable (except lubricating) oil systems, they are to terminate in the open air, where no risk of ignition of spillage from the sounding pipe might arise. In particular, they are not to terminate in passenger or crew spaces. As a general rule, they are not to terminate in machinery spaces. However, where the Society considers that this requirement is impracticable, it may permit termination in machinery spaces on condition that the following provisions are satisfied:

1) in addition, an oil-level gauge is provided meeting the provisions of [2.9.2]

2) the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the fuel oil in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition

3) the terminations of sounding pipes are fitted with self-closing blanking devices and with a small diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that fuel oil is not present. Provision is to be made so as to ensure that any spillage of fuel oil through the control cock involves no ignition hazard.

b) For lubricating oil and fuel oil leakage tanks less than 2 m^3, the oil-level gauge mentioned in a) 1) and the control cock mentioned in a) 3) need not be provided on condition that the sounding pipes are fitted with appropriate means of closure.

c) Short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge provided an overflow system is fitted.

9.2.5 Closing appliances

a) Self-closing appliances are to be fitted with cylindrical plugs having counterweights such as to ensure automatic closing.

b) Closing appliances not required to be of the self-closing type may consist of a metallic screw cap secured to the pipe by means of a chain or a shut-off valve.

9.2.6 Construction of sounding pipes

a) Sounding pipes are normally to be straight. If it is necessary to provide bends in such pipes, the curvature is to be as small as possible to permit the ready passage of the sounding apparatus.

b) In cargo ships, the sounding arrangement of compartments by means of bent pipes passing through other compartments will be given special consideration by the Society. Such an arrangement is normally accepted only if the compartments passed through are cofferdams or are intended to contain the same liquid as the compartments served by the sounding pipes.

c) Bent portions of sounding pipes are to have reinforced thickness and be suitably supported.

d) The internal diameter of sounding pipes is not to be less than 32 mm. Where sounding pipes pass through refrigerated spaces, or through the insulation of refrigerated spaces in which the temperature may be below 0°C, their internal diameter is to be at least 60 mm.

e) Doubling plates are to be placed under the lower ends of sounding pipes in order to prevent damage to the hull. When sounding pipes with closed lower ends are used, the closing plate is to have reinforced scantlings.

9.3 Overflow pipes

9.3.1 Principle

Overflow pipes are to be fitted to tanks:

- which can be filled by pumping and are designed for a hydrostatic pressure lower than that corresponding to the height of the air pipe, or
- where the cross-sectional area of air pipes is less than that prescribed in [9.1.8], item d).

9.3.2 Design of overflow systems

a) Overflow pipes are to be led:

- either outside, or
- in the case of fuel oil or lubricating oil, to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

b) Where tanks containing the same or different liquids are connected to a common overflow system, the arrangement is to be such as to prevent any risk of:

- intercommunication between the various tanks due to movements of liquid when emptying or filling, or due to the inclination of the ship
- overfilling of any tank from another assumed flooded due to hull damage.

For this purpose, overflow pipes are to be led to a high enough point above the deepest load waterline or, alternatively, non-return valves are to fitted where necessary.

c) Arrangements are to be made so that a compartment cannot be flooded from the sea through the overflow in the event of another compartment connected to the same overflow main being bilged. To this end, the openings of overflow pipes discharging overboard are as a rule to be placed above the deepest load waterline and are to be fitted where necessary with non-return valves on the plating, or, alternatively, overflow pipes from tanks are to be led to a point above the deepest load waterline.

d) Where deep tanks which can be used to contain liquid or dry cargo or fuel oil are connected to a common overflow system, arrangements are to be made so that liquid or vapours from other compartments cannot enter such tanks when carrying dry cargo.

e) Where tanks alternately containing fuel oil and ballast water are connected to a common overflow system, arrangements are to be made to prevent the ballast water overflowing into the tanks containing fuel oil and vice-versa.

f) Additional requirements for ships subject to damage stability checks are given in [5.5.3].

9.3.3 Overflow tanks

a) Overflow tanks are to have a capacity sufficient to receive the delivery of the pumps for at least 10 minutes.

b) Overflow tanks are to be fitted with an air pipe complying with [9.1] which may serve as an overflow pipe for the same tank. When the vent pipe reaches a height exceeding the design head of the overflow tank, suitable means are to be provided to limit the actual hydrostatic head on the tank.

Such means are to discharge to a position which is safe in the opinion of the Society.

c) An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight-flow glass is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight-flow glasses are only to be placed on vertical pipes and in readily visible positions.

9.3.4 Specific arrangements for construction of overflow pipes

a) The internal diameter of overflow pipes is not to be less than 50 mm.

b) In each compartment which can be pumped up, the total cross-sectional area of overflow pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

c) The cross-sectional area of the overflow main is to be sufficient to allow the two largest pipes to discharge simultaneously into the main. Where tanks are served by a common filling pipeline and their overflow pipes are discharging into a main overflow dedicated only to these tanks, the cross sectional area of the main overflow pipe is not to be less than 1,25 times the area of the common filling pipeline of these tanks.

d) Sight glasses may be accepted on overflow lines from fuel oil and lubricating oil systems, provided that:

- they are located in a vertically dropping line on readily visible and well lit position
- they are protected against mechanical damages
- the glass is of heat resisting type.

9.4 Constructional requirements applying to sounding, air and overflow pipes

9.4.1 Materials

a) Sounding, air and overflow pipes are to be made of steel or any other material approved for the application considered.

b) Exposed parts of sounding, air and overflow pipes are to be made of approved metallic materials.

9.4.2 Minimum thickness of steel pipes

The minimum thickness of sounding, air and overflow steel pipes is given in Tab 6. See also [9.1.9].

9.4.3 Passage of pipes through certain spaces

a) Air pipes and sounding pipes led through refrigerated cargo holds or spaces are to be suitably insulated.

b) When sounding, air and overflow pipes made of steel are permitted to pass through ballast tanks or fuel oil tanks, they are to be of reinforced thickness, in accordance with Tab 6.

c) Sounding, air and overflow pipes passing through cargo holds are to be adequately protected.

9.4.4 Self-draining of pipes

Air pipes and overflow pipes are to be so arranged as to be self-draining when the ship is on an even keel.

9.4.5 Name plates

Nameplates are to be fixed at the upper part of air pipes and sounding pipes.

10 Cooling systems

10.1 Application

10.1.1 This article applies to all cooling systems using the following cooling media:

- sea water
- fresh water
- lubricating oil.

Air cooling systems will be given special consideration.

10.2 Principle

10.2.1 General

Sea water and fresh water cooling systems are to be so arranged as to maintain the temperature of the cooled media (lubricating oil, hydraulic oil, charge air, etc.) for propulsion machinery and essential equipment within the manufacturers' recommended limits during all operations, including starting and manoeuvring, under the inclination angles and the ambient conditions specified in Ch 1, Sec 1.

10.2.2 Availability of the cooling system

The cooling system is to be so designed that, in the event of one essential component being inoperative, the cooling of propulsion machinery is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

10.3 Design of sea water cooling systems

10.3.1 General

a) Sea water cooling of the propulsion engines, auxiliary engines and other essential equipment is to be capable of being supplied by two different means.

b) Where required, standby pumps are not to be connected to the sea inlet serving the other sea water pumps, unless permitted under [10.7.1], item b).

10.3.2 Centralised cooling systems

a) In the case of centralised cooling systems, i.e. systems serving a group of propulsion engines and/or auxiliary engines, reduction gears, compressors and other essential equipment, the following sea water pumps and heat exchangers are to be arranged:

- one main cooling water pump, which may be driven by the engines, of a capacity sufficient to provide cooling water to all the equipment served
- one independently driven standby pump of at least the same capacity
- two heat exchangers, each having at least 50% of the total capacity necessary to provide cooling water to all the equipment served.

b) Where the cooling system is served by a group of identical pumps, the capacity of the standby pump needs only to be equivalent to that of each of these pumps.

c) Ballast pumps or other suitable sea water pumps of appropriate capacity may be used as standby pumps, provided arrangements are made against overpressure in the cooling system.

d) In ships having one or more propulsion engines, each with an output not exceeding 375 kW, the independent standby pump may be replaced by a complete spare pump of appropriate capacity ready to be connected to the cooling circuit.

e) In cases of centralised cooling systems serving only a group of auxiliary engines, the second means of cooling may consist of a connection to a cooling water pump serving the propulsion plant, provided such pump is of sufficient capacity to provide cooling water to both propulsion plant and auxiliary engines.

10.3.3 Individual cooling of propulsion engines

a) Individual cooling systems of propulsion engines are to include at least:

- one main cooling water pump, which can be driven by the engine
- one independently driven standby pump
- one heat exchanger of appropriate capacity.

Where the output of the engine does not exceed 375 kW, the following arrangements may be accepted:

- one main cooling water pump, which can be driven by the engine
- one spare pump of appropriate capacity ready to be connected to the cooling circuit
- one heat exchanger of appropriate capacity.

b) Where, in ships having more than one engine per propeller or having several propellers, each engine is served by its own cooling circuit, the second means requested in [10.3.1] is to be provided, consisting of:

- a connection to an independently driven pump, such as a ballast pump or any other suitable sea water pump of sufficient capacity provided arrangements against overpressure in the cooling system are made. (See [10.7.4], item b)), or
- a complete spare pump identical to those serving the engines and ready to be connected to the cooling circuit.

This second means may be omitted, however, when safety justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with one cooling circuit disabled.

10.3.4 Individual cooling of auxiliary engines

Where each auxiliary engine is served by its own cooling circuit, no second means of cooling is required.

10.3.5 Cooling of steam plants

a) Steam plants are to be fitted with:

- a main circulating pump
- a standby pump capable of ensuring the circulation in the main condenser in the event of failure of the main circulating pump.

b) Where the installation includes more than one propulsive unit, the standby pump is not required, provided a branch pipe is fitted between the discharges of the circulating pumps of each unit.

c) In lieu of the main circulating pump, a sea inlet scoop system may be accepted, provided that an additional means is fitted to ensure the circulation of sea water to the condenser when the ship is manoeuvring. Such means may be:

- an additional independent pump, or
- a connection to an available pump of sufficient capacity.

10.3.6 Cooling of other essential equipment

a) The second means of cooling required in [10.3.1] for essential equipment may consist of a connection to a ballast pump or other suitable sea water pump of sufficient capacity, provided arrangements are made against overpressure in the cooling system (see [10.7.4], item b)).

b) However, where such essential equipment is duplicate, this second means may be omitted when justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with the cooling circuit of one set of equipment disabled.

10.4 Design of fresh water cooling systems

10.4.1 General

Fresh water cooling systems are to be designed according to the applicable requirements of [10.3].

10.4.2 Cooling systems

a) Fresh water cooling systems of essential equipment are to include at least:
- one main cooling water pump, which can be driven by the equipment
- one independently driven standby pump.

b) The standby pump may be omitted provided an emergency connection to a suitable sea water system is fitted and arranged with a suitable change-over device. Provisions against overpressure in the cooling system are to be made in accordance with [10.7.4], item b).

c) The standby pump may also be omitted in the case of redundancy of the cooled equipment.

10.4.3 Expansion tanks

Fresh water expansion tanks are to be provided with at least:

- a de-aerating device
- a water level indicator
- a filling connection
- a drain.

10.4.4 Protection of contamination by oil

Suitable means are to be provided in fresh water cooling systems comprising fuel oil or lubricating oil heat exchangers in order to detect any contamination of the water by fuel oil or lubricating oil.

If cooling water is used for heating of oil, the heating coils are to be located on the pressure side of the cooling pumps and connected by welding, with no detachable connections where mixing of oil and water may occur. Alternatively a primary and secondary system arrangement may be used.

10.5 Design of oil cooling systems

10.5.1 General

Oil cooling systems are to be designed according to the applicable requirements of [10.3].

10.5.2 Second means of cooling

The second means of cooling requested in [10.3.1] may consist of a satisfactory connection to a lubricating oil pump of sufficient capacity. Arrangements are to be made against overpressure in the cooling system.

10.6 Control and monitoring

10.6.1 Alarms are to be provided for water cooling systems in accordance with Tab 28, in addition to the requirements stated for diesel engines in Ch 1, Sec 2 and for steam plants in Ch 1, Sec 4.

Note 1: Some departures from Tab 28 may be accepted by the Society in the case of ships with a restricted navigation notation.

Table 28 : Cooling systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water pump pressure or flow	L	local					
Fresh water pump pressure or flow	L	local					
Level in cooling water expansion tank	L	local					

10.7 Arrangement of cooling systems

10.7.1 Sea inlets

a) At least two sea inlets complying with [2.8] are to be provided for the cooling system, one for each means of cooling required in [10.3.1].

b) The two sea inlets may be connected by a cross-over supplying both main cooling pump and standby cooling pump.

c) When the second means of cooling is a spare pump, the two sea inlets are to be provided in any event, both serving the main cooling pump.

d) The sea inlets are to be low inlets, so designed as to remain submerged under all normal navigating conditions.

In general, one sea inlet is to be arranged on each side of the ship.

e) One of the sea inlets may be that of the ballast pump or of the general service pump.

10.7.2 Coolers

a) Coolers are to be fitted with isolating valves at the inlets and outlets.

b) Coolers external to the hull (chest coolers and keel coolers) are to be fitted with isolating valves at the shell.

10.7.3 Filters

a) Where propulsion engines and auxiliary engines for essential services are directly cooled by sea water, both in normal service and in emergency operating conditions, filters are to be fitted on the suction of cooling pumps.

b) These filters are to be so arranged that they can be cleaned without interrupting the cooling water supply.

10.7.4 Pumps

a) Cooling pumps for which the discharge pressure may exceed the design pressure of the piping system are to be fitted with relief valves in accordance with [2.5].

b) Where general service pumps, ballast pumps or other pumps may be connected to a cooling system, arrangements are to be made, in accordance with [2.5], to avoid overpressure in any part of the cooling system.

10.7.5 Air venting

Cocks are to be installed at the highest points of the pipes conveying cooling water to the water jackets for venting air or gases likely to accumulate therein. In the case of closed fresh water cooling systems, the cock is to be connected to the expansion tank.

11 Fuel oil systems

11.1 Application

11.1.1 Scope

This Article applies to all fuel oil systems supplying any kind of installation.

The fuel oils used on board are to comply with Ch 1, Sec 1, [2.12].

11.1.2 Requirements applying to fuel oil systems and not contained in this Section

Additional requirements are given:

- for fuel oil supply equipment forming part of engines, gas turbines, boilers, thermal heaters and incinerators, in the corresponding sections
- for the installation of purifiers, in Part C, Chapter 4,
- for the location and scantling of tanks forming part of the ship's structure, in Part B, Chapter 2 and Part B, Chapter 7
- for auxiliary vehicles refuelling facilities, in Ch 4, Sec 11.

11.2 Principle

11.2.1 General

a) Fuel oil systems are to be so designed as to ensure the proper characteristics (purity, viscosity, pressure) of the fuel oil supply to engines and boilers.

b) Fuel oil systems are to be so designed as to prevent:

- overflow or spillage of fuel oil from tanks, pipes, fittings, etc.
- fuel oil from coming into contact with sources of ignition
- overheating and seizure of fuel oil.

c) Fuel oils used for engines and boilers are to have a flashpoint complying with the provisions of Ch 1, Sec 1, [2.12].

11.2.2 Availability of fuel systems

a) Fuel oil systems are to be so designed that, in the event that any one essential auxiliary of such systems becomes inoperative, the fuel oil supply to boilers and engines can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) Fuel oil tanks are to be so arranged that, in the event of damage to any one tank, complete loss of the fuel supply to essential services does not occur.

c) Where engines and boilers are operated with heavy fuel oils, provisions are to be made to supply them with fuel oils which do not need to be heated.

11.3 General

11.3.1 Arrangement of fuel oil systems

a) In a ship in which fuel oil is used, the arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

b) The provisions of [5.10] are to be complied with.

11.3.2 Valve for oil fuel pumps

Stop valves or cocks are to be fitted on both suction and delivery sides of oil fuel pumps. All oil fuel pumps are to be provided with pressure relief valves on the discharge side so that the discharged oil may be led to the suction side of the pump. Pressure relief valves need not be fitted when the system is served only by centrifugal pumps, so designed that the pressure delivered cannot exceed that for which the piping is designed.

11.3.3 Provision to prevent overpressure

Provisions are to be made to prevent overpressure in any oil tank or in any part of the fuel oil system. Any relief valve is to discharge to a safe position.

11.3.4 Ventilation

The ventilation of machinery spaces is to be sufficient under all normal conditions to prevent accumulation of oil vapour.

11.3.5 Access

Spaces where fuel oil is stored or handled are to be readily accessible.

11.4 Design of fuel oil filling and transfer systems

11.4.1 General

a) A system of pumps and piping for filling and transferring fuel oil is to be provided.

b) Provisions are to be made to allow the transfer of fuel oil from any storage, settling or service tank to another tank.

11.4.2 Filling systems

a) Filling pipes of fuel oil tanks are to terminate on open deck or in filling stations isolated from other spaces and efficiently ventilated. Suitable coamings and drains are to be provided to collect any leakage resulting from filling operations.

The means shall be provided for the filling lines to prevent of possible overpressure during the bunkering operation, which could be caused by pumps from outboard filling station. For that purpose a warning label may be accepted with clearly declared design pressure of the filling lines and the local pressure gauge fitted in vicinity of the filling connection.

b) Arrangements are to be made to avoid overpressure in the filling lines which are served by pumps on board. Where safety valves are provided for this purpose, they are to discharge to the overflow tank referred to in [9.3.3] or to other safe positions deemed satisfactory.

11.4.3 Independence of fuel oil transfer lines

Except where permitted in [11.4.4], the fuel oil transfer piping system is to be completely separate from the other piping systems of the ship.

11.4.4 Alternative carriage of fuel oil, ballast water or other liquid and dry cargo

Where certain compartments are likely to contain alternatively fuel oil, ballast water and other liquid or dry cargo, the transfer pipes supplying these compartments are to be fitted with blind flanges or other appropriate change-over devices.

11.4.5 Transfer pumps

a) At least two means of transfer are to be provided. One of these means is to be a power pump. The other may consist of:

- a standby pump, or, alternatively,
- an emergency connection to another suitable power pump.

Note 1: Where provided, purifiers may be accepted as means of transfer.

b) Where necessary, transfer pumps are to be fitted on their discharge side with a relief valve leading back to the suction of the pump or to any other place deemed satisfactory.

11.5 Arrangement of fuel oil tanks and bunkers

11.5.1 Location of fuel oil tanks

a) No fuel oil tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

b) Fuel oil tanks and bunkers are not to be situated immediately above boilers or in locations where they could be subjected to high temperatures, unless specially agreed by the Society. In general, the distance between fuel oil tanks and boilers is not to be less than 450 mm. Where boilers are situated above double bottom fuel oil tanks, the distance between the double bottom tank top and the lower metallic part of the boilers is not to be less than:

- 750 mm for water tube boilers
- 600 mm for cylindrical boilers.

c) As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where such tanks are situated within the boundaries of machinery spaces of category A, they are not to contain fuel oil having a flashpoint of less than 60°C.

Note 1: Machinery spaces of category A are defined in Ch 4, Sec 1.

d) The location of fuel oil tanks is to be in compliance with the requirements of Part B, Chapter 2, particularly as regards the installation of cofferdams, the separation between fuel oil tanks or bunkers and the other spaces of the ship, and the protection of these tanks and bunkers against any abnormal rise in temperature.

e) Attention is drawn to the requirements of Pt D, Ch 7, Sec 4 regarding the segregation of fuel bunkers from the cargo area.

11.5.2 Use of free-standing fuel oil tanks

a) In general the use of free-standing fuel oil tanks is to be avoided except on cargo ships, where their use is permitted in category A spaces.

b) For the design and the installation of independent tanks, refer to Pt B, Ch 5, Sec 6 and Part B, Chapter 7.

11.5.3 Protection against oil pollution in the event of collision or grounding

a) Application

The provisions of [11.5.3] apply to all ships with an aggregate oil fuel capacity of 600 m^3 and above.

They apply to all oil fuel tanks except small oil fuel tanks with a maximum individual capacity not exceeding 30 m^3, provided that the aggregate capacity of such excluded tanks is not greater than 600 m^3.

Note 1: For the purpose of application of this requirement, oil fuel means any oil used as fuel oil in connection with the propulsion and auxiliary machinery of the ship in which such oil is carried.

Note 2: The provisions of this requirement apply to oil fuel overflow tanks except if they are provided with an alarm for detection of oil and kept empty according to the operational procedures.

b) Maximum capacity of oil fuel tanks

Individual oil fuel tanks are not to have a capacity of over 2500 m^3.

c) Oil fuel tank protection

For ships having an aggregate oil fuel capacity of 600 m^3 and above, oil fuel tanks are to be located at a sufficient distance from the bottom shell plating and from the side shell plating in accordance with the relevant provisions of MARPOL 73/78, Annex I, Regulation 12A.

d) Suction wells

Suction wells in oil fuel tanks may protrude in the double bottom provided that the conditions stated in MARPOL 73/78, Annex I, Regulation 12A.10 are satisfied.

e) Valves

Lines of fuel oil piping located at a distance from the ship's bottom or from the ship's side less than those referred to in item c) are to be fitted with valves or similar closing devices within, or immediately adjacent to, the oil fuel tank. These valves are to be capable of being brought into operation from a readily accessible enclosed space the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. The valves are to close in case of remote control system failure and are to be kept closed at sea at any time when the tank contains oil fuel except that they may be opened during oil fuel transfer operations.

11.6 Design of fuel oil tanks and bunkers

11.6.1 General

Tanks such as collector tanks, de-aerator tanks etc. are to be considered as fuel oil tanks for the purpose of application of this sub-article, and in particular regarding the valve requirements.

Tanks with a volume lower than 500 l will be given special consideration by the Society.

11.6.2 Scantlings

The scantlings of fuel oil tanks and bunkers are to comply with the requirements stated in Part B, Chapter 7.

11.6.3 Filling and suction pipes

a) All suction pipes from fuel oil tanks and bunkers, including those in the double bottom, are to be provided with valves.

b) For storage tanks, filling pipes may also be used for suction purposes.

c) For fuel oil tanks located above the double bottom, filling pipes which are not led to the upper part of such tanks, are to be provided with non-return valves, unless they are fitted with valves arranged in accordance with the requirements stated in [11.6.4].

d) For oil piping which is led through engine room bulkheads, shut-off valves are to be fitted in the engine room on the bulkhead, or close to, except where it is demonstrated that possible failure of the piping would not affect the availability of the fuel oil system or the safety of engine room, in general.

e) The valves requested in items a), c) and d) shall be located on the tank or bulkhead itself. However, short distance pieces of reinforced wall thickness as per Tab 6 may be accepted and are to be kept as short as possible.

f) For filling lines entering at the top of a tank and with inside extension towards the bottom, airholes are to be drilled in the pipe near the penetration in order to avoid the siphoning effect.

g) As an alternative to the requirement of shut-off non-return valves of item c), the tank may be fitted with an overflow alarm below the filling line and means, such as a procedure, are to be provided to ensure that the tank will not be filled above this level.

11.6.4 Remote control of valves

a) Every fuel oil pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank having a capacity of 500 l and above situated above the double bottom, is to be fitted with a cock or valve directly on the tank capable of being closed from a safe position outside the space in which such tanks are situated in the event of a fire occurring in such space.

Note 1: For the location of the remote controls, refer to [11.10.3], item c).

b) Such valves and cocks are also to include local control. Indicators are to be provided on the remote and local controls to show whether they are open or shut (see [2.7.3]). Where quick-closing valves are used, the indicators for remote controls may be omitted.

c) In the special case of deep tanks situated in any shaft or pipe tunnel or similar space, valves are to be fitted on the tank but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

Note 2: For cargo ships of less than 500 gross tonnage and non-propelled ships where the fuel oil transfer installation is designed for manual operation, suction valves from fuel oil tanks and bunkers, with the exception of daily service tanks, need not be arranged with remote controls provided they are maintained closed except during transfer operations. Such valves are, however, to be readily accessible and instruction plates are to be fitted in their vicinity specifying that they are to be kept closed except during transfer operations.

11.6.5 Drain pipes

Where fitted, drain pipes are to be provided with self-closing valves or cocks.

11.6.6 Air and overflow pipes

Air and overflow pipes are to comply with [9.1] and [9.3].

11.6.7 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of fuel oil contained in any fuel oil tank are to be provided.

b) Sounding pipes of fuel oil tanks are to comply with the provisions of [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

11.7 Design of fuel oil heating systems

11.7.1 General

a) Where heavy fuel oil is used, a suitable heating system is to be provided for storage tanks, settling tanks and service tanks in order to ensure that the fuel oil has the correct fluidity and the fuel pumps operate efficiently.

b) Where necessary for pumping purposes, storage tanks containing heavy fuel oil are to be provided with heating systems.

c) Where necessary, pumps, filters, pipes and fittings are to be provided with heat tracing systems.

d) Where main or auxiliary engines are supplied with fuel oil which needs to be heated, arrangements are to be made so that the engines can still operate if one oil heating system or the heating power source is out of action. Such arrangements may consist of an alternative supply of the engines in accordance with [11.9.2].

11.7.2 Tank heating systems

a) Oil fuel in storage tanks are not to be heated to temperatures within 10°C below the flashpoint of the fuel oil, except that, where oil fuel in service tanks, settling tanks and any other tanks in supply system is heated, the following arrangements are to be provided:
- the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to below 60°C, or the outlet of the vent pipes is located 3 m away from a source of ignition
- the vent pipes are fitted with flame screens
- there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable)
- enclosed spaces are not to be located directly over such fuel tanks, except for vented cofferdams
- electrical equipment is not to be fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

b) The temperature of the heating medium is not to exceed 220°C.

c) Automatic control sensors are to be provided for each heated tank to maintain the temperature of the fuel oil below the limits prescribed in item a).

For storage tanks, the manual control may be accepted subject to special consideration by the Society in each case.

d) Heated tanks are to be provided with temperature measuring systems.

e) The heating coils inlet and outlet connections at the tank are to be fitted with suitable means for closing. For steam heating coils, additional means are to be provided between tank outlet and closing device to enable testing the condensate for presence of oil.

Heating pipes and coils inside the tanks are to be of material suitable for the heated fluid.

For steel pipes, the thickness is not to be less than the values given in column 4, with Note (4), of Tab 6.

The heating coils within the tanks are to have welded connections and are to be supported in such a way that they are not subject to non permissible stress due to vibration or thermal extension.

11.7.3 Fuel oil heaters

a) Where steam heaters or heaters using other heating media are provided in fuel oil systems, they are to be fitted with at least a high temperature alarm or a low flow alarm in addition to a temperature control, except where temperatures dangerous for the ignition of the fuel oil cannot be reached.

b) Electric heating of fuel oil is to be avoided as far as practicable.

c) However, when electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In all cases a safety temperature switch is to be fitted in order to avoid a surface temperature of 220°C and above. It is to be:
- independent from the automatic control sensor
- designed to cut off the electrical power supply in the event of excessive temperature
- provided with manual reset.

d) Fuel oil heaters are to be fitted with relief valves leading back to the pump suction concerned or to any other place deemed satisfactory.

11.8 Design of fuel oil treatment systems

11.8.1 General

a) Heavy fuel oils used in diesel engines are to be purified and filtered according to the engine manufacturer's requirements.

b) Provisions are to be made to avoid inadvertent entry of non-purified heavy fuel into the daily service tanks, in particular through the overflow system.

Note 1: The "fuel oil treatment system" does not cover the use of additives.

11.8.2 Drains

a) Settling tanks or, where settling tanks are not provided, daily service tanks, are to be provided with drains permitting the evacuation of water and impurities likely to accumulate in the lower part of such tanks.

b) Efficient means are to be provided for draining oily water escaping from the drains.

11.8.3 Purifiers

a) Where fuel oil needs to be purified, at least two purifiers are to be installed on board, each capable of efficiently purifying the amount of fuel oil necessary for the normal operation of the engines.

Note 1: On ships with a restricted navigation notation where fuel oil needs to be purified, one purifier only may be accepted.

b) Subject to special consideration by the Society, the capacity of the standby purifier may be less than that required in a), depending on the arrangements made for the fuel oil service tanks to satisfy the requirement in [11.9.2].

c) The standby purifier may also be used for other services.

d) Each purifier is to be provided with an alarm in case of failures likely to affect the quality of the purified fuel oil.

e) Fuel oil purifiers are to be installed as required in Part C, Chapter 4.

11.9 Design of fuel supply systems

11.9.1 General

a) Except otherwise specified, the propulsion machinery and auxiliary engines which are able to use the same type of fuel may be supplied from the same fuel source, provided that the following is satisfied:

- the viscosity, inlet pressure and outlet pressure required by the engine's manufacturer are to be identical
- the fuel oil preparation unit is to comply with the provisions of [11.9.4]
- the capacity of fuel oil preparation unit is to be sufficient for maximum continuous rating of all supplied engines in normal working conditions
- the fuel oil lines supplying propulsion machinery and those supplying auxiliary engines are to be so arranged that a failure within one of those lines is not to render the other lines inoperable
- the arrangement to stop propulsion from outside the machinery spaces is not to affect the main electrical power supply.

See also Part F for requirements associated with the applicable additional class notations.

b) In ships where heavy fuel oil and marine diesel oil are used, a change-over system from one fuel to the other is to be provided. This system is to be so designed as to avoid:

- overheating of marine diesel oil
- inadvertent ingress of heavy fuel oil into marine diesel oil tanks.

c) When necessary, arrangements are to be made for cooling the marine diesel oil from engine return lines.

11.9.2 Fuel oil service tanks

a) For the application of the below requirements, any fuel oil which requires post service tank heating to achieve the required injection viscosity is not regarded as Marine Diesel Oil (MDO).

b) A service tank is a fuel oil tank which contains only fuel of a quality ready for use i.e. fuel of a grade and quality that meet the specification required by the equipment manufacturer. A service tank is to be declared as such and not to be used for any other purpose.

c) In general, two fuel oil service tanks for each type of fuel used on board necessary for propulsion and vital systems, or equivalent arrangements, are to be provided. Each tank is to have a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

d) For “one fuel ship”, where main and auxiliary engines and boiler(s) are operated with Heavy Fuel Oil (HFO), the arrangements complying with this regulation or acceptable "equivalent arrangements" shall be provided.

The arrangements complying with this regulation shall comprise at least the following tanks:

- two (2) HFO service tanks, each of a capacity sufficient for at least 8 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), and
- one (1) Marine Diesel Oil (MDO) service tank for initial cold starting or repair work of engines or boilers.

Acceptable “equivalent arrangements” shall comprise at least:

- one (1) HFO service tank with a capacity sufficient for at least 8 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), and
- one (1) MDO service tank with a capacity sufficient for at least 8 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), and
- for pilot burners of auxiliary boilers, if provided, an additional MDO service tank for 8 h may be required.

This arrangement only applies where main and auxiliary engines can operate with HFO under all load conditions and, in the case of main engines, during manoeuvring.

e) Where main engines and auxiliary boiler(s) are operated with Heavy Fuel Oil (HFO) and auxiliary engines are operating with Marine Diesel Oil (MDO), the arrangements complying with this regulation or acceptable "equivalent arrangements" shall be provided.

The arrangements complying with this regulation shall comprise at least the following tanks:

- two (2) HFO service tanks, each of a capacity sufficient for at least 8 h operation of main engine(s) and auxiliary boiler(s), and
- two (2) MDO service tanks each of a capacity sufficient for at least 8 h operation of auxiliary engines.

Acceptable “equivalent arrangements” shall comprise at least:

- one (1) HFO service tank with a capacity sufficient for at least 8 h operation of main engine(s) and auxiliary boiler(s), and
- two (2) MDO service tanks, each of a capacity sufficient for:
  - 4 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), or
  - 8 h operation of auxiliary engines and auxiliary boiler(s).

f) The “equivalent arrangements” in items d) and e) apply, provided the propulsion and vital systems using two types of fuel support rapid fuel change over and are capable of operating in all normal operating conditions at sea with both types of fuel (MDO and HFO).

g) The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

h) The use of a settling tank with or without purifiers, or purifiers alone, and one service tank is not acceptable as an “equivalent arrangement” to two service tanks.

Note 1: This requirement [11.9.2] need not be applied to cargo ships of less than 500 gross tonnage and non-propelled ships.

11.9.3 Fuel oil supply to boilers

a) In ships where boilers burning oil under pressure are installed to supply steam to the propulsion machinery or auxiliary machinery serving essential services, the fuel oil supply system is to include at least the following equipment:

- Two independently driven fuel oil service pumps, each one of a capacity sufficient to supply the boilers at their rated output. The pumps are to be arranged such that one may be overhauled while the other is in service.
- Filters or strainers fitted on the suction lines and so arranged that they can be cleaned without interrupting the fuel supply. For that purpose, two filters or strainers fitted in parallel, or one duplex type with a change over facility, may be accepted.
- Two heaters in the case that fuel oil heating is required, each one of a capacity sufficient to supply heated fuel oil to the boilers at their normal operating capacity. The heaters are to be arranged such that one may be overhauled while the other is in service.

For boiler plants where exhaust gas boiler is fitted, such that steam service essential for propulsion can be supplied without the operation of the fuel oil system of the auxiliary boiler and that other essential services, as defined in Pt A, Ch 1, Sec 1, [1.2.1], are not to remain inoperable, only one fuel oil heater may be accepted.

b) The fuel oil supply system is to be capable of supplying the fuel oil necessary to generate enough steam for propulsion purposes and essential services with one unit out of action.

c) A quick-closing valve is to be provided on the fuel supply to the burners of each boiler, arranged to be easily operated in case of emergency, either directly or by remote control.

d) The fuel supply to the burners is to be capable of being automatically cut off when required under Ch 1, Sec 3, [5.1.8].

e) Burners are to comply with Ch 1, Sec 3, [3.2.6].

f) Where burners are provided with fuel oil flow-back to the pump suctions or other parts under pressure, non-return devices are to be provided to prevent fuel oil from flowing back to the burners when the oil supply is cut off.

g) Where fuel oil is supplied to the burners by gravity, a double filter satisfying the provisions of item a) is to be provided in the supply line.

h) Fuel oil supply systems are to be entirely separate from feed, bilge, ballast and other piping systems.

11.9.4 Fuel oil supply to internal combustion engines

a) The suctions of engine fuel pumps are to be so arranged as to prevent the pumping of water and sludge likely to accumulate after decanting at the lower part of service tanks.

b) Internal combustion engines intended for main propulsion are to be fitted with at least two filters, or similar devices, so arranged that one of the filters can be overhauled while the other is in use.

Note 1: Where the propulsion plant consists of:

- two or more engines, each one with its own filter, or
- one engine with an output not exceeding 375 kW,

the second filter may be replaced by a readily accessible and easily replaceable spare filter.

c) Oil filters fitted in parallel are to be so arranged as to minimise the possibility of a filter under pressure being opened by mistake.

Filter chambers are to be provided with suitable means for:

- venting when put into operation
- de-pressurising before being opened.

Valves or cocks used for this purpose are to be fitted with drain pipes led to a safe location.

d) Oil filters are to be so located that in the event of a leakage the fuel oil cannot be pulverised onto the exhaust manifold.

e) When a fuel oil booster pump is fitted which is essential to the operation of the main engine, a standby pump, connected ready for immediate use, is to be provided.

The standby pump may be replaced by a complete spare pump of appropriate capacity ready to be connected, in the following cases:

- where two or more main engines are fitted, each with its own booster pump
- in ships having main engines each with an output not exceeding 375 kW.

f) Where fuel oils require pre-heating in order to have the appropriate viscosity when being injected in the engine, the following equipment is to be provided in the fuel oil line:
   - one viscosity control and monitoring system
   - two pre-heaters, one serving as a standby for the other.

g) Excess fuel oil from pumps or injectors is to be led back to the service or settling tanks, or to other tanks intended for this purpose.

h) De-aeration tanks fitted in pressurised fuel oil return lines are to be equipped with at least:
   - an automatic venting valve or equivalent device discharging to the daily service tank or to other safe place deemed satisfactorily having a device for flow detection.
   - a non-return valve in the return line from the engines.

i) For high pressure fuel oil pipes and other components which may be built-in or attached to the engine, see Ch 1, Sec 2, [2.5].

   Anyhow, the components of a diesel engine fuel oil system are to be designed considering the maximum peak pressure which will be experienced in service, including any high pressure pulses which are generated and transmitted back into the fuel supply and spill lines by the action of fuel injection pumps.

j) Connections within the fuel supply and spill lines are to be constructed having regard to their ability to prevent pressurised fuel oil leaks while in service and after maintenance.

k) In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. The means of isolation are not to affect the operation of the other engines and shall be operable from a position not rendered inaccessible by a fire on any of the engines.

11.10 Control and monitoring

11.10.1 Monitoring

Alarms and safeguards are to be provided for fuel oil systems in accordance with Tab 29.

Note 1: Some departures from Tab 29 may be accepted by the Society in the case of ships with a restricted navigation notation.

11.10.2 Automatic controls

Automatic temperature control is to be provided for:

- steam heaters or heaters using other media
- electric heaters.

11.10.3 Remote controls

a) The remote control arrangement of valves fitted on fuel oil tanks is to comply with [11.6.4].

b) The power supply to:
   - fuel oil burning pumps
   - transfer pumps and other pumps of the fuel oil system, and
   - fuel oil purifiers,

   is to be capable of being stopped from a position within the space containing the pumps and from another position located outside such space and always accessible in the event of fire within the space.

c) Remote control of the valve fitted to the emergency generator fuel tank is to be in a separate location from that of other valves fitted to tanks in the engine room.

   "Separate location" does not mean separate spaces.

d) The positions of the remote controls are also to comply with Part C, Chapter 3.

11.11 Construction of fuel oil piping systems

11.11.1 Materials

a) Fuel oil pipes and their valves are to be of steel or other approved material, except that the use of flexible pipes may be accepted provided they comply with [2.6.4].

b) The materials and/or their surface treatment used for the storage and distribution of oil fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel. In addition to the criterion given in Tab 5, the use of copper or zinc compounds in oil fuel distribution and utilisation piping is not permitted except for small diameter pipes in low pressure systems.

11.11.2 Pipe thickness

The thickness of pipes conveying heated fuel oil, as well as their flanges, is to be calculated for a design pressure determined in accordance with Tab 4.

Table 29 : Fuel oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil overflow tank level	H **(1)**						
Air pipe water trap level on fuel oil tanks	H **(2)**						
Fuel oil temperature after heaters	H **(4)**	local		X **(5)**			
Sludge tank level		local					
Fuel oil settling tank temperature	H **(3)**	local					
Fuel oil level in daily service tank	L+H **(1)**	local					
Fuel oil daily service tank temperature	H **(3)**	local					

(1) Or sightglasses on the over flow pipe, see [9.3.4], item d).
(2) Or alternative arrangement as per [9.1.7], item c).
(3) Applicable where heating arrangements are provided.
(4) Or low flow alarm in addition to temperature control when heated by steam or other media.
(5) Cut off of electrical power supply when electrically heated.

11.11.3 Pipe connections

a) Connections and fittings of pipes containing fuel oil are to be suitable for a design pressure according to Tab 3 and Tab 4.

b) Connections of pipes conveying heated fuel oil are to be made by means of close-fitting flanges, with joints made of a material impervious to oil heated to 160°C and as thin as possible.

11.12 Arrangement of fuel oil piping systems

11.12.1 Passage of fuel oil pipes through tanks

a) Fuel pipes are not to pass through tanks containing boiler feed water, fresh water, other flammable oil or liquid cargo, unless they are contained within tunnels.

b) Transfer pipes passing through ballast tanks are to have a reinforced thickness complying with Tab 6.

11.12.2 Passage of pipes through fuel oil tanks

Boiler feed water, fresh water or liquid cargo pipes are not to pass through fuel oil tanks, unless such pipes are contained within tunnels.

11.12.3 Segregation of fuel oil purifiers

Purifiers for heated fuel oil are to be in accordance with Ch 4, Sec 6, [4.1.2].

12 Lubricating oil systems

12.1 Application

12.1.1 This Article applies to lubricating oil systems serving diesel engines, steam and gas turbines, reduction gears, clutches and controllable pitch propellers, for lubrication or control purposes.

It also applies to separate oil systems intended for the cooling of engine pistons.

12.2 Principle

12.2.1 General

a) Lubricating oil systems are to be so designed as to ensure reliable lubrication of the engines, turbines and other equipment, including electric motors, intended for propulsion:
   - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
   - for all the inclinations angles stated in Ch 1, Sec 1

b) Lubricating oil systems are to be so designed as to ensure sufficient heat transfer and appropriate filtration of the oil.

c) Lubricating oil systems are to be so designed as to prevent oil from entering into contact with sources of ignition.

12.2.2 Availability

a) Lubricating oil systems are to be so designed that, in the event that any one pump is inoperative, the lubrication of the engines and other equipment is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) An emergency lubricating system, such as a gravity system, is to be provided to ensure sufficient lubrication of equipment which may be damaged due to a failure of the pump supply.

12.3 General

12.3.1 Arrangement of lubricating oil systems

a) The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems are to be such as to ensure the safety of the ship and persons on board.

b) The provisions of [5.10] are to be complied with, where applicable.

12.3.2 Filtration

a) In forced lubrication systems, a device is to be fitted which efficiently filters the lubricating oil in the circuit.

b) The filters provided for this purpose for main machinery and machinery driving electric propulsion generators are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

c) The fineness of the filter mesh is to comply with the requirements of the engine or turbine manufacturers.

d) Where filters are fitted on the discharge side of lubricating oil pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

12.3.3 Purification

Where lubricating oil needs to be purified, the arrangement of the purifiers are to comply with [11.8.3].

12.3.4 Heat transfer

Lubricating oil heaters are to comply with [11.7.3].

12.4 Design of engine lubricating oil systems

12.4.1 Lubrication of propulsion engines

a) Main engines are to be provided with at least two power lubricating pumps, of such a capacity as to maintain normal lubrication with any one pump out of action.

b) In the case of propulsion plants comprising:

- more than one engine, each with its own lubricating pump, or
- one engine with an output not exceeding 220 kW, one of the pumps mentioned in item a) may be a spare pump ready to be connected to the lubricating oil system, provided disassembling and reassembling operations can be carried out on board in a short time.

12.4.2 Lubrication of auxiliary engines

a) For auxiliary engines with their own lubricating pump, no additional pump is required.

b) For auxiliary engines with a common lubricating system, at least two pumps are to be provided. However, when such engines are intended for non-essential services, no additional pump is required.

12.4.3 Piston cooling

The requirements in [12.4.2] are also applicable to separate oil systems intended for the cooling of pistons.

12.5 Design of steam turbine lubrication systems

12.5.1 General

An alarm device is to be provided giving audible warning in the event of damage or of an appreciable reduction of the oil pressure.

12.5.2 Lubrication of propulsive turbines and turbogenerators

a) Propulsive turbines and turbogenerators are to be provided with:

- one main lubricating pump, and
- one independently driven standby pump of at least the same capacity.

b) Lubricating systems for propulsive turbines and turbogenerators are to be provided with a device which stops the steam supply to the turbines (see [12.7.1]).

12.5.3 Emergency lubrication of propulsive turbines and turbogenerators

a) Propulsive turbines and turbogenerators are to be provided with an emergency lubricating system arranged for automatic start (see [12.7.1]).

b) When a gravity system is provided for the purpose of a), it is to ensure an adequate lubrication for not less than six minutes and, in the case of turbogenerators, for a period at least equal to the stopping period after unloading.

c) When the emergency supply is fulfilled by means of an emergency pump, it is to be so arranged that its operation is not affected by a failure of the power supply.

d) Suitable arrangements for cooling the bearings after stopping may also be required.

12.5.4 Lubrication of auxiliary turbines intended for essential services

a) Auxiliary turbines intended for essential services are to be provided with:

- one main lubricating pump, and
- one independently driven standby pump of at least the same capacity.

b) The standby pump is to be capable of supplying satisfactory lubrication to the turbines during starting and stopping operations.

12.6 Design of lubricating oil tanks

12.6.1 Remote control of valves

Lubricating oil tanks with a capacity of 500 litres and above are to be fitted with remote controlled valves in accordance with the provisions of [11.6.4].

The remote controlled valves need not be arranged for storage tanks on which valves are normally closed except during transfer operation, or where it is determined that an unintended operation of a quick closing valve on the oil lubricating tank would endanger the safe operation of the main propulsion and essential auxiliary machinery.

12.6.2 Filling and suction pipes

Filling and suction pipes are to comply with the provisions of [11.6.3].

12.6.3 Air and overflow pipes

Air and overflow pipes are to comply with the provisions of [9.1] and [9.3].

12.6.4 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of lubricating oil contained in the tanks are to be provided.

b) Sounding pipes are to comply with the provisions of [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

12.6.5 Oil collecting tanks for engines

a) In ships required to be fitted with a double bottom, wells for lubricating oil under main engines may be permitted by the Society provided it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with Pt B, Ch 2, Sec 2.

b) Where, in ships required to be fitted with a double bottom, oil collecting tanks extend to the outer bottom, a valve is to be fitted on the oil drain pipe, located between the engine sump and the oil drain tank. This valve is to be capable of being closed from a readily accessible position located above the working platform.

Alternative arrangements will be given special consideration.

c) Oil collecting pipes from the engine sump to the oil collecting tank are to be submerged at their outlet ends.

12.7 Control and monitoring

12.7.1 In addition to the requirements in:

- Ch 1, Sec 2 for diesel engines,
- Ch 1, Sec 4 for steam turbines,
- Ch 1, Sec 5 for gas turbines and
- Ch 1, Sec 6 for gears,

alarms are to be provided for lubricating oil systems in accordance with Tab 30.

Note 1: Some departures from Tab 30 may be accepted by the Society in the case of ships with a restricted navigation notation.

Table 30 : Lubricating oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Air pipe water trap level of lubricating oil tank **(1)**	H						
Sludge tank level		local					
(1) See [9.1.7].							

12.8 Construction of lubricating oil piping systems

12.8.1 Materials

The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contaminants or modify the properties of the oil. In addition to the criterion given in Tab 5, the use of cadmium or zinc in lubricating oil systems, where they may normally come into contact with the oil, is not permitted.

12.8.2 Air and overflow pipes

Air and overflow pipes are to comply with [9.1] and [9.3], including [5.10], as applicable.

12.8.3 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of oil contained in any lubricating oil tank are to be provided.

b) Sounding pipes of lubricating oil tanks are to comply with the provisions of [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

13 Thermal oil systems

13.1 Application

13.1.1 This Article applies to all thermal oil systems involving organic liquids heated below their initial boiling temperature at atmospheric pressure by means of:

- oil fired heaters,
- exhaust gas heaters, or
- electric heaters.

13.2 Principle

13.2.1 General

Thermal oil systems are to be so designed as to:

- avoid overheating of the thermal oil and contact with air
- take into account the compatibility of the thermal oil with the heated products in case of contact due to leakage of coils or heater tubes
- prevent oil from coming into contact with sources of ignition.

13.2.2 Availability

Thermal oil systems are to be so designed that, in the event that any one essential auxiliary is inoperative, the thermal oil supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

13.3 General

13.3.1 Limitations on use of thermal oil

a) The oil is to be used in the temperature ranges specified by the producer. The delivery temperature is, however, to be kept 50°C below the oil distillation point.

b) Thermal oil is not to be used for the direct heating of:
   - accommodation
   - fresh drinking water
   - liquid cargoes with flashpoints below 60°C, except where permitted in Part D, Chapter 7.

13.3.2 Location of thermal oil system components

a) Thermal oil heaters are normally to be located in spaces separated from main and auxiliary machinery spaces, as required in Ch 1, Sec 1, [3.7.3].

b) Where demonstrated that the arrangement required in item a) is not practical, thermal oil heaters located in machinery spaces and protected by adequate screening may be accepted, subject to special consideration by the Society for each particular case.

c) Drainage of spaces where thermal oil system components are located is to comply with [5.10.4], item f).

Note 1: For the purpose of application of Part C, Chapter 4, spaces where thermal oil heaters are located are to be considered as machinery spaces of category A.

13.3.3 Provision for quick drainage and alternative arrangements

a) Inlet and outlet valves of oil fired and exhaust fired heaters are to be arranged for remote closing from outside the compartment where they are situated.

As an alternative, thermal oil systems are to be arranged for quick gravity drainage of the thermal oil contained in the system into a draining tank.

b) The expansion tank is to be arranged for quick gravity drainage into a draining tank.

However, where the expansion tank is located in a low fire risk space, the quick drainage system may be replaced by a remote controlled closing device for isolating the expansion tank.

The quick drainage system and the alternative closing device are to be capable of being controlled from inside and outside the space containing the expansion tank.

13.3.4 Ventilation

a) Spaces containing thermal oil heaters are to be suitably mechanically ventilated.

b) Ventilation is to be capable of being stopped from outside these spaces.

13.4 Design of thermal oil heaters and heat exchangers

13.4.1 Thermal oil heaters

Oil fired and exhaust-fired thermal oil heaters are to be designed, equipped and controlled in accordance with the requirements specified in Ch 1, Sec 3.

13.4.2 Heat exchangers

Heat exchangers are to be designed and equipped in accordance with the requirements specified in Ch 1, Sec 3.

13.5 Design of storage, expansion and draining tanks

13.5.1 Storage and draining tanks

a) The capacity of the storage tank is to be sufficient to compensate the losses expected in service.

b) The capacity of the draining tank is to be sufficient to collect the quantity of thermal oil contained in the system, including the expansion tank.

c) Storage and draining tanks may be combined.

13.5.2 Expansion tanks

a) The capacity of the expansion tank is to be sufficient to allow volume variations, due to temperature changes, of all the circulating oil.

b) The expansion tank is to be so designed, installed and connected to the circuit as to ensure that the temperature inside the tank remains below 50°C.

13.5.3 Drain pipes

Where provided, drains pipes of thermal oil tanks are to be fitted with self-closing valves or cocks.

13.5.4 Air pipes

a) Air pipes fitted to the expansion and drainage tanks are to be suitably sized to allow the quick gravity drainage referred to in [13.3.3].

b) The applicable requirements of [9.1] are to be complied with.

13.5.5 Overflow pipes

a) The expansion tank is to be fitted with an overflow pipe led to the drainage tank. This overflow pipe may be combined with the quick draining line provided for in [13.3.3], item b).

b) The applicable requirements of [9.3] are to be complied with.

13.5.6 Sounding pipes and level gauges

a) Sounding pipes are to comply with the provisions of [9.2].

b) Level gauges are to comply with the provisions of [2.9.2].

13.6 Design of circulation and heat exchange systems

13.6.1 Circulating pumps

At least two circulating pumps are to be provided, of such a capacity as to maintain a sufficient flow in the heaters with any one pump out of action.

However, for circulating systems supplying non-essential services, one circulating pump only may be accepted.

13.6.2 Filters

A device which efficiently filters the thermal oil is to be provided in the circuit.

In the case of essential services, the filters provided for this purpose are to be so arranged that they can be easily cleaned without stopping the thermal oil supply.

The fineness of the filter mesh is to comply with the requirements of the thermal oil heating installation manufacturer.

13.7 Control and monitoring

13.7.1 Monitoring

In addition to the requirements specified in Ch 1, Sec 3, [3.3.1], item c) and Ch 1, Sec 3, [5.3] for thermal heaters and heat exchangers, alarms and safeguards for thermal oil systems are to be provided in accordance with Ch 1, Sec 3, Tab 23.

Note 1: Some departures from Ch 1, Sec 3, Tab 23 may be accepted by the Society in the case of ships with a restricted navigation notation.

13.7.2 Remote control

a) Remote control is to be arranged for:

- shut-off of circulating pumps
- quick drainage of the thermal oil system and expansion tank, or shut-off of the alternative devices (see [13.3.3])
- shut-off of the fuel supply to the oil fired heaters or of the exhaust gas supply to the exhaust gas heaters (see Ch 1, Sec 3, [5.3]).

The shut-off of the exhaust gas supply may be ensured either by the engine shut down or by an exhaust gas bypass.

b) Such control is to be possible from the space containing the thermal oil heaters and from another position located outside such space.

13.8 Construction of thermal oil piping systems

13.8.1 Materials

a) Materials are to comply with the provisions of [11.11.1].

b) Casings of pumps, valves and fittings are to comply with the requirements mentioned in [2.1.2], item a) considering classes of piping systems as defined in [1.5.2].

13.8.2 Pipe connections

a) Pipe connections are to comply with Article [2.4] and to be suitable for the design temperature of the thermal oil system.

b) Screw couplings of a type approved by the Society may be accepted for pipes of an outside diameter not exceeding 15 mm provided they are fitted with cutting rings or equivalent arrangements.

c) The materials of the joints are to be impervious to thermal oil.

13.9 Thermal oil piping arrangements

13.9.1 Passage of thermal oil pipes through certain spaces

a) Thermal oil pipes are not to pass through accommodation or public spaces or control stations.

b) Unless they are located in tight manifolds, provided with appropriate means of internal inspection and with a leak collecting system, heat transfer oil pipes are not allowed in main and auxiliary machinery spaces specified in Ch 1, Sec 1, [3.7.4].

13.9.2 Discharge of relief valves

Relief valves are to discharge to the drain tank.

13.9.3 Provision for de-aerating

Provisions are to be made for automatic evacuation of air, steam and gases from the thermal oil system to a safe location.

14 Hydraulic systems

14.1 Application

14.1.1 Hydraulic installations intended for essential services

Unless otherwise specified, this Article applies to all hydraulic power installations intended for essential services as defined in Pt A, Ch 1, Sec 1, [1.2.1] and Ch 2, Sec 1, [3.11].

The hydraulic piping arrangement is also to comply with the provisions of:

- [5.10]
- Ch 1, Sec 7, [2.6] for clutches
- Ch 1, Sec 8, [2.6.2] for the blade pitch control system of controllable pitch propellers, and
- Ch 1, Sec 14, [2.6] for steering gears.

14.1.2 Hydraulic installations intended for non essential services

a) Hydraulic power installations not serving essential services but located in spaces where sources of ignition are present are to comply with the provisions of [5.10], [14.3.2], [14.3.3], [14.4.4], [14.4.5] and [14.5.3].

b) Additionally, hydraulic systems serving lifting or hoisting appliances, including platforms, ramps, hatch covers, lifts etc., are to comply with [14.2.2] item d).

14.1.3 Low pressure or low power hydraulic installations

Hydraulic power installations with a design pressure of less than 2,5 MPa and hydraulic power packs of less than 5 kW will be given special consideration by the Society.

14.1.4 Very high pressure hydraulic installations

Hydraulic power installations with a design pressure exceeding 35 MPa will be given special consideration by the Society.

14.2 Principles

14.2.1 Design requirements

As far as practicable, hydraulic systems are to be so designed as to:

- avoid any overload of the system
- maintain the actuated equipment in the requested position (or the driven equipment at the requested speed)
- avoid overheating of the hydraulic oil
- prevent hydraulic oil from coming into contact with sources of ignition.

14.2.2 Availability

a) As a rule, hydraulic systems are to be so designed that, in the event that any one essential component becomes inoperative, the hydraulic power supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) When a hydraulic power system is simultaneously serving one essential system and other systems, it is to be ensured that:

- operation of such other systems, or
- a single failure in the installation external to the essential system,

is not detrimental to the operation of the essential system.

c) Hydraulic systems serving lifting or hoisting appliances, including platforms, ramps, hatch covers, lifts, etc., are to be so designed that a single failure of any component of the system may not result in a sudden undue displacement of the load or in any other situation detrimental to the safety of the ship and persons on board.

14.3 General

14.3.1 Definitions

a) A power unit is the assembly formed by the hydraulic pump and its driving motor.

b) An actuator is a component which directly converts hydraulic pressure into mechanical action.

14.3.2 Limitations of use of hydraulic oils

a) Oils used for hydraulic power installations are to have a flashpoint not lower than 150°C and be suitable for the entire service temperature range.

b) The hydraulic oil is to be replaced in accordance with the specification of the installation manufacturer.

14.3.3 Location of hydraulic power units

a) Generally, the hydraulic power units are to be located outside machinery spaces containing the boilers, main engine, its auxiliaries or other sources of ignition. See Ch 1, Sec 1, [3.7.4].

This applies in particular for hydraulic equipment delivering pressure over 15 bar to the following equipment:

- controllable pitch propellers or main transverse thrust units
- clutches
- turbine manoeuvring steam valves
- exhaust gas valves of diesel engines or gas damper control systems
- hydraulically operated valves and pumps.

b) Where demonstrated that the arrangement required in item a) is not practical, at least the following is to be provided:

- Shields or similar protections are to be fitted around such hydraulic equipment as in order to avoid any accidental oil spray or mist to the hot surfaces or other sources of ignition.
- The low level alarm required for hydraulic tanks of these circuits is to be triggered as soon as possible.
- The automatic stop of hydraulic pumps is to be operated in the same circumstances, except where this stop can lead to propulsion stop.

14.4 Design of hydraulic pumps and accessories

14.4.1 Power units

a) Hydraulic power installations are to include at least two power units so designed that the services supplied by the hydraulic power installation can operate simultaneously with one power unit out of service. A reduction of the performance may be accepted.

b) Low power hydraulic installations not supplying essential services may be fitted with a single power unit, provided that alternative means, such as a hand pump, are available on board.

14.4.2 Pressure reduction units

Pressure reduction units used in hydraulic power installations are to be duplicated.

14.4.3 Filtering equipment

a) A device is to be fitted which efficiently filters the hydraulic oil in the circuit.

b) Where filters are fitted on the discharge side of hydraulic pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

14.4.4 Provision for cooling

Where necessary, appropriate cooling devices are to be provided.

14.4.5 Provision against overpressure

a) Safety valves of sufficient capacity are to be provided at the high pressure side of the installation.

b) Safety valves are to discharge to the low pressure side of the installation or to the service tank.

14.4.6 Provision for venting

Cocks are to be provided in suitable positions to vent the air from the circuit.

14.4.7 Provision for drainage

Provisions are to be made to allow the drainage of the hydraulic oil contained in the installation to a suitable collecting tank.

14.5 Design of hydraulic tanks and other components

14.5.1 Hydraulic oil service tanks

a) Service tanks intended for hydraulic power installations supplying essential services are to be provided with at least:

- a level gauge complying with [2.9.2]
- a temperature indicator
- a level switch complying with [14.6.2].

b) The free volume in the service tank is to be at least 10% of the tank capacity.

14.5.2 Hydraulic oil storage tanks

a) Hydraulic power installations supplying essential services are to include a storage tank of sufficient capacity to refill the whole installation should the need arise in case of necessity.

b) For hydraulic power installations of less than 5 kW, the storage means may consist of sealed drums or tins stored in satisfactory conditions.

14.5.3 Hydraulic accumulators

The hydraulic side of the accumulators which can be isolated is to be provided with a relief valve or another device offering equivalent protection in case of overpressure.

14.6 Control and monitoring

14.6.1 Indicators

Arrangements are to be made for connecting a pressure gauge where necessary in the piping system.

14.6.2 Monitoring

Alarms and safeguards for hydraulic power installations intended for essential services, except steering gear, for which the provisions of Ch 1, Sec 14 apply, are to be provided in accordance with Tab 31.

Note 1: Some departures from Tab 31 may be accepted by the Society in the case of ships with a restricted navigation notation.

Note 2: Tab 31 does not apply to steering gear.

Table 31 : Hydraulic oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Pump pressure	L						
Service tank level	L **(1) (2)**						X **(2)**

(1) The low level alarm is to be activated before the quantity of lost oil reaches 100 litres or 70% of the normal volume in the tank, whichever is the less.

(2) For hydraulics cranes where no electrical system has been provided, the requirement may be waived if the level gauge, the pressure gauge and the temperature gauge indicators are always visible by the crane operator. In addition, a warning label shall be placed on the tank reminding that, prior to start any operation of the crane, the oil level is to be checked.

15 Steam systems

15.1 Application

15.1.1 Scope

This Article applies to all steam systems intended for essential and non-essential services.

Steam systems with a design pressure of 10 MPa or more will be given special consideration.

15.2 Principle

15.2.1 Availability

a) Where a single boiler is installed, the steam system may supply only non-essential services.

b) Where more than one boiler is installed, the steam piping system is to be so designed that, in the event that any one boiler is out of action, the steam supply to essential services can be maintained.

15.3 Design of steam lines

15.3.1 General

a) Every steam pipe and every connected fitting through which steam may pass is to be designed, constructed and installed such as to withstand the maximum working stresses to which it may be subjected.

b) When the design temperature of the steam piping system exceeds 400°C, calculations of thermal stresses are to be submitted to the Society as specified in [2.3].

c) Steam connections on boilers and safety valves are to comply with the applicable requirements of Ch 1, Sec 3.

15.3.2 Provision against overpressure

a) If a steam pipe or fitting may receive steam from any source at a higher pressure than that for which it is designed, a suitable reducing valve, relief valve and pressure gauge are to be fitted.

b) When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valves are designed, means to relieve the excess pressure are to be provided.

15.3.3 Provision for dumping

In order to avoid overpressure in steam lines due to excessive steam production, in particular in systems where the steam production cannot be adjusted, provisions are to be made to allow the excess steam to be discharged to the condenser by means of an appropriate dump valve.

15.3.4 Provision for draining

Means are to be provided for draining every steam pipe in which dangerous water hammer action might otherwise occur.

15.3.5 Steam heating pipes

a) When heating coils are fitted in compartments likely to contain either fuel oil or liquid or dry cargoes, arrangements such as blind flanges are to be provided in order to disconnect such coils in the event of carriage of dry or liquid cargoes which are not to be heated.

b) The number of joints on heating coils is to be reduced to the minimum consistent with dismantling requirements.

15.3.6 Steam lines in cargo holds

a) Live and exhaust steam pipes are generally not to pass through cargo holds, unless special provisions are made with the Society's agreement.

b) Where steam pipes pass through cargo holds in pipe tunnels, provision is to be made to ensure the suitable thermal insulation of such tunnels.

c) When a steam smothering system is provided for cargo holds, provision is to be made to prevent spurious damage of the cargo by steam or condensate leakage.

15.3.7 Steam lines in accommodation spaces

Steam lines are not to pass through accommodation spaces, unless they are intended for heating purposes.

15.3.8 Turbine connections

a) A sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary.

b) Bled steam connections are to be fitted with non-return valves or other approved means to prevent steam and water returning to the turbines.

15.3.9 Strainers

a) Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or, alternatively, at the inlets to manoeuvring valves.

b) Where required by the manufacturer of the auxiliaries, steam strainers are also to be fitted in the steam lines supplying these auxiliaries.

16 Boiler feed water and condensate systems

16.1 Application

16.1.1 This Article applies to:

- feed water systems of oil fired and exhaust gas boilers
- steam drain and condensate systems.

16.2 Principle

16.2.1 General

Boiler feed water and condensate systems are to be so designed that:

- reserve feed water is available in sufficient quantity to compensate for losses
- feed water is free from contamination by oils or chlorides
- feed water for propulsion systems is suitably de-aerated.

16.2.2 Availability

a) Feed water systems are to be so designed that, in the event of failure of any one component, the steam supply to essential services can be maintained or restored.

b) Condensate systems are to be so designed that, in the event of failure of:

- one condensate pump, or
- the arrangements to maintain vacuum in the condenser,

the steam supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted.

16.3 Design of boiler feed water systems

16.3.1 Number of feed water systems

a) Every steam generating system which supplies essential services is to be provided with not less than two separate feed water systems from and including the feed pumps, noting that a single penetration of the steam drum is acceptable.

b) The requirement stated in a) may be dispensed with for boilers heated exclusively by engine exhaust gases or by steam for which one feed system is considered as sufficient, provided an alternative supply of steam is available on board.

c) Each boiler is to be provided with feed regulators as specified in Ch 1, Sec 3, [3.2.9].

16.3.2 Feed pumps

a) The following pumps are to be provided:
- at least one main feed pump of sufficient capacity to supply the boilers under nominal conditions, and
- one standby feed pump.

b) The capacity of the standby pump may be less than that of the main feed pumps provided it is demonstrated that, taking into account the reduction of the propulsion capability, the ship remains safely operable.

c) Main feed pumps may be either independent or driven by the main turbines. The standby feed pump is to be independent.

d) In twin-screw ships in which there is only one independent feed pump, each main turbine is to be fitted with a driven pump. Where all feed pumps are independent, they are to be so arranged as to be capable of dealing with the feed water necessary to supply steam either to both turbines or to one turbine only.

e) Independent feed pumps for main boilers are to be fitted with a delivery control and regulating system.

f) Unless overpressure is prevented by the feed pump characteristics, means are to be provided which will prevent overpressure in the feed water system.

g) The pressure head of feed pumps is to take into account the maximum service pressure in the boiler as well as the pressure losses in the discharge piping. The suction head of feed pumps is to be such as to prevent cavitation as far as possible.

h) Feed pumps and pipes are to be provided with valves so arranged that any one pump can be overhauled while the boilers are operating at full load.

16.3.3 Harbour feed pumps

a) Where main turbine driven pumps are provided and there is only one independent pump, a harbour feed pump or an ejector is to be fitted in addition to provide the second means for feeding the boilers which are in use when the main turbine is not working.

b) The harbour feed pump may be used for the general service of the ship, but in no case is this pump to be used to convey liquid fuel, lubricating oil or oily water.

c) The suction pipes of the harbour feed pump from the hotwell, from reserve feed water tanks and from filters are to be fitted with non-return valves.

16.3.4 Feed water tanks

a) All ships fitted with main boilers or auxiliary boilers for essential services are to be provided with reserve feed water tanks.

b) Boilers are to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

c) Feed water tanks are not to be located adjacent to fuel oil tanks. Fuel oil pipes are not to pass through feed water tanks.

d) For main boilers, one or more evaporators are to be provided, the capacity of which is to compensate for the losses of feed water due to the operation of the machines, in particular where the fuel supplied to the boilers is atomised by means of steam.

16.3.5 Provision for de-aerating feed water

A de-aerator is to be provided to ensure the de-aeration of the feed water intended for main boilers before it enters such boilers.

16.4 Design of condensate systems

16.4.1 Condensers

a) Appropriate arrangements, such as air ejectors, are to be provided to maintain vacuum in the main condenser or restore it to the required value.

b) Cooling of the main condenser is to comply with the provisions of [10.3.5].

16.4.2 Condensate pumps

a) Condensate pumps are to include at least:
- one main condensate pump of sufficient capacity to transfer the maximum amount of condensate produced under nominal conditions, and
- one independently driven standby condensate pump.

b) The standby condensate pump may be used for other purposes.

16.4.3 Condensate observation tanks

Any condensate from the steam heating pipes provided for fuel oil tanks and bunkers, cargo tanks and fuel oil or lubricating oil heaters is to be led to an observation tank or some other device of similar efficiency located in a well-lighted and readily accessible position.

16.5 Control and monitoring

16.5.1 General

The provisions of this sub-article apply only to feed water and condensate systems intended for propulsion.

16.5.2 Monitoring

Alarms and safeguards are to be provided for feed water and condensate systems in accordance with Tab 32.

Note 1: Some departures from Tab 32 may be accepted by the Society in the case of ships with a restricted navigation notation.

16.5.3 Automatic controls

Automatic level control is to be provided for:

- de-aerators,
- condensers.

Table 32 : Boiler feed and condensate system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water flow or equivalent	L						
Condenser pressure	H	local					
	HH			X			
Water level in main condenser (unless justified)	H	local					
Feed water salinity	H	local					
Feed water pump delivery pressure	L	local					
						X	
Feed water tank level	L						

16.6 Arrangement of feed water and condensate piping

16.6.1

a) Feed water pipes are not to pass through fuel oil or lubricating oil tanks.

b) Pipes connected to feed water tanks are to be so arranged as to prevent the contamination of feed water by fuel oil, lubricating oil or chlorides.

16.7 Arrangement of feed water system for shell type exhaust gas heated economizer

16.7.1 Every shell type exhaust gas heated economizer, that may be isolated from the steam piping system, is to be provided with arrangements for pre-heating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the manufacturer's recommendations.

17 Compressed air systems

17.1 Application

17.1.1 This Article applies to compressed air systems intended for essential services, and in particular to:

- starting of engines,
- control and monitoring.

17.2 Principle

17.2.1 General

a) As a rule, compressed air systems are to be so designed that the compressed air delivered to the consumers:
- is free from oil and water, as necessary
- does not have an excessive temperature.

b) Compressed air systems are to be so designed as to prevent overpressure in any part of the systems.

17.2.2 Availability

a) Compressed air systems are to be so designed that, in the event of failure of one air compressor or one air receiver intended for starting, control purposes or other essential services, the air supply to such services can be maintained. The filling connections of the compressed air receivers shall be fitted with a non-return valve.

b) The compressed air system for starting the main and auxiliary engines is to be arranged so that the necessary initial charge of starting air can be developed on board ship without external aid. If, for this purpose, an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor.

c) Where compressed air is necessary to restore propulsion, the arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead ship condition. For definition of the "dead ship condition", see Ch 1, Sec 1, [1.4.2] and Ch 2, Sec 1, [3.4.1].

The procedure for such condition and relevant calculation is to be submitted.

d) Where the compressed air is necessary for the air whistle or other safety services, it is to be available from two compressed air receivers. At least one of them is to be starting air receiver for main engines. The separate connection, dedicated for this purpose, is to be provided directly from the compressed air main.

17.3 Design of starting air systems

17.3.1 Air supply for starting the main and auxiliary engines

a) The total capacity of the compressed air available for starting purpose is to be sufficient to provide, without replenishment, not less than 12 consecutive starts alternating between ahead and astern of each main engine of the reversible type, and not less than 6 consecutive starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque.

At least 3 consecutive starts is to be possible for each engine driving electric generators and engines for other purposes. The capacity of a starting system serving two or more of the above specified purposes is to be the sum of the capacity requirements.

b) For multi-engine propulsion plants, the capacity of the starting air receivers is to be sufficient to ensure at least 3 consecutive starts per engine. However, the total capacity is not to be less than 12 starts and need not exceed 18 starts.

Regardless of the above, for any other specific installation the number of starts may be specially considered by the Society and depending upon the arrangement of the engines and the transmission of their output to the propellers in each particular case.

17.3.2 Number and capacity of air compressors

a) Where main and auxiliary engines are arranged for starting by compressed air, two or more air compressors are to be fitted with a total capacity sufficient to supply within one hour the quantity of air needed to satisfy the provisions of [17.3.1] charging the receivers from atmospheric pressure. This capacity is to be approximately equally divided between the number of compressors fitted, excluding the emergency compressor fitted in pursuance of item c) below.

b) At least one of the compressors is to be driven independent of the main propulsion unit. The capacity of one of the said independently driven compressors or the combined capacity of independently driven compressors is not to be less than 50% of the total required in item a).

c) Where, for the purpose of [17.2.2], an emergency air compressor is fitted, this unit is to be power driven by internal combustion engine, electric motor or steam engine.

Suitable hand starting arrangement or independent electrical starting batteries may be accepted. In the case of small installations, a hand-operated compressor of approved capacity may be accepted.

17.3.3 Number and capacity of air receivers

a) Where main engines are arranged for starting by compressed air, at least two air receivers are to be fitted of approximately equal capacity and capable of being used independently.

b) The total capacity of air receivers is to be sufficient to provide without replenishment the number of starts required in [17.3.1]. When other users such as auxiliary engine starting systems, low pressure compressed air systems (see [17.4]), control systems, whistle, etc. are connected to the starting air receivers, their air consumption is also to be taken into account.

Compressed air receivers are to comply with the requirements of Ch 1, Sec 3.

17.3.4 Air supply for starting the emergency generating set

Where starting air arrangement is one of two independent means of starting required in Ch 1, Sec 2, [3.1.3] for the emergency generator, the following is to be complied with:

a) The starting air arrangement is to include a compressed air vessel, storing the energy dedicated only for starting of the emergency generator. The capacity of the compressed air available for starting purpose is to be sufficient to provide, without replenishment, at least three consecutive starts.

b) The compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a non-return valve fitted in the emergency generator space, or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard.

c) All of these starting, charging and energy storing devices are to be located in the emergency generator space and is not to be used for any purpose other than the operation of the emergency generating set.

17.4 Design of compressed air systems for essential services

17.4.1 Capacity and availability

a) The arrangements for the supply of compressed air to essential services are to ensure that sufficient compressed air to satisfy the total demand of the essential services is available at all times during normal operation, during maintenance, and in the event of a failure of the compressed air system.

b) Where compressed air is supplied from the engine starting air system, either continuously in normal operation, or periodically during maintenance or in the event of a failure of the compressed air system, the required compressed air demand is not to reduce the capacity and availability of the engine starting air required by [17.3.1].

17.4.2 Design of control and monitoring air systems

a) The control and monitoring air supply to essential services is to be available from two sources of a sufficient capacity to allow normal operation with one source out of service.

b) At least one air vessel fitted with a non-return valve is to be dedicated for control and monitoring purposes, unless the installation is provided with local independent mechanical control and a means for communication with the wheelhouse is permanently fitted at position of local control. For notation **AUT**, see also Pt F, Ch 3, Sec 4, [5.2.2].

c) Pressure reduction units used in control and monitoring air systems intended for essential services are to be duplicated, unless an alternative air supply is provided.

d) Failure of the control air supply is not to cause any sudden change of the controlled equipment which may be detrimental to the safety of the ship.

17.4.3 Pressure control

Arrangements are to be made to maintain the air pressure at a suitable value in order to ensure satisfactory operation of the installation.

17.4.4 Air treatment

In addition to the provisions of [17.8.3], arrangements are to be made to ensure cooling, filtering and drying of the air prior to its introduction in the monitoring and control circuits.

17.5 Design of air compressors

17.5.1 Prevention of excessive temperature of discharged air

Air compressors are to be so designed that the temperature of discharged air cannot exceed 95°C. For this purpose, the air compressors are to provided where necessary with:

- suitable cooling means
- fusible plugs or alarm devices set at a temperature not exceeding 120°C.

17.5.2 Prevention of overpressure

a) Air compressors are to be fitted with a relief valve complying with [2.5.3].

b) Means are to be provided to prevent overpressure wherever water jackets or casings of air compressors may be subjected to dangerous overpressure due to leakage from air pressure parts.

c) Water space casings of intermediate coolers of air compressors are to be protected against any overpressure which might occur in the event of rupture of air cooler tubes.

17.5.3 Crankcase relief valves

Air compressors having a crankcase volume of at least 0,6 m^3 are to be fitted with crankcases explosion relief valves satisfying the provisions of Ch 1, Sec 2, [2.3.4].

17.5.4 Provision for draining

Air compressors are to be fitted with a drain valve.

17.6 Control and monitoring of compressed air systems

17.6.1 Monitoring

Alarms and safeguards are to be provided for compressed air systems in accordance with Tab 33.

Note 1: Some departures from Tab 33 may be accepted by the Society in the case of ships with a restricted navigation notation.

17.6.2 Automatic controls

Automatic pressure control is to be provided for maintaining the air pressure in the air receivers within the required limits.

Table 33 : Compressed air systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Compressor lubricating oil pressure (except where splash lubrication)	L						
Air pressure after reducing valves	H	local					
Starting air pressure before main shut-off valve	L **(2)**	local + R **(1)**					
Air vessel pressure	L						
(1) Remote indication is required if starting of air compressor are remote controlled, from wheelhouse for example **(2)** The low level alarm shall be set at a level to permit further main engine starting operations.							

17.7 Materials

17.7.1 Pipes and valve bodies in control and monitoring air systems and in other air systems intended for non-essential services may be made of plastic in accordance with the provisions of Ch 1, App 3.

17.8 Arrangement of compressed air piping systems

17.8.1 Prevention of overpressure

Suitable pressure relief arrangements are to be provided for all systems.

17.8.2 Air supply to compressors

a) Provisions are to be made to reduce to a minimum the entry of oil into air pressure systems.

b) Air compressors are to be located in spaces provided with sufficient ventilation.

17.8.3 Air treatment and draining

a) Provisions are be made to drain air pressure systems.

b) Efficient oil and water separators, or filters, are to be provided on the discharge of compressors, and drains are to be installed on compressed air pipes wherever deemed necessary.

17.8.4 Lines between compressors, receivers and engines

All discharge pipes from starting air compressors are to be lead directly to the starting air receivers, and all starting pipes from the air receivers to main or auxiliary engines are to be entirely separate from the compressor discharge pipe system.

17.8.5 Protective devices for starting air mains

Non-return valves and other safety devices are to be provided on the starting air mains of each engine in accordance with the provisions of Ch 1, Sec 2, [3.1.1].

18 Exhaust gas systems

18.1 General

18.1.1 Application

This Article applies to:

- exhaust gas pipes from engines and gas turbines
- smoke ducts from boilers and incinerators.

18.1.2 Principle

Exhaust gas systems are to be so designed as to:

- limit the risk of fire
- prevent gases from entering manned spaces
- prevent water from entering engines.

18.1.3 Exhaust gas pollution prevention systems

Additional requirements for the installation of exhaust gas pollution prevention systems and storage and use of chemical treatment fluids consumed in the associated process are given in Ch 1, Sec 11.

Additional requirements for the installation of onboard carbon capture and storage systems are given in Ch 1, Sec 12.

18.2 Design of exhaust systems

18.2.1 General

Exhaust systems are to be so arranged as to minimise the intake of exhaust gases into manned spaces, air conditioning systems and engine intakes.

18.2.2 Limitation of exhaust line surface temperature

a) Exhaust gas pipes and silencers are to be either water cooled or efficiently insulated where:
   - their surface temperature may exceed 220°C, or
   - they pass through spaces of the ship where a temperature rise may be dangerous.

b) The insulation of exhaust systems is to comply with the provisions of Ch 1, Sec 1, [3.7.1].

18.2.3 Limitation of pressure losses

Exhaust gas systems are to be so designed that pressure losses in the exhaust lines do not exceed the maximum values permitted by the engine or boiler manufacturers.

18.2.4 Intercommunication of engine exhaust gas lines or boiler smoke ducts

a) Exhaust gas from different engines is not to be led to a common exhaust main, exhaust gas boiler or economiser, unless each exhaust pipe is provided with a suitable isolating device.

b) Smoke ducts from boilers discharging to a common funnel are to be separated to a height sufficient to prevent smoke passing from a boiler which is operating to a boiler out of action.

18.2.5 Boilers designed for alternative oil firing and exhaust gas operation

Where boilers are designed for alternative oil firing and exhaust gas operation, the exhaust gas pipe from the engine is to be fitted with an isolating device and safety arrangements to prevent the starting of the fuel oil burning units if the isolating device is not in the closed position.

18.2.6 Exhaust gas pipe terminations

a) Where exhaust pipes are led overboard close to the load waterline, means are to be provided to prevent water from entering the engine or the ship. Where a shut-off valve is fitted at the overboard discharge, means are to be provided to prevent the engine from being started when the valve is not fully open.

   Moreover this valve is to be readily operable from an accessible position.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

18.2.7 Control and monitoring

a) A high temperature alarm is to be provided in the exhaust gas manifolds of thermal oil heaters to detect any outbreak of fire.

b) When water-cooled exhaust gas pipes are used, a high temperature alarm must be fitted after the water injection device. Alternatively, an alarm of low sea water flow rate may be fitted.

18.3 Materials

18.3.1 General

Materials of exhaust gas pipes and fittings are to be resistant to exhaust gases and suitable for the maximum temperature expected.

18.3.2 Use of plastics

The use of non-metallic materials may be accepted in water cooled systems in accordance with the provisions of Ch 1, App 3.

18.4 Arrangement of exhaust piping systems

18.4.1 Provision for thermal expansion

a) Exhaust pipes and smoke ducts are to be so designed that any expansion or contraction does not cause abnormal stresses in the piping system, and in particular in the connection with engine turboblowers.

b) The devices used for supporting the pipes are to allow their expansion or contraction.

18.4.2 Provision for draining

a) Drains are to be provided where necessary in exhaust systems, and in particular in exhaust ducting below exhaust gas boilers, in order to prevent water flowing into the engine.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

18.4.3 Flexible hoses

The use of flexible hoses in water cooled exhaust systems will be given special consideration by the Society.

18.4.4 Silencers

Engine silencers are to be so arranged as to provide easy access for cleaning and overhaul.

19 Oxyacetylene welding systems

19.1 Application

19.1.1 This Article applies to centralised fixed plants for oxyacetylene welding installed on ships. It may also be applied, at the discretion of the Society, to other plants using liquefied gas, such as propane.

19.1.2 The acceptance of national and international standards as an alternative to the requirements of this Article may be considered by the Society on a case by case basis.

19.2 Definitions

19.2.1 Centralised plants for oxyacetylene welding

A centralised plant for oxyacetylene welding is a fixed plant consisting of a gas bottle room, distribution stations and distribution piping, where the total number of acetylene and oxygen bottles exceeds 4.

19.2.2 Gas bottle rooms

A gas bottle room is a room containing acetylene and oxygen bottles, where distribution headers, non-return and stop valves, pressure reducing devices and outlets of supply lines to distribution stations are also installed.

19.2.3 Distribution stations

Distribution stations are adequately protected areas or cabinets equipped with stop valves, pressure regulating devices, pressure gauges, non-return valves and oxygen as well as acetylene hose connections for the welding torch.

19.3 Design of oxyacetylene welding systems

19.3.1 General

Except on pontoons and service working ships, no more than two distribution stations are normally permitted.

19.3.2 Acetylene and oxygen bottles

a) The bottles are to be tested under attendance of the Society or by a body recognised by the Society.

b) Bottles with a capacity exceeding 50 litres are not permitted.

c) Bottles supplying the plant and spare bottles are to be installed in the gas bottle room. Installation within accommodation spaces, service spaces, control stations and machinery spaces is not permitted.

d) Bottles are to be installed in a vertical position and are to be safely secured. The securing system is to be such as to allow the ready and easy removal of the bottles.

19.3.3 Piping systems

a) In general, the acetylene and oxygen piping systems are to comply with the following provisions:
   - all valves and fittings as well as welding torches and associated supply hoses are to be adapted to this specific service and suitable for the conditions expected in the different parts of the system
   - acetylene piping is to be of stainless steel or copper alloy containing less than 65% copper and seamless drawn
   - oxygen piping is to be of copper or stainless steel and seamless drawn
   - the connections between the various pipe sections are to be carried out by means of butt welding. Socket-welded connections may be used on the low-pressure side of the installations. Other types of connections including threaded connections and flange connections are not permitted
   - only a minimum number of unavoidable connections are permitted provided they are located in a clearly visible position.

b) High pressure lines (i.e. lines between bottles and pressure reducing devices) are to be installed inside the gas bottle room and are to comply with the following provisions:
   - acetylene and oxygen piping and associated fittings are to be suitable for a design pressure of 30 MPa
   - a non-return valve is to be installed on the connection of each acetylene and oxygen bottle to the header
   - stop valves are to be provided on the bottles and kept shut when distribution stations are not working.

c) Low pressure lines (i.e. lines between pressure reducing devices and distribution stations) are to comply with the following provisions:
   - for low pressure lines, black steel pipes seamless drawn could be also acceptable provided that:
     - a thickness is not less than 2,5 mm when installed in the open air
     - a thickness is not less than 2,0 mm when installed indoor
   - supply lines to each distribution station are to include, at the station inlet:
     - a stop valve to be kept shut when the station is not working
     - devices to protect the supply lines from backflow of gas or flame passage.

d) Safety valves are to be provided on the low pressure side of the pressure reducing devices and led to the open air at least 3 m above the deck in a safe location where no source of ignition is present.

19.4 Arrangement of oxyacetylene welding systems

19.4.1 Gas bottle rooms

a) The gas bottle room is to be located in an independent space over the highest continuous deck and provided with direct access from outside. The limiting bulkheads and decks are to be gas-tight and made of steel.

b) When the total number of gas bottles, including possible spare bottles which are not connected to the plant, does not exceed 8, acetylene and oxygen bottles may be installed in the same room. Otherwise, acetylene and oxygen bottles are to be separated by a gas-tight bulkhead.

c) The bottle room is to be adequately insulated and ventilated so that the temperature inside does not exceed 40°C. If the temperature cannot be controlled by means of natural ventilation, mechanical and independent ventilation is to be provided. Air outlets are to be led at least 3 m away from ignition sources and ventilation intakes and are to be equipped with flameproof wire gauze.

d) The gas bottle room is not to be used for other services on board. Flammable oil or gas piping, except that related to the oxyacetylene welding plant, is not to be led through this room.

Note 1: On pontoons and service working ships, gas bottles may be installed on open deck in a safe position to the satisfaction of the Society. In such case, appropriate protection is to be provided:

- for gas bottles, against sunrays and atmospheric agents, by means of watertight covers,
- for the associated valves, piping and fittings, by means of steel covers, metal grids or similar devices.

Such means of protection are to be easily removable to allow bottle removal, when necessary.

When the total number of bottles exceeds 8, acetylene bottles are to be separated from oxygen bottles.

19.4.2 Distribution stations

Distribution stations are to be located in the engine room or in the workshop, in a well-ventilated position and protected against possible mechanical damage.

Note 1: On pontoons and service working ships, distribution stations may be installed in the open air, enclosed in a cabinet with a locked door, or in controlled access areas, to the satisfaction of the Society.

19.4.3 Piping

a) Piping is not to be led through accommodation or service spaces.

b) Piping is to be protected against any possible mechanical damage.

c) In way of deck or bulkhead penetrations, piping is to be suitably enclosed in sleeves so arranged as to prevent any fretting of the pipe with the sleeve.

19.4.4 Signboards

Signboards are to be posted on board the ship in accordance with Tab 34.

Table 34 : Signboards

Location of the signboard	Signboard to be posted
in the gas bottle room	diagram of the oxyacetylene plant
	"no smoking"
in way of: • bottle stop valves • distribution station stop valves	"to be kept shut when distribution stations are not working"
in way of the pressure reducing devices	indication of the maximum allowable pressure at the pressure reducing device outlet
in way of the safety valve discharge outlet	"no smoking"

20 Certification, inspection and testing of piping systems

20.1 Application

20.1.1 This Article defines the certification and workshop inspection and testing programme to be performed on:

- the various components of piping systems
- the materials used for their manufacture.

On board testing is dealt with in Ch 1, Sec 18.

20.2 Type tests of flexible hoses and expansion joints

20.2.1 General

a) Prototype test programmes are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

b) Prototype test programmes are to be made in accordance with recognised standards which are suitable for the intended service of the flexible hose or of an expansion joint.

c) Tests are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to the installation.

d) All flexible hose assemblies or expansion joints are to be satisfactorily prototype burst tested to an international standard (see Note 1) to demonstrate that they are able to withstand a pressure not less than 4 times their design pressure without indication of failure or leakage.

Note 1: The international standards (e.g. EN or SAE standards) for burst testing of non-metallic hoses require the pressure to be increased until burst without any holding period. Burst is to occur at a pressure greater than 4 times the maximum working pressure.

20.2.2 Flexible hoses

a) For flexible hoses which are to comply with [2.6], prototype tests are to be carried out for each size of hose assembly. However, for ranges with more than 3 different diameters, the prototype tests are to be carried out for at least:

   - the smallest diameter
   - the largest diameter
   - intermediate diameters selected based on the principle that prototype tests carried out for a hose assembly with a diameter D are considered valid only for the diameters ranging between 0,5 D and 2 D.

   For fire resistance tests the specimens are to be selected in accordance with ISO 15540:2016.

b) The flexible hoses subjected to the tests are to be fitted with their connections.

c) Type approval tests are to be carried out in accordance with the prototype test programmes required in [2.6.4], including, but not limited to, the scope of testing specified in Tab 35 for metallic flexible hoses and in Tab 36 for non-metallic flexible hoses.

20.2.3 Expansion Joints

a) For the expansion joints which are to comply with [2.6], relevant type approval tests are to be carried out on a representative sampling on each type and for each pressure range.

b) The expansion joints subjected to the tests are to be fitted with their connections.

c) Type approval tests are to be carried out in accordance with the prototype test programmes required in [2.6.4], including, but not limited to, the scope of testing specified in Tab 37 for metallic expansion joints and in Tab 38 for non-metallic expansion joints.

d) Exemptions from prototype burst test may be granted for expansion joints of large diameter used on sea water lines and to large diameter expansion joints used on exhaust gas lines, except for those which are fitted directly on engines. Testing may be limited to pressure test.

Table 35 : Type tests and procedures for metallic flexible hoses depending on the application

	Burst	Pliability (bending)	Cycle test: U bend (Hoses up to 100 DN)	Cycle test: Cantilever bend (Hoses above DN 100)	Pressure and elongation	Impulse	Vibration
	ISO 10380:2012 **(1)**					**(2)**	Ch 3, Sec 6, Tab 1 **(1)**
Fuel Oil	X	X	X	X	X	**(3)**	**(4)**
Lubricating Oil	X	X	X	X	X	**(3)**	**(4)**
Hydraulic Oil	X	X	X	X	X	**(3)**	**(4)**
Thermal Oil	X	X	X	X	X	**(3)**	**(4)**
Fresh water	X	X	X	X	X	**(3)**	**(4)**
Sea water	X	X	X	X	X	**(3)**	**(4)**
Compressed air	X	X	X	X	X	**(3)**	**(4)**
Bilge	X	X	X	X	X	**(3)**	**(4)**
Exhaust Gas	X	X	X	X	X	**(3)**	**(4)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) Impulse pressure is to be raised from 0 to 1,5 times the design pressure with a frequency equal to 30-100 cycles per minute for at least 150 000 cycles.
(3) For piping systems subject to pressure pulsation.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.

Table 36 : Type tests and procedures for non-metallic flexible hoses depending on the application

	Burst EN ISO 1402:2021 **(1)**	Fire resistance EN ISO 15540:2016 / EN ISO 15541:2016	Visual inspection and dimensional check EN ISO 4671:2022 **(1)**	Change in length EN ISO 1402:202 **(1)**	Resistance against liquid ISO 1817:2022 **(1)**	Cover adhesion EN ISO 8033:2016 **(1)**	Ozone resistance **(2)** ISO 7326:2016 **(1)**	Impulse EN ISO 6802:2018 / EN ISO 6803:2017 **(1)**	Vibration Ch 3, Sec 6, Tab 1 **(1)**	Vacuum EN ISO 7233:2016 **(1)**	Cold flexibility EN ISO 10619-2:2021 **(1)**
Fuel Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Lubricating Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Hydraulic Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Thermal Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Fresh water	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Sea water	X	X	X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Compressed air	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Bilge	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Exhaust Gas	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For rubber hoses only.
(3) For piping systems subject to pressure pulsation.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.
(5) For suction hoses only.
(6) For piping systems subject to low temperature (< 0°C).

Table 37 : Type tests and procedures to be performed for metallic expansion joints

	Burst	Hydrostatic	Cyclic expansion **(1)**	Vibration
	see [20.2.1] d) **(2)**	see [20.5.6] **(2)**	EJMA Code **(3) (2)**	Ch 3, Sec 6, Tab 1 **(2)**
Fuel Oil	X		X	**(4)**
Lubricating Oil	X		X	**(4)**
Hydraulic Oil	X		X	**(4)**
Thermal Oil	X		X	**(4)**
Fresh water	X		X	**(4)**
Sea water	X		X	**(4)**
Compressed air	X		X	**(4)**
Bilge	X		X	**(4)**
Exhaust Gas		X	X	**(4)**

(1) For piping systems subject to expansion cycles.
(2) Other recognized standards may be accepted where agreed by the Society.
(3) Type test is an alternative. A test procedure is to be submitted to the Society for approval.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.

Table 38 : Type tests and procedures for non-metallic expansion joints

	Burst	Fire resistance	Resistance against liquid	Cyclic expansion **(1)**	Ozone resistance	Impulse	Vibration
	[20.2.1], item d) **(2)**	EN ISO 15540:2016 / EN ISO 15541:2016 **(2)**	ISO 1817:2022 **(2)**	**(2) (3)**	ISO 7326:2016 **(2)**	EN ISO 6802:2018 / EN ISO 6803:2017 **(2)**	Ch 3, Sec 6, Tab 1 **(2)**
Fuel Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Lubricating Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Hydraulic Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Thermal Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Fresh water	X			X	**(4)**	**(5)**	**(6)**
Sea water	X	X		X	**(4)**	**(5)**	**(6)**
Compressed air	X			X	**(4)**	**(5)**	**(6)**
Bilge	X			X	**(4)**	**(5)**	**(6)**

(1) For piping systems subject to expansion cycles.
(2) Other recognized standards may be accepted where agreed by the Society.
(3) Test procedure is to be submitted to the Society for approval
(4) For rubber expansion joints only.
(5) For piping systems subject to pressure pulsation.
(6) Where fitted to engines, pumps, compressors or other sources of high vibrations

20.3 Type tests of air pipe closing appliances

20.3.1 Testing of air pipe automatic closing devices

Each type and size of air pipe automatic closing device is to be surveyed and type tested at the manufacturer's works or a recognized laboratory accepted by the Society. The test requirements for an air pipe automatic closing device are to include the following:

a) Determination of the flow characteristics

The flow characteristics of the air pipe closing device are to be determined.

Measuring of the pressure drop versus rate of volume flow is to be carried out using water and with any intended flame or insect screens in place.

b) Tightness test during immersion/emerging in water

An automatic closing device is to be subjected to a series of tightness tests involving not less than two immersion cycles under each of the following conditions:

- The automatic closing device is to be submerged slightly below the water surface at a velocity of approximately 4 m/min. and then returned to the original position immediately. The quantity of leakage is to be recorded.
- The automatic closing device is to be submerged to a point slightly below the surface of the water. The submerging velocity is to be approximately 8 m/min and the air pipe vent head is to remain submerged for not less than 5 minutes. The quantity of leakage is to be recorded.
- Each of the above tightness tests is to be carried out in the normal position as well as at an inclination of 40° under the strictest conditions for the device. In cases where such strictest conditions are not clear, tests are to be carried out at an inclination of 40° with the device opening facing in three different directions: upward, downward, sideways (left or right). See Fig 6 and Fig 7.

The maximum allowable leakage per cycle is not to exceed 2 ml/mm of nominal diameter of inlet pipe during any individual test.

Figure 6 : Example of normal position

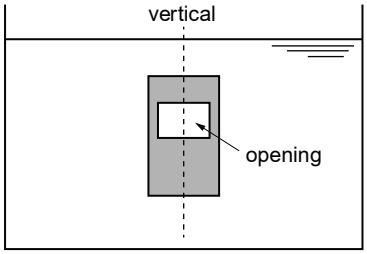
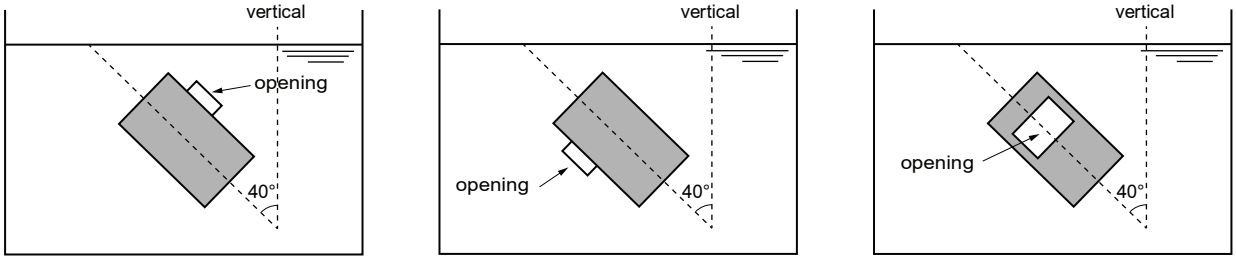


Figure 7 : Examples of inclination of 40° with different directions of the device opening



Device opening facing upward | Device opening facing downward | Device opening facing sideways

c) Discharge / Reverse flow test:

1) The air pipe head is to allow the passage of air to prevent excessive vacuum developing in the tank.

Reverse flow test:

- A reverse flow test is to be performed. A vacuum pump or another suitable device is to be connected to the opening of the air pipe leading to the tank. The flow velocity is to be applied gradually at a constant rate until the float gets sucked and blocks the flow, and
- The velocity at the point of blocking is to be recorded. A mention of 80% of the value recorded is to be stated in the type approval certificate.

2) Alternative to the reverse flow test:

- For pipe heads of 400 mm nominal diameter and above, as an alternative to the reverse flow test, a numerical simulation test based on computational fluid dynamics (CFD), to be carried out in conjunction with limited representative testing to establish the validity of the CFD modelling and results, may be accepted
- CFD predictions for air pipe heads can be validated against the available actual reverse flow test results of same size and type of air pipe heads
- The accuracy of the CFD modelling and the major assumptions used for the calculation are to be documented
- Mesh convergence studies are to be carried out and documented, and
- The velocity at the point of blocking is to be recorded. A mention of 80% of the value recorded is to be stated in the type approval certificate.

20.3.2 Testing of non-metallic floats

Impact and compression loading tests are to be carried out on the floats before and after pre-conditioning, as per Tab 39.

a) Impact test

The impact test may be conducted on a pendulum type testing machine. The floats are to be subjected to 5 impacts of 2,5 Nm each and are not to suffer permanent deformation, cracking or surface deterioration at this impact loading.

Subsequently the floats are to be subjected to 5 impacts of 25 Nm each. At this impact energy level, some localised surface damage at the impact point may occur. No permanent deformation or cracking of the floats is to appear.

b) Compression loading test

Compression tests are to be conducted with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the float seating with which the tested float is intended to be used. For ball type float, loads are to be applied through a concave cap of the same internal radius as the test float and bearing on an area of the same diameter as the seating. For a disc type float, loads are to be applied through a disc of equal diameter as the float.

A load of 350 kg is to be applied over one minute and maintained for 60 minutes. The deflection is to be measured at intervals of 10 minutes after attachment of the full load. The record of deflection against time is to show no continuing increase in deflection and, after release of the load, there is to be no permanent deflection.

20.3.3 Testing of metallic floats

Tests are to be conducted in accordance with [20.3.2], item a) above. The tests are to be carried out at room temperature and in the dry condition.

Table 39 : Pre-conditioning of floats

Test condition	Test temperature		
	–25°C	+20°C	+85°C
Dry	+	+	+
After immerging in water	+	+	+
After immerging in fuel oil	–	+	–
Note 1: Immerging in water and fuel oil is to be for at least 48 hours.			

20.4 Testing of materials

20.4.1 General

a) Requirements for material tests are given in NR216 Materials and Welding.

b) The requirements of this Article do not apply to piping systems subjected to low temperatures, such as cargo piping of liquefied gas carriers.

20.4.2 Tests for materials

a) Where required in Tab 40, materials used for pipes, valves and other accessories are to be subjected to the following tests:

- tensile test at ambient temperature
- flattening test or bend test, as applicable
- when designed to be used at high temperatures on the basis of their high-temperature strength characteristics, a hot tensile test is to be performed on one test specimen per serie and per size, except if one of the following conditions is met:
  - the design temperature is below 200°C
  - the mechanical properties of the material at high temperature have been approved according to a recognized standard
  - the scantling of the pipes is based on reduced values of the permissible stress.

b) Plastic materials are to be subjected to the tests specified in Ch 1, App 3.

c) For piping systems included in engine, turbine or gearbox installation in contact with flammable fluids, requirements mentioned in Ch 1, Sec 1, [3.7.2] are to be applied when other materials than steel are used. Especially, piping systems might need to be tested according to ISO 19921:2005 / 19922:2005.

20.5 Hydrostatic testing of piping systems and their components

20.5.1 General

Pneumatic tests are to be avoided wherever possible. Where such testing is absolutely necessary in lieu of the hydraulic pressure test, the relevant procedure is to be submitted to the Society for acceptance prior to testing.

20.5.2 Hydrostatic pressure tests of piping

a) Hydrostatic pressure tests are to be carried out to the Surveyor's satisfaction for:
- all class I and II pipes and their integral fittings
- all steam pipes, feed water pipes, compressed air pipes, and fuel oil and other flammable oil pipes with a design pressure greater than 0,35 MPa and their associated integral fittings.

b) These tests are to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

Note 1: Classes of pipes are defined in [1.5.2].

c) Pressure testing of small bore pipes (less than 15 mm) may be waived at the discretion of the Surveyor, depending on the application.

d) Where the design temperature does not exceed 300°C, the test pressure is to be equal to 1,5 p.

e) Where the design temperature exceeds 300°C, the test pressure is to be as follows:
- for carbon and carbon-manganese steel pipes, the test pressure is to be equal to 2 p
- for alloy steel pipes, the test pressure P_H is to be determined by the following formula, but need not exceed 2 p:

$$p_H = 1,5\frac{K_{100}}{K_T}p$$

where:

K_{100} : Permissible stress for 100°C, as stated in Tab 11

K_T : Permissible stress for the design temperature, as stated in Tab 11.

Note 2: Where alloy steels not included in Tab 11 are used, the permissible stresses will be given special consideration.

f) Where it is necessary to avoid excessive stress in way of bends, branches, etc., the Society may give special consideration to the reduction of the test pressure to a value not less than 1,5 p. The membrane stress is in no case to exceed 90% of the yield stress at the testing temperature.

g) While satisfying the condition stated in b), the test pressure of pipes located on the discharge side of centrifugal pumps driven by steam turbines is not to be less than the maximum pressure liable to be developed by such pumps with closed discharge at the operating speed of their overspeed device.

h) Hydrostatic testing may be carried out after assembly on board of the piping sections under the conditions stated in Ch 1, Sec 18, [3.12.1].

For pressure tests of piping after assembly on board, see Ch 1, Sec 18, [3.12.1], Ch 1, Sec 18, [3.12.2] and Ch 1, Sec 18, [3.12.3].

For pressure tests of plastic pipes after assembly on board, see Ch 1, App 3, [4.9].

20.5.3 Hydrostatic tests of valves, fittings and heat exchangers

a) Valves and fittings non-integral with the piping system and intended for class I and II pipes are to be subjected to hydrostatic tests in accordance with standards recognised by the Society, at a pressure not less than 1,5 times the design pressure P defined in [1.3.2].

b) Valves and distance pieces intended to be fitted on the ship side below the load waterline are to be subjected to hydrostatic tests under a pressure not less than 0,5 MPa.

c) The shells of appliances such as heaters, coolers and heat exchangers which may be considered as pressure vessels are to be tested under the conditions specified in Ch 1, Sec 3.

d) The nests of tubes or coils of heaters, coolers and heat exchangers are to be submitted to a hydraulic test under the same pressure as the fluid lines they serve.

e) For coolers of internal combustion engines, see Ch 1, Sec 2.

20.5.4 Hydrostatic tests of fuel oil bunkers and tanks not forming part of the ship's structure

Fuel oil bunkers and tanks not forming part of the ship's structure are to be subjected to a hydrostatic test under a pressure corresponding to the maximum liquid level in such spaces or in the air or overflow pipes, with a minimum of 2,40 m above the top. The minimum height is to be 3,60 m for tanks intended to contain fuel oil with a flashpoint below 60°C.

20.5.5 Hydrostatic tests of pumps and compressors

a) Cylinders, covers and casings of pumps and compressors are to be subjected to a hydrostatic test under a pressure at least equal to the test pressure p_H, in MPa, determined by the following formulae:
- $p_H = 1,5\ p$ where $p \le 4$
- $p_H = 1,4\ p + 0,4$ where $4 < p \le 25$
- $p_H = p + 10,4$ where $p > 25$

where:

p : Design pressure, in MPa, as defined in [1.3.2].

p_H is not to be less than 0,4 MPa.

b) While satisfying the condition stated in a), the test pressure for centrifugal pumps driven by steam turbines is not to be less than 1,05 times the maximum pressure likely to be recorded with closed discharge at the operating speed of the overspeed device.

c) Intermediate coolers of compressors are to undergo a hydrostatic test under a pressure at least equal to the pressure p_H defined in a). When determining p_H, the pressure p to be considered is that which may result from accidental communication between the cooler and the adjoining stage of higher pressure, allowance being made for any safety device fitted on the cooler.

d) The test pressure for water spaces of compressors and their intermediate coolers is not to be less than 1,5 times the design pressure in the space concerned, subject to a minimum of 0,2 MPa.

e) For air compressors and pumps driven by internal combustion engines, see Ch 1, Sec 2.

20.5.6 Hydrostatic test of flexible hoses and expansion joints

a) Each flexible hose or expansion joint, together with its connections, is to undergo a hydrostatic test under a pressure at least equal to 1,5 times the maximum service pressure.

b) During the test, the flexible hose or expansion joint is to be repeatedly deformed from its geometrical axis.

20.6 Testing of piping system components during manufacturing

20.6.1 Pumps

a) Bilge and fire pumps are to undergo a performance test.

b) Rotors of centrifugal feed pumps for main boilers are to undergo a balancing test.

20.6.2 Centrifugal separators

Centrifugal separators used for fuel oil and lubricating oil are to undergo a running test, normally with a fuel water mixture.

20.7 Inspection and testing of piping systems

20.7.1 The inspections and tests required for piping systems and their components are summarised in Tab 40.

Table 40 : Inspection and testing at works for piping systems and their components

Item **(5)**		Tests for the materials **(1)**		Inspections and tests for the product **(1)**		
		Tests required	Type of material certificate **(2)**	During manufacturing (NDT)	After completion	Type of product certificate **(2)**
Raw pipes	class I, ND ≥ 50 class II, ND ≥ 100	[20.4.1]	W **(3)**	NR216	NR216	C
	class I, ND < 50 class II, ND < 100		W **(3)**			W
Pipe fittings **(10)**	class I, ND ≥ 50 class II, ND ≥ 100	[20.4.1]	W **(3)**	NR216	NR216	C
	class I, ND < 50 class II, ND < 100		W **(3)**			W
Pipe assemblies and their integral fittings, if any	class I			[3.6.2], [3.6.3] **(4)**	[20.5.2]	C
	class II					
	class III					W
Valves **(9)**	class I, ND ≥ 50 class II, ND ≥ 100	[20.4.1] **(6)**	C	[3.6.2], [3.6.3] **(4)**	[20.5.3]	C
	class I, ND < 50 class II, ND < 100		W			C
	class III		W			W

Item **(5)**		Tests for the materials **(1)**		Inspections and tests for the product **(1)**		
		Tests required	Type of material certificate **(2)**	During manufacturing (NDT)	After completion	Type of product certificate **(2)**
Pipes, valves and fittings connected to the ship side or to the collision bulkhead	ND ≥ 100	[20.4.1] **(6)**	C **(6)** for valves W **(3)** for pipes and fitting	[3.6.2], [3.6.3] **(4)**	[20.5.3], b)	C
	ND < 100		W **(3)** **(6)**			
Flexible hoses and expansion joints		[20.4.1]	W		[20.5.6]	C
Pumps and compressors within piping systems covered by Sections of Part C, Chapter 1 **(8)**	when belonging to a class I piping system	[20.4.1] **(6)**	C		[20.5.5]	C
	when belonging to a class II piping system	[20.4.1] **(6)**	W		[20.5.5]	C
	bilge and fire pump	[20.4.1] **(6)**	W		[20.5.5] [20.6.1], a)	C
	feed pumps for main boilers	[20.4.1] **(6)**	C	[3.6.2], [3.6.3] **(4)** **(7)**	[20.5.5] [20.6.1], b)	C
	forced circulation pumps for main boilers	[20.4.1] **(6)**	C		[20.5.5]	C
	when belonging to one of the following class III piping systems if design pressure exceeds 0,35 MPa: • boiler feed water or forced circulating • fuel oil or other flammable oil • compressed air	[20.4.1] **(6)**	W		[20.5.5]	C
	when belonging to other class III piping systems				[20.5.5]	W
Centrifugal separators					[20.6.2]	C

(1) [x.y.z] = test required, as per referent regulation. In general, the material are to comply with [2.1.2]

(2) "C" indicates that a Society certificate is required. "W" indicates that a manufacturer's document is required. See NR216 Materials and Welding, Ch 1, Sec 1, [4.2]

(3) Refers to the materials used to manufacture the pipes or fittings (e.g. bars, plates).

(4) If of welded construction.

(5) ND = Nominal diameter of the pipe, valve or fitting, in mm.
Class of piping systems is to be determined in accordance with [1.5.2].

(6) Where required by the table, material tests are to be carried out for the components subject to pressure, such as valve body, pump and compressor casings, etc. They are also to be carried out for the assembling bolts of feed water pumps and forced circulating pumps serving main boilers. Requirements for material testing are detailed in NR 216 Materials and Welding.

(7) For main parts, before assembling.

(8) For other pumps and compressors, see additional Rules relevant for related system.

(9) Valves under static pressure connected to oil fuel tanks or lubricating oil tanks belong to class II.

(10) Fittings refer to piping components such as sleeves, elbows, tees, bends, flanges, etc., which are used to join together sections of pipe.

Section 11 Exhaust Gas Pollution Prevention System

1 General

1.1 Application

1.1.1 This Section applies to installation, storage of chemical treatment fluids, piping system and equipment dedicated to the treatment of exhaust gas.

1.1.2 The requirements of this Section are additional to those of Ch 1, Sec 10, [18].

1.1.3

a) Requirements for exhaust gas pipes from engines, gas turbines, boilers and incinerators are given in Ch 1, Sec 10, [18].

b) General requirements applying to the installation of any exhaust gas pollution prevention system are contained in Article [2].

c) Additional requirements for the storage and use of urea as reductant in SCR are given in Article [3].

d) Additional requirements for the storage and use of sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) in exhaust gas cleaning system - scrubbers are given in Article [4].

e) Additional requirements for any other chemical treatment fluids used in exhaust gas are given in Article [5].

1.1.4 When an onboard carbon capture and storage system is installed, the ship is to comply with the requirements of Ch 1, Sec 12.

1.2 Definitions

1.2.1 Exhaust gas pollution prevention system

Exhaust gas pollution prevention system means any system including scrubber (or exhaust gas cleaning system), SCR (selective catalytic Reduction) and EGR (Exhaust Gas Recirculation), used to reduce polluting emissions from the exhaust gas.

1.2.2 Chemical treatment fluid

Unless otherwise specified, chemical treatment fluid means any chemical consumed in a process for the treatment of exhaust gas.

1.2.3 Exhaust gas cleaning system (EGCS)

EGCS refers to SOx scrubbers' complete installation, including:

- a scrubbing vessel, used to remove sulphur content from the exhaust of marine engines or boilers,
- a treatment plant to manage the washwater after the scrubbing process, and
- a sludge management system (a holding tank with outboard discharge to port facilities).

1.2.4 Selective catalytic reduction (SCR) equipment

SCR means equipment used to reduce NOx emissions from the exhaust of marine engines using selective catalytic reduction process.

1.2.5 Exhaust gas recirculation (EGR)

EGR means exhaust gas recirculation, i.e. a means method used to reduce NOx emissions at the exhaust of marine engines at the source using partial recirculation of the exhaust gas to the engine air inlet.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

In case of a retrofit, all drawings showing modifications related to the exhaust gas pollution prevention system installation are to be submitted. Especially, attention is drawn on the documents listed in Tab 2.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	General arrangement of the exhaust gas pollution prevention system
2	A	Diagrams of sea water and / or fresh water piping systems **(3)**
3	A	Diagram of washwater treatment and sludge piping systems **(3)**
4	A	Diagram of chemical piping system, including filling, storage and dosing **(3)**
5	I	Risk analysis report covering a failure of the exhaust gas pollution prevention system, a leakage of washwater, sludge or chemical, or a fire, as detailed in [2.3.1], [2.4.3], [3.1.1] or [5] when applicable

(1) A = to be submitted for approval ; I = to be submitted for information
(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems
(3) Where applicable, depending on the design of the exhaust gas pollution prevention system

Table 2 : Documents to be submitted in case of a retrofit

No.	I/A **(1)**	Document
1	I	General arrangement and Machinery general arrangement
2	A	Fire control plan
3	A	Damage control plan, damage stability booklet and tank capacity plan
4	A	Ventilation, extinction and detection
5	A	Power supply arrangement
6	A	Single line diagram of the control system
7	A	List of alarms and monitored parameters and safety systems
8	I	Test program of the control system
9	I	Ship electrical power balance
10	I	Instruction and operation manuals
11	A	Diagram of scrubber installation, fixation diagram, strength calculation for scrubber transverse supports
12	A	Structural modification (Holes and Penetrations drawing, modification of the Sea Chest, Funnel and Casing)
13	A	Diagrams of the exhaust gas pollution prevention system and exhaust gas piping
14	A	Pressure losses calculation in the exhaust line
15	A	Diagram of ancillaries system modification (compressed air, ventilation,…)
16	A	Diagram of the tanks vent system
17	A	Diagram of the bilge system
18	A	Filling up piping system for chemical products and storage of the product and preparation/handling of the product
19	I	Risk analysis (availability of essential systems of ship related to failure of exhaust gas pollution prevention system, use of chemical products)
20	A	Exhaust gas boiler modification
21	I	Test program and reports

(1) A: To be submitted for approval ; I: To be submitted for information.

2 Installation requirements

2.1 General

2.1.1 Exhaust gas pollution prevention systems are to be designed, arranged and installed in accordance with the following requirements.

EGCS are to be tested in accordance with the requirements of [2.5], under the survey and to the satisfaction of the Society's Surveyor.

2.2 Installation requirements

2.2.1 Design

Attention is drawn on IMO Guidelines regarding the environmental performance of equipment such as ECGS and SCR systems.

For ships with the additional class notation **EGCS-SCRUBBER**, the provisions of Pt F, Ch 9, Sec 7, [2] are to be complied with.

2.2.2 Tank design and construction requirements are given in Pt B, Ch 2, Sec 2, [10].

2.2.3 The chemical treatment fluids tanks are to be included in the ship's stability calculation.

2.2.4 Additional requirements about retention of treatment water on board are to be fulfilled in case **CLEANSHIP** notation is granted (see Pt F, Ch 9, Sec 2, [2.10]).

2.3 Availability

2.3.1 The availability of the machinery served by the exhaust gas pollution prevention system is to be substantiated by a risk analysis.

The exhaust gas pollution prevention equipment is to be so arranged that, in the case of failure of such equipment, propulsion power and auxiliary power supplying essential functions are not affected. Where necessary, a bypass is to be installed.

In case of blackout, automatic starting of engines, if provided, is to remain effective as if no exhaust gas pollution prevention system were installed and not detrimental to the exhaust gas pollution prevention installation.

2.4 Arrangement

2.4.1 Exhaust systems connections

As mentioned in Ch 1, Sec 10, [18.2.4], no interconnection is permitted between different exhaust piping systems for engines. In case of one exhaust gas pollution prevention system used for several installations, interconnections may be acceptable with additional devices installed as follows:

- Individual isolating devices for exhaust pipes are to be provided on each individual exhaust pipe; and
- Forced ventilation is to be installed at the outlet of the common exhaust pipe, preventing any backflow of exhaust gases in individual exhaust ducts in any possible working conditions.

  As an alternative to forced ventilation, exhaust systems interconnections might be accepted on a case-by-case basis and considering an exhaust gas back pressure analysis according to the guidance given in Ch 1, App 7, to the satisfaction of the Society.

2.4.2 Bypass

When the exhaust gas pollution prevention system may be bypassed, proper means are to be installed providing double barrier upstream from the exhaust gas pollution prevention system, in order to enable safe inspection in exhaust gas pollution prevention equipment in any working configuration of combustion units.

For a SCR, the requirements about having a double barrier is to be disregarded provided that a label mentioning “Do not open when engine in operation” is visible on the SCR.

2.4.3 Filling systems for chemical treatment fluids

Filling systems for chemical treatment fluids are to be located in places where no interference with other ship activities would happen. In case interference is unavoidable, a risk analysis is to be provided in order to evaluate occurrence and level of danger for crew and passengers if any.

Drainage of coamings if any and outlet of safety valves are to be led to a tank designed for that purpose.

2.4.4 Materials

Materials used for equipment and piping systems are to be suitable with fluids conveyed, not leading to early corrosion or creating hazardous gases when in contact with treatment liquid or vapours. This requirement is also valid for drip trays, fans and ducts being part of exhaust gas pollution prevention system.

2.4.5 Discharge water piping

Piping intended to convey discharge water from exhaust gas pollution prevention systems are to be protected against corrosion either by selection of their constituent materials or by an appropriate coating or treatment, with due consideration of the expected composition and acidity of the discharge water. In addition, the distance piece between the overboard discharge valve and the shell plating is to have at least extra-reinforced wall thickness as defined in Ch 1, Sec 10, Tab 6.

Attention is also drawn on distance piece thickness survey requirements given in Pt A, Ch 3, Sec 1, [3.1.6].

The discharge outlet is to be widely separated from the ship seawater inlet. In addition, surfaces of the hull, seachests, and hull appendages in the vicinity of the discharge outlet are to be suitably protected against the corrosive effects of low pH discharge water.

2.4.6 Control and monitoring

Alarms and indications are to be provided in accordance with Tab 3.

For ships to be granted an **AUT** additional class notation, those alarms and indications are to be provided at the centralised control position, see Pt F, Ch 3, Sec 1, [4.8.9].

Information related to exhaust gas pollution prevention device and washwater, discharge measurements is to be made available in a control station.

2.5 Certification, Inspection and testing

2.5.1 EGC unit tower

Welded joints are to be made in accordance with qualified welding procedures by qualified welders. Welder's certificates, welding procedures and their qualification records are to be submitted to the Society for review.

Welded joints, including the inside wherever possible, are to be visually examined by the manufacturer.

Magnetic particle or liquid penetrant testing is to be performed on welded joints selected according to manufacturer's plan.

2.5.2 Inspection and testing of EGCS components

Inspection and testing of EGCS components are defined in Tab 4.

Table 3 : Control and monitoring for exhaust gas pollution prevention systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Failure of exhaust fans (each fan)	X						
Exhaust temperature before entering in plastic parts or Cooling medium flow	H L	local local					
Chemical treatment fluids storage tank level **(1)**	H **(2)**	local **(2)**					
(1) Not applicable to process tanks **(2)** High level alarm is to be independent from the tank level indicator.							

Table 4 : Inspection and testing at works for EGCS components

Item	Tests for the materials **(1)**		Inspections and tests for the product **(1)**		
	Tests required **(2)**	Type of material certificate **(3)**	During manufacturing (NDT)	After completion	Type of product certificate **(3)**
Water pumps				Ch 1, Sec 10, [20.5.5]	W
Treatment chemical pumps	Ch 1, Sec 10, [20.4.2]	W		Ch 1, Sec 10, [20.5.5]	C **(4)**
EGC unit tower		W	[2.5.1]		C **(4)**
(1) [x.y.z] = test required, as per referent regulation. In general, the material are to comply with Ch 1, Sec 10, [2.1.2] **(2)** Where required by the table, material tests are to be carried out for the components subject to pressure, such as valve body, pump and compressor casings, etc. Requirements for material testing are detailed in NR 216 Materials and Welding **(3)** C = class certificate ; W = works' certificate (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2]) **(4)** Or alternative type of certificate, depending on the Survey Scheme. See NR320 Certification scheme of materials and equipment					

3 Storage and use of SCR reductant

3.1 Application

3.1.1 The following requirements apply to urea/water solutions used in SCR. However, the requirements [3.2.3], [3.2.5], [3.3.1], [3.3.2] and [3.5.1] do not apply to daily tanks and buffer tanks with a volume below 500L.

For other reductants falling in the scope of IMDG Code like aqueous ammonia or anhydrous ammonia, the following conditions are to be fulfilled:

- It is to be demonstrated that the use of urea based reductant is not practicable and, in case of use of anhydrous ammonia, that the use of aqueous ammonia is not practicable either

Note 1: It is reminded that use of anhydrous ammonia may require the agreement of the Flag Administration.

- A risk analysis is to be provided regarding the loading, carriage and use of the product
- Requirements mentioned in Article [5] are to be fulfilled.

3.2 Storage tank

3.2.1 The storage tank is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank.

3.2.2 The storage tank may be located in the engine room.

3.2.3 Each urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are also to be provided.

3.2.4 Where urea based ammonia solution is stored in integral tanks, these tanks are to be coated with appropriate anti-corrosion coating and are not to be located adjacent to any fuel oil or fresh water tank.

3.2.5 Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

3.3 Ventilation

3.3.1 If a urea storage tank is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be independent from the ventilation systems of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

Alternatively, where a urea storage tank is located within an engine room, a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

3.3.2 The requirements specified in [3.3.1] also apply to closed compartments normally entered:

- when they are adjacent to the urea integral tanks and there are possible leak points (e.g. manhole, fittings) from these tanks; or
- when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925°C and with fully welded joints.

3.4 Piping

3.4.1 The reductant piping and venting systems are to be independent of other ship service piping and/or systems. Reductant piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the urea tank.

3.5 Materials

3.5.1 Reductant tanks are to be of steel or other equivalent material with a melting point above 925°C. Pipes/piping systems are to be of steel or other equivalent material with melting point above 925°C, except downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire. In such case, type approved plastic piping may be accepted even if it has not passed a fire endurance test.

Reductant tanks and pipes/piping systems are to be made with a material compatible with the reductant or coated with appropriate anti-corrosion coating.

Copper is to be avoided for equipment and piping systems in contact with fluids containing ammonia.

3.6 Protection of crew members

3.6.1 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash are to be provided, the location and number of these eyewash stations are to be derived from the detailed installation arrangements.

4 Chemical treatment fluids used for exhaust gas cleaning systems

4.1 Application

4.1.1 The following requirements apply to sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$)) used in exhaust gas cleaning system, which are carried on board in bulk.

4.2 Storage tank

4.2.1 The storage tank for chemical treatment fluids is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank.

In cases where such valves are provided below the top of tank, they are to be arranged with quick acting shut-off valves capable of being remotely operated from a position accessible even in the event of chemical treatment fluid leakages.

4.2.2 The storage tank may be located in the engine room.

4.2.3 Each storage tank for chemical treatment fluids is to be provided with level monitoring arrangements and high/low level alarms. In cases where heating and/or cooling systems are provided, high and/or low temperature alarms or temperature monitoring are also to be provided accordingly.

4.2.4 The storage tanks are to have sufficient strength to withstand a pressure corresponding to the maximum height of a fluid column in the overflow pipe, with a minimum of 2,4 m above the top plate taking into consideration the specific density of the treatment fluid.

4.2.5 Where chemical treatment fluid is stored in integral tanks these tanks are to be coated with appropriate anti-corrosion coating and are to be segregated by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner as well as any food stores, oil tanks and fresh water tanks.

4.2.6 Storage tanks for chemical treatment fluids are to be arranged so that they can be safely emptied of the fluids and ventilated by means of portable or permanent systems.

4.3 Ventilation

4.3.1 If a storage tank for chemical treatment fluids is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of other spaces. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is be provided outside the compartment adjacent to each point of entry.

4.3.2 If the storage tank is located in the engine room, the requirements of [4.3.1] are to be complied with, except that a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

4.3.3 The requirements specified in [4.3.1] also apply to closed compartments normally entered by persons:

- when they are adjacent to the integral storage tank for chemical treatment fluids and there are possible leak points (e.g. manhole, fittings) from these tanks; or
- when the treatment fluid piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 °C and with fully welded joints.

4.4 Piping

4.4.1 The chemical treatment fluid piping and venting systems are to be independent of other ship service piping and/or systems. The chemical treatment fluid piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the tank for chemical treatment fluids.

4.4.2 Regardless of design pressure and temperature, piping systems containing chemical treatment fluids only are to comply with the requirements applicable to Class I piping systems. As far as practicable, e.g. except for the flange connections that connect to tank valves, the piping systems are to be joined by welding.

4.5 Exhaust Gas Cleaning Systems discharge water pipeline

4.5.1 Overboard discharges from exhaust gas cleaning system (EGCS) are not to be interconnected to other systems.

4.5.2 Due consideration is to be given to the location of overboard discharges with respect to vessel propulsion features, such as thrusters, propellers or to prevent any discharge water onto survival craft during abandonment.

4.5.3 The piping material for the EGCS discharge water pipeline system is to be selected based on the corrosive nature of the liquid media.

4.5.4 Special attention is to be paid to the corrosion resistivity of EGCS overboard discharge piping. Where applicable, adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals.

4.5.5 In case distance piece is fitted between the outboard discharge valve and the shell plating, it shall be made of corrosion resistant material steel or be coated with an anti-corrosive material suitable for the operating environment. The thickness of the distance piece shall be at least the minimum values specified below:

- 12 mm in cases where complete pipe is made of corrosion resistant material steel.
- 15 mm of mild steel in cases where the inside the pipe is treated with an anticorrosive coating or fitted with a sleeve of corrosion resistant material.

4.6 Materials

4.6.1 Storage tanks, pipes/piping systems and drip trays for chemical treatment fluids which transfer undiluted chemical treatment fluids are to be of steel or other equivalent material with a melting point above 925 °C.

4.6.2 Storage tanks and pipes/piping systems for chemical treatment fluids are to be made with a material compatible with chemical treatment fluids, or coated with appropriate anti-corrosion coating.

Aluminium and zinc are to be avoided for equipment and piping systems in contact with fluids like caustic soda (NaOH).

4.7 Containment of leakage

4.7.1 The following connections are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:

- detachable connections between pipes (flanged connections and mechanical joints, etc.)
- detachable connections between pipes and equipment such as pumps, strainers, heaters, valves
- detachable connections between equipment such as pumps, strainers, heaters, valves.

The drip trays are to be fitted with drain pipes which lead to appropriate tanks, such as residue tanks, which are fitted with high level alarm, or are to be fitted with alarms for leak detection. In cases where such tank is an integral tank, [4.2.5] is to be applied to the tank.

4.8 Protection of crew members

4.8.1 For the protection of crew members, the ship is to have on board suitable personal protective equipment (PPE). The number of PPE carried onboard is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure; but in no case is there to be less than two sets available on board.

4.8.2 Personal protective equipment (PPE) is to consist of protective clothing, boots, gloves and tight-fitting goggles.

4.8.3 Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

- in the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck then one eyewash and safety shower station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck.
- an eyewash station and safety shower is to be provided in the vicinity of a chemical bunkering station on-deck. If the bunkering connections are located on both port and starboard sides, then consideration is to be given to providing two eyewash stations and safety showers, one for each side.
- an eyewash station and safety shower is to be provided in the vicinity of any part of the system where a spillage/drainage may occur and in the vicinity of system connections/components that require periodic maintenance.

4.9 Safety measures against the residues which have hazardous properties

4.9.1 Tanks for residues generated from the exhaust gas cleaning process are to satisfy the following requirements:

- the tanks are to be independent from other tanks, except in cases where these tanks are also used as the over flow tanks for chemical treatment fluids storage tank.
- tank capacities are to be decided in consideration of the number and kinds of installed exhaust gas cleaning systems as well as the maximum number of days between ports where residue can be discharged ashore. In the absence of precise data, a figure of 30 days is to be used.
- where residue tanks used in closed loop chemical treatment systems are also used as the overflow tanks for chemical treatment fluids storage tank, the requirements for storage tanks apply.

5 Storage and use of other substances mentioned in IMDG Code

5.1 Application

5.1.1 For exhaust gas pollution prevention systems using chemical treatment fluids other than those mentioned in [3] and [4], the following requirements are to be followed. Additionally a risk analysis is to be conducted, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas pollution prevention systems, to an extent equivalent to systems complying with Article [3] and Article [4].

5.2 Risk analysis

5.2.1 For compartment containing chemical treatment fluid tanks a risk analysis is to be provided, taking into account normal or abnormal operating conditions (failure, fluid leakage, fire) regarding human health and damage to essential equipment contained in compartment.

5.2.2 In case of use of substances classed in IMO IMDG Code in categories 1, 2.1, 3, 4.1, 4.2, 4.3, 5.1, 6.1, 8 or 9, application of IEC standard 60079-10-1 is required regarding electric installations, hazardous areas definition and ventilation, and a specific risk analysis is to be submitted.

5.3 Containment of leakage

5.3.1 In case substances mentioned in IMO IMDG Code are used in exhaust gas pollution prevention systems, drainage and/or bilge pumping of compartments where such systems are located is to be separated from ship bilge system. Retention of potential leakages using drip trays associated to spill kits is to be implemented. Draining pipes from drip trays are to be led to a tank designed for that purpose.

5.4 Storage tank

5.4.1 Chemical treatment fluids tanks are not to be contiguous with tanks containing sea water, fresh water, fuel, lubricating tanks. A ventilated cofferdam between treatment chemical tanks and above mentioned tanks is an acceptable solution. Arrangement of the ventilation system is to be in accordance with [5.5].

Chemical treatment fluids tanks are not to be located in category A machinery spaces unless a specific risk analysis, as required in [5.2], is submitted to the Society for approval.

Chemical treatment fluids tanks when located adjacent to or within a compartment used for other purposes are to be surrounded by coamings delimitating space fitted with a high level alarm.

Bilge system of this compartment may be connected to ship bilge system provided arrangements are made to isolate this bilge suction. An additional fixed pumping system is to be installed in order to pump liquid with chemical substance from bilge and inside drip trays to draining tank. Isolation means and additional pumping system are to be remotely controlled.

5.4.2 Toxic or flammable product pipes, which, if damaged, would allow the product to escape from a tank, are to be fitted with a quick closing valve directly on the tank, capable of being closed from a safe position outside the compartment involved.

5.4.3 Overflow

Overflow pipes of chemical treatment fluids tanks are to be led to a specific tank dedicated for one kind of product. If several chemical treatment fluids tanks exist for a same product, overflow tank may be common.

5.4.4 Sounding and air pipes

Sounding pipes and air pipes are to end in an open space above freeboard deck. Means in order to prevent water entry through these pipe ends in any circumstances are to be provided.

5.5 Ventilation

5.5.1 Ventilation of compartments where chemical treatment fluids are stored or used is to be of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be separated from any other ventilation system. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

The ventilation system is to be included in the risk analysis requested in [5.2].

5.6 Piping

5.6.1 Piping systems involved in process are not to pass through accommodations, control stations or service spaces.

Section 12 Onboard Carbon Capture and Storage Systems

1 General

1.1 Application

1.1.1 This Section applies to ships fitted with an onboard carbon capture and storage (CCS) system intended to separate the carbone dioxide (CO_2) from the exhaust gases and store it on board.

Note 1: Such ships will be assigned the additional service feature **OCC**, as defined in Pt A, Ch 1, Sec 2, [4.16].

1.1.2 This Section addresses CCS systems where CO_2 is:

- emitted from an internal combustion engine, a boiler or a fuel cell supplied with carbon-based fuel
- separated using an absorption process with amine-based chemical solvent

Note 1: Other technologies or solvents will be considered on a case-by-case basis.

- compressed / liquefied
- stored
- offloaded.

1.1.3 This Section covers the design and installation of the CCS system, with respect to ship safety. The performance of the system is not covered. In particular, the following aspects are not addressed by this Section:

- CO_2 capture rate
- quality of the captured CO_2 for later use
- possible formation and emission of polluting substances (such as nitrosamines)
- quality of the solvent (degradation)
- solvent storage capacity
- CO_2 storage capacity.

Note 1: The attention is drawn to national or international regulations on CCS systems, concerning in particular their emissions and performance.

1.2 Documentation to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted.

1.2.2 In the case where a CCS system is retrofitted to an existing ship, the documents listed in Tab 2 are to be provided in addition to those referred to in [1.2.1].

1.3 Definitions

1.3.1 Carbon capture and storage (CCS) system

The carbon capture and storage (CCS) system consists of the following:

- solvent system
- separation system
- CO_2 system.

1.3.2 CO_2 system

CO_2 system means all equipment necessary for:

- the compression and liquefaction of the CO_2
- the transfer and storage of the CO_2 and
- the offloading of CO_2

1.3.3 Fuel

Fuel in the context of this Section means a carbon-based fuel such as oil fuel, LNG, LPG, methanol or ethanol.

1.3.4 Fuel consumer

Fuel consumer means internal combustion engine, boiler or fuel cell from which CO_2 present in the exhaust gases is captured.

1.3.5 Separation system

Separation system means all equipment necessary for the separation of the CO_2 from the exhaust gases emitted by the fuel consumers. It includes in particular:

- the exhaust gas cooler
- the exhaust gas blower
- the absorber
- the desorber (regenerator or stripper).

1.3.6 Solvent / rich solvent / lean solvent / waste solvent

- Solvent means a chemical (e.g. amine-based solvent) intended for the absorption of CO_2 or an aqueous solution thereof.
- Rich solvent means the solvent which contains captured CO_2.
- Lean solvent means the solvent from which CO_2 has been separated.
- Waste solvent means the solvent that needs to be replaced due to degradation.

1.3.7 Solvent system

Solvent system means all equipment necessary for the filling, storage, transfer, cooling and heating of the clean, working and waste solvent. It includes in particular:

- pumps
- heat exchangers
- tanks.

1.3.8 Triple point

Triple point is the temperature and pressure at which a material exists simultaneously as a solid, liquid, and gas. For carbon dioxide, the triple point is –56,6 °C and 5,18 bar abs.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1		CARBON CAPTURE SYSTEM **(3)**:
	A	• General arrangement
	I	• Specification with operating parameters (temperatures, pressures)
	I	• Operating manual, including operating, troubleshooting and maintenance instruction manuals, safety data sheets and details for handling of the solvent, parts list, electrical drawings, functional block diagram, pressure and instrumentation diagrams
	I	• Test program and procedures for installation and commissioning
2		EXHAUST GAS AND FLUE GAS SYSTEMS:
	A	• Diagram
	A	• Pressure loss calculation
	A	• Drawing of the exhaust gas cooler (direct contact cooler or quencher) **(4)**
	A	• Drawing of the blower, where provided **(4)**
	A	• Drawing of knock out drums, where provided **(4)**
	A	• Drawing of exhaust gas cleaning water treatment system, where provided
3		SOLVENT SYSTEM:
	A	• Diagram (including solvent filing, recovery, transfer, draining, reclaiming, sampling, discharge and tank venting)
	A	• Drawings of the absorber and desorber **(4)**
	A	• Drawings of the rich solvent / lean solvent heat exchanger **(4)**
	A	• Drawing of the reserve (clean) solvent tank and waste solvent tanks **(4)**
	A	• Drawing of buffer tanks for solvent solutions, where fitted **(4)**
	A	• Drawings of the rich solvent/ lean solvent circulating and make up pumps **(4)**

(1) A = to be submitted for approval ; I = to be submitted for information

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems including emergency shutdown arrangements

(3) Performance data of the CCS system need not be provided

(4) With material specification

No.	I/A **(1)**	Document **(2)**
4		CO_2 SYSTEM:
	A	• Diagram
	A	• Specification and drawings of the compression and liquefaction equipment (compressors, pumps, coolers, separators) **(4)**
	A	• Drawings of the CO_2 storage tank including the safety valves and their discharge, the pump if fitted and the manifold arrangement for offloading **(4)**
	A	• Specification of the means to maintain the CO_2 tank pressure and temperature within their design range and justification of the relevant capacities
5	A	Diagram of the cooling water system, including heat exchangers and pumps **(4)**
6	A	Diagram of the desorber heating system including the reboiler and its material specification
7	A	Diagram and specification of the solvent detection system
8	A	Diagram and specification of the CO_2 detection system
9	I	Report of the risk analysis
(1)	A = to be submitted for approval ; I = to be submitted for information	
(2)	Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems including emergency shutdown arrangements	
(3)	Performance data of the CCS system need not be provided	
(4)	With material specification	

Table 2 : Additional drawings to be submitted in the case where a CCS system is retrofitted to an existing ship

No	I/A **(1)**	Document **(2)**
1	A	General arrangement and machinery arrangement of the ship showing the location of the main components of the CCS system
2	I	Longitudinal strength calculations and stability calculations covering the loading conditions assuming the CCS system in operating conditions and specifying the allowable filling level of the CO_2 storage tank **(3)**
3	I	Calculations of the local structural reinforcements in way of the main components of the CCS system
4	I	Revised electrical balance
5	A	Revised steam balance
6	A	Revised compressed air and heat balances for cooling water (if cooling fresh water is used for heat exchangers)
7	A	Revised exhaust gas arrangement in engine room and casing
8		General arrangement of the electrical components:
	A	• General layout specifying the interconnection of the major electrical components of the CCS system
	A	• Ingress protection (IP) of the electrical panels and associated devices (junction boxes, electrical motors, etc.)
	A	• Interconnection diagram or document describing the link between the CCS and the ship's alarm system
9	A	List of alarms and safeties of the CCS system
10	A	Characteristics and certifications of the electrical devices added during the integration of the CCS system: electrical cables, detectors, etc.
11	A	Single line diagram showing the power electrical arrangement to supply the CCS system
12	I	Type of cables to be installed provided with the related Type Approval Certificates
13		For spaces containing CCS system components:
	A	• Diagram of the ventilation system
	A	• Diagram of the bilge system
	A	• Fire detection arrangements
	A	• Fire-extinguishing arrangements
	A	• Structural fire protection
	I	• Eye-washing showers and personal protective equipment (PPE) storage spaces
(1)	A = to be submitted for approval ; I = to be submitted for information	
(2)	Performance data of the CCS system need not be provided	
(3)	The variation of the ship deadweight during the CCS operation, due to the simultaneous consumption of fuel and capture of CO_2, is to be taken into account, considering the conversion factor CF given in IMO Resolution MEPC.308 (73)	

1.4 Risk analysis

1.4.1 HAZID and HAZOP analysis

And HAZID analysis is to be carried out for the whole CCS system, including:

- the solvent loading, storage and offloading installation and
- the CO_2 compression, liquefaction, storage and offloading installation.

The HAZID analysis is to cover at least the following events:

- solvent leakage
- CO_2 leakage
- failure of a CCS system component or abnormal operation.

The HAZID analysis is to address:

- the flammability of the solvent
- the toxicity of the solvent
- the toxicity and the asphyxiating effect of the carbon dioxide in case of exposure of the crew members or passengers
- the availability of propulsion and main source of power, see [2.1.4].

2 Design and construction of the carbon capture and storage system

2.1 General

2.1.1 The components of the CCS system and their associated piping systems and fittings are to be of a design and construction adequate for the intended service in accordance with the provisions of Part C, Chapter 1, in particular:

- Heat exchangers are to comply with the provisions of Ch 1, Sec 3.
- Solvent and CO_2 vapour piping systems are to comply with the provisions of Ch 1, Sec 10.
- The design of the liquid CO_2 piping system is to comply with the relevant provisions of Pt D, Ch 9, Sec 5.

2.1.2 Inclinations

The CCS system is to be so designed that it can withstand the loads corresponding to the static and dynamic inclination angles specified in Ch 1, Sec 1, [2.4.1].

2.1.3 Ambient conditions

The CCS system is to be designed for the ambient conditions specified in Ch 1, Sec 1, [2.5.1].

2.1.4 Availability

The CCS system is to be so designed that the exhaust back-pressure allowed by the fuel consumer manufacturer is not exceeded over the operating range at which the fuel consumer is intended to operate. Where necessary, an exhaust gas blower is to be installed. For internal combustion engines, see Ch 1, Sec 11, [2.4.1] and Ch 1, App 7.

Note 1: Increased exhaust back pressure may affect the engine performance, in particular its specific fuel consumption.

The CCS system is to be so designed that in case of failure of a CCS system component, the normal operation of the fuel consumer can be maintained. This is to be demonstrated by the risk analysis.

2.1.5 Arrangements for solvent replacement

Where necessary, arrangements for storage and transfer are to be made to allow the replacement of the solvent, in accordance with the operating manual of the plant.

2.2 Materials

2.2.1 Materials used in the components of the CCS system containing the solvent are to be resistant to corrosion, taking into account the exhaust gas composition, the nature of the solvent and the temperature in the concerned areas. The risk of corrosion due to the presence of impurities is to be taken into account.

2.2.2 Storage tanks and pipes / piping systems for the solvent are to be made with a material compatible with the solvent, or coated with appropriate anticorrosion coating. The melting point of the material in not to be less than 925 °C.

Note 1: Materials having lower melting point may be utilized provided their use is specially considered on a case-by-case basis in relation to the risk of fire.

2.2.3 In general, copper and aluminum as well as their alloys, zinc and galvanized steel are not to be used in any component of the CCS system in contact with the solvent.

2.2.4 Materials used in the components containing liquefied CO_2 are to comply with the provisions of Pt D, Ch 9, Sec 6.

2.2.5 Materials used in CO_2 tanks and piping system are to be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the CO_2 at the set pressure of the automatic safety system intended to maintain the CO_2 at a pressure above the triple point.

2.3 Design and construction of the separation system

2.3.1 Welded joints of the exhaust gas cooler, absorber and desorber shells are to be made in accordance with qualified welding procedures by qualified welders. Welder's certificates, welding procedures and their qualification records are to be submitted to the Society for review.

2.4 Design and construction of the solvent filling, storage, transfer, cooling and heating systems

2.4.1 General

The requirements of the present sub-article apply to storage tanks and piping systems containing the solvent. They also apply to the tank and piping systems intended for the storage and transfer of waste solvent

Regardless of design pressure and temperature, piping systems containing solvent are to comply with the requirements applicable to class I piping systems. Vent and drain pipes, irrespective of the service temperature, belong to class III.

2.4.2 Leakage prevention and containment

The solvent filling, storage tank and transfer system are to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All tank pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. In cases where such valves are provided below top of tank, they are to be arranged with quick acting shutoff valves which are to be capable of being remotely operated from a position remaining accessible in the event of solvent leakages.

2.4.3 Protection against high or low temperatures

The solvent storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration of the solvent solution. Depending on the operational area of the ship, this may require the fitting of heating and/or cooling systems.

2.4.4 Integral tanks

The solvent may be stored in integral tanks provided they are coated with appropriate anti-corrosion coating.

Solvent tanks are to be segregated from accommodation, cargo spaces containing cargoes which react with the solvent in a hazardous manner as well as any food stores, oil tanks and fresh water tanks by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces.

Solvent storage tanks are to be located aft of the collision bulkhead and forward of the after peak bulkhead.

2.4.5 Independence of piping systems

The solvent piping and venting systems are to be independent of other ship service piping and/or systems.

2.4.6 Prevention of contamination by the solvent

Means, such as pH or pressure monitoring, are to be provided to detect any contamination of the water cooling or heating system or steam heating system by the solvent through heat exchangers.

2.4.7 Use of electric heaters

When electric heaters are used to supply heat to the desorber, a safety temperature switch is to be fitted in order to avoid excessive heating. It is to be:

- independent from the automatic temperature control sensor
- designed to cut off the electrical power supply in the event of excessive temperature
- provided with manual reset.

2.4.8 Pipe connections

As far as practicable, e.g. except for the flange connections that connect to tank valves, the piping systems are to be joined by welding.

The following connections are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:

a) detachable connections between pipes (flanged connections and mechanical joints, etc.)

b) detachable connections between pipes and equipment such as pumps, strainers, heaters, valves

c) detachable connections between equipment mentioned in item b).

2.5 Design and construction of the CO_2 separation system

2.5.1 Exhaust gas cooling and treatment

Exhaust gases are to be suitably cooled and treated so that their temperature and contaminant content (in particular SOx and NOx) are within the range required for the CO2 absorption process.

Where exhaust gas cooling is made through a Direct Contact Cooling (DCC) exchanger, it is to comply with the applicable requirements of Ch 1, Sec 11.

The discharge water from the exhaust gas cooling system is to meet the relevant quality criteria laid down in IMO Resolution MEPC.340 (77): 2021 Guidelines for exhaust gas cleaning systems.

2.5.2 Heating system

The capacity of the rich solvent heating system is to be within the range required for the CO_2 desorption process.

2.6 Design of the CO_2 compression, liquefaction and storage systems

2.6.1 Gaseous CO_2 piping

Regardless of design pressure and temperature, piping systems containing gaseous CO_2 are to comply with the requirements applicable to Class I piping systems.

Remotely closable valves are to be provided where necessary to isolate a section of the CO_2 piping system in case of leakage.

The pipes conveying gaseous captured CO_2 are to be so marked that they can be readily distinguished from any pipe containing CO_2 intended for fire extinguishing. The pipes may pass through accommodations providing that:

- they are of substantial thickness (see Ch 1, Sec 10, Tab 6)
- they are joined only by welding
- they are not fitted with drains or other openings within such spaces.

The pipes are not to pass through refrigerated spaces.

2.6.2 Liquid CO_2 storage tanks

CO_2 storage tanks are to comply with the provisions of:

- Pt D, Ch 9, Sec 4 for the tank design
- Pt D, Ch 9, Sec 7 for tank pressure and temperature control
- Pt D, Ch 9, Sec 17, [21], for tank pressure control and monitoring and safety valve arrangement.

In particular, the following requirements are to be considered:

a) The pressure and temperature of CO_2 at the triple point depend on its purity. Where the CO_2 is stored at a pressure and temperature close to the triple point, the set pressure of the tank instrumentation is to be properly adjusted in order to prevent the tank contents from changing from the liquid to the solid state.

b) With the exception of tanks designed to withstand the critical pressure of CO_2, one of the following means are to be provided to maintain the tank pressure and temperature within their design range at all times:
   - reliquefaction of CO_2 vapours
   - liquid CO_2 cooling
   - pressure accumulation.

c) Venting of the CO_2 vapours is not an acceptable means to maintain the tank pressure and temperature within their design range, except in emergency situations.

2.6.3 Compressed CO_2 storage tanks

Tanks intended for the storage of high pressure compressed CO_2 are to comply with the design principles given in Ch 4, Sec 15, [4.1.3].

2.7 Control and monitoring

2.7.1 Alarms and indications are to be provided in accordance with Tab 3.

For ships to be granted an **AUT** additional class notation, those alarms and indications are to be provided at the centralised control position, see Pt F, Ch 3, Sec 1, [4.8.11].

Table 3 : Control and monitoring for carbon capture and storage system (CSS)

Symbol convention: H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Exhaust gas temperature at the absorber inlet	H + L	X					
Solvent temperature at the regenerator (stripper) inlet	H + L	X					
(1) High level alarm is to be independent from the tank level indicator							

Symbol convention: H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Solvent temperature at the regenerator (stripper) outlet	H + L	X					
Solvent storage tank level	H **(1)**	X					
	L						
Solvent storage tank temperature	H	X					
	L						
Drain tank level	H **(1)**	X					
Compressed CO_2 storage tank pressure	H	X					
Liquid CO_2 storage temperature	H	X					
(1) High level alarm is to be independent from the tank level indicator							

3 Arrangement and installation of the solvent components

3.1 Solvent tanks and piping system

3.1.1 Location of the solvent piping systems

The solvent piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the open deck, away from passageways, ventilation inlets and outlets and from any opening to accommodation, service spaces or control stations and the tank venting system is to be arranged to prevent entrance of water into the tank for solvents.

3.1.2 Drip trays

Drip trays are to be fitted in way of the solvent system components where leakage may occur. They are to be provided with leak detection arrangements and with drain pipes which lead to dedicated drain tank. Drain tanks are to be fitted with a high level alarm. In case this dedicated drain tank is an integral tank, it is to comply with the requirements of [2.4.4].

3.1.3 Monitoring and alarms

The storage tank is to be provided with level monitoring arrangements and high/low level alarms. Additionally, high and/or low temperature alarms or temperature monitoring are also to be provided.

3.2 Absorbers

3.2.1 A common absorber may be used by several engines provided that:

- a remotely operated and effective isolation device with means for leakage detection is provided on each engine exhaust line, in order to prevent exhaust gases from an engine in operation to penetrate into an engine not in operation, which could cause corrosion damage and result in exhaust gases entering the engine compartment
- where necessary a forced ventilation is installed in accordance with Ch 1, Sec 11, [2.4.1].

3.3 Solvent leakage detection

3.3.1 Except where the liquid spill detectors required for the drip trays (see [3.1.2]) are proved to be sufficient by the risk analysis, permanently installed solvent vapour detectors are to be fitted in all enclosed spaces where a leakage from the solvent system is likely to occur, as evidenced by the risk analysis.

3.3.2 The detection of solvent liquid or vapour leakage is to activate an alarm and the automatic closing of an isolating valve located outside the space where the leakage has occurred.

3.3.3 The solvent vapour detectors are to be located in areas where the solvent may accumulate.

3.3.4 Two portable solvent vapour detection equipment are to be available on board the ship.

3.4 Bilge system and scuppers

3.4.1 Bilge and scuppers lines from spaces containing a potential source of solvent leakage are to be independent from bilge lines serving other spaces.

3.4.2 Bilge water and drained water from spaces containing a potential source of solvent leakage is to be retained on board in dedicated holding tanks for subsequent discharge to reception facilities.

3.5 Ventilation

3.5.1 Enclosed spaces where solvent storage tanks are installed are to be served by an effective mechanical ventilation system of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be independent from the ventilation systems serving accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the space. A warning notice requiring the use of such ventilation before entering the space is to be provided outside the compartment adjacent to each point of entry.

3.5.2 The provisions of [3.5.1] also apply to the following spaces, if normally entered.

a) spaces adjacent to the integral solvent storage tanks and containing possible leak points (e.g. manhole, fittings) from these tanks

b) spaces containing solvent piping systems, unless they have fully welded joints.

3.5.3 Where the solvent storage tank is located within the engine room, a separate ventilation system, as per [3.5.1] is not required when the general ventilation system for the space providing not less than 6 air changes per hour is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

3.5.4 The exhausts of the ventilation systems required in [3.5.1] to [3.5.3] are to be located at least 3m away from inlets for other ventilation systems and from normal passageways.

3.6 Fire safety

3.6.1 Applicable requirements for spaces intended for the storage or handling of solvent are listed in:

- Ch 4, Sec 3, [3.1.1] for fire detection arrangements
- Ch 4, Sec 5 for fire integrity requirements.
- Ch 4, Sec 6, [4.5.2] for fire-extinguishing arrangements.

4 Arrangement and installation of the CO_2 system components

4.1 CO_2 tanks

4.1.1 CO_2 tank location

CO_2 tank location is to comply with the requirements of Pt D, Ch 9, Sec 2, [4] as applicable to type 3G ships.

CO_2 tank may be installed on the open deck, in a dedicated compartment or in the cargo area of tankers or offshore supply vessels. Where the CO_2 tank is installed in an enclosed space, the access is to be arranged only from the open deck and the access door is to open outwards.

Alternatively, access to the enclosed space containing the CO_2 storage tank may be from another enclosed space through an airlock, provided that the space containing the CO_2 storage tank is fitted with:

- an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour
- at least two oxygen detectors fitted at suitable positions in the compartment and arranged to provide an alarm when the oxygen level falls below 19%. The alarm is to be both visible and audible inside and outside the compartment and placed in such a position that it is immediately received by responsible members of the crew.

4.1.2 CO_2 tank venting

Discharge piping from safety relief valves are to be designed so that they prevent clogging by dry ice formation upon safety release. Where arrangements are made to avoid dry ice formation, it should be demonstrated that the outlet flow velocity does not reach the critical speed (sonic velocity). Protective screens are not to be fitted to the outlets of relief valve discharge piping.

4.1.3 Longitudinal strength and stability

The impact of the liquid stored in CO_2 tank on the ship's longitudinal strength and stability is to be taken into account as indicated in Pt B, Ch 3, App 2, [1.2.20].

4.2 CO_2 vapour detection

4.2.1 CO_2 concentration monitoring

Spaces containing CO_2 tanks, CO_2 compression and liquefaction equipment and other enclosed spaces where CO_2 could accumulate are to be fitted with continuous monitoring for CO_2 build-up.

4.3 Ventilation

4.3.1 Spaces containing CO_2 tanks, CO_2 compression and liquefaction equipment and other enclosed spaces where CO_2 could accumulate are to be continuously ventilated with minimum six air changes per hour such that any release of CO_2 will be effectively dispersed in order to prevent the formation of a low oxygen atmosphere. The ventilation system serving such spaces is to be independent mechanical ventilation of the extraction type.

4.3.2 Where the spaces referred to in [4.3.1] may be entered in normal operation, the ventilation capacity is to be automatically increased to 10 air changes per hour in case of CO_2 leakage detection.

5 Personal protection

5.1 Protective equipment

5.1.1 For the protection of crew members, the ship is to have on board personal protective equipment (PPE) suitable for solvent handling. The number of PPE carried on board is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure; but in no case is there to be less than two sets available on board.

5.1.2 Personal protective equipment (PPE) is to consist of:

- low temperature- and solvent-resistant protective clothing, boots, gloves and tight-fitting goggles and
- two self-contained breathing apparatus.

5.2 Emergency equipment

5.2.1 Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements.

6 Certification and surveys at works

6.1 General

6.1.1 Certification and workshop inspections are to be performed on:

- the various components of CCS system
- the materials used for their manufacture.

6.2 Type approval

6.2.1 The following CCS components are to be of a type approved by the Society:

- Solvent system:
  - Hoses, see Ch 1, Sec 10, [20.2]
- CO_2 system:
  - Pumps, see Pt D, Ch 9, Sec 5, [13.2]
  - Expansion bellows, see Pt D, Ch 9, Sec 5, [13.4]
  - Hoses, see Pt D, Ch 9, Sec 5, [11.7].

6.3 Inspection and testing

6.3.1 The CCS components are to be inspected and tested at works in accordance with the requirements of Tab 4.

Table 4 : Inspection and testing for the CCS system components

Item	Tests for the materials		Inspections and tests for the product		
	Tests required	Type of material certificate	During manufacturing (NDT)	After completion	Type of product certificate
EXHAUST GAS SYSTEM AND SEPARATION SYSTEM					
Exhaust gas (direct contact) cooler shell			Magnetic particle or liquid penetrant testing **(1)**	Ch 1, Sec 10, [20.5.5]	C
Exhaust gas blower				Ch 1, Sec 10, [20.5.5]	C
(1) To be performed on welded joints selected according to manufacturer's plan **(2)** For parts in contact with the fluid **(3)** For welded joints					

Item	Tests for the materials		Inspections and tests for the product		
	Tests required	Type of material certificate	During manufacturing (NDT)	After completion	Type of product certificate
Absorber shell	Chemical composition	W	Magnetic particle or liquid penetrant testing **(1)**		C
Desorber shell	Chemical composition	W	Magnetic particle or liquid penetrant testing **(1)**		C
Pipes, valves and fittings	Requirements of Ch 1, Sec 10, Tab 40 applicable to a class III piping system are to be complied with				
SOLVENT SYSTEM					
Heat exchangers	Ch 1, Sec 3, [9.1.3]	C		Ch 1, Sec 10, [20.5.3]	C
Independent tanks	Chemical composition	C			
Pumps	• Chemical composition **(2)** • Material tests as per Ch 1, Sec 10, [20.4.2]	C		Pressure test as per Ch 1, Sec 10, [20.5.5]	C
Pipes, valves and fittings	Requirements of Ch 1, Sec 10, Tab 40 applicable to a class I piping system are to be complied with				
Flexible hoses				Pressure test as per Ch 1, Sec 10, [20.5.6]	C
CO_2 SYSTEM - VAPOUR					
Compressors	• Chemical composition **(2)** • Material tests as per Ch 1, Sec 10, [20.4.2]	C		Pressure test as per Ch 1, Sec 10, [20.5.5]	C
Pipes, valves and fittings	Requirements of Ch 1, Sec 10, Tab 40 applicable to a class I piping system are to be complied with				
CO2 SYSTEM - LIQUID					
Condensers, heat exchangers and other equipment of the liquefaction plant	• Chemical composition **(2)** as per Pt D, Ch 9, Sec 6 • Material tests as per Pt D, Ch 9, Sec 6	C	NDT as per Pt D, Ch 9, Sec 5, [9.3] **(3)**	Pressure test as per Pt D, Ch 9, Sec 4, [10.6]	C
Storage tank	• Chemical composition as per Pt D, Ch 9, Sec 6 • Material tests as per Pt D, Ch 9, Sec 6, [5.6]	C	NDT as per Pt D, Ch 9, Sec 6, [5.6]]	Pressure test as per Pt D, Ch 9, Sec 4, [10.6]	C
Safety valves	• Chemical composition **(2)** as per Pt D, Ch 9, Sec 6 • Material tests as per Pt D, Ch 9, Sec 6	C		Pressure test and set pressure verification as per Pt D, Ch 9, Sec 5, [13.3.3]	C
Liquefied CO_2 Pumps	• Chemical composition **(2)** as per Pt D, Ch 9, Sec 6 • Material tests as per Pt D, Ch 9, Sec 6	C		Pressure test as per Pt D, Ch 9, Sec 5, [13.2]	C
Expansion bellows	• Chemical composition as per Pt D, Ch 9, Sec 6 • Material tests as per Pt D, Ch 9, Sec 6	C		Pressure test as per Pt D, Ch 9, Sec 5, [13.5]	C
Offloading hoses			NDT as per Pt D, Ch 9, Sec 5, [9.3] **(3)**	Pressure test as per Pt D, Ch 9, Sec 5, [11.7.5]	C
Pipes, valves and fittings	Requirements of Pt D, Ch 9, Sec 5, [9]; Pt D, Ch 9, Sec 5, [12] and Pt D, Ch 9, Sec 5, [13], as applicable, are to be complied with				

(1) To be performed on welded joints selected according to manufacturer's plan

(2) For parts in contact with the fluid

(3) For welded joints

Section 13 Ballast Water Management Systems

1 General

1.1 Application

1.1.1 Installation

Requirements for the installation of ballast water management systems (BWMS), are given in Articles [2] to [4] and:

- Ch 4, Sec 3, [3] for fire detection arrangement in spaces containing a ballast water management system
- Ch 4, Sec 6, [7] for fire-extinguishing arrangements for ballast water management rooms
- Ch 4, Sec 5 for fire integrity requirements applicable to ballast water management room (BWMR) and to spaces intended for the storage of liquid or solid chemicals for BWMS.

1.1.2 Certification

Requirements for the certification of ballast water management systems (BWMS) are given in Article [5].

1.2 Acronyms

1.2.1 The following acronyms are used in this Section:

AOT : Advanced oxidation technology

BWM : Ballast water management

BWMP : Ballast water management plan

BWMR : Ballast water management room

BWMS : Ballast water management system

IGG : Inert gas generator

TAC : Type approval certificate

TiO_2 : Titanium dioxide catalyst used in combination with UV treatment

TRC : Treatment rated capacity.

1.3 Definitions

1.3.1 Ballast water management system (BWMS) means any system which processes ballast water such that it meets or exceeds the ballast water performance standard in Regulation D-2 of IMO BWM Convention. The BWMS includes ballast water equipment, all associated piping arrangements as specified by the manufacturer, control and monitoring equipment and sampling facilities. The categorization of BWMS technologies is given in Tab 1. Applicability of the requirements for each BWMS technology is in accordance with Tab 2.

Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in Tab 1.

1.3.2 Cargo area of tankers is defined:

- for oil tankers and FLS tankers, in Pt D, Ch 7, Sec 1, [1.3.1]
- for chemical tankers, in paragraph 1.3.6 of the IBC Code as amended by IMO resolutions up to MSC.460 (101)
- for gas carriers, in Pt D, Ch 9, Sec 1, [4.1.8]
- for offshore support vessels, in Pt E, Ch 3, Sec 1, [1.6.6].

1.3.3 Dangerous gas means any gas which may develop an atmosphere being hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation, corrosivity or reactivity and for which due consideration of the hazards is required, e.g. hydrogen (H_2), hydrocarbon gas, oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), chlorine (Cl_2) and chlorine dioxide (ClO_2), etc.

1.3.4 Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

1.3.5 Hazardous area is defined in Ch 2, Sec 1, [3.13]. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

1.3.6 Non-hazardous area means an area which is not a hazardous area as defined in [1.3.5].

1.3.7 A ballast water management room (BWMR) is any space containing equipment belonging to the BWMS. A space containing remote controls for the BWMS or a space dedicated to the storage of liquid or solid chemicals for BWMS need not be considered as a BWMR for the purposes of this Section.

1.4 Documents to be submitted

1.4.1 The documents listed in Tab 3 are to be submitted.

1.4.2 In the case of installation of a BWMS on an existing ship, the documents listed in Tab 4 are to submitted in addition to those required in [1.4.1].

Table 1 : Categorization of BWMS technologies

		BWMS's Technology category										
		1	2	3a	3b	3c	4	5	6	7a	7b	8
	Characteristics	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 Generator)	In-line-de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis **(2)**	In-line (stored) chemical injection	In-line side- stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
Des-infection when ballasting	Making use of active substance			X		In-tank technology: No treatment when ballasting or de-ballasting	X	X	X	X	X	In-tank technology: No treatment when ballasting or de-ballasting
	Full flow of ballast water is passing through the BWMS	X	X	X	X		X				X	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							X				
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X									X	
	Injection of neutralizer						X	X	X	X	X	
	Not required by the Type Approval Certificate issued by the Flag Administration		X	X								
Examples of dangerous gas as defined in [1.3.3]			**(1)**	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	**(1)**	O_2 O_3 N_2		O_2 N_2

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting).

Table 2 : Applicability of the requirements for each BWMS technology

Applicable requirements	BWMS's Technology category										
	1	2	3a	3b	3c	4	5	6	7a	7b	8
	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 Generator)	In-line-de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis	In-line (stored) chemical injection	In-line side- stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
[1]	X	X	X	X	X	X	X	X	X	X	X
[2.1]	X	X	X	X	X	X	X	X	X	X	X
[2.2.1] **(1)**		X				X	X	X	X	X	
[2.2.2]									X	X	
[2.2.3] **(2)**		X	X	X	X	X	X	X	X	X	X
[2.3.1]			X	X	X						X
[2.3.2] **(3)**			X	X	X						X
[2.4.1]	X	X	X	X	X	X	X	X	X	X	X
[2.4.2] and [2.4.3]			X	X	X						X
[2.4.4]				X						X	
[2.5.1]	X	X	X	X	X	X	X	X	X	X	X
[2.5.4]	X	X	X	X	X	X	X	X	X	X	X
[2.6]	X	X	X	X	X	X	X	X	X	X	X
[2.7]			X	X	X						X
[2.8.1] **(4)**		X	X	X	X	X	X	X	X	X	X
[2.8.2]			X								X
[2.8.3]						X	X				
[2.8.4]									X	X	
[2.8.5]		X	X	X	X	X	X	X	X	X	X
[2.8.6]	X	X	X	X	X	X	X	X	X	X	X
[2.8.7]		X	X	X	X	X	X	X	X	X	X
[2.10.1], [2.10.2] and [2.10.3] **(5)**		X				X	X	X	X	X	
[2.10.4] **(5)**	X	X	X	X	X	X	X	X	X	X	X
[2.10.5]									X	X	
[2.10.6] **(5)**	X	X	X	X	X	X	X	X	X	X	X

(1) This requirement may be reduced if the BWMS does not use any flammable or toxic chemical substances

(2) This requirement may be reduced if no dangerous gas as defined in [1.3.3] will be generated by the BWMS

(3) This requirement may be reduced if the stored chemicals are neither toxic not flammable

(4) This requirement may be reduced if no toxic chemical is stored and no toxic gas will be generated by the BWMS

(5) The requirements applicable to BWMS storing, utilizing or introducing chemicals may be reduced if no toxic chemical is used or will be generated by the BWMS

Applicable requirements	BWMS's Technology category										
	1	2	3a	3b	3c	4	5	6	7a	7b	8
	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 Generator)	In-line-de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side stream electrolysis	In-line (stored) chemical injection	In-line side- stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
[3.2.1]				X	X				X	X	
[3.2.2]						X	X	X			
[3.3]	X	X	X	X		X	X	X	X	X	
[3.4]	X	X	X	X		X	X	X	X	X	
[3.5]	X	X	X	X	X	X	X	X	X	X	X
[3.6]	X	X	X	X		X	X	X	X	X	
[4.2.1]		X	X		X	X	X	X	X	X	X
[4.2.2]			X	X	X				X	X	X
[4.2.3]									X	X	
[4.2.4]						X	X	X	X	X	
[4.2.5]						X	X	X			
[4.2.6]			X	X	X	X	X	X	X	X	X
[4.3.2] to [4.3.5]		X	X	X	X	X	X	X	X	X	X
[4.3.6]			X			X	X	X	X	X	X
[4.3.7]			X						X	X	X
[4.3.8]			X			X	X	X	X	X	X
[4.3.9]			X			X	X	X	X	X	X
[4.4]		X				X	X	X	X	X	
[5.1]	X	X	X	X	X	X	X	X	X	X	X
[5.2]						X	X	X	X	X	
[5.3]	X	X	X	X	X	X	X	X	X	X	X

(1) This requirement may be reduced if the BWMS does not use any flammable or toxic chemical substances

(2) This requirement may be reduced if no dangerous gas as defined in [1.3.3] will be generated by the BWMS

(3) This requirement may be reduced if the stored chemicals are neither toxic not flammable

(4) This requirement may be reduced if no toxic chemical is stored and no toxic gas will be generated by the BWMS

(5) The requirements applicable to BWMS storing, utilizing or introducing chemicals may be reduced if no toxic chemical is used or will be generated by the BWMS

Table 3 : List of documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Diagram of the ballast system (inside and outside machinery spaces)
2	A	Diagram of the BWMS with location of ballast water sampling facilities
3	I	Type Approval Certificate of the BWMS
4	A	In case active substances are used: • Storage tanks and day tanks containing chemicals including: - Filling, drain system, venting system, drip trays, soundings,… - Tanks capacity in regards of the expected rate of consumption, capacity of the ballast water system and required endurance • Safety documentation for active substance used, such as material safety data sheet (MSDS) from supplier
5	I	Technical description of the BWMS's operating principles, containing also operational and maintenance procedures, and backup procedures in case of equipment malfunction. It is to include a risk assessment if at least one of the following conditions is met: • The system uses noxious chemical • Dangerous gases or vapors may accumulate within the ballast system during operation • Accelerated corrosion or deterioration of tank coating may occur due to the treated ballast water
6	I	Technical installation specification which was submitted in support of the BWMS statutory approval, with: • Initial calibration procedures • Installation commissioning procedures
7	I	BWMS safety and manual operating containing chemical injection procedures, alarm systems, measures in case of emergency, etc. Equipment manuals for major components of the BWMS
8	A	Electrical load analysis, demonstrating the adequacy of the generating plant capacity under normal operating conditions of ballasting and de-ballasting given in the ballast water management plan (BWMP) **(3)**

(1) A = to be submitted for approval I = to be submitted for information.

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

(3) For retrofit installation to existing ships, a revised electrical load analysis with preferential trips of non-essential services can be accepted.

Table 4 : List of additional documents to be submitted in the case of installation of a BWMS on an existing ship

No.	I/A **(1)**	Document **(2)**
1	A	General arrangement plan of the BWMS in the ship
2	I	Shipboard test plan for sea and/or quay trial
3	A	Other piping and instrument diagram, if the BWMS is connected to others systems (control air, bilge, fresh water, cooling system,…)
4	A	General arrangement of the electrical components: • General layout specifying the interconnection of the major electrical components of the system • Ingress protection (IP) of the electrical panels and associated devices (junction boxes, electrical motors, etc.) • Interconnection diagram or document describing the link between the BWMS and the ship's alarm system
5	A	Safety and protection: • List of alarms and safeties of the system • List of electrical sensors/components in hazardous areas, when applicable • Characteristics and certifications of the electrical devices added during the integration of the BWMS: electrical cables, detectors, etc.
6	A	Single line diagram showing the power electrical arrangement to supply the BWMS unit
7	I	Type of cables to be installed provided with the related Type Approval Certificates
8	A	Structural fire protection plan, including fire categorization, at least for the modified/new spaces, and including traces of the previous arrangement

(1) A = to be submitted for approval I = to be submitted for information.

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

(3) The installation of the BWMS may have an impact on the ship's stability, such as on the lightweight, position of the center of gravity, position of watertight bulkhead (the watertight integrity). In order to evaluate the impact of the added weight of the BWMS on the stability, the weight of the added BWMS and the exact position of its center of gravity (VCG, LCG, and TCG) are to be provided. Subject to the Society's satisfaction, the submission of the documents may not be required.

No.	I/A **(1)**	Document **(2)**
9	A	Type approval certificates of newly installed materials with regards to fire protection, including especially pipe and/or cable penetrations in fire divisions
10	A	Ventilation, fire extinguishing and detection systems, to be documented if the integration of BWMS on board the ship has impact on such systems
11	A	Updated fire control plan
12	A	Updated hazardous area plan
13	A	In case the installation of the BWMS requires structural modifications of the vessel (relocation of watertight bulkheads, new openings, new pipe routings in the damage zone which may lead to progressive flooding) **(3)**: • Updated damage control plan and booklet • Updated damage stability booklet
14	A	In case a deviation from lightship displacement or longitudinal center of gravity exceeding the recommended deviation is found, in comparison with the approved stability booklet **(3)**: • Inclining experiment report • Updated trim and stability booklet
15	A	Updated structural drawings, reflecting the new arrangement, and including the supporting structure and information on reaction loads
16	I	In case of capacity creation: Updated capacity plan, including the density of the liquid to be loaded

(1) A = to be submitted for approval I = to be submitted for information.

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

(3) The installation of the BWMS may have an impact on the ship's stability, such as on the lightweight, position of the center of gravity, position of watertight bulkhead (the watertight integrity). In order to evaluate the impact of the added weight of the BWMS on the stability, the weight of the added BWMS and the exact position of its center of gravity (VCG, LCG, and TCG) are to be provided. Subject to the Society's satisfaction, the submission of the documents may not be required.

2 Installation

2.1 General requirements

2.1.1 Maximum treatment rated capacity

In case the maximum capacity of the ballast pump(s) exceeds the maximum treatment rated capacity (TRC) of the BWMS specified in the TAC issued by the Flag Administration, there should be a limitation on the BWMP giving a maximum allowable flow rate for operating the ballast pump(s) that is not to exceed the maximum TRC of the BWMS.

Additionally, in case the TRC is exceeded the system shall give an alarm which is to be recorded.

2.1.2 By-pass or override arrangements

a) The BWMS is to be provided with bypass or override arrangement to effectively isolate it from any essential ship system to which it is connected.

b) Any by-pass or override operation is to trigger an audible and visual alarm and these events are to be automatically recorded in control equipment. This requirement is also applicable to gravity ballast pipes.

c) Where the ship's ballast pump flow rates need to be limited in order to ensure operation of the BWMS within the limits of the BWMS TAC, the arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the Flag Administration's type approval.

2.2 Location and arrangement of BWMR and chemical substance storage rooms

2.2.1 BWMS using chemical substances

For BWMS storing, introducing or generating chemicals, the BWMR and chemical substance storage rooms are not to be located in the accommodation area. Any ventilation exhaust or other openings from these rooms are to be located not less than 3m from entrances, air inlets and openings to accommodation spaces.

This requirement need not apply in case the BWMS is located in the engine room.

2.2.2 Ozone-based BWMS

Ozone-based BWMS (i.e. cat.7a and 7b) are to be located in dedicated compartment, separated from any other space by gastight boundaries. Access to the BWMR from any other enclosed space is to be through airlock only, except if the only access to that space is from the open deck.

Access to the ozone based BWMR may be provided through the engine room only provided:

- access from the engine room to the BWMR is through airlock
- an alarm repeater is provided in the BWMR, which will repeat any alarm activated in the engine room.

A sign is to be affixed on the door providing personnel with a warning that ozone may be present and with the necessary instructions to be followed before entering the room.

2.2.3 Doors

BWMR containing equipment for BWMS of the following types are to be equipped with tested gastight and self-closing doors without any holding back arrangements:

- BWMS storing, introducing or generating chemical substances
- de-oxygenation based on inert gas generator
- electrolysis
- ozone injection.

Doors leading to the open deck need however not to be self-closing.

2.3 Location of chemical substance storage tanks

2.3.1 When the chemical substances are stored inside integral tanks, the ship's shell plating is not to form any boundary of the tank.

2.3.2 Tanks containing chemicals are to be segregated from accommodation, service spaces, control stations, machinery spaces not related to the BWMS and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel storage tank, BWMR or other similar space. On-deck stowage of permanently attached deck tanks or installation of independent tanks in otherwise empty hold spaces should be considered as satisfying this provision.

2.4 Piping systems

2.4.1 All valves, piping fittings and flanges are to comply with the relevant requirements of Ch 1, Sec 10. In addition, special consideration may be given to the material used for this service with the agreement of the Society.

2.4.2 Where a vacuum or overpressure may occur in the ballast piping or in the ballast tanks due to the height difference or injection of inert gas or nitrogen (N_2), a suitable protection device is to be provided (i.e. P/V valves, P/V breakers, P/V breather valves or pressure safety relief valve or high/low pressure alarms). The pressure and vacuum settings of the protection device are not to exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as relevant.

2.4.3 For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to discharge to a safe location on the open deck. See [2.9].

2.4.4 When cavitation is the BWMS treatment process (for example by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (for example by use of “smart pipe” or “special pipe” in BWMS category 7b or by use of “venturi pipe” in BWMS technology 3b) or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is to be specifically considered.

2.5 Electrical and automation systems

2.5.1 The capacity of the generating plant is to be sufficient to support the operation of the BWMS under normal operating conditions of ballasting and de-ballasting given in the Ballast Water Management Plan (BWMP).

2.5.2 Overcurrent or overvoltage protection is to be installed to protect UV type BWMS.

2.5.3 Electrolysis reactors are to be provided with at least two independent means of monitoring operation. The monitoring system is to initiate audible and visual alarms and automatic shutdown of the BWMS in the event that an anomaly is detected.

If a pressure relief valve is also provided, the vent of this valve is to be led to a safe location on the open deck, as clarified in Tab 8. The valve is to be positioned to optimally remove gas from the electrolysis reactor.

2.5.4 When it is required to have an automatic shutdown of the BWMS for safety reasons, this is to be initiated by a safety system independent of the BWM control system.

2.5.5 For ships to be assigned an **AUT** additional class notation, alarms and indications required by the present sub-article are to be provided at the centralised control position, see Pt F, Ch 3, Sec 1, [4.8.10].

2.6 Hazardous areas

2.6.1 Extension of hazardous areas related to the cargo vapours

When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to IEC 60092-502:1999, section 4.2.2.9 the areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of their outlets are to be categorized hazardous zone 1 and with reference to IEC 60092- 502:1999, section 4.2.3.1, an additional 1,5 m surrounding the 1,5 m hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker is to be located outside the hazardous areas.

2.6.2 Hazardous areas related to the flammable vapours from the treatment substances or generated by the BWMS

Where products covered by IEC 60092-502:1999 are stored on board or generated during operation of the BWMS, the requirements of this standard are to be followed in order to:

- define hazardous areas and acceptable electrical equipment
- design ventilation systems.

2.6.3 Electric and electronic components are not to be installed in a hazardous area unless they are of a certified safe type for use in this area. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

2.7 Inert gas systems

2.7.1 Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

a) Ch 4, Sec 15, [13]:

- Ch 4, Sec 15, [13.2.1], items b) and c)
- Ch 4, Sec 15, [13.3.1]

  Ch 4, Sec 15, [13.3.2], items a), b), c) and f)

  Ch 4, Sec 15, [13.3.4] except requirements for low pressure gas alarm in items e) 1) and e) 3)
- Ch 4, Sec 15, [13.4.2], items a) 2), b), d) 2), e) and f)

  Ch 4, Sec 15, [13.4.3] except item b) requirement for an alarm for insufficient fuel oil supply to the oil-fired inert gas generator
- Ch 4, Sec 15, [13.5.2], items c) and d)

  Ch 4, Sec 15, [13.5.3]
- For inert gas systems installed for in-tank de-oxygenation BWMS (category 8):

  Ch 4, Sec 15, [13.3.3] items a) and b) except b) 6), b) 7) and b) 10).

In general, when applying Ch 4, Sec 15, [13] requirements to inert-gas based BWMS, the following modifications are to be considered:

- the terms “cargo tank” and “cargo piping” are to be replaced by “ballast water tank” or “ballast water piping” as relevant
- the term “cargo control room” is to be replaced by “BWMS control station” as relevant
- requirements for slop tanks on combination carriers are to be disregarded
- when applying Ch 4, Sec 15, [13.3.4] item e) 1), the acceptable oxygen content is to be specified by the manufacturer, 5% oxygen content need not necessarily be applied.

b) Pt D, Ch 7, Sec 6, [5.2.2]

Pt D, Ch 7, Sec 6, [5.3.1]

Pt D, Ch 7, Sec 6, [5.3.3]

Pt D, Ch 7, Sec 6, [5.3.7]

Pt D, Ch 7, Sec 6, [5.3.8]

Pt D, Ch 7, Sec 6, [5.4.4]. In applying Pt D, Ch 7, Sec 6, [5.4.4], the terms “cargo tanks” and “cargo piping” are to be understood as “ballast tanks” and “ballast piping” respectively. For de-oxygenation BWMS (categories 3a, 3b, 3c and 8), the requirements in item a) prevail.

2.8 Ventilation systems

2.8.1 The ventilation systems for BWMR containing BWMS of the following types is to be independent of the ventilation systems serving any other spaces:

- BWMS storing, introducing or generating chemical substances
- de-oxygenation, including pasteurization and de-oxygenation (cat.3 and cat.8 as per Tab 1)
- electrolysis
- ozone injection.

2.8.2 The ventilation exhaust for BWMR containing a nitrogen generator is to be located in the lower part of the room in order to efficiently evacuate dangerous gases (as defined in [1.3.3]) heavier than air.

2.8.3 The ventilation exhaust for BWMR containing electrolysis systems is to be located so as to be able to efficiently evacuate dangerous gases (as defined in [1.3.3]) that could be generated during the electrolysis process. Due regard is to be paid to the expected quantity and density of such gases when designing the ventilation exhaust.

2.8.4 The following requirements apply to ventilation ducts serving BWMR for ozone-based BWMS:

- the part of the ducts located outside of the BWMR are to be made of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0,075 m^2 and 0,45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0,45 m^2
- the ducts are to be suitably supported and stiffened
- the outside openings of the ducts are to be fitted with protective screens of not more than 13 mm square mesh.

2.8.5 The ventilation system for BWMR containing ozone-based BWMS or ventilation system for hydrogen de gas arrangement as required by [4.3.6] is to be interlocked with the BWMS such that:

- in case of loss of ventilation (primary and secondary), a visual and audible alarm is be triggered both inside and outside the BWMR and at a place where a responsible member of the crew is on duty. If the ventilation is not restored after a pre-set time, the BWMS is then to be automatically shut down. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence
- it is not possible to start the BWMS without the ventilation running.

For ventilation systems serving BWMR and containing or conveying a dangerous gas, relevant requirements in [4] are to be satisfied.

2.8.6 An adequate power ventilation system is to be provided in enclosed BWMR.

2.8.7 The ventilation capacity is to be at least 30 air changes per hour where explosive or toxic gases may be generated during operation of the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and ''safety hazard'' as listed in Chapter 17 of IBC code are to be used as references for identifying those cases.

The ventilation capacity may be reduced as per Tab 5.

Table 5 : Reduced ventilation capacity

Type of BWMS	Reduced ventilation capacity (air changes per hour) **(1)**
Flocculation-type BWMS	6
De-oxygenation, including pasteurization and de-oxygenation (cat.3 and cat.8 as per Tab 1)	6
Full flow electrolysis	6
Side-stream electrolysis	20
Ozone injection	20
Chemical injection	6
(1) More stringent ventilation capacity requirements may arise from other applicable rules, e.g. Part D, Chapter 8 for spaces located in the cargo area of ships having the service notation **chemical tanker**.	

2.9 Safe locations for venting

2.9.1 Safe locations referred to in [2.4.3] are to comply with the provisions of Tab 6.

2.9.2 Safe location needs to address the specific types of discharges separately.

2.9.3 Signboards or similar warnings at the discharge areas are to be provided.

Table 6 : Safe locations for venting

Nature of the discharged gas	Concerned BWMS category	Origin of the discharge or vent	Acceptable safe locations of the discharge or vent outlet on the open deck
Inert gas or nitrogen product enriched air	In-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS	Protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any)	• Not within 3 m of areas traversed by personnel • Not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.
	In-line ozone injection BWMS (categories 7a and 7b)	Oxygen generator	
Oxygen-enriched air	In-line and in-tank de-oxygenation BWMS (categories 3a and 8)	Nitrogen generator	• Outside of hazardous area • Not within 3 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard • Not within 3 m of areas traversed by personnel • Not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.
	In-line ozone injection BWMS (categories 7a and 7b)	Protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices	
Hydrogen by-product enriched gas	In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6)	Hydrogen de-gas arrangement (when provided)	• Not within 5 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard • Not within 3 m of areas traversed by personnel • Not within 5 m of air intakes from non-hazardous enclosed spaces. **(1)**
Gas from O_3 destructor device (ODS)	In-line ozone injection BWMS (categories 7a and 7b)	ODS fulfilling the following conditions: • the ODS are duplicated; and • the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BWMS • ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in case the ODS is not working.	The safe locations defined for oxygen-enriched air apply
		ODS not fulfilling one of the above conditions	• Outside of hazardous area • Not within 3 m of any source of ignition • Not within 6 m of areas traversed by personnel • Not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

(1) The areas on open deck, or semi-enclosed spaces on open deck, within 3 m of the outlets are to be categorized hazardous area zone 1 plus an additional 1,5 m surrounding the 3 m hazardous area zone 1 is to be categorized hazardous area zone 2. Electrical apparatus located in the above hazardous areas zone 1 and zone 2 is to be suitable for at least IIC T1.

2.10 Personal equipment

2.10.1 Suitable protection equipment are to be available on board for the protection of the crew members who are engaged in the servicing, maintenance and repair of BWMS storing, introducing or generating chemicals, as recommended by the product manufacturers. The protection equipment is to consist of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant materials, and tight fitting goggles or face shields or both. The protective clothing and equipment are to cover all skin so that no part of the body is unprotected. This protection equipment is to be provided separately without taking into account equipment required by other mandatory requirements.

2.10.2 Work clothes and protective equipment are to be kept in easily accessible places and in special lockers. Such equipment are not to be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. Notwithstanding the above, storage rooms for such equipment may be located within accommodation spaces if adequately segregated from living spaces such as cabins, passageways, dining rooms, bathrooms, etc.

2.10.3 When a BWMS storing, introducing or generating chemicals is installed on board, suitably marked decontamination showers and an eyewash are to be available in a convenient location in close proximity to the BWMS and the chemical store room(s).

2.10.4 An emergency escape breathing apparatus (EEBD) is to be provided in the BWMR. This emergency escape breathing apparatus may be one of the EEBDs provided in accordance with the requirements of SOLAS II-2/13.

An EEBD need not be required for BWMS of cat.1 as per Tab 1.

2.10.5 A personal ozone detector, calibrated as per the manufacturer's specifications, is to be provided for each person engaged in the servicing, maintenance and repair of BWMS utilizing ozone.

2.10.6 A two-way portable radiotelephone apparatus dedicated for the BWMS service, maintenance and repair is to be provided, in addition to those required by SOLAS for fire-fighting purposes. This two-way radiotelephone apparatus is to be properly identified in order to avoid mix-up with the apparatus intended for fire-fighting operations. Where the BWMS may release explosive gases, this two-way radiotelephone apparatus is to be of a certified safe type suitable for use in zone 1 hazardous areas, as defined in IEC Publication 60079. Where the BWMS stores, utilizes or introduces chemicals, the apparatus is to undergo deep cleaning or de-contamination after use.

A two-way portable radiotelephone apparatus need not be required for BWMS of cat.1 as per Tab 1.

3 Additional requirements for tankers and offshore service vessels

3.1 Application

3.1.1 The requirements of this Article apply to:

- oil tankers and FLS tankers (excluding ships carrying only products with flashpoint > 60°C)
- chemical tankers
- gas carriers
- offshore support vessels carrying flammable or hazardous liquid substances in bulk.

3.2 Location of BWMS

3.2.1 BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with Ch 4, Sec 15, [13.4.2], item a) 2).

This requirement does not apply to nitrogen generators.

3.2.2 In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored on board (category 6) can be located inside the hazardous areas with due consideration of the requirement of [2.6.3] but are not to be located inside the cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that could be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H_2 generation):

- do not lead to an upgrade of the hazardous area categorization of the cargo pump room
- are not reactive with the cargo vapours expected to be present in the cargo pump room
- are not reactive with the fire-extinguishing medium provided inside the cargo pump room
- are not impacting the performance of the existing fire-fighting systems provided inside the cargo pump room
- are not introducing additional hazards inside the cargo pump room such as toxicity hazards that would not have been addressed before by suitable counter measures.

In-line full flow electrolysis BWMS (category 4) may be accepted in cargo compressor rooms of liquefied gas carriers and inside cargo pump rooms of oil tankers or chemical tankers if that cargo pump room is located above the cargo tank deck.

For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the "cargo pump room".

Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the "cargo pump room".

3.3 Independent BWMS

3.3.1 In general, two independent BWMS are required i.e. one for ballast tanks located within the cargo area and the other one for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 4, 5, 6, 7a and 7b) could be accepted are given in [3.7].

3.4 Case of tankers where the fore peak ballast tank and other ballast tanks within the cargo area are served by a common piping system

3.4.1 When the fore peak tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with Pt D, Ch 7, Sec 4, [2.3.8] or Pt D, Ch 8, Sec 3, [5.1.3], the ballast water of the fore peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

3.5 Isolation means

3.5.1 Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with [3.5.2] to [3.5.8]

3.5.2 Interconnection between the ballast piping serving the ballast tanks located within the cargo area and the ballast piping serving the ballast tanks located outside the cargo area may be accepted if appropriate isolation arrangement is provided in accordance with [3.7].

3.5.3 The means of appropriate isolation described in [3.5.6] is necessary for the interconnection specified in [3.5.6] regardless of the diameter of the piping.

3.5.4 As indicated in [3.7], the means of appropriate isolation described in [3.5.6] is necessary for the interconnection specified in [3.5.6] in the case of the active substance piping such as N_2 gas piping, inert gas piping, neutralizer piping, fresh water piping for filter cleaning, compressed air piping for remaining water purge and sea water piping for adjusting the salinity etc.

3.5.5 The means of appropriate isolation described in [3.5.6] for the interconnection specified in [3.5.6] need not be applied to the sampling lines described in [3.6].

3.5.6 The means of appropriate isolation is to be one of the following (see Tab 7):

a) Two non-return valves with positive means of closing in series with a spool piece (also mentioned "means of dis-connection" in [3.7])

Note 1: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece.

b) Two non-return valves with positive means of closing in series with a liquid seal at least 1,5 m in depth, provided with freeze protection arrangement in the case of ships operating in cold weather conditions

Note 2: As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the liquid seal.

Note 3: A portable heating system may be accepted as freeze protection arrangement.

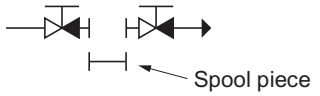
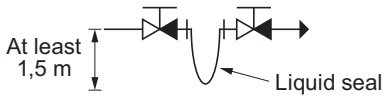
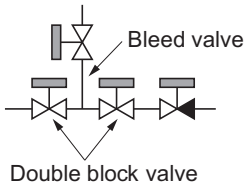
c) Automatic double block and bleed valves and a non-return valve with positive means of closing.

Note 4: As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve.

3.5.7 The means of appropriate isolation mentioned in [3.5.6] is to be provided on the open deck in the cargo area.

3.5.8 When the fore peak tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with Pt D, Ch 7, Sec 4, [2.3.8] or Pt D, Ch 8, Sec 3, [5.1.3], the means of appropriate isolation described in [3.5.6] and [3.5.7] is not required in between the fore peak tank and the common ballast water piping serving the other ballast water tanks within the cargo area.

Table 7 : Isolation mean

Two non-return valves with positive means of closing in series with a spool piece	Two non-return valves with positive means of closing in series with a liquid sea	Automatic double block and bleed valves and a non-return valve with positive means of closing
		

3.6 Sampling arrangements

3.6.1 In general, sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of the following:

- for any BWMS: ballast water sampling required by the G2 Guideline of the BWM Convention (2004)
- for BWMS technologies categories 4, 5, 6, 7a and 7b: total residual oxidant (TRO) analysis in closed loop system

are not to be led into a non-hazardous enclosed space outside the cargo area.

However, the sampling lines may be led into a non-hazardous enclosed space outside the cargo area provided the following requirements are fulfilled (See Fig 1):

a) The sampling facility (for BWMS monitoring/control) is to be located within a gastight enclosure (hereinafter, referred to as a 'cabinet'), and the following 1) through 4) are to be complied

1) in the cabinet, a stop valve is to be installed on each sampling line

2) gas detection equipment is to be installed in the cabinet and the valves specified in item a) 1) are to be automatically closed upon activation of the gas detection equipment

3) audible and visual alarm signals are to be activated both locally and at the BWMS control station when the concentration of explosive gases reaches a pre-set value, which is not to be higher than 30% of the lower flammable limit (LFL). Upon activation of the alarm, the electrical power to the cabinet is to be automatically disconnected except for electrical equipment of certified safe type

4) the cabinet is to be vented to a safe location in a non-hazardous area on the open deck and the vent is to be fitted with a flame arrester.

b) The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

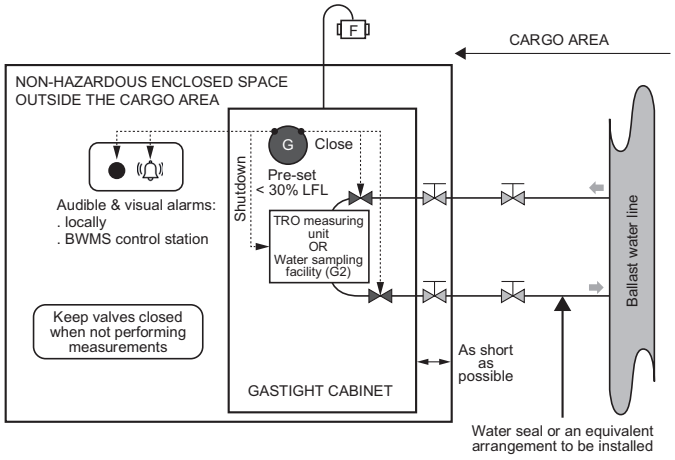
c) The cabinet is to be installed as close as possible to the bulkhead facing the cargo area, and the sampling lines located outside the cargo area are to be routed on their shortest ways.

d) Stop valves are to be located in the non-hazardous enclosed space outside the cargo area, in both the suction and return lines close to the penetrations through the bulkhead facing the cargo area. A warning plate stating “Keep valve closed when not performing measurements” is to be posted near the valves. Furthermore, in order to prevent backflow, a water seal or equivalent arrangement is to be installed on the hazardous area side of the return pipe.

e) A stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).

f) The samples which are extracted from the ballast water piping system serving the tanks within the cargo area are not to be discharged to a tank located outside the cargo area nor to a piping line supplying the spaces located outside the cargo area.

Figure 1 : Arrangement of the sampling facility when located outside the cargo area



3.7 Acceptability of single BWMS installation on tankers

3.7.1 Acceptable arrangements of single BWMS for in-line BWMS's technologies

Arrangement of one single BWMS located outside the cargo area of tankers may be accepted in accordance with the provisions of Tab 8.

The detailed arrangements of BWMS are given in [3.7.2].

Note 1: [3.7] does not cover In-tank technologies categories 3c and 8.

3.7.2 Detailed arrangements of single BWMS installed outside the cargo area

The detailed arrangements of single BWMS installed outside the cargo area are listed in Tab 9 and shown in Fig 2 to Fig 8.

The key to symbols used in these figures are given in Tab 9.

Table 8 : Acceptable arrangements of one single BWMS depending on the BWMS' technology category

Characteristics		BWMS's Technology category								
		1	2	3a	3b	4	5	6	7a	7b
		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 Generator)	In-line-de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-line full flow electrolysis	In-line side stream electrolysis **(3)**	In-line (stored) chemical injection	In-line side- stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side- stream ozone injection with gas/liquid separation tank and without discharge water treatment tank
Des-infection when ballasting	Making use of active substance		X			X	X	X	X	X
	Full flow of ballast water is passing through the BWMS	X	X	X	X	X				X
	Only a small part of ballast water is passing through the BWMS to generate the active substance						X			
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X								X
	Injection of neutralizer					X	X	X	X	X
	Not required by the Type Approval Certificate issued by the Flag Administration		X	X						
Examples of dangerous gas as defined in [1.3.3]			**(1)**	O_2N_2	CO_2 CO	H_2 Cl_2	H_2 Cl_2	**(1)**	O_2, O_3, N_2	
Arrangement of one single BWMS	BWMS is located outside the cargo area	Not acceptable	Case 1.2 **(2)**	Case 1.3a **(2)**	Case 1.3b	Case 1.4 **(2)**	Case 1.5	Case 1.6	Case 1.7a	Case 1.7b **(2)**

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) Only «Means of dis-connection» as described in [3.5.6], item a) are to be applied.

(3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or deballasting).

Table 9 : Detailed arrangements of single BWMS installed outside the cargo area

Case 1.2 (Technology category 2): Flocculation Case 1.3a (Technology category 3a): De-oxygenation with N_2 generator	See Fig 2
Case 1.3b (Technology category 3b): De-oxygenation with Inert Gas Generator	See Fig 3
Case 1.4 (Technology category 4): Full-flow electrolysis	See Fig 4
Case 1.5 (Technology category 5): Side-stream electrolysis	See Fig 5
Case 1.6 (Technology category 6): Stored chemical injection	See Fig 6
Case 1.7a (Technology category 7a): Side-stream ozone injection without gas-liquid separation tank and without discharge water treatment tank	See Fig 7
Case 1.7b (Technology category 7b): Side-stream ozone injection with gas-liquid separation tank and discharge water treatment tank	See Fig 8

Key to symbols used in Fig 2 to Fig 8:

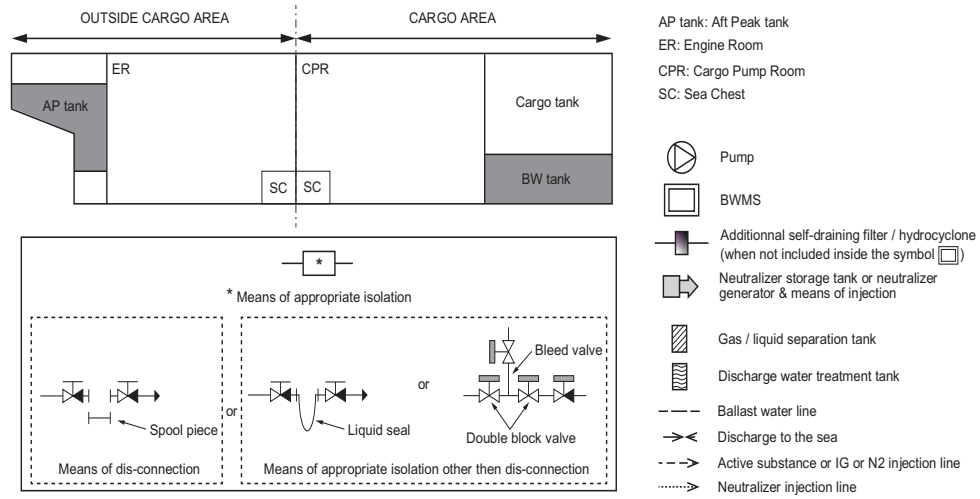


Figure 2 : Case 1.2 - Floculation and Case 1.3a - De-oxygenation with N_2 generator

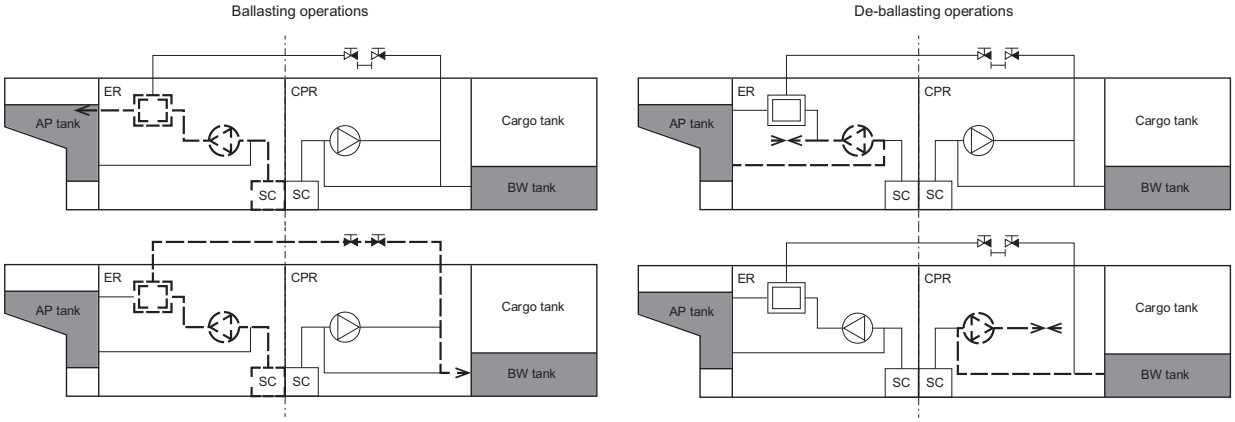


Figure 3 : Case 1.3b - De-oxygenation with Inert Gas Generator

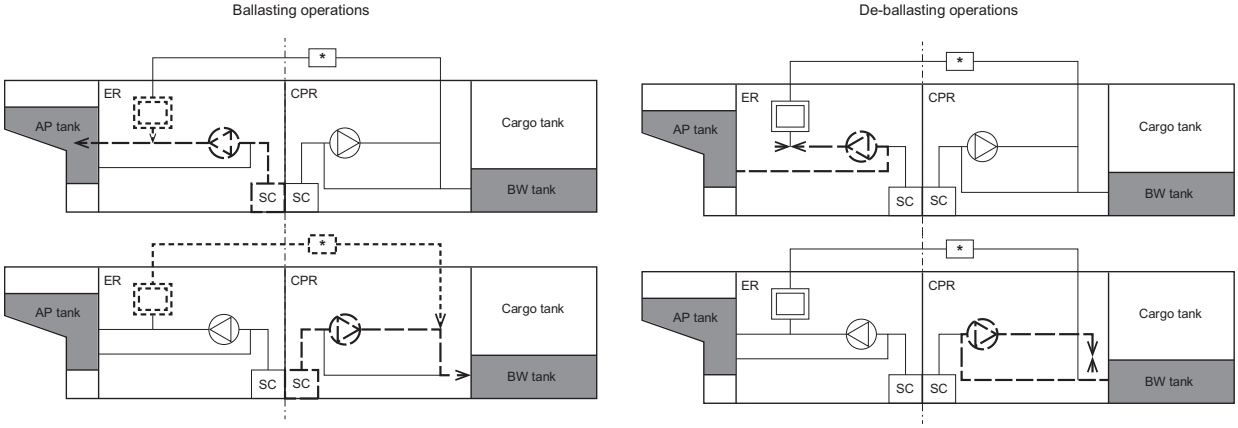


Figure 4 : Case 1.4 - Full-flow electrolysis

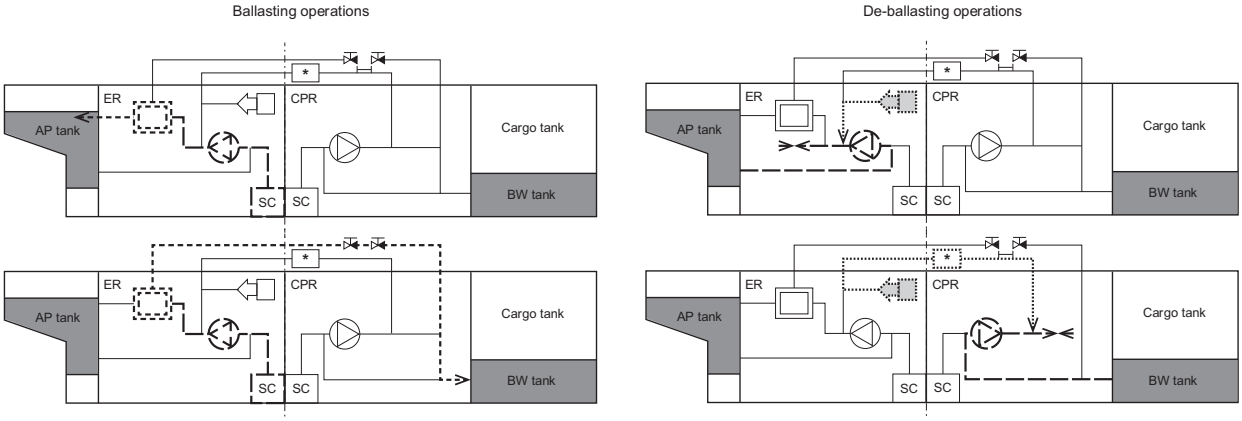


Figure 5 : Case 1.5 - Side-stream electrolysis

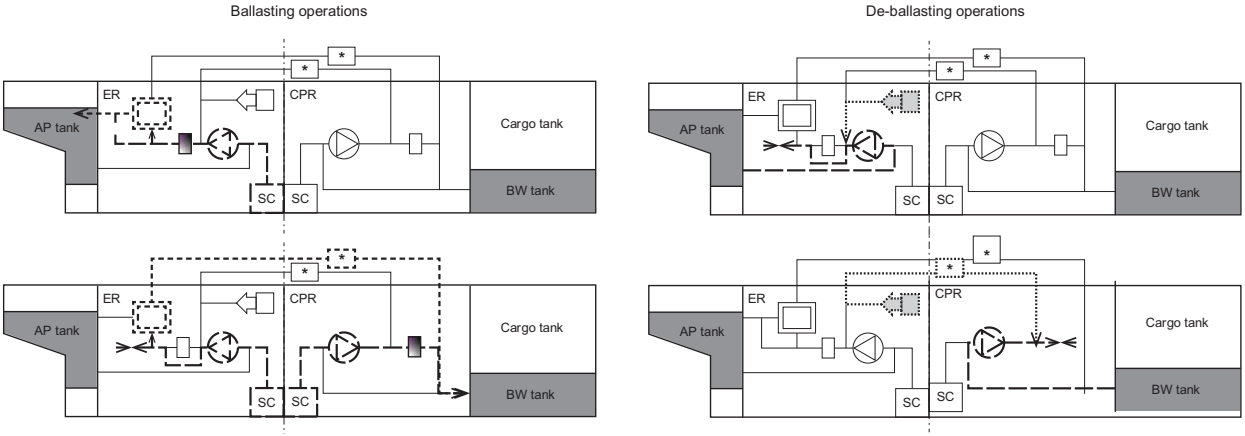


Figure 6 : Case 1.6 - Stored chemical injection

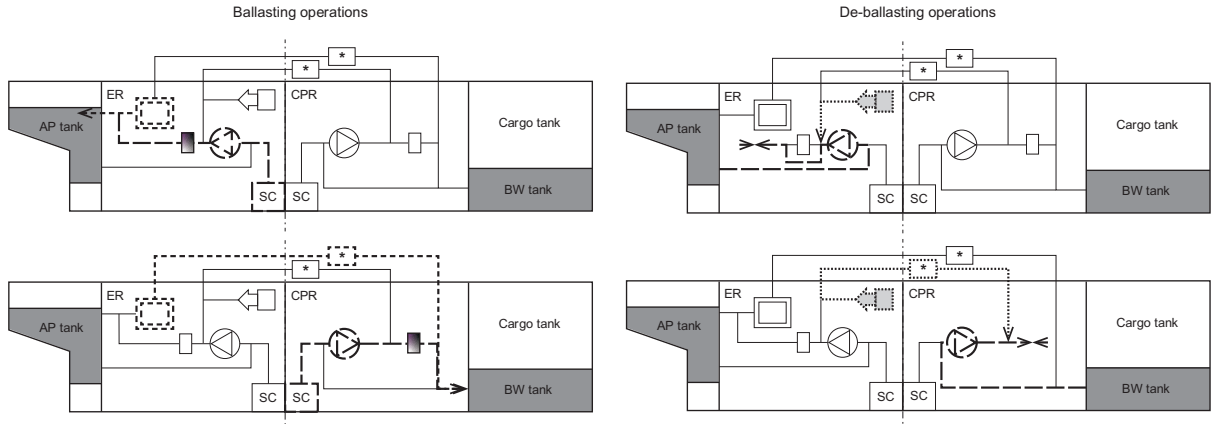


Figure 7 : Case 1.7a - Side-stream ozone injection without gas-liquid separation tank and without discharge water treatment tank

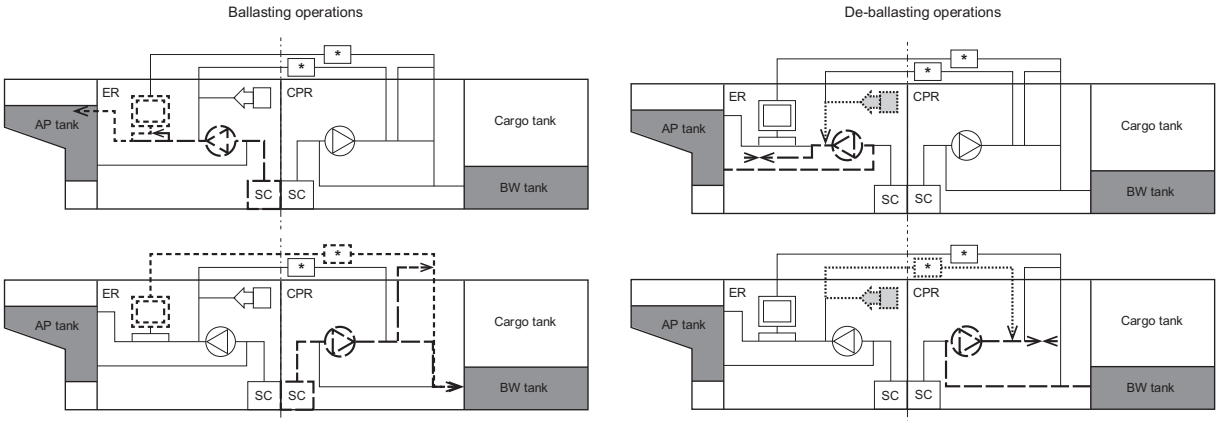
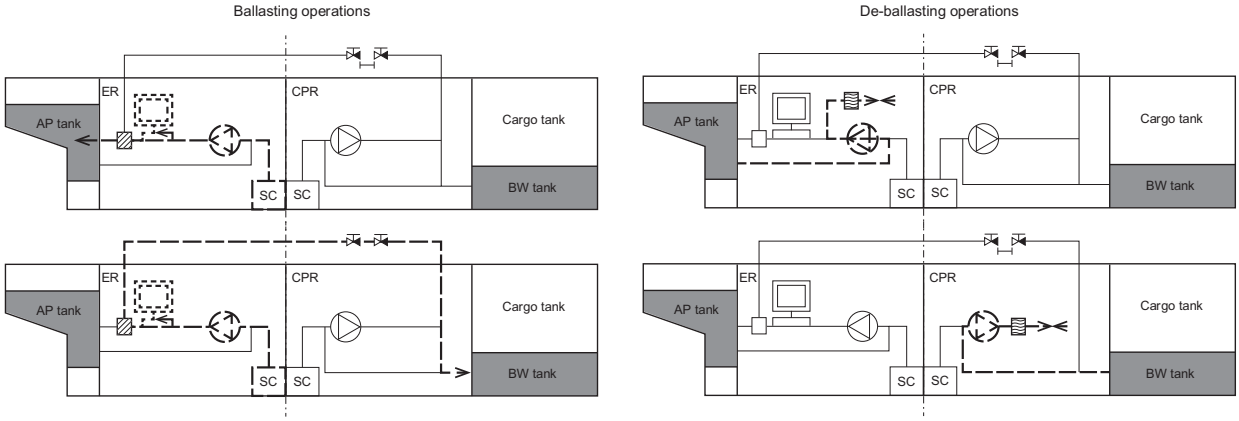


Figure 8 : Case 1.7b - Side-stream ozone injection with gas-liquid separation tank and discharge water treatment tank



4 Special requirements for BWMS generating dangerous gas or dealing with dangerous liquids

4.1 Application

4.1.1 The provisions of this Article apply to BWMS categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

4.2 BWMS involving the generation of a dangerous gas

4.2.1 Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage.

The gas detectors are to be located as close as possible to the BWMS components where the dangerous gas may accumulate.

For flammable gases and explosive atmosphere including but not limited to H_2, the construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1:2016, IEC 60079-29-2:2015, IEC 60079-29-3:2014 and / or IEC 60079-29-4:2009, as applicable.

Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to the Society is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.

4.2.2 In spaces where inert gas generator systems are fitted (BWMS categories 3b and 3c) or nitrogen generators are fitted (BWMS categories 3a and 8), at least two oxygen sensors are to be positioned at appropriate locations, as required by Ch 4, Sec 15, [13.3.4], item e), 4), to alarm when the oxygen level falls below 19%. The alarms are to be both audible and visual and are to be activated:

- inside the space
- at the entry into the space
- inside the BWMS control station.

For BWMS categories 7a and 7b, at least two oxygen sensors are to be positioned at appropriate locations in the following spaces:

- spaces where ozone generators are fitted
- spaces where ozone destructors are fitted
- spaces where ozone piping is routed

to alarm when the oxygen level rises above 23%. The alarms are to be both audible and visual and are to be activated at the following locations:

- inside the space
- at the entry into the space
- inside the BWMS control station.

Automatic shutdown of the BWMS is to be arranged when the oxygen level rises above 25%. Audible and visual alarms independent from those specified in the preceding paragraph are to be activated prior to this shutdown.

4.2.3 For BWMS In-line side-stream ozone injection categories 7a and 7b, at least one ozone sensor is to be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in Tab 6 to alarm when the ozone concentration level rises above 0,1 ppm. The alarms are to be both audible and visual and are to be activated in the BWMS control room. In addition, at least two ozone sensors are to be positioned at appropriate locations in the following spaces:

- spaces where ozone generators are fitted
- spaces where ozone destructors are fitted
- spaces where ozone piping is routed

to alarm when the ozone concentration level rises above 0,1 ppm. The alarms are to be both audible and visual and are to be activated at the following locations:

- inside the space
- at the entry into the space
- inside the BWMS control station.

Automatic shutdown of the BWMS is to be arranged when the ozone concentration measured from one of the two sensors inside the space rises above 0,2 ppm.

4.2.4 Inside double walled spaces or pipe ducts constructed as the special safeguard for the purpose of [4.3.1] sensors are to be provided for the detection of H_2 leakages (BWMS categories 4, 5 and 6 when relevant) or O_2 leakages (BWMS categories 7a and 7b) or O_3 leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shutdown of the BWMS at the high-high level settings described in [4.2.1] to [4.2.3].

Note 1: As an alternative to the sensor for the gas detection, monitored under-pressurization inside the double walled spaces or pipe ducts may be provided with an automatic alarm and shutdown of the BWMS in case of loss of the under-pressurization. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

4.2.5 For in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored on board (category 6): the hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system.

In addition the ventilation fan is to be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H_2 gas may be present in dangerous concentrations.

Audible and visual alarms and automatic shutdown of the BWMS are to be arranged for respectively high and high-high levels of H_2. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location on the open deck. Refer to [4.3.10].

4.2.6 The open ends of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location on the open deck. Refer to [4.3.10].

4.3 Piping conveying dangerous gas or liquid

4.3.1 Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gases or dangerous liquids as defined respectively in [1.3.3]and [1.3.4], the following requirements are to be satisfied.

Requirement [4.3.2] to [4.3.9] is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted.

Note 1: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) may be used for assessing the hazards that could be expected from the media conveyed by the BWMS piping.

4.3.2 Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by Ch 1, Sec 10, Tab 3. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on board are to be as required in Ch 1, Sec 10, [2] to Ch 1, Sec 10, [5]. Mechanical joints, where allowed, are to be selected in accordance with Ch 1, Sec 10, Tab 18.

For piping class II with special safeguards conveying dangerous gas like hydrogen (H_2), oxygen (O_2) or ozone (O_3), the special safeguards are to be either double walled pipes or pipe duct. For piping class II with special safeguards conveying dangerous liquids, other special safeguards may be considered like shielding, screening, etc.

Plastic pipes may be accepted after due assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of Ch 1, App 3 apply.

4.3.3 The length of pipe and the number of connections are to be minimised.

4.3.4 Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of [4.3.2] are to be equipped with mechanical exhaust ventilation leading to a safe location on the open deck. Refer to [4.3.10].

4.3.5 The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be suitably supported and protected from mechanical damage.

4.3.6 Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

4.3.7 H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O_3 piping (BWMS categories 7a and 7b) are not to be routed through accommodation spaces, services spaces and control stations.

4.3.8 O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) are not to be routed through hazardous areas unless arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of [4.3.2] and provided with suitable gas detection as described in [4.2.4] and mechanical exhaust ventilation as described in [4.3.4].

4.3.9 The routing of H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer's recommendation.

4.3.10 Safe locations referred to in [4.2.1] are to comply with the provisions of Tab 6.

4.4 Handling and storage of chemicals and preparations used to treat ballast water

4.4.1 Procedures

For BWMS using chemical substances or dangerous gas which are stored on board for either:

- storage or preparation of the active substances (BWMS categories 2 and 6)
- storage or preparation of the neutralizers (BWMS categories 4, 5, 6, 7a and 7b)
- recycling the wastes produced by the BWMS (BWMS category 2)

procedures are to be in accordance with the Material Safety Data Sheet and IMO Circular BWM.2/Circ.20 “Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the ship and crew resulting from the treatment process”.

4.4.2 Design, construction, arrangement and testing of tanks containing chemical substances

a) The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances.

b) Chemical substances (even if they are not defined as dangerous liquid in the sense of [1.3.4] and gas storage tanks are to be designed, constructed, tested, inspected, certified and maintained in accordance with:
   - for independent tanks permanently fixed on board containing dangerous liquids (eg. sulfuric acid H_2SO_4) or dangerous gas (eg. oxygen O_2):
     Ch 1, Sec 3
   - for independent tanks permanently fixed on board not containing dangerous liquid (eg. sodium sulphite, sodium biosulphite or sodium thiosulfphate neutralizers) and not containing dangerous gas (eg. nitrogen N_2):
     Ch 1, Sec 3 or other recognized standard accepted by the Society
   - for portable tanks:
     IMO IMDG Code or other recognized standard accepted by the Society.

c) Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location on the open deck. Refer to [4.3.10].

d) An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept on board.

e) Dangerous liquid storage tanks and their associated components like pumps and filters, are to be provided with spill trays or secondary containment system of sufficient volume to contain potential leakages from tank openings, gauge glasses, pumps, filters and piping fittings.

   Further to the safety and/or pollution assessment of the concerned chemical substances, consideration is to be provided for segregation of the drains from such spill trays (or secondary containment system) or piping systems from engine room bilge system or from cargo pump room bilge system, as applicable. When necessary, arrangement is to be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas as defined respectively in [1.3.3] and [1.3.4].

Note 1: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) may be used for this assessment.

5 Certification

5.1 Type approval and design review

5.1.1 BWMS are to be of a type approved by the Society. For this purpose:

a) They are to be type approved by the Administration according to IMO Code for approval of ballast water management systems (BWMS Code, IMO Resolution MEPC.300(72)).

Note 1: It should be noted that some Flag Administrations request the IMO Type Approval to be issued on their behalf.

b) Their design is to comply with the requirements of:

- Ch 1, Sec 3 for pressure vessels
- Ch 1, Sec 10 for piping
- Ch 2, Sec 15 for the type approval tests of electrical components
- Ch 3, Sec 3 for the computer-based systems

Note 2: In general, monitoring functions of BWMS belong to system category I under the application of Ch 3, Sec 3. However, in case a bypass valve is integrated in the valve remote control system, the bypass valve belongs to the system category II Ballast transfer remote control system.

- Ch 3, Sec 6 for the type approval tests of automation systems.

The relevant documentation to be submitted is listed in Tab 10.

Table 10 : Documentation and information to be submitted for type approval of BWMS

No.	Documentation and information to be submitted	Approval status **(1)**
1	BWMS specifications / Limitations	I
2	Dedicated technical manual of the BWMS	I
3	General drawings of the BWMS	A
4	General Arrangement	A
5	Main Piping diagram	A
6	Main Electrical diagram	A
7	List of components	I
8	Manufacturer's procedures for production check and production tests	I
9	Manufacturer's procedures for onboard installation checks, onboard installation tests and installation commissioning procedures	I
10	Type approval certificates of the BWMS	I
11	Pressure vessels: Documents and information according to Ch 1, Sec 3, Tab 3	See Ch 1, Sec 3, Tab 3
12	Storage tanks for chemicals substances: detailed drawings	A
13	Piping systems: Documents according to Ch 1, Sec 10, Tab 1 and Ch 1, Sec 10, Tab 2	See Ch 1, Sec 10, Tab 1 and Ch 1, Sec 10, Tab 2
14	Electrical power and control cabinets: detailed drawings / diagrams with list of components	A
	Sensors and valve actuators:	
15	• detailed drawings / diagrams with location	A
16	• list and reference of type approval	I
17	Electrical cables: list and reference of type approval	I
(1) A: To be submitted for approval ; I: To be submitted for information.		

5.2 Risk assessment

5.2.1 A risk assessment is to be conducted in a generic manner during the design review mentioned in [5.1.1] and submitted to the Society for approval for the following BWMS categories:

- BWMS category 4: in all cases
- BWMS category 5: in all cases
- BWMS category 6: when one of the MSDS indicates that the chemical substance stored on board is either flammable, toxic, corrosive or reactive
- BWMS category 7a and 7b: in all cases.

Note 1: The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) may be used as a reference for this assessment.

5.2.2 The recommended risk assessment techniques for BWMS and other guidances are listed below but not limited to:

- FMEA, FMECA, HAZID, HAZOP, etc
- ISO 31010:2009 - Risk Assessment Techniques
- ISO/TS 18683:2021, Section 7: Risk assessment.

5.2.3 The risk assessment is to ensure that the equipment supplied by the BWMS's manufacturer is intrinsically safe and/or provides mitigation measures to the hazards created by the BWMS which have been identified during the design review mentioned in [5.1.1] but that need to be implemented during the installation on board.

5.3 Inspection and testing

5.3.1 A BV product certificate (Society Certificate (C)) is required for the BWMS and its components including pressure vessels, piping class I or II, filters, switchboards, etc.

5.3.2 The tests listed in Tab 11 are to be carried out with the attendance of the Surveyor.

Table 11 : Tests for BWMS to be carried out during manufacturing with the attendance of the Surveyor

Equipment to be tested	Tests to be carried out
BWMS	Functional tests: • normal operations • forced operations • test of fault alarms • test of bypass alarms • test of remote starting/stop
Pressure vessels and their fittings	Pressure test (see Ch 1, Sec 3, [9.3.2]) Water tightness test
Skid piping and relevant fittings	Pressure test (see Ch 1, Sec 10, [20.5]) Tightness test
Valves for fresh water and backwash	Pressure test (see Ch 1, Sec 10, [20.5]) Tightness test Functional test
Chemical storage tank	Hydraulic test
Sensors and valve actuators	Functional test

Section 14 Steering Gear

1 General

1.1 Application

1.1.1 Scope

Unless otherwise specified, the requirements of this Section apply to the steering gear systems of all mechanically propelled ships, and to the steering mechanism of thrusters used as means of propulsion.

1.1.2 Ships assigned the additional service feature SPxxx or SPxxx-capable

Ships assigned additional service feature **SPxxx** or **SPxxx-capable** are to comply with the requirements of this Section, considering the ship:

- as a passenger ship, when xxx is greater than 240
- as a cargo ship, when xxx is less than or equal to 240.

where:

xxx : Total number of persons onboard including crew, special personnel and passengers (maximum twelve).

1.1.3 Ships assigned the additional service feature IPxxx or IPxxx-capable

Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** are to comply with the requirements of this Section, considering the ship:

- as a passenger ship, when xxx is greater than 240
- as a cargo ship, when xxx is less than or equal to 240.

where

xxx : Total number of persons onboard including crew, industrial personnel and passengers (maximum twelve).

1.1.4 Cross references

In addition to those provided in this Section, steering gear systems are also to comply with the requirements of:

- Ch 1, Sec 18, as regards sea trials
- Pt B, Ch 12, Sec 1, as regards the rudder and the rudder stock
- Pt D, Ch 7, Sec 4, [7], when fitted to oil tankers, chemical tankers or gas carriers
- Pt D, Ch 15, Sec 4, [24], when fitted to fishing vessels.

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for all steering gear

Before starting construction, all plans and specifications listed in Tab 1 are to be submitted to the Society for approval.

1.2.2 Additional documents

The following additional documents are to be submitted:

- analysis in relation to the risk of single failure, where required by [2.4.2]
- analysis in relation to the risk of hydraulic locking, where required by [2.4.5]
- fatigue analysis and/or fracture mechanics analysis, where required by Pt D, Ch 7, Sec 4, [7.2.2] and Pt D, Ch 7, Sec 4, [7.3.1].

Table 1 : Documents to be submitted for steering gear

No.	I/A **(2)**	Description of the document **(1)**
1	I	Assembly drawing of the steering gear including sliding blocks, guides, stops and other similar components
2	I	General description of the installation and of its functioning principle
3	I	Operating manuals of the steering gear and of its main components
4	I	Description of the operational modes intended for steering in normal and emergency conditions
5	A	For hydraulic steering gear, the schematic layout of the hydraulic piping of power actuating systems, including the hydraulic fluid refilling system, with indication of: • the design pressure • the maximum working pressure expected in service • the diameter, thickness, material specification and connection details of the pipes • the hydraulic fluid tank capacity • the flashpoint of the hydraulic fluid
6	I	For hydraulic pumps of power units, the assembly longitudinal and transverse sectional drawings and the characteristic curves
7	A	Assembly drawings of the rudder actuators and constructional drawings of their components, with, for hydraulic actuators, indication of: • the design torque • the maximum working pressure • the relief valve setting pressure
8	I	Constructional drawings of the relief valves for protection of the hydraulic actuators, with indication of: • the setting pressure • the relieving capacity
9	A	Diagrams of the electric power circuits
10	A	Functional diagram of control, monitoring and safety systems including the remote control from the navigation bridge, with indication of the location of control, monitoring and safety devices
11	A	Constructional drawings of the strength parts providing a mechanical transmission of forces to the rudder stock (tiller, quadrant, connecting rods and other similar items), with the calculation notes of the shrink-fit connections
12	I/A	For azimuth thrusters used as steering means, the specification and drawings of the steering mechanism and, where applicable, documents 2 to 6 and 8 to 11 above

(1) Constructional drawings are to be accompanied by the specification of the materials employed and, where applicable, by the welding details and welding procedures.

(2) A = to be submitted for approval ; I = to be submitted for information.

1.3 Definitions

1.3.1 Steering system

Steering system means ship's directional control system, including main steering gear, auxiliary steering gear, steering gear control system and rudder if any.

1.3.2 Steering gear control system

Steering gear control system is the equipment by which orders are transmitted from the navigation bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

Steering gear control system is also understood to cover the equipment required to control the steering gear power actuating system.

1.3.3 Main steering gear

Main steering gear is the machinery, rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.3.4 Steering gear power unit

Steering gear power unit is:

- *in the case of electric steering gear, an electric motor and its associated electrical equipment*
- *in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump*
- *in the case of other hydraulic steering gear, a driving engine and connected pump.*

1.3.5 Auxiliary steering gear

Auxiliary steering gear is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.3.6 Power actuating system

Power actuating system is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

1.3.7 Rudder actuator

Rudder actuator is the component which directly converts hydraulic pressure into mechanical action to move the rudder.

1.3.8 Maximum ahead service speed

Maximum ahead service speed is the greatest speed which the ship is designed to maintain in service at sea at the deepest seagoing draught.

1.3.9 Maximum astern speed

Maximum astern speed is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest seagoing draught.

1.3.10 Maximum working pressure

Maximum working pressure is the maximum expected pressure in the system when the steering gear is operated to comply with the provisions of [2.2.1], item b).

1.3.11 Hydraulic locking

Hydraulic locking means all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "bypass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

1.4 Symbols

1.4.1 The following symbols are used for strength criteria of steering gear components:

V : Maximum service speed, in knots, with the ship on summer load waterline. When the speed is less than 10 knots, V is to be replaced by the value (V+20)/3

d_s : Rule diameter of the rudder stock in way of the tiller, in mm, defined in Pt B, Ch 12, Sec 1, [4] and calculated with a material factor $k_1 = 1$

d_{se} : Actual diameter of the upper part of the rudder stock in way of the tiller, in mm
(in the case of a tapered coupling, this diameter is measured at the base of the assembly)

T_R : Rule design torque of the rudder stock given, in kN.m, by the following formula:

$$T_R = 13{,}5 \cdot d_s^3 \cdot 10^{-6}$$

T_E : For hand emergency operation, design torque due to forces induced by the rudder, in kN.m, given by the following formulae:

$$T_E = 0{,}62 \cdot \left(\frac{V_E + 2}{V + 2}\right)^2 \cdot T_R$$

where:

- $V_E = 7$ where $V \leq 14$
- $V_E = 0{,}5\ V$ where $V > 14$

T_G : For main hydraulic or electrohydraulic steering gear, torque induced by the main steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 1: for hand-operated main steering gear, the following value is to be used:

$T_G = 1{,}25.T_R$

T_A : For auxiliary hydraulic or electrohydraulic steering gears, torque induced by the auxiliary steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 2: for hand-operated auxiliary steering gear, the following value is to be used:

$T_A = 1{,}25.T_E$

T'_G : For steering gear which can activate the rudder with a reduced number of actuators, the value of T_G in such conditions

σ : Normal stress due to the bending moments and the tensile and compressive forces, in N/mm^2

τ : Tangential stress due to the torsional moment and the shear forces, in N/mm^2

σ_a : Permissible stress, in N/mm^2

σ_c : Combined stress, determined by the following formula:

$$\sigma_c = \sqrt{\sigma^2 + 3\tau^2}$$

R : Value of the minimum specified tensile strength of the material at ambient temperature, in N/mm^2

R_e : Value of the minimum specified yield strength of the material at ambient temperature, in N/mm^2

R'_e : Design yield strength, in N/mm^2, determined by the following formulae:

- $R'_e = R_e$, where $R \geq 1,4\ R_e$
- $R'_e = 0,417\ (R_e + R)$ where $R < 1,4\ R_e$

2 Design and construction

2.1 General

2.1.1 *Unless expressly provided otherwise, every ship shall be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.*

2.2 Strength, performance and power operation of the steering gear

2.2.1 Main steering gear

The main steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s

Where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch, ships may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

Note 1: "even keel" means that the vessel is an acceptable trim condition

Note 2: "fully submerged" means A_T is greater than $0.95 \cdot A_F$, where A_T and A_F are defined in [2.2.3].

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the main steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition. The speed of the ship shall correspond to the number of maximum continuous revolutions of the main engine and maximum design pitch of the propeller;

Specific requirements of [2.2.3] are to be applied for trials not performed at full load condition*;*

c) operated by power where necessary to meet the requirements of b) *and in any case when the Society requires a rudder stock of over 120 mm diameter in way of the tiller, excluding strengthening for navigation in ice, and*

d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

Note 3: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm^2, i.e. with a material factor $k_1 = 1$.

2.2.2 Auxiliary steering gear

The auxiliary steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency

b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

Where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater, ships may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

Note 1: "even keel" means that the vessel is an acceptable trim condition.

Note 2: "fully submerged" means A_T is greater than $0.95 \cdot A_F$, where AT and AF are defined in [2.2.3].

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the auxiliary steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition;

Specific requirements of [2.2.3] are to be applied for trials not performed at full load condition;

and

c) operated by power where necessary to meet the requirements of b) *and in any case when the Society requires a rudder stock of over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice.*

Note 3: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm^2, i.e. with a material factor $k_1 = 1$.

2.2.3 Steering gear test with the vessel not at the deepest seagoing draught

In order to meet the performance stated in item b) of [2.2.1] and item b) of [2.2.2] the following requirements are applicable.

When it is justified that the trials cannot practically be performed with the vessel at the deepest seagoing draught, the loading condition can be accepted on the conditions that:

a) The estimated steering actuator hydraulic pressure in the deepest seagoing draught condition P_F has been extrapolated from the maximum measured actuator hydraulic pressure in the trial condition P_T using one of the following methods:

1) P_F is obtained according to the following formula:

$$P_F = P_T \cdot \alpha$$

$$\alpha = 1{,}25\left(\frac{A_F}{A_T}\right)\left(\frac{V_F}{V_T}\right)^2$$

where:

P_F : estimated steering actuator hydraulic pressure in the deepest seagoing draught condition

P_T : maximum measured actuator hydraulic pressure in the trial condition.

α : extrapolation factor

A_F : total immersed projected area of the movable part of the rudder in the deepest seagoing condition

A_T : total immersed projected area of the movable part of the rudder in the trial condition

V_F : contractual design speed of the vessel corresponding to the maximum continuous revolutions of the main engine at the deepest seagoing draught

V_T : measured speed of the vessel (considering current) in the trial condition.

Note 1: Above formulae assumes that the rudder actuator system pressure is shown to have a linear relationship to the rudder stock torque.

2) The following methodology is applied for determination of P_F:

- The designer or builder uses computational fluid dynamic (CFD) studies or experimental investigations to predict the estimated rudder stock moment at the full sea going draught condition and service speed Q_F

  These calculations or experimental investigations are to be to the satisfaction of the Society.
- the rudder torque at the trial loading condition Q_T have been reliably predicted based on the maximum measured actuator hydraulic pressure in the trial condition P_T
- The estimated steering actuator hydraulic pressure in the deepest seagoing draught condition is obtained according to the following formula:

$$P_F = P_T \frac{Q_F}{Q_T}$$

b) Where constant volume fixed displacement pumps are utilised, the estimated steering actuator hydraulic pressure at the deepest draught P_F is to be less than the specified maximum working pressure of the rudder actuator.

Where a variable delivery pump is utilised, the pump data is to be supplied and interpreted to estimate the delivered flow rate corresponding to the deepest seagoing draught in order to calculate the estimated steering time, not to be greater than to the required time specified in [2.2.1] or [2.2.2], as applicable.

c) In any case for the main steering gear trial, the speed of the ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

2.3 Control of the steering gear

2.3.1 Main and auxiliary steering gear control

Steering gear control shall be provided:

a) for the main steering gear, both on the navigation bridge and in the steering gear compartment

b) where the main steering gear is arranged in accordance with [2.4.2], by two independent control systems, both operable from the navigation bridge and the steering gear compartment. This does not require duplication of the steering wheel or steering lever. Where the control system consists in a hydraulic telemotor, a second independent system need not be fitted, except in a tanker, chemical tanker or gas carrier of 10 000 gross tonnage and upwards

The two independent steering gear control systems are to be:

- so arranged that a mechanical or electrical failure in one of them will not render the other one inoperative, and
- in accordance with [2.3.3]

c) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigation bridge and to be independent of the control system for the main steering gear.

Note 1: The term "steering gear control system" is to be understood to cover "the equipment required to control the steering gear power actuating system".

2.3.2 Control systems operable from the navigation bridge

Any main and auxiliary steering gear control system operable from the navigation bridge shall comply with the following:

- *if electrical, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit*
- *means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigation bridge from the steering gear it serves*
- *the system shall be capable of being brought into operation from a position on the navigation bridge*
- *in the event of failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigation bridge, and*
- *short-circuit protection only shall be provided for steering gear control supply circuits.*

2.3.3 Installation

a) Duplicated steering gear control systems with their associated components are to be separated as far as practicable.

b) Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles are to be separated as far as practicable.

Where physical separation is not practicable, separation may be achieved by means of a fire-retardant plate.

c) All electrical components of the steering gear control systems are to be duplicated. This does not require duplication of the steering wheel or steering lever.

d) If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, the connections for the control systems are to be divided accordingly and separated from each other by an isolating plate or air gap.

e) In the case of double follow-up control, the amplifier is to be designed and fed so as to be electrically and mechanically separated. In the case of non-follow-up control and follow-up control, it is to be ensured that the follow-up amplifier is protected selectively.

f) Control circuits for additional control systems, e.g. steering lever or autopilot, are to be designed for all-pole disconnection.

g) The feedback units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

2.4 Availability

2.4.1 Arrangement of main and auxiliary steering gear

The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one will not render the other inoperative.

2.4.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that:

a) in a passenger ship, the main steering gear is capable of operating the rudder as required in [2.2.1] *while any one of the power units is out of operation*

b) in a cargo ship, the main steering gear is capable of operating the rudder as required in [2.2.1] *while operating with all power units*

c) the main steering gear is so arranged that after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

Steering gear other than of the hydraulic type is to achieve standards equivalent to the requirements of this paragraph to the satisfaction of the Society.

2.4.3 Hydraulic power supply

The hydraulic system intended for main and auxiliary steering gear is to be independent of all other hydraulic systems of the ship.

2.4.4 Non-duplicated components

Special consideration is to be given to the suitability of any essential component which is not duplicated.

2.4.5 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

2.4.6 Additional requirements for ships of 70 000 gross tonnage and above

In ships of 70,000 gross tonnage and upwards, the main steering gear shall comprise two or more identical power units complying with the provisions of [2.4.2].

2.5 Mechanical components

2.5.1 General

a) All steering gear components and the rudder stock are to be of sound and reliable construction to the satisfaction of the Society.

b) Any non-duplicated essential component is, where appropriate, to utilise anti-friction bearings, such as ball bearings, roller bearings or sleeve bearings, which are to be permanently lubricated or provided with lubrication fittings

c) The construction is to be such as to minimise local concentration of stress.

d) All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

2.5.2 Materials and welds

a) All steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material complying with the requirements of NR216 Materials and Welding. In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

b) The use of grey cast iron is not permitted, except for redundant parts with low stress level, subject to special consideration by the Society. It is not permitted for cylinders.

c) The welding details and welding procedures are to be submitted for approval.

d) All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

2.5.3 Scantling of components

The scantling of steering gear components is to be determined considering the design torque M_T and the permissible value σ_a of the combined stress, as given in:

- Tab 2 for components which are protected against overloads induced by the rudder
- Tab 3 for components which are not protected against overloads induced by the rudder.

Table 2 : Scantling of components protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_G	• if $T_G \le 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T_G \ge 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R'_e$
Normal operation, with a reduced number of actuators	T'_G	• if $T'_G \le 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T'_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T'_G \ge 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0,8\ T_A$	$0,69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,69\ R'_e$
Emergency operation achieved by hand	T_E	$0,69\ R'_e$

Table 3 : Scantling of components not protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_R	$0,55\ R'_e$
Normal operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0,8\ T_A$	$0,69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,69\ R'_e$
Emergency operation achieved by hand	T_E	$0,69\ R'_e$

2.5.4 Tillers, quadrants and rotors

a) The scantling of the tiller is to be determined as follows:

- the depth H_0 of the boss is not to be less than $0,75.d_s$
- the radial thickness of the boss in way of the tiller is not to be less than the greater of:
  - $0,3 \cdot d_s \cdot \sqrt{\frac{235}{R'_e}}$
  - $0,25 \cdot d_s$
- the section modulus of the tiller arm in way of the end fixed to the boss is not to be less than the value Z_b, in cm^3, calculated from the following formula:

$$Z_b = \frac{0,147 \cdot d_s^3}{1000} \cdot \frac{L'}{L} \cdot \frac{R_e}{R'_e}$$

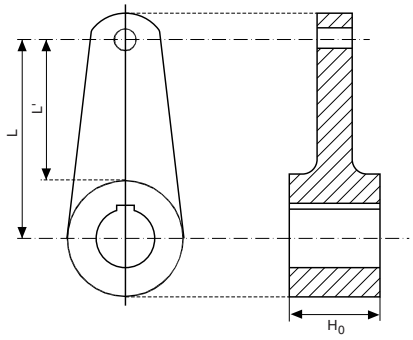
where:

L : Distance from the centreline of the rudder stock to the point of application of the load on the tiller (see Fig 1)

L′ : Distance between the point of application of the above load and the root section of the tiller arm under consideration (see Fig 1)

- the width and thickness of the tiller arm in way of the point of application of the load are not to be less than one half of those required by the above formula
- in the case of double arm tillers, the section modulus of each arm is not to be less than one half of the section modulus required by the above formula.

Figure 1 : Tiller arm



b) The scantling of the quadrants is to be determined as specified in a) for the tillers. When quadrants having two or three arms are provided, the section modulus of each arm is not to be less than one half or one third, respectively, of the section modulus required for the tiller.

Arms of loose quadrants not keyed to the rudder stock may be of reduced dimensions to the satisfaction of the Society, and the depth of the boss may be reduced by 10 per cent.

c) Keys are to satisfy the following provisions:

- the key is to be made of steel with a yield stress not less than that of the rudder stock and that of the tiller boss or rotor without being less than 235 N/mm^2
- the width of the key is not to be less than $0,25.d_s$
- the thickness of the key is not to be less than $0,10.d_s$
- the ends of the keyways in the rudder stock and in the tiller (or rotor) are to be rounded and the keyway root fillets are to be provided with small radii of not less than 5 per cent of the key thickness.

d) Bolted tillers and quadrants are to satisfy the following provisions:

- the diameter of the bolts is not to be less than the value d_b, in mm, calculated from the following formula:

$$d_b = 153 \sqrt{\frac{T_R}{n(b + 0,5 d_{se})} \cdot \frac{235}{R_{eb}}}$$

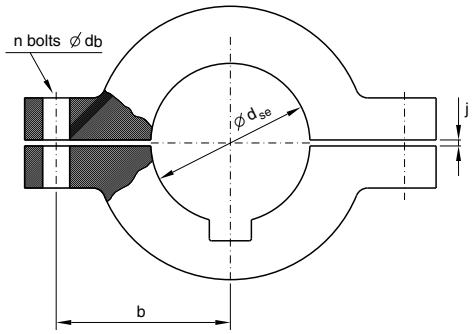
where:

n : Number of bolts located on the same side in respect of the stock axis (n is not to be less than 2)

b : Distance between bolts and stock axis, in mm (see Fig 2)

R_{eb} : Yield stress, in N/mm^2, of the bolt material

Figure 2 : Bolted tillers



- the thickness of each of the tightening flanges of the two parts of the tiller is not to be less than the following value:

$$1,85 \cdot d_b \cdot \sqrt{\frac{n \cdot (b - 0,5 \cdot D_e)}{H_0} \cdot \frac{R_{eb}}{R'_e}}$$

Where:

D_e : External boss diameter, in mm (average value)

- in order to ensure the efficient tightening of the coupling around the stock, the two parts of the tiller are to bored together with a shim having a thickness not less than the value j, in mm, calculated from the following formula:

$j = 0,0015 \cdot d_s$

e) Shrink-fit connections of tiller (or rotor) to stock are to satisfy the following provisions:

- the safety factor against slippage is not to be less than:
  - 1 for keyed connections
  - 2 for keyless connections
- the friction coefficient is to be taken equal to:
  - 0,15 for steel and 0,13 for spheroidal graphite cast iron, in the case of hydraulic fit
  - 0,17 in the case of dry shrink fitting
- the combined stress according to the von Mises criterion, due to the maximum pressure induced by the shrink fitting and calculated in way of the most stressed points of the shrunk parts, is not to exceed 80 per cent of the yield stress of the material considered

Note 1: Alternative stress values based on FEM calculations may also be considered by the Society.

- the entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

2.5.5 Piston rods

The scantling of the piston rod is to be determined taking into account the bending moments, if any, in addition to compressive or traction forces and is to satisfy the following provisions:

a) $\sigma_c \leq \sigma_a$

where:

σ_c : Combined stress as per [1.4.1]

σ_a : Permissible stress as per [2.5.3]

b) in respect of the buckling strength:

$$\frac{4}{\pi D_2^2} \cdot \left(\omega F_c + \frac{8M}{D_2}\right) \leq 0,9\sigma_a$$

with:

D_2 : Piston rod diameter, in mm

F_c : Compression force in the rod, in N, when it extends to its maximum stroke

M : Possible bending moment in the piston rod, in N.mm, in way of the fore end of the cylinder rod bearing

$$\omega = \beta + \sqrt{\beta^2 - \alpha}$$

$$\alpha = 0,0072\left(\frac{\ell_s}{D_2}\right)^2 \frac{R'_e}{235}$$

$$\beta = 0,48 + 0,5\alpha + 0,1\sqrt{\alpha}$$

ℓ_s : Length, in mm, of the maximum unsupported reach of the cylinder rod.

2.6 Hydraulic system

2.6.1 General

a) The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in [3], taking into account any pressure which may exist in the low pressure side of the system.

At the discretion of the Society, high cycle and cumulative fatigue analysis may be required for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

b) The power piping for hydraulic steering gear is to be arranged so that transfer between units can be readily effected.

c) Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

d) The hydraulic piping system, including joints, valves, flanges and other fittings, is to comply with the requirements of Ch 1, Sec 10 for class I piping systems, and in particular with the requirements of Ch 1, Sec 10, [14], unless otherwise stated.

2.6.2 Materials

a) Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings are to be of steel or other approved ductile material.

b) In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

Grey cast iron may be accepted for valve bodies and redundant parts with low stress level, excluding cylinders, subject to special consideration.

2.6.3 Isolating valves

Shut-off valves, non-return valves or other appropriate devices are to be provided:

- to comply with the availability requirements of [2.4]
- to keep the rudder steady in position in case of emergency.

In particular, for all ships with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

2.6.4 Flexible hoses

a) Flexible hoses may be installed between two points where flexibility is required but are not to be subjected to torsional deflexion (twisting) under normal operation. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery.

b) Hoses are to be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

c) They are to be of a type approved by the Society.

d) The burst pressure of hoses is to be not less than four times the design pressure.

2.6.5 Relief valves

a) Relief valves shall be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves shall not exceed the design pressure. The valves shall be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

b) The setting pressure of the relief valves is not to be less than 1,25 times the maximum working pressure.

c) The minimum discharge capacity of the relief valve(s) is not to be less than the total capacity of the pumps which can deliver through it (them), increased by 10%. Under such conditions, the rise in pressure is not to exceed 10% of the setting pressure. In this respect, due consideration is to be given to the foreseen extreme ambient conditions in relation to oil viscosity.

2.6.6 Hydraulic oil reservoirs

Hydraulic power-operated steering gear shall be provided with the following:

- *a low level alarm for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms shall be given on the navigation bridge and in the machinery space where they can be readily observed.*
- *a fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank shall be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and shall be provided with a contents gauge.*

Note 1: For cargo ships of less than 500 gross tonnage and for fishing vessels, the storage means may consist of a readily accessible drum, of sufficient capacity to refill one power actuating system if necessary.

2.6.7 Hydraulic pumps

a) Hydraulic pumps are to be type tested in accordance with the provisions of [6.1.1].

b) Special care is to be given to the alignment of the pump and the driving motor.

2.6.8 Filters

a) Hydraulic power-operated steering gear shall be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

b) Filters of appropriate mesh fineness are to be provided in the piping system, in particular to ensure the protection of the pumps.

2.6.9 Accumulators

Accumulators, if fitted, are to be designed in accordance with Ch 1, Sec 10, [14.5.3].

2.6.10 Rudder actuators

a) Rudder actuators, other than non-duplicated rudder actuators fitted to tankers, chemical carriers and gas carriers of 10000 gross tonnage and above, are to be designed in accordance with the relevant requirements of Ch 1, Sec 3 for class 1 pressure vessels also considering the following provisions.

b) The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{R}{A} \quad \text{or} \quad \frac{R_e}{B}$$

where A and B are given in Tab 4.

c) Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal or equivalent type.

d) Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

e) The strength and connection of the cylinder heads (or, in the case of actuators of the rotary type, the fixed vanes) acting as rudder stops are to comply with the provisions of [5.3.1].

Table 4 : Value of coefficients A and B

Coefficient	Steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

2.7 Electrical systems

2.7.1 General design

The electrical systems of the main steering gear and the auxiliary steering gear are to be so arranged that the failure of one will not render the other inoperative.

2.7.2 Power circuit supply

a) Electric or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard; however, one of the circuits may be supplied through the emergency switchboard.

b) Auxiliary electric or electrohydraulic steering gear, associated with main electric or electrohydraulic steering gear, may be connected to one of the circuits supplying the main steering gear.

c) The circuits supplying electric or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

d) When, in a ship of less than 1600 gross tonnage, auxiliary steering gear which is required by [2.2.2], item c) to be operated by power is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.

e) Where the rudder stock is required to be over 230 millimetres in diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment is to be provided, sufficient at least to supply the steering gear power unit such that the latter is able to perform the duties of auxiliary steering gear.

This power source is to be activated automatically, within 45 seconds, in the event of failure of the main source(s) of electrical power.

The independent source is to be used only for this purpose.

The alternative power source is also to supply the steering gear control system, the remote control of the power unit and the rudder angle indicator.

f) In every ship of 10 000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes.

2.7.3 Motors and associated control gear

a) To determine the required characteristics of the electric motors for power units, the breakaway torque and maximum working torque of the steering gear under all operating conditions are to be considered. The ratio of pull-out torque to rated torque is to be at least 1,6.

b) Motors for steering gear power units may be rated for intermittent power demand.

The rating is to be determined on the basis of the steering gear characteristics of the ship in question; the rating is always to be at least:

- S3 - 40% for motors of electric steering gear power units
- S6 - 25% for motors of electrohydraulic steering gear power units and for convertors.

c) Each electric motor of a main or auxiliary steering gear power unit is to be provided with its own separate motor starter gear, located within the steering gear compartment.

2.7.4 Supply of motor control circuits and steering gear control systems

a) Each control for starting and stopping of motors for power units is to be served by its own control circuits supplied from its respective power circuits.

b) Any electrical main and auxiliary steering gear control system operable from the navigation bridge is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit. The power supply systems are to be protected selectively.

c) The remote control of the power unit and the steering gear control systems is to be supplied also by the alternative power source when required by [2.7.2], item e).

2.7.5 Circuit protection

a) Short-circuit protection is to be provided for each control circuit and each power circuit of electric or electrohydraulic main and auxiliary steering gear.

b) No protection other than short-circuit protection is to be provided for steering gear control system supply circuits.

c) Protection against excess current (e.g. by thermal relays), including starting current, if provided for power circuits, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents.

d) Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current, including starting current, of not less than twice the full load current of the motor. The required overload alarm is to be set to a value not greater than the normal load of the electronic converter.

Note 1: "Normal load" is the load in normal mode of operation that approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer's operating instructions.

e) Where fuses are fitted, their current ratings are to be two step higher than the rated current of the motors. However, in the case of intermittent service motors, the fuse rating is not to exceed 160% of the rated motor current.

f) The instantaneous short-circuit trip of circuit breakers is to be set to a value not greater than 15 times the rated current of the drive motor.

g) The protection of control circuits is to correspond to at least twice the maximum rated current of the circuit, though not, if possible, below 6 A.

2.7.6 Starting and stopping of motors for steering gear power units

a) Motors for power units are to be capable of being started and stopped from a position on the navigation bridge and from a point within the steering gear compartment.

b) Means are to be provided at the position of motor starters for isolating any remote control starting and stopping devices (e.g. by removal of the fuse-links or switching off the automatic circuit breakers).

c) Main and auxiliary steering gear power units are to be arranged to restart automatically when power is restored after a power failure.

2.7.7 Installation

a) Duplicated electric power circuits are to be separated as far as practicable.

b) Cables for duplicated electric power circuits with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

c) Actuators controlling the power systems of the steering gear, e.g. magnetic valves, are to be duplicated and separated.

2.8 Alarms and indications

2.8.1 Power units

a) In the event of a power failure to any one of the steering gear power units, an audible and visual alarm shall be given on the navigation bridge.

b) Means for indicating that the motors of electric and electrohydraulic steering gear are running shall be installed on the navigation bridge and at a suitable main machinery control position.

c) Where a three-phase supply is used, an alarm shall be provided that will indicate failure of any one of the supply phases.

d) An overload alarm shall be provided for each motor of electric or electrohydraulic steering gear power units.

e) The alarms required in c) and d) *shall be both audible and visual and situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled.*

2.8.2 Hydraulic system

a) Hydraulic oil reservoirs are to be provided with the alarms required in [2.6.6].

b) Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided on the navigation bridge.

Note 1: This alarm is to be activated when, for example:

- the position of the variable displacement pump control system does not correspond with the given order, or
- an incorrect position in the 3-way valve, or similar, in the constant delivery pump system is detected.

2.8.3 Control system

In the event of a failure of electrical power supply to the steering gear control systems, an audible an visual alarm shall be given on the navigation bridge.

2.8.4 Rudder angle indication

The angular position of the rudder is to be:

a) indicated on the navigation bridge, if the main steering gear is power operated. The rudder angle indication is to be independent of the steering gear control system and be supplied through the emergency switchboard, or by an alternative and independent source of electrical power such as that referred to in [2.7.2], item e);

b) recognisable in the steering gear compartment.

2.8.5 Steering gear failure

The steering gear failures likely to cause uncontrolled movements of rudder are to be clearly identified. In the event of detection of such failure, the rudder is to stop in the current position without manual intervention or, subject to the discretion of the Society, is to return to the midship/neutral position. For mechanical failures such as sticking valves and failure of static components (pipes, cylinders), the system response without manual intervention is not mandatory, and the operator can follow instructions on the signboard in case of such failures, in accordance with [5.5.1].

Additionally for hydraulic locking failure, refer also to [2.8.2] item b).

2.8.6 Summary table

Displays and alarms are to be provided in the locations indicated in Tab 5.

Table 5 : Location of displays and alarms

Item		Display	Alarms (audible and visible)	Location		
				Navigation Bridge	Engine Control Room **(3)**	Steering gear compartment
Indication that electric motor of each power unit is running		X		X	X	
Rudder angle indicator		X		X		X
Power failure of each power unit			X	X	X	
Power failure of each control system			X	X	X	
Overload of electric motor of each power unit			X	X	X	
Phase failure of electric motor of each power unit			X	X	X	
Earth fault on AC and DC circuits			X	X	X	
Control system failures	Loop failures in closed loop systems, both command and feed back loops **(1)**		X	X	X	
	Data communication errors		X	X	X	
	Programmable system failures (Hardware and software failures)		X	X	X	
	Deviation between rudder order and feedback **(2)**		X	X	X	
Low level of each hydraulic fluid reservoir			X	X	X	
Hydraulic lock			X	X		

(1) Normally short circuit, broken connections and earth faults

(2) Deviation alarm is to be initiated if the rudder's actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures.

(3) Common alarm may be accepted if individual alarms are available locally.

3 Design and construction - Requirements for ships equipped with several rudders

3.1 Principle

3.1.1 General

In addition to the provisions of Article [2], ships equipped with two or more aft rudders are to comply with the provisions of the present Article.

3.1.2 Availability

Where the ship is fitted with two or more rudders, each having its own actuation system, the latter need not be duplicated.

3.1.3 Equivalent rudder stock diameter

Where the rudders are served by a common actuating system, the diameter of the rudder stock referred to in [2.2.1], item c), is to be replaced by the equivalent diameter d obtained from the following formula:

$$d = \sqrt[3]{\sum_i d_j^3}$$

with:

d_j : Rule diameter of the upper part of the rudder stock of each rudder in way of the tiller, excluding strengthening for navigation in ice.

3.2 Synchronisation

3.2.1 General

A system for synchronising the movement of the rudders is to be fitted, either:

- by a mechanical coupling, or
- by other systems giving automatic synchronising adjustment.

3.2.2 Non-mechanical synchronisation

Where the synchronisation of the rudder motion is not achieved by a mechanical coupling, the following provisions are to be met:

a) the angular position of each rudder is to be indicated on the navigation bridge

b) the rudder angle indicators are to be independent from each other and, in particular, from the synchronising system

c) in case of failure of the synchronising system, means are to be provided for disconnecting this system so that steering capability can be maintained or rapidly regained. See also Pt D, Ch 7, Sec 4, [7.2.2].

4 Design and construction - Requirements for ships equipped with thrusters as steering means

4.1 Principle

4.1.1 General

The main and auxiliary steering gear referred to in Article [3] may consist of thrusters of the following types:

- azimuth thrusters
- water-jets
- cycloidal propellers

complying with the provisions of Ch 1, Sec 15, as far as applicable.

4.1.2 Control system

Where the steering means of the ship consists of two or more thrusters, their control system is to include a device ensuring an automatic synchronisation of the thruster rotation, unless each thruster is so designed as to withstand any additional forces resulting from the thrust exerted by the other thrusters.

4.2 Steering arrangements

4.2.1 General

The requirements in this sub-article apply to ships fitted with alternative propulsion and steering arrangements, such as but not limited to, azimuthing propulsors or water jet propulsion systems.

4.2.2 Steering arrangements for ships fitted with multiple steering-propulsion units

For a ship fitted with multiple steering-propulsion units, such as, but not limited to, azimuthing propulsors or water jet propulsion systems, each of the steering-propulsion units is to be provided with a main steering gear and an auxiliary steering gear or with two or more identical steering actuating systems in compliance with [4.2.7]. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

4.2.3 Steering arrangements for ships fitted with single steering-propulsion unit

For a ship fitted with a single steering-propulsion unit, the steering gear is to be provided with two or more steering actuating systems complying with [4.2.7]. A detailed risk assessment is to be submitted in order to demonstrate that in the case of any single failure in the steering gear, control system and power supply, the ship steering is maintained.

4.2.4 Design of components used in steering arrangements

All components used in steering arrangements for ship directional control are to be of sound reliable construction to the satisfaction of the Administration or recognized organizations acting on its behalf. Special consideration should be given to the suitability of any essential component which is not duplicated. Any such essential component is, where appropriate, to utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which should be permanently lubricated or provided with lubrication fittings.

4.2.5 Main steering arrangements

The main steering arrangements for ship directional control are to be:

- of adequate strength and capable of steering the ship at maximum ahead service speed which should be demonstrated
- capable of changing direction of the steering-propulsion unit from one side to the other at declared steering angle limits at an average turning speed of not less than 2,3°/s with the ship running ahead at maximum ahead service speed
- for all ships, operated by power; and
- so designed that they will not be damaged at maximum astern speed; this design requirement need not be proved by trials at maximum astern speed and declared steering angle limits.

Note 1: Declared steering angle limits are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers' guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the “declared steering angle limits” are to be declared by the directional control system manufacturer for each ship specific non-traditional steering mean.

Note 2: Ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (IMO Resolution MSC.137(76)) should be carried out with steering angles not exceeding the declared steering angle limits.

4.2.6 Auxiliary steering arrangements

The auxiliary steering arrangements for ship directional control are to be:

- of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency
- capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average turning speed, of not less than 0.5°/s; with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
- for all ships, operated by power where necessary to meet the requirements of SOLAS regulation II-1/29.4.2 and in any ship having power of more than 2,500 kW propulsion power per steering-propulsion unit.

Note 1: The definition of “declared steering angle limits”, set out in [4.2.5], applies.

Note 2: Ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (IMO Resolution MSC.137(76)) should be carried out with steering angles not exceeding the declared steering angle limits.

4.2.7 Omission of the auxiliary steering gear

a) For a ship fitted with a single steering-propulsion unit where the main steering gear comprises two or more identical power units and two or more identical steering actuators, an auxiliary steering gear need not be fitted provided that the steering gear:
   - in a passenger ship, is capable of satisfying the requirements in [4.2.5] while any one of the power units is out of operation
   - in a cargo ship, is capable of satisfying the requirements in [4.2.5]while operating with all power units; and
   - is arranged so that after a single failure in its piping system or in one of the power units, steering capability can be maintained or speedily regained.

b) For a ship fitted with multiple steering-propulsion units, where each main steering system comprises two or more identical steering actuating systems, an auxiliary steering gear need not be fitted provided that each steering gear:
   - in a passenger ship, is capable of satisfying the requirements in [4.2.5] while any one of the steering gear steering actuating systems is out of operation
   - in a cargo ship, is capable of satisfying the requirements in [4.2.5] while operating with all steering gear steering actuating systems
   - is arranged so that after a single failure in its piping or in one of the steering actuating systems, steering capability can be maintained or speedily regained; and
   - the above capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units.

Note 1: For the purposes of alternative steering arrangements, the steering gear power unit should be considered as defined in [1.3.4]. For electric steering gears, refer to [1.3.4]; electric steering motors should be considered as part of the power unit and actuator.

4.2.8 Case of the steering-propulsion units having a residual steering capability when propulsion power is lost

This requirement applies to steering-propulsion units having a certain proven steering capability due to ship speed also in case propulsion power has failed.

Where the propulsion power exceeds 2,500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of [2.2.2], item b), and also its associated control system and the steering gear response indicator, is to be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power is to be used only for this purpose. In every ship of 10,000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

4.2.9 Additional requirement for ships fitted with multiple electric or electrohydraulic steering systems

For a ship fitted with multiple electric or electrohydraulic steering systems, the requirements of [2.7.2], items a), b) and c), are to be applied to each of the steering systems.

4.3 Use of water-jets

4.3.1 The use of water-jets as steering means will be given special consideration by the Society.

5 Arrangement and installation

5.1 Steering gear room arrangement

5.1.1 *The steering gear compartment shall be:*

a) readily accessible and, as far as practicable, separated from machinery spaces, and

b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

5.2 Rudder actuator installation

5.2.1

a) Rudder actuators are to be installed on foundations of strong construction so designed as to allow the transmission to the ship structure of the forces resulting from the torque applied by the rudder and/or by the actuator, considering the strength criteria defined in [2.5.3] and [5.3.1]. The structure of the ship in way of the foundations is to be suitably strengthened.

b) Where the rudder actuators are bolted to the hull, the grade of the bolts used is not to be less than 8.8. Unless the bolts are adjusted and fitted with a controlled tightening, strong shocks are to be fitted in order to prevent any lateral displacement of the rudder actuator.

5.3 Overload protections

5.3.1 Mechanical rudder stops

a) The steering gear is to be provided with strong rudder stops capable of mechanically stopping the rotation of the rudder at an angle slightly greater than its maximum working angle. Alternatively, these stops may be fitted on the ship to act on another point of the mechanical transmission system between the rudder actuator and the rudder blade. These stops may be built in with the actuator design.

b) The scantlings of the rudder stops and of the components transmitting to the ship's structure the forces applied on these stops are to be determined for the greater value of the torques T_R or T_G.

   Where $T_G \geq 1,5T_R$, the rudder stops are to be fitted between the rudder actuator and the rudder stock, unless the rudder stock as well as all the components transmitting mechanical forces between the rudder actuator and the rudder blade are suitably strengthened.

5.3.2 Rudder angle limiters

a) Power-operated steering gear is to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control.

b) For power-operated steering gears and where the rudder may be oriented to more than 35° at very reduced speed, it is recommended to fit a limit system 35° for full speed. A notice is to be displayed at all steering wheel stations indicating that rudder angles of more than 35° are to be used only at very reduced speed.

5.3.3 Relief valves

Relief valves are to be fitted in accordance with [2.6.5].

5.3.4 Buffers

Buffers are to be provided on all ships fitted with mechanical steering gear. They may be omitted on hydraulic gear equipped with relief valves or with calibrated bypasses.

5.4 Means of communication

5.4.1 *A means of communication is to be provided between the navigation bridge and the steering gear compartment.*

If electrical, it is to be fed through the emergency switchboard or to be sound powered.

5.5 Operating instructions

5.5.1 For steering gear comprising two identical power units intended for simultaneous operation, both normally provided with their own (partly or mutually) separate control systems, the following standard notice is either to be placed on a signboard fitted at a suitable place on the steering control post on the bridge or incorporated into the operation manual:

CAUTION

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY, THE RUDDER MAY NOT RESPOND TO THE HELM. IF THIS HAPPENS STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

6 Certification, inspection and testing

6.1 Type tests of hydraulic pumps

6.1.1 Each type of power unit pump is to be subjected in the workshop to a type test of not less than 100 hours' duration.

The test arrangements are to be such that the pump may run both:

- in idling conditions, and
- at maximum delivery capacity at maximum working pressure.

During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board.

During the test, no abnormal heating, excessive vibration or other irregularities are permitted.

After the test, the pump is to be disassembled and inspected.

Note 1: Type tests may be waived for a power unit which has been proven to be reliable in marine service.

6.2 Testing of materials

6.2.1 Components subject to pressure or transmitting mechanical forces

a) Materials of components subject to pressure or transmitting mechanical forces, specifically:
   - cylindrical shells of hydraulic cylinders, rams and piston rods
   - tillers, quadrants
   - rotors and rotor housings for rotary vane steering gear
   - hydraulic pump casings
   - and hydraulic accumulators, if any,

   are to be duly tested, including examination for internal defects, in accordance with the requirements of NR216 Materials and Welding.

b) A works' certificate may be accepted for low stressed parts, provided that all characteristics for which verification is required are guaranteed by such certificate.

6.2.2 Hydraulic piping, valves and accessories

Tests for materials of hydraulic piping, valves and accessories are to comply with the provisions of Ch 1, Sec 10, [20.4].

6.3 Inspection and tests during manufacturing

6.3.1 Components subject to pressure or transmitting mechanical forces

a) The mechanical components referred to in [6.2.1] are to be subjected to appropriate non-destructive tests. For hydraulic cylinder shells, pump casings and accumulators, refer to Ch 1, Sec 3.

b) Defects may be repaired by welding only on forged parts or steel castings of weldable quality. Such repairs are to be conducted under the supervision of the Surveyor in accordance with the applicable requirements of NR216 Materials and Welding.

6.3.2 Hydraulic piping, valves and accessories

Hydraulic piping, valves and accessories are to be inspected and tested during manufacturing in accordance with Ch 1, Sec 10, [20], for a class I piping system.

6.4 Inspection and tests after completion

6.4.1 Hydrostatic tests

a) Hydraulic cylinder shells and accumulators are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 3.

b) Hydraulic piping, valves and accessories and hydraulic pumps are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 10, [20.5].

6.4.2 Shipboard tests

After installation on board the ship, the steering gear is to be subjected to the tests detailed in Ch 1, Sec 18, [3.13].

6.4.3 Sea trials

For the requirements of sea trials, refer to Ch 1, Sec 18.

Section 15 Thrusters

1 General

1.1 Application

1.1.1 Thrusters developing power equal to 110 kW or more

The requirements of this Section apply to the following types of thrusters developing power equal to 110 kW or more:

- transverse thrusters intended for manoeuvring
- thrusters intended for propulsion and steering.

For azimuth thrusters intended for dynamic positioning, the additional requirements in Pt F, Ch 11, Sec 5 are to be complied with.

Thrusters intended for propulsion and steering of ships with an **ICE CLASS** notation are to comply with the additional requirements of Part F, Chapter 8. Transverse thrusters intended for manoeuvring of ships with an **ICE CLASS** notation are required to comply with additional requirement Pt F, Ch 8, Sec 3, [3.5.1] only. Thrusters intended for propulsion and steering of ships with an additional class notation **POLAR CLASS** or a service notation **icebreaker** are to comply with the relevant requirements of NR527.

1.1.2 Thrusters developing power less than 110 kW

Thrusters of less than 110 kW are to be built in accordance with sound marine practice and tested as required in [3.2] to the satisfaction of the Surveyor.

1.2 Definitions

1.2.1 Thruster

A thruster is a propeller installed in a revolving nozzle or in a special transverse tunnel in the ship, or a water-jet. A thruster may be intended for propulsion, manoeuvring and steering or any combination thereof. Propulsion propellers in fixed nozzles are not considered thrusters (see Ch 1, Sec 8, [1.1.1]).

1.2.2 Transverse thruster

A transverse thruster is an athwartship thruster developing a thrust in a transverse direction for manoeuvring purposes.

1.2.3 Azimuth thruster

An azimuth thruster is a thruster which has the capability to rotate through 360° in order to develop thrust in any direction.

1.2.4 Water-jet

A water-jet is equipment constituted by a tubular casing (or duct) enclosing an impeller. The shape of the casing is such as to enable the impeller to produce a water-jet of such intensity as to give a positive thrust. Water-jets may have means for deviating the jet of water in order to provide a steering function.

1.3 Thrusters intended for propulsion

1.3.1 In general, at least two azimuth thrusters are to be fitted in ships where these are the sole means of propulsion. Single azimuth thruster installations will be specially considered by the Society on a case by case basis.

This requirement also applies to water-jets.

1.4 Documentation to be submitted

1.4.1 Plans to be submitted for athwartship thrusters and azimuth thrusters

For thrusters developing power equal to 110 kW or more, the plans listed in Tab 1 are to be submitted.

1.4.2 Plans to be submitted for water-jets

The plans listed in Tab 2 are to be submitted.

1.4.3 Additional data to be submitted

The data and documents listed in Tab 3 are to be submitted by the manufacturer together with the plans.

Table 1 : Plans to be submitted for athwartship thrusters and azimuth thrusters

No.	A/I **(1)**	ITEM
General requirements for all thrusters		
1	I	General arrangement of the thruster
2	A	Propeller, including the applicable details mentioned in Ch 1, Sec 8
3	A	Bearing details
4	A	Propeller and intermediate shafts
5	A	Gears, including the applicable details mentioned in Ch 1, Sec 6
Specific requirements for transverse thrusters		
6	A	Structure of the tunnel showing the materials and their thickness
7	A	Structural equipment or other connecting devices which transmit the thrust from the propeller to the tunnel
8	A	Sealing devices (propeller shaft gland and thruster-tunnel connection)
9	A	For the adjustable pitch propellers: pitch control device and corresponding monitoring system
Specific requirements for rotating and azimuth thrusters		
10	A	Structural items (nozzle, bracing, etc.)
11	A	Structural connection to hull
12	A	Rotating mechanism of the thruster
13	A	Thruster control system
14	A	Piping systems connected to thruster
(1) A = to be submitted for approval I = to be submitted for information		

Table 2 : Plans to be submitted for water-jets

No.	A/I **(1)**	ITEM
1	I	General arrangement of the water-jet
2	A	Casing (duct) (location and shape) showing the materials and the thicknesses as well as the forces acting on the hull
3	A	Details of the shafts, flanges, keys
4	I	Sealing gland
5	A	Bearings
6	A	Impeller
7	A	Steering and reversing buckets and their control devices as well as the corresponding hydraulic diagrams
(1) A = to be submitted for approval I = to be submitted for information		

Table 3 : Data and documents to be submitted for athwartship thrusters, azimuth thrusters and water-jets

No.	A/I **(1)**	ITEM
1	I	Rated power and revolutions
2	I	Rated thrust
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties
4	A	Where parts of thrusters are of welded construction, all particulars on the design of welded joints, welding procedures, heat treatments and non-destructive examinations after welding
5	I	Where applicable, background information on previous operating experience in similar applications
(1) A = to be submitted for approval I = to be submitted for information		

2 Design and Construction

2.1 Materials

2.1.1 Propellers

For requirements relative to material intended for propellers, see Ch 1, Sec 8, [2.1.1].

2.1.2 Other thruster components

For the requirements relative to materials intended for other parts of the thrusters, such as gears, shaft, couplings, etc., refer to the applicable parts of the Rules.

2.2 Transverse thrusters and azimuth thrusters

2.2.1 Prime movers

a) Diesel engines intended for driving thrusters are to comply with the applicable requirements of Ch 1, Sec 2.

b) Electric motors intended for driving thrusters and their feeding systems are to comply with the requirements of Ch 2, Sec 4. In particular:

- provisions are to be made to prevent starting of the motors whenever there are insufficient generators in operation
- intermittent duty thrusters will be the subject of special consideration by the Society.

2.2.2 Propellers

a) For propellers of thrusters intended for propulsion, the requirements of Ch 1, Sec 8, [2.5] apply.

b) For propellers of thrusters intended for manoeuvring only, the requirements of Ch 1, Sec 8, [2.5] also apply, although the increase in thickness of 10% does not need to be applied.

2.2.3 Shafts

a) For propeller shafts of thrusters intended for propulsion, the requirements of Ch 1, Sec 7, [2.2.3] apply.

b) For propellers of thrusters intended for manoeuvring only, the minimum diameter d_S of the shaft, in mm, is not to be less than the value obtained by the following formula:

$$d_S = [(C \cdot M_T)^2 + (D \cdot M)^2]^{1/6} \cdot \left(\frac{1}{1 - Q^4}\right)^{1/3}$$

where:

M_T : Maximum transmitted torque, in N·m; where not indicated, M_T may be assumed as 9550 (P/N)

where:

P : Maximum power of the thruster prime mover, in kW

N : Rotational speed of the propeller, in rev/min

M : Bending moment, in N·m, at the shaft section under consideration

C : Coefficient equal to:

$$C = 10{,}2 + \frac{28000}{R_{S,MIN}}$$

D : Coefficient equal to:

$$D = \frac{170000}{412 + R_{S,MIN}}$$

$R_{S,MIN}$: Minimum yield strength of the shaft material, in N/mm^2

Q : 0 for solid shafts

The ratio between the diameter of the hole and the external diameter of the shaft, in the case of hollow shafts. If $Q \leq 0{,}3$, Q may be assumed equal to 0.

The above diameter is to be increased by 10% in the case of keyed connection to the propeller in way of key.

2.2.4 Gears

a) Gears of thrusters intended for propulsion are to be in accordance with the applicable requirements of Ch 1, Sec 6, applying the safety factors for propulsion gears.

b) Gears of thrusters intended for manoeuvring only are to be in accordance with the applicable requirements of Ch 1, Sec 6, applying the safety factors for auxiliary gears.

2.2.5 Nozzles and connections to hull for azimuth thrusters

a) For the requirements relative to the nozzle structure, see Part B, Chapter 12.

b) The scantlings of the nozzle connection to the hull and the welding type and size will be specially considered by the Society, which reserves the right to require detailed stress analysis in the case of certain high power installations.

c) For steerable thrusters, the equivalent rudder stock diameter is to be calculated in accordance with the requirements of Part B, Chapter 12.

2.2.6 Transverse thruster tunnel

a) The thickness of the tunnel is not to be less than the adjacent part of the hull.

b) Special consideration will be given by the Society to tunnels connected to the hull by connecting devices other than welding.

2.3 Water-jets

2.3.1 Shafts

The diameter of the shaft supporting the impeller is not to be less than the diameter d_2, in mm, obtained by the following formula:

$$d_2 = 100 f h \cdot \left(\frac{P}{N}\right)^{1/3} \cdot \left(\frac{1}{1-Q^4}\right)^{1/3}$$

where:

P : Power, in kW

N: : Rotational speed, in rpm

f : Calculated as follows:

$$f = \left(\frac{560}{R_m + 160}\right)^{1/3}$$

where R_m is the ultimate tensile strength of the shaft material, in N/mm^2

h: :
- h = 1 when the shaft is only transmitting torque loads, and when the weight and thrust of the propeller are totally supported by devices located in the fixed part of the thruster
- h = 1,22 where the impeller is fitted with key or shrink-fitted.

Q : 0 for solid shafts

The ratio between the diameter of the hole and the external diameter of the shaft, in the case of hollow shafts. If $Q \leq 0,3$, Q may be assumed equal to 0.

The shafts are to be protected against corrosion by means of either a continuous liner or an oil-gland of an approved type, or by the nature of the material of the shaft.

2.3.2 Guide vanes, shaft support

a) Guide vanes and shaft supports, if any, are to be fitted in accordance with direction of flow. Trailing and leading edges are to be fitted with rounded profiles.

b) Fillet radius are generally not be less than the maximum local thickness of concerned element.Fatigue strength calculation is to be submitted.

2.3.3 Stator and impellers

a) Design is to take into account the loads developed in free going conditions and also in peculiar manoeuvres like crash stop.

b) Tip clearance is to take into account vibratory behaviours, displacements and any other expansion mode in all operating conditions of the water jet.

c) Fillet radii are generally not to be less than the maximum local thickness of concerned element.

d) There is to be no natural frequency of stator blades or rotor blades in the vicinity of the excitation frequencies due to hydrodynamic interaction between stator blades and rotor blades. Calculations are to be submitted for maximum speed and any currently used speed.

2.3.4 Nozzle and reversing devices

Design of nozzle and reversing devices are to take into account the loads developed in all operating conditions of the water jet, including transient loads.

2.3.5 Steering performance

Steering performance and emergency steering availability are to be at least equivalent to the requirements in Ch 1, Sec 14, [4.2] and Ch 1, Sec 14, [4.3].

2.4 Alarm, monitoring and control systems

2.4.1 Steering thruster controls

a) Controls for steering are to be provided from the navigation bridge, the machinery control station and locally.

b) Means are to be provided to stop any running thruster at each of the control stations.

c) A thruster angle indicator is to be provided at each steering control station. The angle indicator is to be independent of the control system.

2.4.2 Alarm and monitoring equipment

Tab 4 summarises the minimum alarm and monitoring requirements for propulsion and steering thrusters. See also Ch 1, Sec 14, [4].

Table 4 : Azimuth thrusters

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Thruster			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Steering oil pressure	L						
Oil tank level	L						

3 Testing and certification

3.1 Material tests

3.1.1 Propulsion and steering thrusters

All materials intended for parts transmitting torque and for propeller/impeller blades are to be tested in accordance with the requirements of Ch 1, Sec 8, [4.1] in the presence of a Surveyor.

3.1.2 Transverse thrusters

Material testing for parts of athwartship thrusters does not need to be witnessed by a Surveyor, provided full test reports are made available to him.

3.2 Testing and inspection

3.2.1 Thrusters

Thrusters are to be inspected as per the applicable requirements in Ch 1, Sec 8, [4.2].

3.2.2 Prime movers

Prime movers are to be tested in accordance with the requirements applicable to the type of mover used.

3.3 Certification

3.3.1 Certification of thrusters

Thrusters are to be individually tested and certified by the Society.

3.3.2 Mass produced thrusters

Mass produced thrusters of a type as mentioned in [1.1] may be accepted within the framework of the type approval program of the Society.

Section 16 Refrigerating Installations

1 General

1.1 Application

1.1.1 Refrigerating installations on all ships

The minimum safety requirements addressed in this Section are to be complied with for any refrigerating plant installed on board a ship to be classed by the Society. These requirements do not cover any operation or availability aspect of the plants, which are not the subject of class requirements, unless an additional notation is requested.

1.1.2 Additional notations

Where one or more of the following additional notations:

- **REF-CARGO**
- **REF-CONT**
- **REF-STORE**

is requested, the requirements of Part F, Chapter 7 are to be complied with, as applicable.

2 Minimum design requirements

2.1 Refrigerating installation components

2.1.1 General

In general, the specific requirements stated in Part C of the Rules for various machinery and equipment are also applicable to refrigerating installation components.

2.1.2 Pressure vessels and heat exchangers

a) Pressure vessels of refrigerating plants are to comply with the relevant requirements of Ch 1, Sec 3.

b) Vessels intended to contain ammonia or toxic substances are to be considered as class 1 pressure vessels as indicated in Ch 1, Sec 3, [1.4].

c) The materials used for pressure vessels are to be appropriate to the fluid that they contain. Where ammonia is the refrigerant, copper, bronze, brass and other copper alloys are not to be used.

d) Notch toughness of steels used in low temperature plants is to be suitable for the thickness and the lowest design temperature. A check of the notch toughness properties may be required where the working temperature is below minus 40°C.

2.1.3 Piping systems

a) Refrigerant pipes are generally to be regarded as pressure pipes.

b) Refrigerant, brine and sea water pipes are to satisfy the requirements of Ch 1, Sec 10 as applicable.

c) Refrigerant pipes are to be considered as belonging to the following classes:
   - class I: where they are intended for ammonia or toxic substances or with a design pressure > 4 MPa
   - class II: for other refrigerants
   - class III: for brine.

d) In general, the pipes conveying the cooling medium are not to come into direct contact with the ship's structure; they are to be carefully insulated on their run outside the refrigerated spaces, and more particularly when passing through bulkheads and decks.

e) The materials used for the pipes are to be appropriate to the fluids that they convey. Copper, brass, bronze and other copper alloys are not to be used for pipes likely to convey ammonia. Methods proposed for joining such pipes are to be submitted to the Society for consideration.

f) Notch toughness of the steels used is to be suitable for the application concerned.

g) Where necessary, cooling medium pipes within refrigerated spaces or embedded in insulation are to be externally protected against corrosion; for steel pipes, this protection is to be ensured by galvanisation or equivalent. All useful precautions are to be taken to protect the joints of such pipes against corrosion.

h) The use of plastic pipes will be considered by the Society on a case by case basis.

2.2 Refrigerants

2.2.1 Prohibited refrigerants

The use of the following refrigerants is not allowed for shipboard installations:

- Chlorofluorocarbons (CFC)
- Hydrochlorofluorocarbons (HCFC)
- Perfluorocarbons (PFC)
- Chloromethane (R-40)
- Ethane (R-170)
- Ethylene (R-1150)
- Other substances with lower explosion limit in air of less than 3,5%.

2.2.2 Allowed refrigerants

The refrigerants listed in this requirement are allowed (non exhaustive list):

- R-32/1234yf/744 Mixture (R-455)
- 1,3,3,3-Tetrafluoropropene (R-1234ze)
- 2,3,3,3-Tetrafluoropropene (R-1234yf)
- Ammonia (R-717) following requirements of [2.3]
- CO2 (R-744).

2.2.3 Statutory requirements

Particular attention is to be paid to any limitation on the use of refrigerants imposed by the Administration of the State whose flag the ship is flying.

2.2.4 Toxic or flammable refrigerants

The arrangement of refrigerating machinery spaces of plants using toxic or flammable refrigerants will be the subject of special consideration by the Society.

For specific requirements on spaces intended for plants using ammonia as a refrigerant, see [2.3].

2.3 Special requirements for ammonia (R717)

2.3.1 Refrigerating machinery compartment

a) Ammonia refrigerating machinery is to be installed in dedicated gastight spaces, complying with items b) to e).

Ammonia plants with a quantity of ammonia not greater than 25 kg are however allowed to be located in the engine room, provided that the requirements of [2.3.2] are fulfilled.

Note 1: For fishing vessels, refer to Pt D, Ch 15, Sec 4, [21.3].

b) At least two access doors are to be provided. One of these doors is to lead directly to the open deck. The doors are to open outwards and are to be self-closing.

c) Dedicated spaces containing ammonia machinery (including process vessels) are to be fitted with:

1) A negative ventilation system independent of ventilation systems serving other ship spaces and having a capacity not less than 30 air changes per hour based upon the total volume of the space. Other suitable arrangements which ensure an equivalent effectiveness may be considered. Provision is to be made for starting and stopping the ventilation fans from outside the space.

Where the access to the ammonia machinery space is from an accommodation or machinery space, the ventilation of the ammonia machinery space may not be designed to keep it under negative pressure with respect to the adjacent space, provided that the access is through an airlock.

2) A fixed ammonia detector system with audible and visual alarms inside and outside the space. This system is also to stop the compressor when a dangerous gas concentration is reached.

3) Water screens above all access doors, operable manually from outside the space. Water for the water screens may be supplied from the fire pumps.

4) an independent bilge system.

d) At least two sets of breathing apparatus and protective clothing are to be available outside and in the vicinity of the ammonia machinery space.

e) Ammonia piping is not to pass through accommodation spaces.

2.3.2 Ammonia plant located in the engine room

When installation of an ammonia plant is allowed in the engine room in accordance with the provision of [2.3.1] item a), the area where the ammonia machinery is installed is to be served by a hood with a negative pressure ventilation system, having a capacity of not less than 30 air changes per hour, independent from any other ship ventilation system, so as to prevent any leakage of ammonia from dissipating into other areas in the engine room.

A water-spray system is to be provided for the said area, covering the whole ammonia machinery and operable locally and from the outside of the engine room.

The provisions of items c) 2), d) and e) of requirement [2.3.1] are also to be complied with.

Section 17 Turbochargers

1 General

1.1 Application

1.1.1 These requirements are applicable for turbochargers with regard to design approval, type testing and certification and their matching on engines.

Turbochargers are to be type approved, either separately or as a part of an engine. The requirements are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

1.1.2 The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger (e.g. for a V-engine with one turbocharger for each bank the size is half of the total engine power).

1.1.3 Turbochargers are categorised in three groups depending on served power by cylinder groups with:

- Category A: ≤ 1000 kW
- Category B: > 1000 kW and ≤ 2500 kW
- Category C: > 2500 kW.

1.2 Documentation to be submitted

1.2.1 The documentation to be submitted is listed in:

- Tab 1 for category A turbochargers
- Tab 2 for category B and C turbochargers
- Tab 2 and Tab 3 for category C turbochargers.

Table 1 : Documentation to be submitted on request for Category A turbochargers

No.	I/A **(1)**	Document
1	A	Containment test report
2	A	Cross sectional drawing with principal dimensions and names of components
3	A	Test program
(1) A = to be submitted for approval; I = to be submitted for information		

Table 2 : Documentation to be submitted for Category B turbochargers

No.	I/A **(1)**	Document
1	I	Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation
2	A	Documentation of containment in the event of disc fracture, see [2.2]
3	I	Operational data and limitation as: **(2)** • Maximum permissible operating speed (rpm) • Alarm level for over-speed • Maximum permissible exhaust gas temperature before turbine • Alarm level for exhaust gas temperature before turbine • Minimum lubrication oil inlet pressure • Lubrication oil inlet pressure low alarm set point • Maximum lubrication oil outlet temperature • Lubrication oil outlet temperature high alarm set point • Maximum permissible vibration levels, i.e. self- and externally generated vibration
4	A	Arrangement of lubrication system, all variants within a range.
5	I	Type test reports.
6	A	Test program.
(1) A = to be submitted for approval; I = to be submitted for information **(2)** Alarm levels may be equal to permissible limits but shall not be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110%.		

Table 3 : Additional documentation to be submitted for Category C turbochargers

No	I/A **(1)**	Document
1	A	Drawings of the housing and rotating parts including details of blade fixing
2	I	Material specifications (chemical composition and mechanical properties) of all parts mentioned above
3	A	Welding details and welding procedure of above mentioned parts, if applicable
4	A	Documentation **(2)** of safe torque transmission when the disc is connected to the shaft by an interference fit, see [2.3]
5	I	Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue
6	I	Operation and maintenance manuals **(2)**
(1) A = to be submitted for approval; I = to be submitted for information **(2)** Applicable to two sizes in a generic range of turbochargers.		

2 Design and construction

2.1 General

2.1.1 The turbochargers are to be designed to operate under conditions given in Ch 1, Sec 1, Tab 1 and Ch 1, Sec 2, [1.3.3]. The component lifetime and the alarm level for speed are to be based on 45°C air inlet temperature.

2.1.2 The air inlet of turbochargers is to be fitted with a filter.

2.2 Containment

2.2.1 Turbochargers are to ensure containment in the event of a rotor burst. This means that, in case of a rotor burst, no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it is to be assumed that the discs disintegrate in the worst possible way.

2.2.2 For category B and C turbochargers, containment is to be documented by testing. A generic range of turbochargers may be deemed to ensure containment based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it is to be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

Note 1: A generic range means a series of turbochargers which are of the same design, but scaled to each other.

2.2.3 The minimum test speeds, relative to the maximum permissible operating speed, are:

- For the compressor: 120%.
- For the turbine: 140% or the natural burst speed, whichever is lower.

2.2.4 Containment tests shall be performed at a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

2.2.5 Manufacturers are to determine whether cases more critical than those defined in [2.2.3] and [2.2.4] exist with respect to containment safety. Where such a case is identified, evidence of containment safety is also to be provided for that case.

2.2.6 A numerical analysis simulation such as Finite Element Method (FEM) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:

- The numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test shall be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.
- The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.
- Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated.
- The design of the turbocharger regarding geometry and kinematics is to be similar to the turbocharger that was used for the reference containment test.

2.2.7 In cases where a totally new design is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.

Note 1: Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design:

- Maximum permissible exhaust gas temperature
- Number of bearings
- Number of turbine blades
- Number of turbine wheels and/or compressor wheels
- Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation)
- Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type).

2.3 Disc-shaft shrinkage fit

2.3.1 Where the disc of category C turbochargers is connected to the shaft with interference fit, calculations are to be performed to substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

2.4 Alarms and monitoring

2.4.1 For all turbochargers of Categories B and C, indications and alarms as listed in Tab 4 are required.

2.4.2 In addition to [2.4.1], the general requirements given in Part C, Chapter 3 apply.

Table 4 : Alarms and monitoring

No	Monitored Parameters	Category of turbochargers				Notes
		B		C		
		Alarm	Indication	Alarm	Indication	
1	Speed	High **(1)**	X **(1)**	High **(1)**	X **(1)**	
2	Exhaust gas at each turbocharger inlet, temperature	High **(2)**	X **(2)**	High	X	High temp. alarms for each cylinder at engine is acceptable **(3)**
3	Lub. oil at turbocharger outlet, temperature			High	X	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger inlet, pressure	Low	X	Low	X	Only for forced lubrication systems **(4)**

(1) On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.

(2) For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.

(3) Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.

(4) Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil system.

3 Certification, inspection and testing

3.1 Type tests

3.1.1 Category B or C turbochargers are to be type tested according to the present sub-article.

3.1.2 The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.

3.1.3 Turbochargers for the low, medium, and high-speed engines are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, see Ch 1, Sec 2, [4.1.4].

3.1.4 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.

3.1.5 The rotor vibration characteristics are to be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.

3.1.6 The type test is to be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbocharger is to be opened for examination, with focus on possible rubbing and the bearing conditions.

3.2 Workshop inspections and testing

3.2.1 Category B and C turbochargers inspections and testings as well as their associated certificates are to be done in accordance with Tab 5.

3.3 Certification

3.3.1 The manufacturer is to adhere to a certification scheme according to NR320 to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings.

- For category C turbochargers, certification scheme for IBV product is to be selected. Each turbocharger is to be delivered with a Class certificate.
- For category B turbochargers, certification scheme for HBV product is to be selected. Each turbocharger is to be delivered with a works' certificate.
- For category A turbochargers, certification scheme for HBV product is to be selected. Each turbocharger is to be delivered with a works' certificate.

Table 5 : Inspections and testings

No	Inspections and testings	Type of certificate **(1)**	
		category B	category C
1	Chemical composition of material for the rotating parts.	W	W
2	Mechanical properties of the material of a representative specimen for the rotating parts and the casing	W	W
3	UT and crack detection of rotating parts	W	W
4	Dimensional inspection of rotating parts	W	W
5	Rotor balancing	W	C
6	Hydraulic testing of cooling spaces to 4 bars or 1.5 times maximum working pressure, whichever is higher	W	C
7	Overspeed test of all compressor wheels for a duration of 3 minutes at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method	W	C
(1) C indicates that a Society certificate is required; W indicates that a manufacturer's document is required			

Section 18 Tests on Board

1 General

1.1 Application

1.1.1 This Section covers shipboard tests, both at the moorings and during sea trials. Such tests are additional to the workshop tests required in the other Sections of this Chapter.

For computerized machinery systems, requirements contained in Part C, Chapter 3 shall be referred to.

1.2 Purpose of shipboard tests

1.2.1 Shipboard tests are intended to demonstrate that the main and auxiliary machinery and associated systems are functioning properly, in respect of the criteria imposed by the Rules. The tests are to be witnessed by a Surveyor.

1.3 Documentation to be submitted

1.3.1 A comprehensive list of the shipboard tests intended to be carried out by the shipyard is to be submitted to the Society.

For each test, the following information is to be provided:

- scope of the test
- parameters to be recorded.

2 General requirements for shipboard tests

2.1 Trials at the moorings

2.1.1 Trials at the moorings are to demonstrate the following:

a) satisfactory operation of the machinery

b) quick and easy response to operational commands

c) protection of the various installations, as regards:
   - the protection of mechanical parts
   - the safeguards for personnel

d) accessibility for cleaning, inspection and maintenance.

Where the above features are not deemed satisfactory and require repairs or alterations, the Society reserves the right to require the repetition of the trials at the moorings, either wholly or in part, after such repairs or alterations have been carried out.

2.2 Sea trials

2.2.1 Scope of the tests

Sea trials are to be conducted after the trials at the moorings and are to include the following:

a) demonstration of the proper operation of the main and auxiliary machinery, including monitoring, alarm and safety systems, under realistic service conditions

b) check of the propulsion capability when one of the essential auxiliaries becomes inoperative

c) detection of dangerous vibrations by taking the necessary readings when required.

3 Shipboard tests for machinery

3.1 Conditions of sea trials

3.1.1 Displacement of the ship

Except in cases of practical impossibility, or in other cases to be considered individually, the sea trials are to be carried out at a displacement as close as possible to the deadweight (full load) or to one half of the deadweight (half load).

3.1.2 Power of the machinery

a) The power developed by the propulsion machinery in the course of the sea trials is to be as close as possible to the power for which classification has been requested. In general, this power is not to exceed the maximum continuous power at which the weakest component of the propulsion system can be operated. In cases of diesel engines and gas turbines, it is not to exceed the maximum continuous power for which the engine type concerned has been approved.

b) Where the rotational speed of the shafting is different from the design value, thereby increasing the stresses in excess of the maximum allowable limits, the power developed in the trials is to be suitably modified so as to confine the stresses within the design limits.

3.1.3 Determination of the power and rotational speed

a) The rotational speed of the shafting is to be recorded in the course of the sea trials, preferably by means of a continuous counter.

b) In general, the power is to be determined by means of torsiometric readings, to be effected with procedures and instruments deemed suitable by the Society.

As an alternative, for reciprocating internal combustion engines and gas turbines, the power may be determined by measuring the fuel consumption and on the basis of the other operating characteristics, in comparison with the results of bench tests of the prototype engine.

Other methods of determining the power may be considered by the Society on a case by case basis.

3.2 Starting from dead ship conditions

3.2.1 The capability of the machinery installations to be brought into operation from a dead ship condition without external aid is to be demonstrated.

3.2.2 The capability of the propulsion to be restored from dead ship conditions within 30 minutes is to be demonstrated.

3.3 Navigation and manoeuvring tests

3.3.1 Speed trials

a) Where required by the Rules (see Pt A, Ch 1, Sec 2, [4.16.2]), the speed of the ship is to be determined using procedures deemed suitable by the Society.

b) The ship speed is to be determined as the average of the speeds taken in not less than two pairs of runs in opposite directions.

3.3.2 Astern trials

a) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the ship to rest within reasonable distance from maximum ahead service speed, shall be demonstrated and recorded.

b) The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propellers to navigate and manoeuvre with one or more propellers inoperative, shall be available on board for the use of the Master or designated personnel.

c) Where the ship is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means shall be demonstrated and recorded as referred to in paragraphs a) and b).

d) For electric propulsion systems, see [3.9].

e) Main propulsion systems are to undergo tests to demonstrate the astern response characteristics.The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these shall be included in the test plan.

f) The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials.

3.4 Tests of boilers

3.4.1 General

The satisfactory operation of the main and auxiliary boilers supplying essential services is to be ascertained in all operating conditions during the trials at the moorings and the sea trials.

3.4.2 Tests to be performed

After installation on board, the following tests are to be carried out in the presence of the Surveyor:

a) Test in the hot condition of boilers and superheaters

b) Accumulation tests and setting of safety valves of boilers and superheaters

- Safety valves are to be set to lift at a pressure not exceeding 103% of the design pressure
- For boilers fitted with superheaters, the safety valves of the latter are to be set to lift before or, at the latest, at the same time as the valves of the saturated steam chest

c) Verification that, at the maximum steaming rate, the boiler pressure does not exceed 110% of the design pressure when the stop valves of the boiler, except those which must remain open for the burning operation, are closed. The boiler is to be fed so that the water level remains normal throughout the test. The test is to last:
   - 15 minutes for fire tube boilers
   - 7 minutes for water tube boilers.

d) Test and simulation of all safety devices, alarms, shut-off and automatic starting of standby equipment.

3.4.3 Alternative requirement

a) When it is recognised, for certain types of boilers, that accumulation tests might endanger the superheaters, the omission of such tests may be considered.

b) Such omission can be permitted, however, only if the drawings and the size of safety valves have been reviewed by the Society, and provided that the safety valves are of a type whose relieving capacity has been established by a test carried out in the presence of the Surveyor, or in other conditions deemed equivalent to those of the actual boiler.

c) When the Society does not agree to proceed with an accumulation test, the valve manufacturer is to supply, for each safety valve, a certificate specifying its relieving capacity for the working conditions of the boiler. In addition, the boiler manufacturer is to supply a certificate specifying the maximum steam capacity of the boiler.

3.5 Tests of diesel engines

3.5.1 Objectives

The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine / shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

3.5.2 Starting capacity

Starting manoeuvres are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

3.5.3 Monitoring and alarm system

The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

3.5.4 Test loads

a) Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

b) The suitability of the engine to operate on fuels intended for use is to be demonstrated.

c) Tests other than those listed below may be required by statutory instruments (e.g. EEDI verification).

d) Propulsion engines driving fixed pitch propeller or impeller.
   - At rated engine speed n_0: at least 4 hours.
   - At engine speed 1,032 n_0 (if engine adjustment permits): 30 min.
   - At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
   - Minimum engine speed to be determined.
   - The ability of reversible engines to be operated in reverse direction is to be demonstrated.

Note 1: During stopping tests according to IMO Resolution MSC.137 (76), see [3.5.5] for additional requirements in the case of a barred speed range.

e) Propulsion engines driving controllable pitch propellers.
   - At rated engine speed n0 with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached): at least 4 hours.
   - At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
   - With reverse pitch suitable for manoeuvring, see [3.5.5] for additional requirements in the case of a barred speed range.

f) Engine(s) driving generator(s) for electrical propulsion and/or main power supply
   - At 100% power (rated electrical power of generator): at least 60 min.
   - At 110% power (rated electrical power of generator): at least 10 min.

Note 2: Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.
   - Demonstration of the generator prime movers' and governors' ability to handle load steps as described in Ch 1, Sec 2, [2.7].

g) Propulsion engines also driving power take off (PTO) generator.
- 100% engine power (MCR) at corresponding speed n_0: at least 4 hours.
- 100% propeller branch power at engine speed n_0 (unless covered in previous bullet point): 2 hours.
- 100% PTO branch power at engine speed n0: at least 1 hour.

h) Engines driving auxiliaries.
- 100% power (MCR) at corresponding speed n_0: at least 30 min.
- Approved intermittent overload: testing for duration as approved.

3.5.5 Torsional vibration - barred speed range

Where a barred speed range (bsr) is required, passages through this bsr, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times stipulated in the approved documentation, if any. This also includes when passing through the bsr in reverse rotational direction, especially during the stopping test.

Note 1: Applies both for manual and automatic passing-through systems.

The ship's draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.

The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

3.6 Test of air starting system for main and auxiliary engines

3.6.1 The capability of the starting air system to charge the air receivers within one hour from atmospheric pressure to a pressure sufficient to ensure the number of starts required in Sec 10, [17.3.1] for main and auxiliaries engines is to demonstrated.

3.7 Tests of steam turbines

3.7.1 Main propulsion turbines

Main turbines are to be subjected during dock trials and subsequent sea trials to the following tests:

- operation at rated rpm for at least 3 hours
- reversing manoeuvres
- astern revolutions equal to at least 70% of the rated ahead rpm.

During astern and subsequent forward operation, the steam pressures and temperatures and the relative expansion are not to assume magnitudes liable to endanger the safe operation of the plant.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

Note 1: Note 1: The astern trial is to be limited to 30 minutes or in accordance with manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

3.7.2 Auxiliary turbines

Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% of rated power.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.8 Tests of gas turbines

3.8.1 Main propulsion turbines

Main turbines are to be subjected during dock trials and subsequent sea trials to the following tests:

- operation at rated rpm for at least 3 hours
- ship reversing manoeuvres.

During the various operations, the pressures, temperatures and relative expansion are not to assume magnitudes liable to endanger the safe operation of the plant.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.8.2 Auxiliary turbines

Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% of rated power.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.9 Tests of electric propulsion system

3.9.1 Dock trials

a) The dock trials are to include the test of the electrical production system, the power management and the load limitation.

b) A test of the propulsion plant at a reduced power, in accordance with dock trial facilities, is to be carried out. During this test, the following are to be checked:

- electric motor rotation speed variation
- functional test, as far as practicable (power limitation is to be tested with a reduced value)
- protection devices
- monitoring and alarm transmission including interlocking system.

c) Prior to the sea trials, an insulation test of the electric propulsion plant is to be carried out.

3.9.2 Sea trials

Testing of the performance of the electric propulsion system is to be effected in accordance with an approved test program.

This test program is to include at least:

- Speed rate of rise
- Endurance test:
  - operation at normal continuous cruise power for at least 4 hours
  - 1 hour at 100% rated output power with winding temperature rise below 2°K per hour, according to IEC publication 60034-1
  - operation in reverse direction of propeller rotation at the maximum torque or thrust allowed by the propulsion system for 10 minutes.
- Check of the crash astern operation in accordance with the sequence provided to reverse the speed from full ahead to full astern, in case of emergency. During this test, all necessary data concerning any effects of the reversing of power on the generators are to be recorded, including the power and speed variation
- Test of functionality of electric propulsion, when manoeuvring and during the ship turning test
- Test of power management performance: reduction of power due to loss of one or several generators to check, in each case, the power limitation and propulsion availability.

3.10 Tests of gears

3.10.1 Tests during sea trials

During the sea trials, the performance of reverse and/or reduction gearing is to be verified, both when running ahead and astern.

In addition, the following checks are to be carried out:

- check of the bearing and oil temperature
- detection of possible gear hammering, where required by Ch 1, Sec 9, [3.5.1]
- test of the monitoring, alarm and safety systems.

3.10.2 Check of the tooth contact

a) Prior to the sea trials, the tooth surfaces of the pinions and wheels are to be coated with a thin layer of suitable coloured compound.

Upon completion of the trials, the tooth contact is to be inspected. The contact marking is to appear uniformly distributed without hard bearing at the ends of the teeth and without preferential contact lines.

The tooth contact is to comply with Tab 1.

b) The verification of tooth contact at sea trials by methods other than that described above will be given special consideration by the Society.

c) In the case of reverse and/or reduction gearing with several gear trains mounted on roller bearings, manufactured with a high standard of accuracy and having an input torque not exceeding 20000 N·m, the check of the tooth contact may be reduced at the Society's discretion.

Such a reduction may also be granted for gearing which has undergone long workshop testing at full load and for which the tooth contact has been checked positively.

In any case, the teeth of the gears are to be examined by the Surveyor after the sea trials. Subject to the results, additional inspections or re-examinations after a specified period of service may be required.

Table 1 : Tooth contact for gears

Heat treatment and machining	Percentage of tooth contact	
	across the whole face width	of the tooth working depth
quenched and tempered, cut	70	40
• quenched and tempered, shaved or ground • surface-hardened	90	40

3.11 Tests of main propulsion shafting and propellers

3.11.1 Shafting alignment

Where alignment calculations are required to be submitted in pursuance of Ch 1, Sec 7, [3.3.1], the alignment conditions are to be checked on board by the Shipyard, as follows:

a) General

The shaft alignment procedure that will be used by the yard is to be submitted for review and is to reflect the approved shaft alignment calculations.

When carrying out measurements relevant to shaft alignment, the ship should be in a condition where:

- The ship's hull portions within shafting areas and superstructures have been welded to their respective places, while main engines, boilers, generators and other large pieces of equipment have been at least hoisted to their respective places. There is no movement of large equipment or change of ballasting during the alignment, shafting installation and inspection on board.
- The temperatures of hull structures are stable and as far as practicable, uniform; the bore sighting should be carried out during the night or cloud covered sky conditions.
- The immersion of the propeller should be as close as practicable to that indicated in calculations, if the ship is in a floating condition.

If the ship cannot be in the conditions above, the influence of the modifications introduced after final bore sighting is to be clearly assessed and documented, (such as hull deflections due to engine and accommodation block installation). Completion level dependent on shipyard experience and vessel type, is to be discussed and agreed upon, with the Society.

The shaft alignment procedure is to include the following steps (see Fig 1) to be conducted sequentially, unless allowed and documented in the calculations.

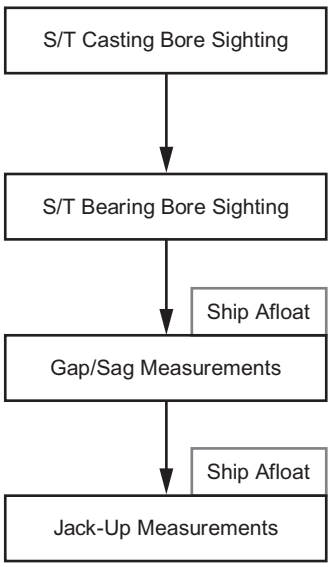
As an alternative approach to Gap/Sag measurements, final sighting, as defined below in item d) 2), can be acceptable as replacement for Gap/Sag measurements, before Jack-Up tests.

b) Stern tube casting bore sighting

The yard should document the results of stern tube casting bore sighting before bearings fitting, showing the stern tube bore offsets, vertical and horizontal in at least three longitudinal positions for each bush position and by defining the off-center corrections for machining the aft and forward stern tube bearings outside diameters.

A reference line is to be established in correspondence with Shaft Alignment Calculation Report and reported.

Figure 1 : Usual shaft alignment procedure



c) Stern Tube Bearing Sighting

Stern tube bearing bush sighting is to be conducted, after the stern tube bearings are fitted, to verify:

- The aft and forward bush slope(s) and offset, as installed. The measurements is to be taken in respect of the reference line, in at least three longitudinal positions for each slope segment in the aft bush.
- In cases with no forward stern tube bearing:
  - The aft bush slope and offset and the offset of the aftmost intermediate bearing, as installed, in respect of the reference line. The aftmost intermediate bearing is to be set to its final position and its offset in respect of the reference line should not be changed after the bore sighting is complete.
  - Exception to the above would be if the hull deflections between dry-dock and afloat lightship condition are known and are accounted for the correction of the intermediate bearing offset, or final bore sighting is carried out in afloat condition.
  - If adjustments to the intermediate bearing are required, then the shaft alignment calculations are to be reviewed and confirmed to evaluate the impact on the relative slope, between the shaft and the aft sterntube bearing.

d) Gap/Sag measurements - Vessel Afloat

1) Alignment of shafts (carried out in afloat condition) by gap and sag

Alignment to be carried out through the Gap and Sag method, involves adjusting the bearing vertical position until the gap and sag values of the unconnected flange pairs correlate to the respective calculation for the applicable ship loading condition. The temporary supports can be adjusted in both the vertical and transverse directions in order to meet the specified calculated values.

If gap and sag are out of specified tolerances, then offset of bearings may be modified to achieve expected values except the following should be taken into account:

In cases with no forward stern tube bearing, the offset of the aftmost intermediate bearing should not be modified unless the overall effect of the offset modification, including sterntube bearing - shaft relative slope, is evaluated and then considered as acceptable by the Society.

2) Final Sighting (Prior to installation of shafting)

The final sighting is defined as a sighting process that should extend from the aftermost bearing, (sterntube or strut, as applicable), up to the engine, or gearbox output flange, and is to be used to adjust the relative position and slope of the engine/gearbox and intermediate bearings in respect of the reference line, except in the case of single sterntube bearing arrangements. This type of complete system sighting is normally not carried out for newbuildings, but can be used as an alternative method to Gap/Sag measurements.

A sufficient number of targets is to be utilized during the sighting-through, to ensure satisfactory accuracy in verification of bearing offsets.

The sighting procedure is to be carried out by recognized methods, such as, optical sighting, or laser sighting.

e) Bearing Load Measurements through jack-up

Jack up test is to be carried out to all types of powertrains including those with electric motors as prime movers, as well as to all accessible shaftline bearings and to bearings which can be subjected to jack-up tests, excluding for example, rolling element type of bearings or similar. Complementary to the jack-up tests, the shaft alignment may be further verified by using an approved strain gauge measurement technique.

The jack-up load measurements are to be carried out at least after chocking of the engine or gearbox. Load verification is to be carried out in floating condition with draft as similar as possible to the condition(s) considered in the calculations. The load on the stern tube forward bearing, intermediate bearings and last three bearings of the main engine (direct drive propulsion system) or gearbox output shaft bearing (if any) is to be measured.

For the first of a series of vessels, at least one jack-up test is to be carried out at hot static condition at a draft specified in the calculations, in accordance with the vessel's loading manual.

In arrangements without forward stern tube bearing, the offset of the aftmost intermediate bearing is not to be modified unless the overall effect of the offset modification, including sterntube bearing - shaft relative slope, is evaluated and then considered as acceptable by the Society. Adjustment of engine or gearbox offsets and re-chocking may anyway be needed.

A report from the jack-up tests is to be submitted to the Society for future reference purposes.

f) Engine (or gearbox) installation

The following parameters are to be measured, with floating ship:

- check of the engine (or gearbox) flanged coupling parameters (gap and sag)
- check of the crankshaft deflections before and after the connection of the engine with the shaft line, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine.

3.11.2 Shafting vibrations

Torsional vibration measurements are to be carried out where required by Ch 1, Sec 9. The type of the measuring equipment and the location of the measurement points are to be specified.

3.11.3 Bearings

a) A bearing run-in procedure is to be conducted with fully immersed propeller. If this is not possible due to shallow waters, then the lowest possible RPM for navigation and the lowest possible helm angles should be used to avoid exposing the new bearings into high stresses and temperatures.

b) During the bearing run-in, the aft stern tube bearing temperature is to be closely monitored. If bearing temperature rises at a rate faster than a previously agreed rate, such as 5°C/min, or exceeds temperature alarm threshold, then the rudder angle should be immediately set to zero and the engine speed should be reduced to minimum or shut down - until the bearing temperature lowers to an acceptable level and stabilizes accordingly. Temperatures exceeding the high temperature alarm threshold and high temperature increase rate should be investigated (e.g. by oil sampling) and reported.

   If limits/criteria/alarms are exceeded, the shipyard may request to repeat the bearing run-in procedure. Repeating should be subject to agreement; otherwise, further investigation is to be carried out.

   In the absence of an aft-most bearing temperature sensor (e.g. for oil lubricated synthetic bearings), weardown measurement (poker gauge) readings should is to be taken before and after sea trials.

c) Once a bearing run-in procedure is completed satisfactorily, the parts of the sea trials addressing the propulsion system and shaftline may commence.

d) The temperature of the bearings is to be checked under the machinery power conditions specified in [3.1.2].

3.11.4 Shaft alignment verification during sea trials

The sea trial should be carried out with 100% propeller immersion and with sterntube lubricant according to specification in the shaft alignment calculation report. The aft stern tube bearing temperature should be recorded during the foreseen steering gear tests, during vessel sea trials

In the absence of a specific sea trial program, according to IMO Resolution MSC.137(76), the following movements should be included in the sea trial program after the vessel stabilizes at a full ahead condition, at a zero-rudder angle (straight ahead) and ballast condition:

a) Perform one 360 degree turn to the port by swiftly changing the rudder angle from 0 to maximum declared steering angle, as defined in Ch 1, Sec 14, [2.2.1] and a full ahead setting. At the completion of the turn, return the rudder angle to zero (straight ahead).

b) Keep the rudder angle to zero for five (5) minutes at a full ahead setting.

c) Perform one 360 degree turn to the starboard by swiftly changing the rudder angle from 0 to maximum declared steering angle, as defined in Ch 1, Sec 14, [2.2.1] and a full ahead setting. At the completion of the turn, return the rudder angle to zero (straight ahead).

d) Keep the rudder angle to zero for five (5) minutes and at a full ahead setting.

Provided the recorded bearing temperature rate of rise does not exceed a previously agreed rate, such as 5°C/min, or triggers a temperature alarm then the sea trial bearing performance for shaft alignment may be regarded as satisfactory. If limits/criteria/alarms are exceeded then the whole test (a, b, c, d, as above) may be repeated and considered passed if satisfactory results are demonstrated twice. The results of the test (maximum rate of temperature rise and maximum bearing temperature, as well as alarm set point) should be included in the sea trial report and can be sent to the Society, to be retained for information purposes only. Temperatures exceeding the high temperature alarm threshold and high temperature increase rate should be investigated (e.g. by oil sampling) and reported.

A root cause analysis should be initiated to reveal the possible cause of the damage, if a bearing is deemed to be damaged.

Jack-up tests should be carried out at the required conditions, in accordance with [3.11.1], item e) and are to be submitted to the Society.

3.11.5 Stern tube sealing gland

The stern tube oil system is to be checked for possible oil leakage through the stern tube sealing gland.

3.11.6 Control system of controllable pitch propellers

a) The control system of controllable pitch propellers is to be tested during sea trial to demonstrate:

- the functioning of the system controlling the pitch from full ahead to full astern position. It is also to be checked that this system does not induce any overload of the engine
- that the propelling thrust is not significantly altered when transferring control from one location to another and in case of failures in the pitch command and control or feedback signals.
- that the pitch response times measured during the test do not exceed the maximum value to be defined by the pitch control system manufacturer or integrator.

b) The test procedure is to be established with the manufacturer and is to be approved by the Society. It is to include:

- Pitch response test

  A full range of tests is to be carried out to get the pitch response and verify that it coincides with the combinator curve of the propeller. The tests are to be carried out for at least three positions of the control lever in ahead and astern directions (e.g., dead slow ahead / astern, half ahead / astern, full ahead / astern).

  The tests are to be carried out in normal and emergency operating conditions.

  Tests that are not affected by the control position may be carried out from one control position only.

- Test of the fail-to-safe characteristics

  A test of the fail-to-safe characteristics of the propeller pitch control system is to be carried out to demonstrate that failures in the pitch command and control or feedback signals are alarmed and do not cause any change of thrust. Such failures are to be clearly identified and included in the test procedure.

Note 1: The combinator curve is the relationship between the propeller pitch setting and the propeller speed.

c) The list of the parameters to be recorded is to be established with the manufacturer and is to be approved by the Society. It is to include at least the following parameters:

- position of the control handle
- actual pitch indication (local indication, remote indications)
- rotational speed of the propeller
- response time between the pitch change order (modification of the lever position) and the instant when the pitch and propeller speed have reached their final position
- propelling thrust variation during the transfer of the control from one location to another one.

3.12 Tests of piping systems

3.12.1 Hydrostatic tests of piping after assembly on board

a) When the hydrostatic tests of piping referred to in Ch 1, Sec 10, [20.5.2] are carried out on board, they may be carried out in conjunction with the leak tests required in [3.12.2].

b) Low pressure pipes, such as bilge or ballast pipes are to be tested, after fitting on board, under a pressure at least equal to the maximum pressure to which they can be subjected in service. Moreover, the parts of such pipes which pass, outside pipe tunnels, through compartments for ballast water, fresh water, fuel or liquid cargo, are to be fitted before the hydraulic test of the corresponding compartments.

c) Heating coils in oil fuel tanks or in liquid cargo tanks and fuel pipes are to be subjected, after fitting on board, to a hydraulic test under a pressure not less than 1,5 times the design pressure, with a minimum of 4 bars.

d) For pressure tests of plastic pipes after assembly on board, see Ch 1, App 3, [4.9].

3.12.2 Leak tests

Except otherwise permitted by the Society, all piping systems are to be leak tested under operational conditions after completion on board.

Pneumatic leak testing may be carried out on water sensitive systems, in lieu of hydrostatic testing. In certain circumstances, a combined hydrostatic – pneumatic strength test may also be applied, where the system is partially filled with water and the free space above is pressurized with a test gas (typically air or nitrogen). When pneumatic tests cannot be avoided, the relevant safety precautions are to be observed. See Ch 1, Sec 10, [20.5.1].

3.12.3 Functional tests

During the sea trials, piping systems serving propulsion and auxiliary machinery, including the associated monitoring and control devices, are to be subjected to functional tests at the nominal power of the machinery. Operating parameters (pressure, temperature, consumption) are to comply with the values recommended by the equipment manufacturer.

3.12.4 Performance tests

The Society reserves the right to require performance tests, such as flow rate measurements, should doubts arise from the functional tests.

3.13 Tests of steering gear

3.13.1 General

a) The steering gear is to be tested during the sea trials under the conditions stated in [3.1] in order to demonstrate, to the Surveyor's satisfaction, that the applicable requirements of Ch 1, Sec 14 are fulfilled.

b) For controllable pitch propellers, the propeller pitch is to be set at the maximum design pitch approved for the maximum continuous ahead rotational speed.

c) If the ship cannot be tested at the deepest draught, alternative trial conditions will be given special consideration by the Society. In such case, the ship speed corresponding to the maximum continuous number of revolutions of the propulsion machinery may apply.

3.13.2 Tests to be performed

Tests of the steering gear are to include at least:

a) functional test of the main and auxiliary steering gear with demonstration of the performances required by Ch 1, Sec 14, [2.3]

b) test of the steering gear power units, including transfer between steering gear power units

c) test of the isolation of one power actuating system, checking the time for regaining steering capability

d) test of the hydraulic fluid refilling system

e) test of the alternative power supply required by Ch 1, Sec 14, [2.7.2], item e)

f) test of the steering gear controls, including transfer of controls and local control

g) test of the means of communication between the navigation bridge, the engine room and the steering gear compartment

h) test of the alarms and indicators

i) where the steering gear design is required to take into account the risk of hydraulic locking, a test is to be performed to demonstrate the efficiency of the devices intended to detect this.

Note 1: Tests d) to i) may be carried out either during the mooring trials or during the sea trials.

Note 2: For ships of less than 500 gross tonnage and for fishing vessels, the Society may accept departures from the above list, in particular to take into account the actual design features of their steering gear.

Note 3: Azimuth thrusters are to be subjected to the above tests, as far as applicable.

4 Inspection of machinery after sea trials

4.1 General

4.1.1

a) For all types of propulsion machinery, those parts which have not operated satisfactorily in the course of the sea trials, or which have caused doubts to be expressed as to their proper operation, are to be disassembled or opened for inspection.

Machinery or parts which are opened up or disassembled for other reasons are to be similarly inspected.

b) Should the inspection reveal defects or damage of some importance, the Society may require other similar machinery or parts to be opened up for inspection.

c) An exhaustive inspection report is to be submitted to the Society for information.

4.2 Diesel engines

4.2.1

a) In general, for all diesel engines, the following items are to be verified:

- the deflection of the crankshafts
- the cleanliness of the lubricating oil filters.

b) In the case of propulsion engines for which power tests have not been carried out in the workshop, some parts, agreed upon by the interested parties, are to be disassembled for inspection after the sea trials.

Appendix 1 Calculation for Internal Combustion Engine Crankshafts

Symbols

B : Width of the web, in mm (see Fig 3)
In case of 2-stroke semi-built crankshafts, B is to be taken in way of crankpin fillet radius centre according to Fig 3

D : Crankpin diameter, in mm (see Fig 3 and Fig 4)

D_A : Outside diameter of web, in mm, as defined in [1.2.1], item p)

D_{BG} : Diameter of axial bore in journal, in mm (see Fig 3 and Fig 4)

D_{BH} : Diameter of axial bore in crankpin, in mm (see Fig 3)

D_G : Journal diameter, in mm (see Fig 3 and Fig 4)

D_O : Diameter of oil bore in crankpin, in mm (see Fig 5)

D_S : Shrink-fit diameter, in mm (see Fig 4)

E : Pin eccentricity, in mm (see Fig 3)

F : Area, in mm^2, related to the reference cross-section of web, equal to:
$F = B\ W$

K : Crankshaft manufacturing process factor, as defined in [6.1.1], item a)

K_e : Empirical factor considering to some extent the influence of adjacent crank and bearing restraint, and taken as follows:
- $K_e = 0,8$ for 2-stroke engines
- $K_e = 1,0$ for 4-stroke engines

L_S : Axial length of the shrink-fit, in mm (see Fig 4)

M_{BO} : Bending moment calculated at the outlet of crankpin oil bore, in N·m, equal to:
$M_{BO} = M_{BTO} \cos \psi + M_{BRO} \sin \psi$

M_{BOmax} : Maximum value of the bending moment M_{BO} within one working cycle, in N·m

M_{BOmin} : Minimum value of the bending moment M_{BO} within one working cycle, in N·m

M_{BON} : Alternating bending moment calculated at the outlet of crankpin oil bore, in N·m, defined in [2.1.2], item d)

M_{BRF} : Bending moment acting in web, in N·m, as defined in [2.1.1], item c)

M_{BRFmax} : Maximum value of the bending moment $M_{BRF\ within\ one\ working\ cycle}$, in N·m

M_{BRFmin} : Minimum value of the bending moment $M_{BRF\ within\ one\ working\ cycle}$, in N·m

M_{BRFN} : Alternating bending moment related to the centre of the web, in N·m, defined in [2.1.2], item b)

M_{BRO} : Bending moment of the radial component of the connecting rod force, in N·m (see Fig 5)

M_{BTO} : Bending moment of the tangential component of the connecting rod force, in N·m (see Fig 5)

M_T : Torque, in N·m

M_{Tmax} : Maximum value of the torque M_T within one working cycle, in N·m

M_{Tmin} : Minimum value of the torque M_T within one working cycle, in N·m

M_{TN} : Alternating torque, in N·m, as defined in [2.2.2]

Q_1 : Acceptability factor for the crankpin fillet, as defined in [7.1.1]

Q_2 : Acceptability factor for the journal fillet, as defined in [7.1.1]

Q_3 : Acceptability factor for the crankpin outlet of oil bore, as defined in [7.1.1]

Q_{RF} : Radial force acting in web, in N, as defined in [2.1.1], item c)

Q_{RFmax} : Maximum value of the radial force Q_{RF} within one working cycle, in N

Q_{RFmin} : Minimum value of the radial force Q_{RF} within one working cycle, in N

Q_{RFN} : Alternating radial force related to the web, in N, as defined in [2.1.2], item c)

R_G : Fillet radius of journal, in mm (see Fig 3 and Fig 4)

R_H : Fillet radius of crankpin, in mm (see Fig 3)

R_m : Minimum specified tensile strength of crankshaft material, in N/mm^2

S : Pin overlap, in mm, given by the following formula (see Fig 3):

$$S = \frac{D + D_G}{2} - E$$

Where pins do not overlap, the negative value of S calculated by the above formula is to be considered

T_G : Recess of journal fillet, in mm (see Fig 3)

T_H : Recess of crankpin fillet, in mm (see Fig 3)

W : Axial web thickness, in mm (see Fig 3)

W_e : Section modulus related to the cross-section of axially bored crankpin, in mm^3, equal to:

$$W_e = \frac{\pi}{32}\left(\frac{D^4 - D_{BH}^4}{D}\right)$$

W_{eqw} : Section modulus related to the cross-section of web, in mm^3, equal to:

$$W_{eqw} = \frac{B \cdot W^2}{6}$$

W_{PG} : Polar section modulus related to cross-section of axially bored journal, in mm^3, equal to:

$$W_{PG} = \frac{\pi}{16}\left(\frac{D_G^4 - D_{BG}^4}{D_G}\right)$$

W_{PH} : Polar section modulus related to cross-section of axially bored crankpin, in mm^3, equal to:

$$W_{PH} = \frac{\pi}{16}\left(\frac{D^4 - D_{BH}^4}{D}\right)$$

W_{red} : Reduced axial web thickness, in mm, to be considered instead of W in the case of 2-stroke semi-built crankshafts with $T_H > R_H$ and to be taken as equal to (see Fig 3):

$W_{red} = W - (T_H - R_H)$

α_B : Stress concentration factor for bending in crankpin fillet, as evaluated in [3.1.2], item a)

α_T : Stress concentration factor for torsion in crankpin fillet, as evaluated in [3.1.2], item b)

β_B : Stress concentration factor for bending in journal fillet, as evaluated in [3.1.3], item a)

β_Q : Stress concentration factor for compression due to radial force in journal fillet, as evaluated in [3.1.3], item b)

β_T : Stress concentration factor for torsion in journal fillet, as evaluated in [3.1.3], item c)

γ_B : Stress concentration factor for bending in crankpin oil bore, as evaluated in [3.1.4]

γ_T : Stress concentration factor for torsion in outlet of crankpin oil bore, as evaluated in [3.1.4]

σ_{add} : Additional bending stress, in N/mm^2, due to misalignment, as defined in [4.1.1]

σ_{BFN} : Nominal alternating bending stress related to the web, in N/mm^2, as defined in [2.1.2], item b)

σ_{BG} : Alternating bending stress in journal fillet, in N/mm^2, as defined in [2.1.3], item b)

σ_{BH} : Alternating bending stress in crankpin fillet, in N/mm^2, as defined in [2.1.3], item a)

σ_{BO} : Alternating bending stress in outlet of crankpin oil bore, in N/mm^2, as defined in [2.1.4]

σ_{BON} : Nominal alternating bending stress related to the crankpin diameter, in N/mm^2, as defined in [2.1.2], item d)

σ'_{DW} : Allowable alternating bending fatigue strength of crankshaft in the crankpin fillet area, in N/mm^2, as defined in [6.1.1], item a)

σ''_{DW} : Allowable alternating bending fatigue strength of crankshaft in the journal fillet area, in N/mm^2, as defined in [6.1.1], item b)

σ'''_{DW} : Allowable alternating bending fatigue strength of crankshaft in the crankpin oil bore area, in N/mm^2, as defined in [6.1.1], item c)

σ_{QFN} : Nominal alternating compressive stress due to radial force related to the web, in N/mm^2, as defined in [2.1.2], item c)

σ_{TO} : Alternating torsional stress in outlet of crankpin oil bore, in N/mm^2, as defined in [2.2.3], item c)

σ'_V : Equivalent alternating stress in way of crankpin fillet, in N/mm^2, as defined in [5.2.1], item a)

σ''_V : Equivalent alternating stress in way of journal fillet, in N/mm^2, as defined in [5.2.1], item b)

σ'''_V : Equivalent alternating stress in way of outlet of crankpin oil bore, in N/mm^2, as defined in [5.2.1], item c)

τ_G : Alternating torsional stress in journal fillet, in N/mm^2, as defined in [2.2.3], item b)

τ_H : Alternating torsional stress in way of crankpin fillet, in N/mm^2, as defined in [2.2.3], item a)

τ_{NG} : Nominal alternating torsional stress related to journal diameter, in N/mm^2, as defined in [2.2.2]

τ_{NH} : Nominal alternating torsional stress related to crankpin diameter, in N/mm^2, as defined in [2.2.2]

ψ : Angular position, in deg (see Fig 5).

1 General

1.1 Application

1.1.1

a) These Rules for the design of crankshafts are to be applied to I.C. engines for propulsion and auxiliary purposes, where the engines are capable of continuous operation at their rated power when running at rated speed.

Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted to the Society in order to demonstrate equivalence to the Rules.

b) These Rules apply only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between main bearings.

1.2 Documentation to be submitted

1.2.1 The following documents and particulars required for the calculation of crankshafts as indicated in Ch 1, Sec 2, Tab 1 and Ch 1, Sec 2, Tab 2 are to be submitted:

a) engine builder

b) crankshaft drawings containing all the data in respect of the geometrical configurations of the crankshaft

c) engine type designation

d) kind of engine:
- in-line engine or V-type engine with adjacent connecting rods
- V-type engine with forked/inner connecting rods
- V -type engine with articulated-type connecting rods
- crosshead engine or trunk piston engine

e) operating method: 2-stroke or 4-stroke cycle

f) combustion method: direct injection, precombustion chamber, etc

g) number of cylinders
diameter of cylinders, in mm
length of piston stroke, in mm
length of connecting rod (between bearing centers), in mm

h) rated power, in kW
rated engine speed, in rpm
mean effective pressure, in bar
mean indicated pressure, in bar
maximum net cylinder pressure Pmax, in bar
charge air pressure (before inlet valves or scavenge ports, whichever applies), in bar
nominal compression ratio

i) direction of rotation: clockwise or counter clockwise (see Fig 1)

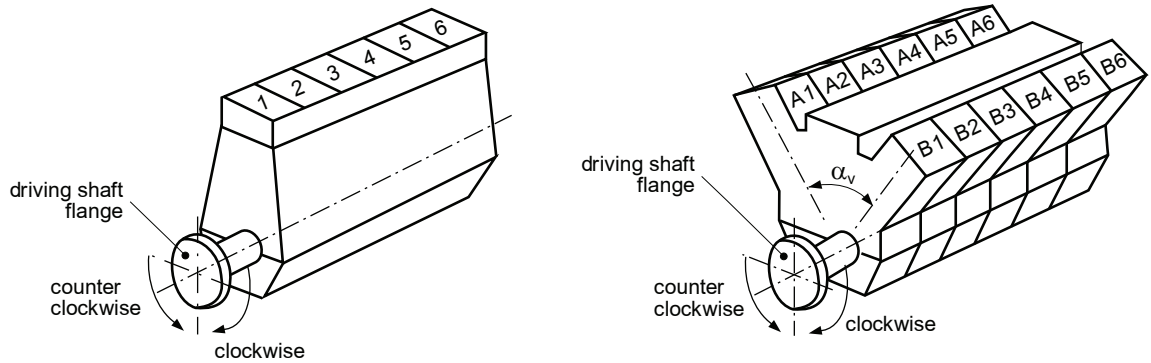
j) firing order (corresponding to item i) with the respective ignition intervals, in deg

k) oscillating mass of one cylinder (mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod), in kg
mass of connecting rod, in kg, and position of gravity centre

l) digitalized gas pressure curve presented at equidistant intervals, in bar versus crank angle (at least every 5° CA)

m) for V-type engines: V-angle α_v, in deg (see Fig 1)

Figure 1 : Designation of the cylinders



n) data of crankshaft:
- drawing number
- kind of crankshaft (e.g. solid-forged crankshaft, semi-built crankshaft, etc.)
- method of manufacture (e.g. free form forged, continuous grain flow forged, drop-forged, etc.), with description of the forging process
- heat treatment (e.g. tempered)
- every surface treatment affecting fillets or oil holes
- particulars of alternating torsional stress calculations (see [2.2])

o) crank dimensions necessary for the calculation of stress concentration factors, in mm unless other specified (see Fig 2 and Fig 3):
- crankpin diameter D
- diameter of axial bore in crankpin D_{BH}
- fillet radius of crankpin R_H
- recess of crankpin fillet T_H
- journal diameter D_G
- diameter of axial bore in journal D_{BG}
- fillet radius of journal R_G
- recess of journal fillet T_G
- web thickness W
- web width B
- bending length L_1
- bending length L_2
- bending length L_3
- diameter of oil bore in crankpin D_O
- smallest edge radius of oil bore
- surface roughness of oil bore fillet
- inclination of oil bore axis related to shaft axis Y, in deg.

p) additional data for shrink-fits of semi-built crankshafts, in mm unless other specified (see Fig 4):
- shrink diameter D_S
- length of shrink-fit L_S
- outside diameter of web D_A or twice the minimum distance x (see Fig 4) between centreline of journals and outer contour of web, whichever is less
- distance y between the adjacent generating lines of journal and pin connected to the same web

  In general: $y \geq 0,05\ D_S$

  Where y is less than $0,1\ D_S$, special consideration is to be given by the Society to the effect of the stress due to the shrink-fit on the fatigue strength at the crankpin fillet
- amount of shrink-fit (upper and lower tolerances)
- maximum torque, in N·m
- maximum nominal alternating torsional stress (ascertained by means of a harmonic synthesis and related to cross-sectional area of bored crankpin), in N/mm²
- engine speed (at which the maximum nominal alternating torsional stress occurs), in rpm
- minimum engine speed (for which the harmonic synthesis was carried out), in rpm

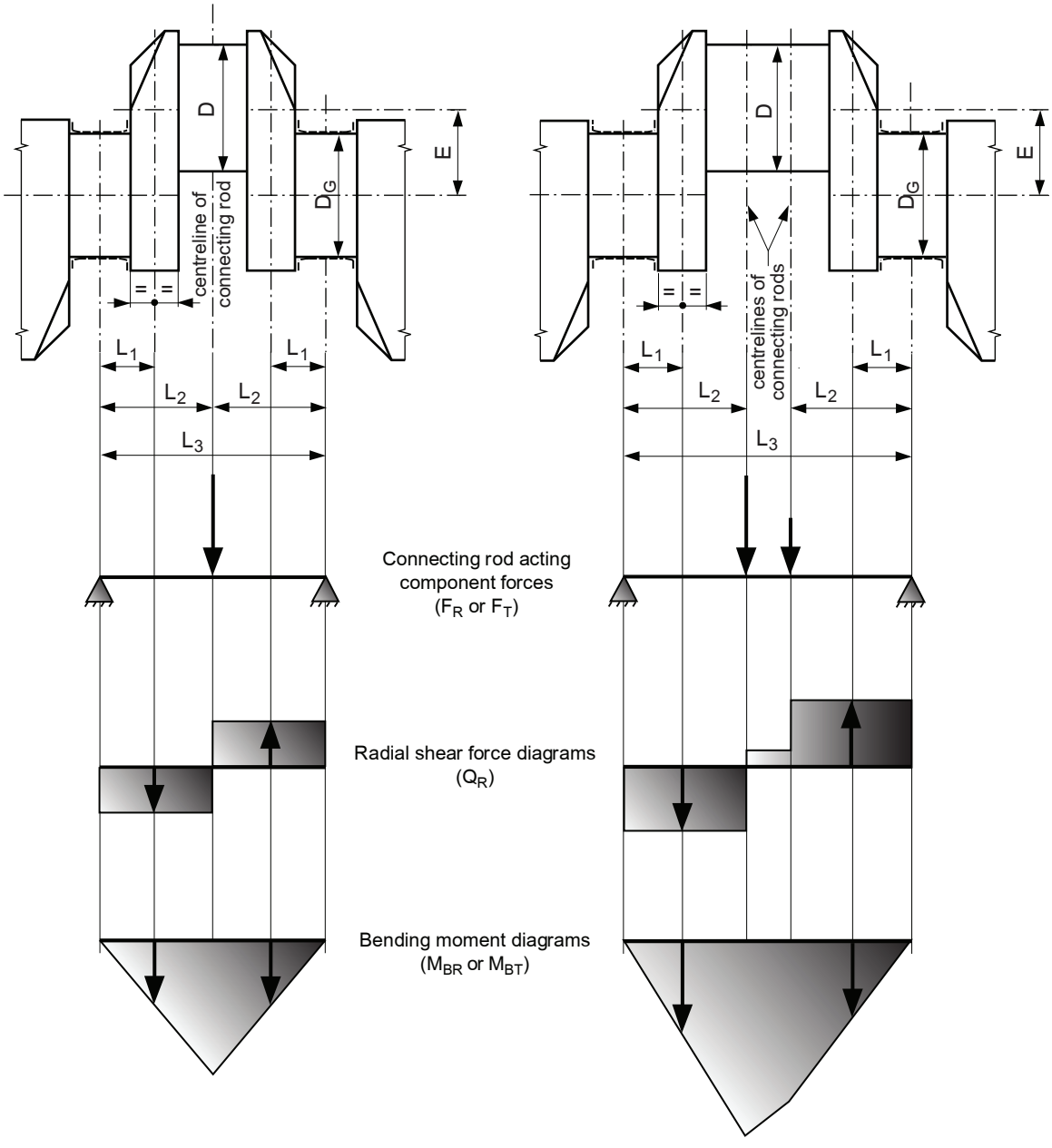
q) details of crankshaft material:
- material designation (according to ISO, EN, DIN, AISI, etc.)
- mechanical properties of material (minimum values obtained from longitudinal test specimens):
  - tensile strength, in N/mm²
  - yield strength, in N/mm²
  - reduction in area at break, in %
  - elongation A_5, in %
  - impact energy – KV, in J
  - Young's modulus, in N/mm²
- method of crankshaft material melting process (e.g. open-hearth furnace, electric furnace, etc.)

r) data of stress concentration factors (S.C.F.) to be given only when data for stress concentration factors and/or fatigue are furnished by the engine manufacturer on the basis of measurements (full supporting details are to be enclosed):

- S.C.F. for bending in crankpin fillet α_B
- S.C.F. for torsion in crankpin fillet α_T
- S.C.F. for bending in journal fillet β_B
- S.C.F. for torsion in journal fillet β_T
- S.C.F. for compression in journal fillet β_Q

allowable fatigue strength of crankshaft σ_{DW}, in N/mm^2.

Figure 2 : Crank throw of solid crankshaft



(a) Crankthrow for in-line engine (with one connecting rod)

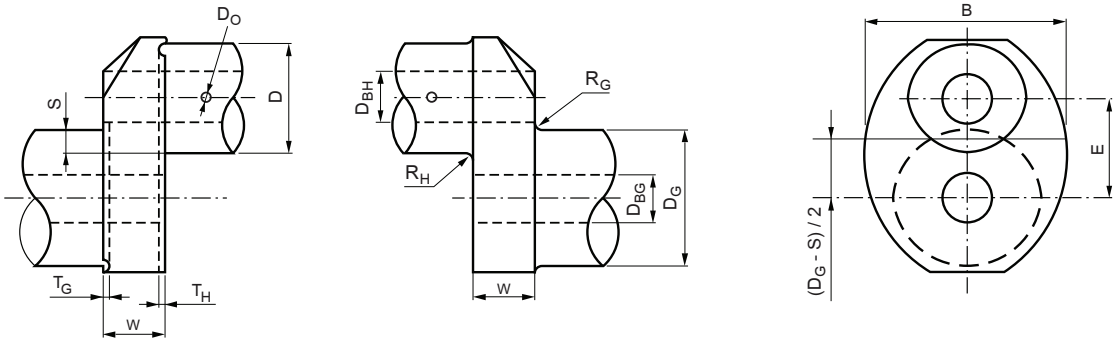
(b) Crankthrow for V-type engine (with two adjacent connecting rods)

L_1 : Distance between main journal centreline and crankweb centre (see also Fig 3 for crankshaft without overlap)

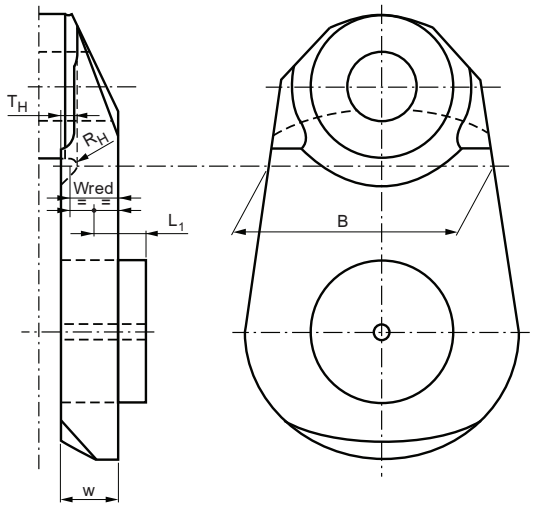
L_2 : Distance between main journal centreline and connecting rod centre

L_3 : Distance between two adjacent main journal centrelines.

Figure 3 : Reference area of crankweb cross-section and crank dimensions

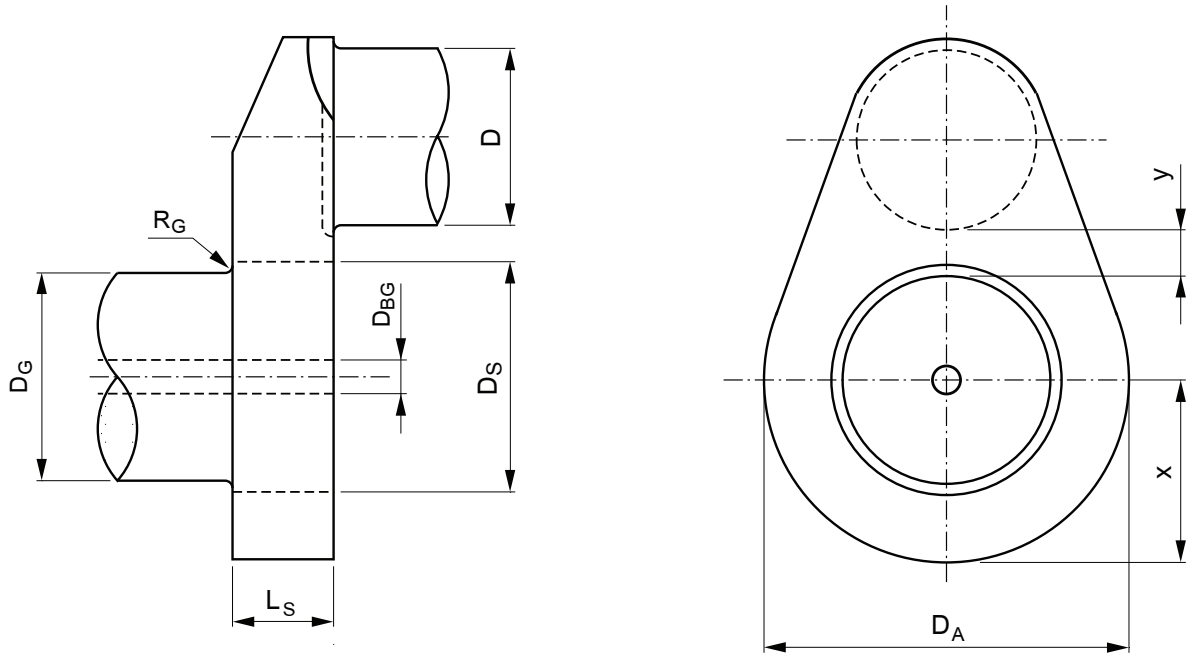


Overlapped crankshaft



Crankshaft without overlap

Figure 4 : Crank throw of semi-built crankshaft



1.3 Principles of calculation

1.3.1 The design of crankshafts is based on an evaluation of safety against fatigue in the highly stressed areas.

The calculation is also based on the assumption that the areas exposed to highest stresses are:

- fillet transitions between the crankpin and web as well as between the journal and web
- outlets of crankpin oil bores.

When the journal diameter is equal to or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending (see [2.1]) and nominal alternating torsional stresses (see [2.2]) which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion (von Mises' Criterion, see [3]), result in an equivalent alternating stress (uni-axial stress, see [5]). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see [6]). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (see [7]).

2 Calculation of alternating stresses

2.1 Calculation of alternating stresses due to bending moments and radial forces

2.1.1 Assumptions

a) The calculation is based on a statically determined system, composed of a single crank throw supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints (distance L_3, see Fig 2 (a) and Fig 2 (b)).

b) The bending moments M_{BR} and M_{BT} are calculated in the relevant section based on triangular bending moment diagrams due to the radial component F_R and the tangential component F_T of the connecting rod force, respectively (see Fig 2 (a)).

For crank throws with two connecting rods acting upon one crankpin, the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (see Fig 2 (b)).

c) Bending moments and radial forces acting in web

The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1 in Fig 2) and are derived from the radial component of the connecting rod force.

The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crank web:

- at the centre of the overlap S in cases of overlap of the pins (see Fig 3), and
- at the centre of the distance y between the adjacent generating lines of the two pins in cases of pins which do not overlap (see Fig 4).

This reference cross-section results from the web thickness W and the web width B (see Fig 3).

Mean stresses are neglected.

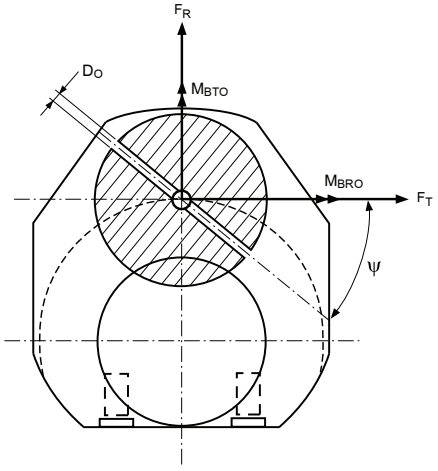
d) Bending acting in outlet of crankpin oil bore

The two relevant bending moments M_{BRO} and M_{BTO} (see Symbols and Fig 5) are taken in the crankpin cross-section through the oil bore.

The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin.

Mean bending stresses are neglected.

Figure 5 : Crankpin section through the oil bore



2.1.2 Calculation of nominal alternating bending and compressive stresses in web

a) The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting rod position will be calculated over one working cycle.

A simplified calculation of the radial forces may be used at the discretion of the Society.

Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments M_{BRF}, M_{BRO}, M_{BTO} and radial forces Q_{RF} (see Symbols) will be then calculated.

In case of V-type engines, the bending moments (progressively calculated from the gas and inertia forces and for the various crank angles) of the two cylinders acting on one crank throw are superposed according to phase. Different designs (forked connecting rod, articulated-type connecting rod or adjacent connecting rods) shall be taken into account.

Where there are cranks of different geometrical configurations (e.g. asymmetrical cranks) in one crankshaft, the calculation is to cover all crank variants.

b) Nominal alternating bending stress in web cross-section

The nominal alternating bending stress σ_{BFN} related to the web is calculated, in N/mm^2, as follows:

$$\sigma_{BFN} = \pm \frac{M_{BRFN}}{W_{eqw}} \cdot K_e \cdot 10^3$$

where:

M_{BRFN} : Alternating bending moment related to the centre of the web, in N·m, equal to (see Fig 2 (a) and Fig 2 (b)):

$M_{BRFN} = \pm 0,5\ (M_{BRFmax} - M_{BRFmin})$

W_{eqw}, K_e, M_{BRFmax}, M_{BRFmin} : As defined in Symbols.

c) Nominal alternating compressive stress in web cross-section

The nominal alternating compressive stress σ_{QFN} due to radial force related to the web is calculated, in N/mm^2, as follows:

$$\sigma_{QFN} = \pm \frac{Q_{RFN}}{F} \cdot K_e$$

where:

Q_{RFN} : Alternating radial force related to the web, in N, equal to (see Fig 2 (a) and Fig 2 (b)):

$Q_{RFN} = \pm 0,5\ (Q_{RFmax} - Q_{RFmin})$

F, K_e, Q_{RFmax}, Q_{RFmin} : As defined in Symbols.

d) Nominal alternating bending stress in outlet of crankpin oil bore

The nominal alternating bending stress σ_{BON} related to the crankpin diameter is calculated, in N/mm^2, as follows:

$$\sigma_{BON} = \pm \frac{M_{BON}}{W_e} \cdot 10^3$$

where:

M_{BON} : Alternating bending moment calculated at the outlet of crankpin oil bore, in N·m, equal to:

$M_{BON} = \pm 0,5\ (M_{BOmax} - M_{BOmin})$

W_e, M_{BOmax}, M_{BOmin} : As defined in Symbols.

2.1.3 Calculation of alternating bending stresses in fillets

a) The alternating bending stress σ_{BH} in crankpin fillet is calculated, in N/mm^2, as follows:

$$\sigma_{BH} = \pm (\alpha_B \cdot \sigma_{BFN})$$

b) The alternating bending stress σ_{BG} in journal fillet is calculated, in N/mm^2, as follows (not applicable to semi-built crankshafts):

$$\sigma_{BG} = \pm (\beta_B \cdot \sigma_{BFN} + \beta_Q \cdot \sigma_{QFN})$$

where:

α_B, β_B, β_Q : Stress concentration factors as defined in [3.1]

σ_{BFN}, σ_{QFN} : Stresses as defined in [2.1.2], item b) and item c) respectively.

2.1.4 Calculation of alternating bending stress in outlet of crankpin oil bore

The alternating bending stress σ_{BO} in outlet of crankpin oil bore is calculated, in N/mm^2, as follows:

$$\sigma_{BO} = \pm (\gamma_B \cdot \sigma_{BON})$$

where:

γ_B : Stress concentration factor as defined in [3.1.4]

σ_{BON} : Stress as defined in [2.1.2], item d).

2.2 Calculation of alternating torsional stresses

2.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in [2.2.2].

The maximum nominal alternating torsional stress is to be specified by the manufacturer.

The maximum value obtained from such calculations will be used by the Society when determining the equivalent alternating stress according to the provisions of Article [5].

In the absence of such a maximum value, the Society reserves the right to incorporate a fixed value in the calculation for the crankshaft dimensions, to be established at its discretion in each case.

In the event of the Society being entrusted to carry out a forced vibration calculation on behalf of the engine manufacturer to determine the torsional vibration stresses expected in the engine and where relevant in the shafting, the following data are to be submitted in addition to those required in [1.2.1]:

a) equivalent dynamic system of the engine, comprising:
   - mass moment of inertia of every mass point, in kg.m^2
   - inertialess torsional stiffnesses, in N·m/rad, of all crankshaft parts between two mass points

b) vibration dampers, specifying:
   - type designation
   - mass moments of inertia, in kg.m^2
   - inertialess torsional stiffnesses, in N·m/rad
   - values of the damping coefficients, in N·m.s

c) flywheels, specifying:
   - mass moment of inertia, in kg·m^2.

Where the whole propulsion system is to be considered, the following information is also to be submitted:

a) elastic couplings, specifying:
   - dynamic characteristics and damping data, as well as the permissible value of alternating torque

b) gearing and shafting, specifying:
   - shaft diameters of gear shafts, thrust shafts, intermediate shafts and propeller shafts, mass moments of inertia, in kg·m^2, of gearing or important mass points, gear ratios and, for gearboxes of complex type, the schematic gearing arrangement

c) propellers, specifying:
   - propeller diameter
   - number of blades
   - pitch and developed area ratio
   - mass moment of inertia of propeller in air and with entrained water, in kg·m^2 (for controllable pitch propellers both the values at full pitch and at zero pitch are to be specified)
   - damping characteristics, if available and documented

d) natural frequencies with their relevant modes of vibration and the vector sums for the harmonics of the engine excitation

e) estimated torsional vibration stresses in all important elements of the system with particular reference to clearly defined resonance speeds of rotation and continuous operating ranges.

2.2.2 Calculation of nominal alternating torsional stresses

The maximum and minimum values of the alternating torques are to be ascertained for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines.

In performing this calculation, allowance is to be made for the damping that exists in the system and for unfavourable conditions (e.g., misfiring in one of the cylinders).

Note 1: Misfiring is defined as cylinder condition when no combustion occurs but only compression cycle.

The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

Where barred speed ranges are necessary, they shall be arranged so that satisfactory operation is possible despite their existence. There are to be no barred speed ranges above a speed ratio of $\lambda \geq 0,8$ for normal firing conditions.

The values received from such calculation are to be submitted to the Society for consideration.

The nominal alternating torsional stresses referred to crankpin (τ_{NH}) and journal (τ_{NG}) in every mass point which is essential to the assessment result, in N/mm^2, from the following formulae:

$$\tau_{NH} = \pm \frac{M_{TN}}{W_{PH}} \cdot 10^3$$

$$\tau_{NG} = \pm \frac{M_{TN}}{W_{PG}} \cdot 10^3$$

where:

M_{TN} : Maximum alternating torque, in N·m, equal to:

$M_{TN} = \pm 0,5 \ (M_{Tmax} - M_{Tmin})$

W_{PH}, W_{PG}, M_{Tmax}, M_{Tmin} : As defined in Symbols.

Bored crankpins and journals whose bore longitudinal axis does not coincide with the axis of the said crankpins and journals, will be considered by the Society in each case.

For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in further calculations is the highest calculated value, according to above method, occurring at the most torsionally loaded mass point of the crankshaft system.

Where barred speed ranges exist, the torsional stresses within these ranges are not to be considered for assessment calculations.

The approval of crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer).

Thus, for each installation, it is to be ensured by suitable calculation that this approved nominal alternating torsional stress is not exceeded. This calculation is to be submitted to the Society for assessment (see Ch 1, Sec 9).

2.2.3 Calculation of alternating torsional stresses in fillets and outlet of crankpin oil bore

The calculation of the alternating torsional stresses is to be carried out for the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore, as follows:

a) the alternating torsional stress τ_H, in N/mm², in way of crankpin fillet is given by the following formula:

$\tau_H = \pm (\alpha_T \cdot \tau_{NH})$

b) the alternating torsional stress τ_G, in N/mm², in way of journal fillet is given by the following formula (not applicable to semi-built crankshafts):

$\tau_G = \pm (\beta_T \cdot \tau_{NG})$

c) the alternating torsional stress σ_{TO}, in N/mm², in way of outlet of crankpin oil bore is given by the following formula:

$\sigma_{TO} = \pm (\gamma_T \cdot \tau_{NH})$

where:

α_T, β_T, γ_T, τ_{NG}, τ_{NH} : As defined in Symbols.

3 Evaluation of stress concentration factors (SCF)

3.1 General

3.1.1 The stress concentration factors are evaluated by means of the formulae according to [3.1.2], [3.1.3] and [3.1.4] applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. It is to be noticed that stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil hole. All formulae are based on investigations of FVV (Forschungsvereinigung Verbrennungskraftmaschinen) for fillets and on investigations of ESDU (Engineering Science Data Unit) for oil holes.

Where the geometry of the crankshaft is outside the boundaries of the analytical stress concentration factors, the calculation method detailed in Article [9] may be undertaken.

All crank dimensions necessary for the calculation of stress concentration factors are shown in Fig 3.

The stress concentration factors for bending (α_B and β_B) are defined as the ratio of the maximum equivalent von Mises stress (occurring in the fillets under bending load) to the nominal bending stress related to the web cross-section.

The stress concentration factor for compression (β_Q) in the journal fillet is defined as the ratio of the maximum equivalent von Mises stress (occurring in the fillet due to the radial force) to the nominal compressive stress related to the web cross-section.

The stress concentration factors for torsion (α_T and β_T) are defined as the ratio of the maximum equivalent shear stress (occurring in the fillets under torsional load) to the nominal torsional stress related to the axially bored crankpin or journal cross-section.

The stress concentration factors for bending (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress (occurring at the outlet of the crankpin oil hole under bending and torsional loads) to the corresponding nominal stress related to the axially bored crankpin cross-section.

When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their analysis method have to be submitted to the Society in order to demonstrate their equivalence to the present rule evaluation. This is always to be performed when dimensions are outside of any of the validity ranges for the empirical formulae presented in [3.1.2] to [3.1.4].

Articles [9] and [12] describes how FE analyses can be used for the calculation of the stress concentration factors. Care should be taken to avoid mixing equivalent (von Mises) stresses and principal stresses.

For the calculation of stress concentration factors in crankpin and journal fillets, the related dimensions given in Tab 1 are to be applied.

Stress concentration factors are valid for the following ranges of related dimensions for which the investigations have been carried out:

$0,03 \leq r_H \leq 0,13$

$0,03 \leq r_G \leq 0,13$

$s \leq 0,50$

$0,20 \leq w \leq 0,80$

$1,10 \leq b \leq 2,20$

$0 \leq d_o \leq 0,20$

$0 \leq d_H \leq 0,80$

$0 \leq d_G \leq 0,80$

Low range of s can be extended down to large negative values provided that:

- if the value of calculated factor f(recess) is less than 1, then f(recess) = 1 is to be considered
- if $s < -0,5$ then f(s,w) and f(r,s) are to be evaluated replacing the actual value of s by $s = -0,5$.

Table 1 : Related dimensions for calculation of stress concentration factors

Crankpin fillet	Journal fillet
$r_H = R_H / D$	$r_G = R_G / D$
$s = S / D$	
$w = W / D$ for crankshafts with overlap $w = W_{red} / D$ for crankshafts without overlap	
$b = B / D$	
$d_o = D_O / D$	
$d_H = d_{BH} / D$	$d_G = D_{BG} / D$
$t_H = T_H / D$	$t_G = T_G / D$

3.1.2 Crankpin fillet

a) The stress concentration factor for bending α_B is equal to:

$\alpha_B = 2,6914 \cdot f(s,w) \cdot f_1(w) \cdot f_1(b) \cdot f(r_H) \cdot f(d_G) \cdot f(d_H) \cdot f(recess)$

where:

$f(s,w) = -4,1883 + 29,2004\ w - 77,5925\ w^2 + 91,9454\ w^3 - 40,0416\ w^4 + (1 - s)\ (9,5440 - 58,3480\ w + 159,3415\ w^2 - 192,5846\ w^3 + 85,2916\ w^4) + (1 - s)^2\ (-3,8399 + 25,0444\ w - 70,5571\ w^2 + 87,0328\ w^3 - 39,1832\ w^4)$

$f_1(w) = 2,1790\ w^{0,7171}$

$f_1(b) = 0,6840 - 0,0077\ b + 0,1473\ b^2$

$f(r_H) = 0,2081\ r_H^{-0,5231}$

$f(d_G) = 0,9993 + 0,27\ d_G - 1,0211\ d_G^2 + 0,5306\ d_G^3$

$f(d_H) = 0,9978 + 0,3145\ d_H - 1,5241\ d_H^2 + 2,4147\ d_H^3$

$f(recess) = 1 + (t_H + t_G)\ (1,8 + 3,2\ s)$

b) The stress concentration factor for torsion α_T is equal to:

$\alpha_T = 0,8 \cdot f(r_H,s) \cdot f_2(b) \cdot f_2(w)$

where:

$f(r_H,s) = r_H^x$ with $x = -0,322 + 0,1015\ (1 - s)$

$f_2(b) = 7,8955 - 10,654\ b + 5,3482\ b^2 - 0,857\ b^3$

$f_2(w) = w^{-0,145}$

3.1.3 Journal fillet (not applicable to semi-built crankshaft)

a) The stress concentration factor for bending β_B is equal to:

$\beta_B = 2,7146 \cdot f_B(s,w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r_G) \cdot f_B(d_G) \cdot f_B(d_H) \cdot f(recess)$

where:

$f_B(s,w) = -1,7625 + 2,9821\ w - 1,5276\ w^2 + (1 - s)\ (5,1169 - 5,8089\ w + 3,1391\ w^2) + (1 - s)^2\ (-2,1567 + 2,3297\ w - 1,2952\ w^2)$

$f_B(w) = 2,2422\ w^{0,7548}$

$f_B(b) = 0,5616 + 0,1197\ b + 0,1176\ b^2$

$f_B(r_G) = 0,1908\ r_G^{-0,5568}$

$f_B(d_G) = 1,0012 - 0,6441\ d_G + 1,2265\ d_G^2$

$f_B(d_H) = 1,0022 - 0,1903\ d_H + 0,0073\ d_H^2$

f(recess) : As defined in [3.1.2], item a).

b) The stress concentration factor for compression β_Q due to the radial force is equal to:

$\beta_Q = 3,0128 \cdot f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r_G) \cdot f_Q(d_H) \cdot f(recess)$

where:

$f_Q(s) = 0,4368 + 2,1630\ (1 - s) - 1,5212\ (1 - s)^2$

$$f_Q(w) = \frac{w}{0,0637 + 0,9369w}$$

$f_Q(b) = -0,5 + b$

$f_Q(r_G) = 0,5331\ r_G^{-0,2038}$

$f_Q(d_H) = 0,9937 - 1,1949\ d_H + 1,7373\ d_H^2$

f(recess) : As defined in [3.1.2], item a).

c) The stress concentration factor for torsion β_T is equal to:

- if $D = D_G$ and $R_H = R_G$:

  $\beta_T = \alpha_T$

- if $D \neq D_G$ and/or $R_H \neq R_G$:

  $\beta_T = 0,8 \cdot f(r_H,s) \cdot f_2(b) \cdot f_2(w)$

  with $f(r_H,s)$, $f_2(b)$ and $f_2(w)$ determined in accordance with [3.1.2], item b), but taking $r_H = R_G / D_G$ instead of $r_H = R_H / D$ for the calculation of $f(r_H,s)$.

3.1.4 Outlet of crankpin oil bore

The stress concentration factors for bending γ_B and for torsion γ_T are equal to:

$\gamma_B = 3 - 5,88\ d_o + 34,6\ d_o^2$

$\gamma_T = 4 - 6\ d_o + 30\ d_o^2$

4 Additional bending stresses

4.1 General

4.1.1 In addition to the alternating bending stresses in fillets (see [2.1.3]), further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered, applying σ_{add} as given in Tab 2.

It is recommended that a value of ± 20 N/mm² be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated values may be used instead.

Table 2 : Additional bending stress σ_{add}

Type of engine	σ_{add}, in N/mm²
Crosshead engine	± 30 **(1)**
Trunk piston engine	± 10

(1) The additional stress of ± 30 N/mm² is composed of two components:
- an additional stress of ± 20 N/mm² resulting from axial vibration
- an additional stress of ± 10 N/mm² resulting from misalignment/bedplate deformation.

5 Calculation of equivalent alternating stress

5.1 General

5.1.1 In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time-phased and the corresponding peak values occur at the same location.

As a result, the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet, using von Mises criterion.

At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time-phased.

The above two different ways of equivalent stress evaluation both lead to stresses which may be compared to the same fatigue strength value of crankshaft assessed according to von Mises criterion.

5.2 Equivalent alternating stresses

5.2.1 The equivalent alternating stresses, in N/mm^2, are calculated according to the following formulae:

a) equivalent alternating stress σ'_V in way of crankpin fillet:

$$\sigma'_V = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3\tau_H^2}$$

b) equivalent alternating stress σ''_V in way of journal fillet:

$$\sigma''_V = \pm\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3\tau_G^2}$$

c) equivalent alternating stress σ'''_V in way of outlet of crankpin oil bore:

$$\sigma'''_V = \pm\frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right]$$

6 Calculation of fatigue strength

6.1 General

6.1.1 The fatigue strength is to be understood as that value of von Mises equivalent alternating stress which a crankshaft can permanently withstand at the most highly stressed points.

The fatigue strength may be evaluated by means of the following formulae:

a) allowable alternating bending fatigue strength of crankshaft σ'_{DW}, in N/mm^2, in the crankpin fillet area:

$$\sigma'_{DW} = \pm KR'_m\left(0{,}264 + \frac{1{,}073}{D^{0,2}} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{R_H}}\right)$$

b) allowable alternating bending fatigue strength of crankshaft σ''_{DW}, in N/mm^2, in the journal fillet area:

$$\sigma''_{DW} = \pm KR'_m\left(0{,}264 + \frac{1{,}073}{D_G^{0,2}} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{R_G}}\right)$$

c) allowable alternating bending fatigue strength of crankshaft σ'''_{DW}, in N/mm^2, in the crankpin oil bore area:

$$\sigma'''_{DW} = \pm KR'_m\left(0{,}264 + \frac{1{,}073}{D^{0,2}} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{2}{D_O}}\right)$$

where:

K : Factor equal to:

- for different types of crankshafts without surface treatment (values greater than 1,00 are only applicable to fatigue strength in fillet area):
  - K = 1,05 for continuous grain flow forged or drop-forged crankshafts
  - K = 1,00 for free form forged crankshafts (without continuous grain flow)
- for cast steel crankshafts with cold rolling treatment in fillet area:
  - K = 0,93 for cast steel crankshafts manufactured by companies using a cold rolling process approved by the Society

$R'_m = 0{,}42\ R_m + 39{,}3$

When a surface treatment process is applied, it is to be approved by the Society. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Article [11].

These formulae are subject to the following conditions:

- surfaces of the fillet, the outlet of the oil bore and inside the oil bore (down to a minimum depth equal to 1,5 times the oil bore diameter) are to be smoothly finished
- for calculation of σ'_{DW}, σ''_{DW} and σ'''_{DW}, the values of R_G, R_H and $D_O/2$ are to be taken as not less than 2 mm.

As an alternative, the fatigue strength of the crankshaft can be determined by experiment based either on full size crank throw (or crankshaft) or on specimens taken from a full size crank throw. For evaluation of test results, see Article [10].

7 Acceptability criteria

7.1

7.1.1 The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison has to be carried out for the crankpin fillet, the journal fillet, the outlet of crankpin oil bore and is based on the following acceptability factors Q_i:

$$Q_1 = \frac{\sigma'_{DW}}{\sigma'_V}$$

$$Q_2 = \frac{\sigma''_{DW}}{\sigma''_V}$$

$$Q_3 = \frac{\sigma'''_{DW}}{\sigma'''_V}$$

Adequate dimensioning of the crankshaft is ensured if these acceptability factors satisfy the criterion:

$Q_i \geq 1,15$ with i = 1 to 3

8 Calculation of shrink-fits of semi-built crankshaft

8.1 General

8.1.1 Respecting the radius of the transition R_G from the journal diameter D_G to the shrink diameter D_S, the following criterion is to be complied with:

$R_G \geq \text{Max}\ (0,015\ D_G\ ;\ 0,5\ (D_S - D_G))$

The actual oversize Z of the shrink-fit is to be within the limits Z_{min} and Z_{max} calculated in accordance with [8.3] and [8.4].

In the case where the condition in [8.2] cannot be fulfilled then calculation methods of Z_{min} and Z_{max} according to [8.3] and [8.4] are not applicable due to multizone-plasticity problems.

In such a case, Z_{min} and Z_{max} have to be established based on FEM calculations.

8.2 Maximum permissible hole in journal pin

8.2.1 The hole diameter in the journal pin D_{BG}, in mm, is to satisfy the following criterion:

$$D_{BG} \leq D_S \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot R_{SP}}}$$

where:

D_S, L_S : As defined in Symbols

S_R : Safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments

M_{max} : Absolute maximum value of the torque M_{Tmax} (see Symbols), in N·m

μ : Coefficient for static friction, however a value not greater than 0,2 is to be taken unless documented by experiments

R_{SP} : Minimum yield strength of material for journal pin, in N/mm^2.

This condition serves to avoid plasticity in the hole of the journal pin.

8.3 Necessary minimum oversize of shrink-fit

8.3.1 The necessary minimum oversize Z_{min} of the shrink-fit, in mm, is determined by the greater value calculated according to:

$$Z_{min} \geq \frac{R_{SW} \cdot D_S}{E_m}$$

and

$$Z_{min} \geq \frac{4000}{\pi \cdot \mu} \cdot \frac{S_R \cdot M_{max}}{E_m \cdot D_S \cdot L_S} \cdot \frac{1 - \left(\frac{D_S}{D_A}\right)^2 \cdot \left(\frac{D_{BG}}{D_S}\right)^2}{\left[1 - \left(\frac{D_S}{D_A}\right)^2\right] \cdot \left[1 - \left(\frac{D_{BG}}{D_S}\right)^2\right]}$$

where:

R_{SW} : Minimum yield strength of material for crank web, in N/mm^2

E_m : Young's modulus of material for crank web, in N/mm^2

μ, S_R, M_{max} : As defined in [8.2.1].

8.4 Maximum permissible oversize of shrink-fit

8.4.1 The maximum permissible oversize Z_{max} of the shrink-fit, in mm, is calculated according to:

$$Z_{max} \leq \frac{R_{SW} \cdot D_S}{E_m} + \frac{0{,}8 D_S}{1000}$$

where:

R_{SW}, D_S, E_m : As defined in [8.3.1].

This condition concerning the maximum permissible oversize serves to restrict the shrinkage induced mean stress in the journal fillet.

9 Guidance for calculation of stress concentration factors in the web fillet radii of crankshafts by utilizing FEM

9.1 General

9.1.1 The objective of the analysis is to develop Finite Element Method (FEM) calculated figures as an alternative to the analytically calculated stress concentration factors (SCF) at the crankshaft fillets. The analytical method is based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of these formulae is limited to those geometries.

The SCFs calculated according to this Appendix are defined as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the method of the present Article [9] or with the alternative methods, von Mises stresses shall be calculated for bending and principal stresses for torsion.

The procedure, as well as evaluation guidelines, are valid for both solid cranks and semi-built cranks (except journal fillets).

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

The calculation of SCF at the oil bores is not covered by this Appendix.

It is advised to check the element accuracy of the FE solver in use, e.g. by modeling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

Boundary Element Method (BEM) may be used instead of FEM.

9.2 Model requirements

9.2.1 The basic recommendations and perceptions for building the FE-model are presented in [9.2.2]. It is obligatory for the final FE-model to fulfill the requirement in [9.2.4].

9.2.2 Element mesh recommendations

In order to fulfil the mesh quality criteria it is advised to construct the FE model for the evaluation of Stress Concentration Factors according to the following recommendations:

a) The model consists of one complete crank, from the main bearing centreline to the opposite side main bearing centreline.

b) Element types used in the vicinity of the fillets:
- 10 node tetrahedral elements
- 8 node hexahedral elements
- 20 node hexahedral elements.

c) Mesh properties in fillet radii

The following applies to ±90 degrees in circumferential direction from the crank plane:
- Maximum element size a = r / 4 through the entire fillet as well as in the circumferential direction.

  When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to 5 a.

  In the case of multi-radii fillet, r is the local fillet radius.

  If 8 node hexahedral elements are used even smaller element size is required to meet the quality criteria.

- Recommended manner for element size in fillet depth direction:
  - 1rst layer thickness equal to element size of a
  - 2nd layer thickness equal to element size of 2 a
  - 3rd layer thickness equal to element size of 3 a
- Minimum 6 elements across web thickness

d) Generally the rest of the crank should be suitable for numeric stability of the solver

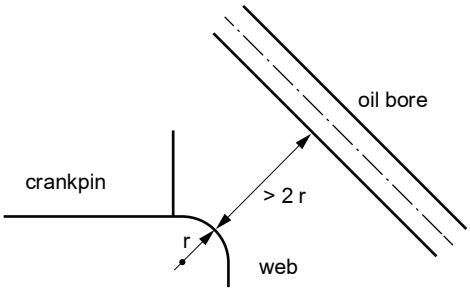
e) Counterweights have to be modeled only when influencing the global stiffness of the crank significantly

f) Modeling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than 2 r (see Fig 6)

g) Drillings and holes for weight reduction have to be modeled

h) Sub-modeling may be used as far as the software requirements are fulfilled.

Figure 6 : Oil bore proximity to fillet



9.2.3 Material

The present Appendix does not consider material properties such as Young's Modulus (E) and Poisson's ratio (ν). In FE analysis, those material parameters are required, as strain is primarily calculated and stress is derived from strain using the Young's Modulus and Poisson's ratio.

Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

For steel, the following values are advised:

$E = 2{,}05\ 10^5$ MPa and $\nu = 0{,}3$

9.2.4 Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed:

- Principal stress criterion

  The quality of the mesh should be assured by checking the stress component normal to the surface of the fillet radius. Ideally, this stress should be zero. With principal stresses σ_1, σ_2 and σ_3, the following criterion is required:

  $\text{Min}(|\sigma_1| ; |\sigma_2| ; |\sigma_3|) < 0{,}03\ \text{Max}(|\sigma_1| ; |\sigma_2| ; |\sigma_3|)$

- Averaged / unaveraged stress criterion

  The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF.

  Unaveraged nodal stress results calculated from each element connected to a node i should differ less than by 5% from the 100% averaged nodal stress results at this node i at the examined location.

9.3 Load cases

9.3.1 To substitute the analytically determined SCF in this Appendix, the following load cases have to be calculated.

9.3.2 Torsion

In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in pure torsion. In the model, surface warp at the end faces is suppressed.

Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions (see Fig 7) are valid for both in-line and V-type engines.

For all nodes in both the journal and crank pin fillets, principal stresses are extracted and the equivalent torsional stress τ_{equiv} is calculated:

$$\tau_{equiv} = \text{Max}\left(\frac{|\sigma_1 - \sigma_2|}{2} ; \frac{|\sigma_2 - \sigma_3|}{2} ; \frac{|\sigma_1 - \sigma_3|}{2}\right)$$

The maximum value for crankpin fillet $\tau_{equiv,\alpha}$ and for journal fillet $\tau_{equiv,\beta}$ is used for the subsequent calculation of the SCF α_T and β_T:

$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_{NH}}$$

$$\beta_T = \frac{\tau_{equiv,\beta}}{\tau_{NG}}$$

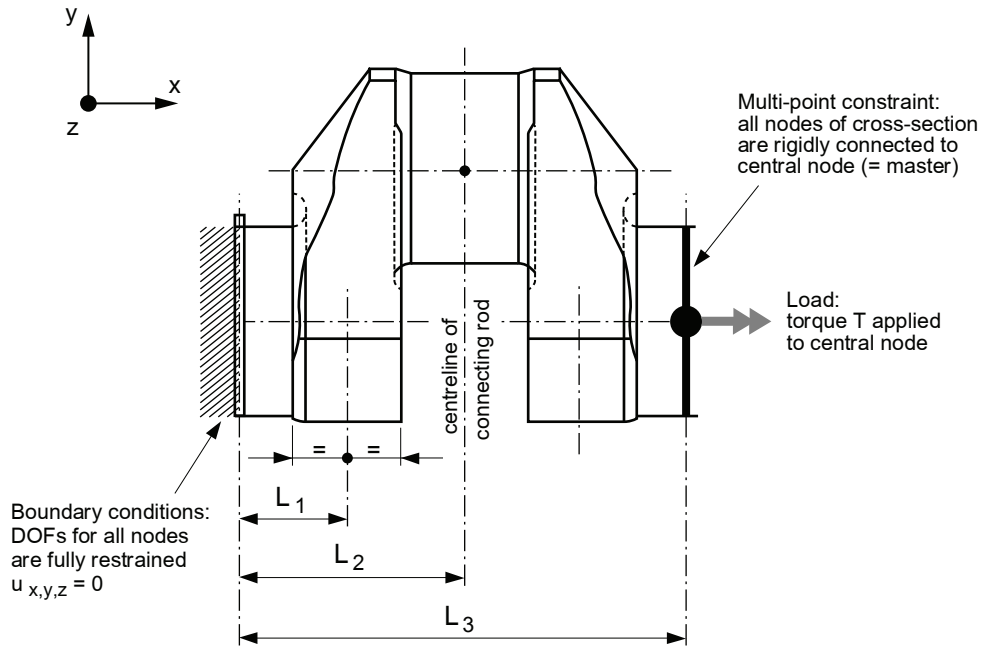
where:

τ_{NH}, τ_{NG} : Nominal torsional stresses, in N/mm², referred to the crankpin and the journal, respectively, and calculated as per [2.2.2] with the torsional torque T (see Fig 7):

$$\tau_{NH} = \pm \frac{T}{W_{PH}} \cdot 10^3$$

$$\tau_{NG} = \pm \frac{T}{W_{PG}} \cdot 10^3$$

Figure 7 : Boundary and load conditions for the torsion load case



9.3.3 Pure bending (4-point bending)

In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in pure bending. In the model, surface warp at the end faces is suppressed.

The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions (see Fig 8) are valid for both in-line- and V- type engines.

For all nodes in both the journal and crankpin fillets, von Mises equivalent stresses σ_{equiv} are extracted.

The maximum value for crankpin fillet $\sigma_{equiv,\alpha}$ and for journal fillet $\sigma_{equiv,\beta}$ is used for the subsequent calculation of the SCF α_B and β_B:

$$\alpha_B = \frac{\sigma_{equiv,\alpha}}{\sigma_N}$$

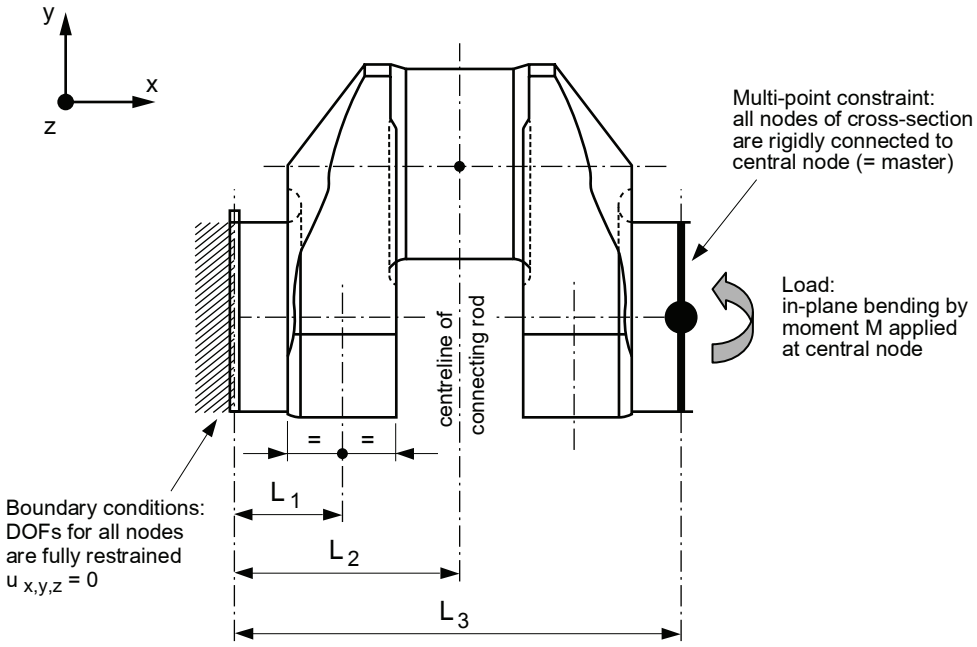
$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_N}$$

where:

σ_N : Nominal bending stress, in N/mm², related to the web cross-section and calculated as per [2.1.2] item b) with the bending moment M (see Fig 8):

$$\tau_N = \pm \frac{M}{W_{eqw}} \cdot 10^3$$

Figure 8 : Boundary and load conditions for the pure bending load case



9.3.4 Bending with shear force (3-point bending)

This load case is calculated to determine the SCF for pure transverse force (radial force, β_Q) for the journal fillet.

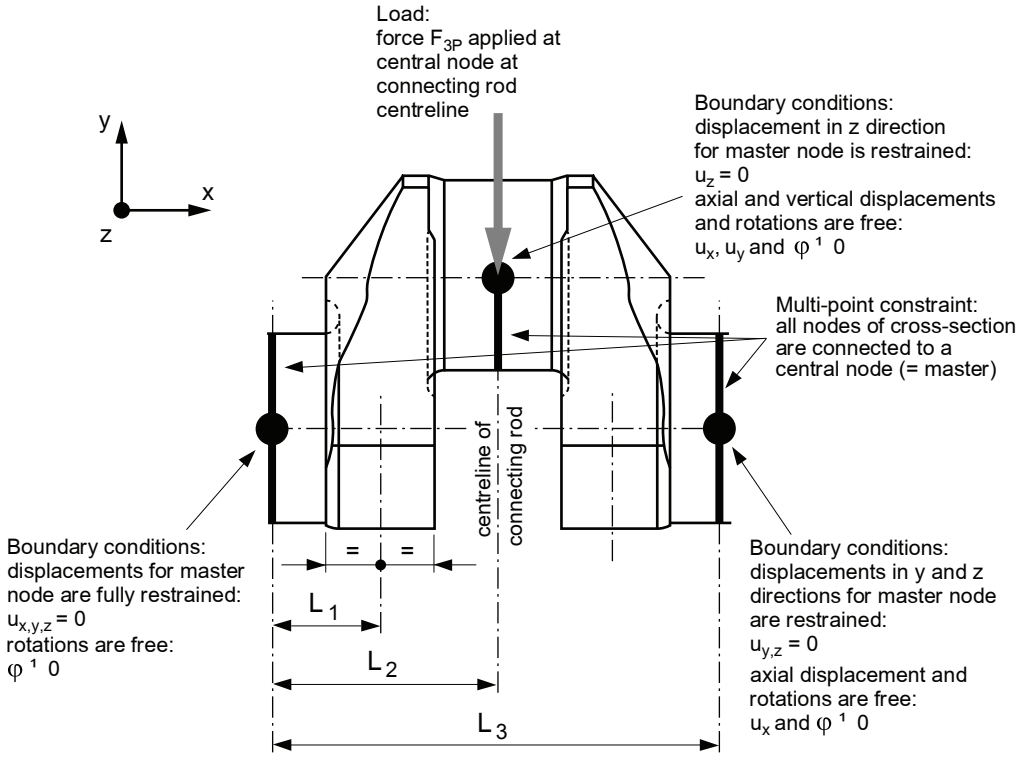
In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in 3-point bending. In the model, surface warp at the both end faces is suppressed.

All nodes are connected rigidly to the central node; boundary conditions are applied to the central nodes. These nodes act as master nodes with 6 degrees of freedom.

The force is applied to the central node located at the pin centreline of the connecting rod. This node is connected to all nodes of the pin cross-sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions are valid for in-line engines (see Fig 9) and V-type engines. V-type engines can be modeled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

Figure 9 : Boundary and load conditions for the 3-point bending load case of an in-line engine



The maximum equivalent von Mises stress σ_{3P} in the journal fillet is evaluated. The SCF in the journal fillet can be determined with one of the two following methods:

a) Method 1

This method is analogue to the FVV investigation. The results from 3-point and 4-point bending are combined as follows:

$$\sigma_{3P} = \sigma_{N3P}\,\beta_B + \sigma_{Q3P}\,\beta_Q$$

where:

σ_{3P} : As found by the FE calculation

σ_{N3P} : Nominal bending stress in the web centre due to the force F_{3P}, in N, applied to the centreline of the actual connecting rod (see Fig 10)

β_B : SCF as determined in [9.3.3]

$$\sigma_{Q3P} = \frac{Q_{3P}}{BW}$$

with:

Q_{3P} : Radial (shear) force in the web due to the force F_{3P}, in N, applied to the centreline of the actual connecting rod (see also Fig 2).

b) Method 2

This method is not analogous to the FVV investigation. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the SCF in the journal fillet can be found directly by the 3-point bending FE calculation.

The SCF is then calculated according to:

$$\beta_{BQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

where:

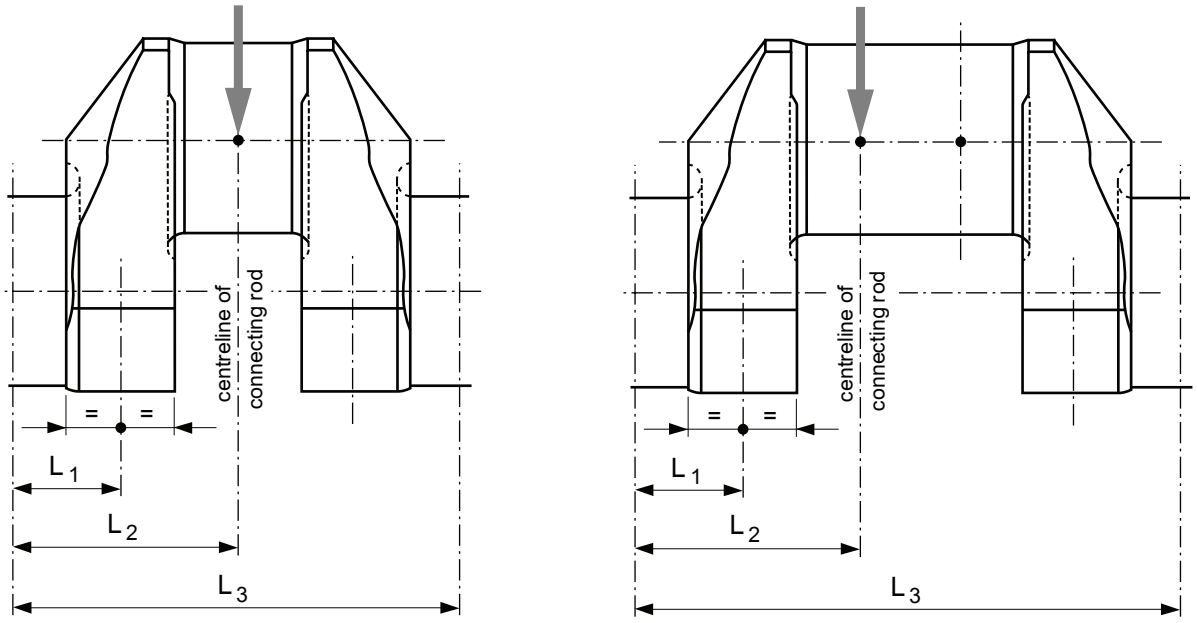
σ_{3P}, σ_{N3P}: As defined in item a) above.

When using this method, the radial force and stress determination in this Appendix becomes superfluous. The alternating bending stress in the journal fillet as per [2.1.3] is then evaluated:

$$\sigma_{BG} = \pm\,|\beta_{BQ} \cdot \sigma_{BFN}|$$

Note 1: The use of this method does not apply to the crankpin fillet and this SCF must not be used in connection with calculation methods other than those assuming a statically determined system as in this Appendix.

Figure 10 : Load applications for in-line and V-type engines



10 Guidance for evaluation of fatigue tests

10.1 Introduction

10.1.1 Fatigue testing can be divided into two main groups; testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

10.1.2 Small specimen testing

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes e.g. axial, bending and torsion, with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

10.1.3 Full-size crank throw testing

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3 or 4 point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to R = –1.

10.2 Evaluation of test results

10.2.1 Principles

Prior to fatigue testing the crankshaft must be tested as required by quality control procedures, e.g. for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.

The test samples should be prepared so as to represent the “lower end” of the acceptance range e.g. for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc. Otherwise the mean value test results should be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in this Appendix, shall be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90% confidence interval as mentioned above. The standard deviation should be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation must be based on the real (measured) mechanical properties, not on the specified minimum properties.

The calculation technique presented in [10.2.4] was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

10.2.2 Staircase method

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous, i.e. a survivor is always followed by the next using a stress one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 10^7 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

10.2.3 Modified staircase method

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this same specimen is subjected to a stress level one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation. This is continued with the same specimen until failure.

Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens. The number of run-outs, counted as the highest level where 10^7 cycles were reached, also equals the number of specimens.

The acquired result of a modified staircase method should be used with care, since some results available indicate that testing a runout on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this "training effect" is less pronounced for high strength steels (e.g. UTS > 800 MPa).

If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

10.2.4 Calculation of sample mean and standard deviation

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:

- Number of samples:

  n = 10

Furthermore, the method distinguishes between:

- Less frequent event is failures:

  C = 1

- Less frequent event is run-outs:

  C = 2

The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.

In the modified staircase method, the number of run-outs and failures are usually equal. However, the testing can be unsuccessful, e.g. the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure. On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.

Dixon and Mood's approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test. The sample mean can be calculated as follows:

$$\overline{S_a} = S_{a0} + d\left(\frac{A}{F} - \frac{1}{2}\right) \qquad \text{when} \qquad C = 1$$

$$\overline{S_a} = S_{a0} + d\left(\frac{A}{F} + \frac{1}{2}\right) \qquad \text{when} \qquad C = 2$$

The standard deviation can be found by:

$$s = 1,62\,d\left(\frac{FB - A^2}{F^2} + 0,029\right)$$

where:

S_{aO} : Lowest stress level for the less frequent occurrence

d : Stress increment

$F = \Sigma\, fi$

$A = \Sigma i\, fi$

$B = \Sigma i^2\, fi$

i : Stress level numbering

fi : Number of samples at stress level i.

The formula for the standard deviation is an approximation and can be used when:

$$\frac{BF - A^2}{F^2} > 0,3 \qquad \text{and} \qquad 0,5s < d < 1,5s$$

If any of these two conditions are not fulfilled, a new staircase test should be considered or the standard deviation should be taken quite large in order to be on the safe side.

If increment d is greatly higher than the standard deviation s, the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference between the increment and the standard deviation is relatively small. Respectively, if increment d is much less than the standard deviation s, the procedure leads to a higher standard deviation and a slightly lower sample mean.

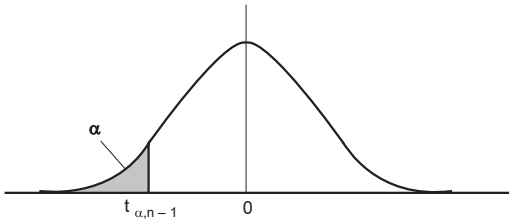
10.2.5 Confidence interval for mean fatigue limit

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.

The confidence interval for the sample mean value with unknown variance is known to be distributed according to the t-distribution (also called student's t-distribution) which is a distribution symmetric around the average.

Note 1: The confidence level normally used for the sample mean is 90%, meaning that 90% of sample means from repeated tests will be above the value calculated with the chosen confidence level. Fig 11 shows the t value for $(1 - \alpha)$ 100% confidence interval for the sample mean.

Figure 11 : Student's t-distribution



If S_a is the empirical mean and s is the empirical standard deviation over a series of n samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the $(1 - \alpha)$ 100% confidence interval for the mean is:

$$P\left(S_a - t_{\alpha, n-1}\frac{s}{\sqrt{n}} < S_{aX\%}\right) = 1 - a$$

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{aX\%} = S_a - t_{\alpha, n-1}\frac{s}{\sqrt{n}}$$

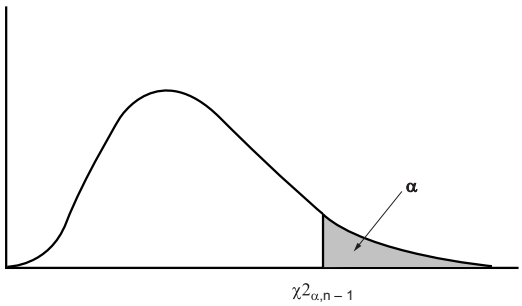
which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

10.2.6 Confidence interval for standard deviation

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with n – 1 degrees of freedom.

Note 1: The confidence level on the standard deviation is used to ensure that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. Fig 12 shows the chi-square for $(1 - \alpha)$ 100% confidence interval for the variance.

Figure 12 : Chi-square distribution



An assumed fatigue test value from n samples is a normal random variable with a variance of σ^2 and has an empirical variance α^2. Then a $(1 - \alpha)$ 100% confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < \chi^2_{a, n-1}\right) = 1 - \alpha$$

A $(1 - \alpha)$ 100% confidence interval for the standard deviation is obtained by the square root of the upper limit of the confidence interval for the variance and can be found by:

$$s_{\chi\%} = \sqrt{\frac{n-1}{\chi^2_{a, n-1}}}s$$

This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

10.3 Small specimen testing

10.3.1 In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens shall be representative for the fillet fatigue strength, they should be taken out close to the fillets, as shown in Fig 13.

It should be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilizing the finite element method.

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

10.3.2 Determination of bending fatigue strength

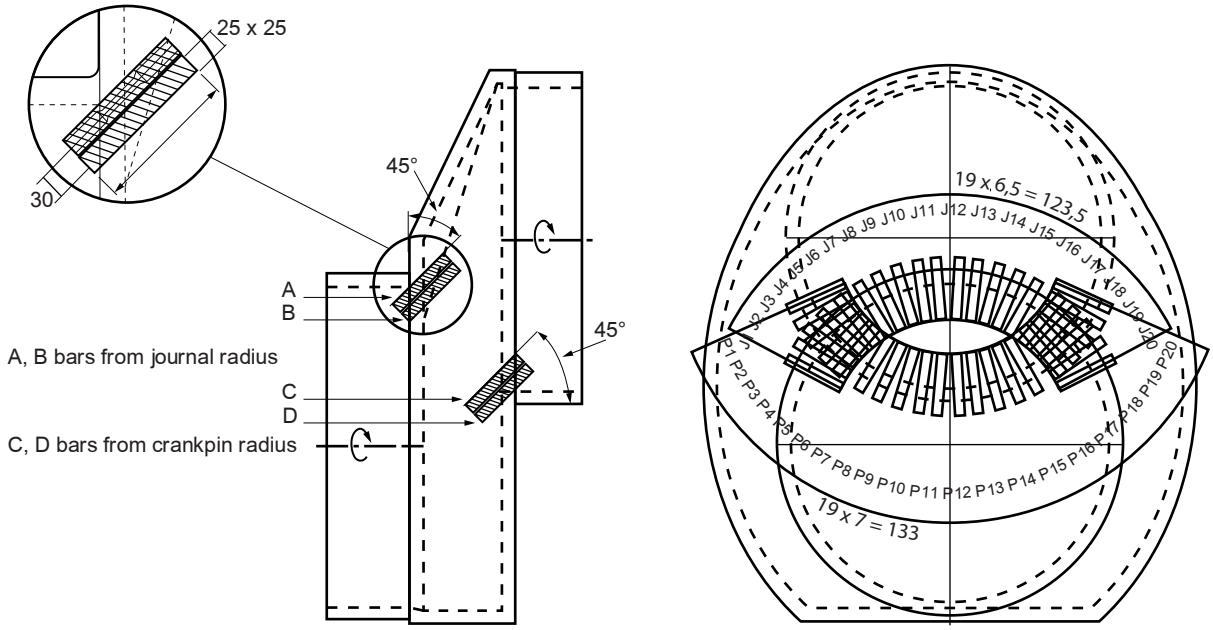
It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio R = -1) is preferred, but especially for the purpose of critical plane criteria other stress ratios and methods may be added.

In order to ensure principal stress direction in push-pull testing to represent the full-size crank throw principal stress direction and when no further information is available, the specimen shall be taken in 45 degrees angle as shown in Fig 13.

a) If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See Fig 13.

b) If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens should be restricted to the vicinity of the crank plane.

Figure 13 : Specimen locations in a crank throw



10.3.3 Determination of torsional fatigue strength

a) If the specimens are subjected to torsional testing, the selection of samples should follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.

b) If the specimens are tested in push-pull and no further information is available, the samples should be taken out at an angle of 45 degrees to the crank plane in order to ensure collinearity of the principal stress direction between the specimen and the full size crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin centre point making it possible to resample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

10.3.4 Other test positions

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to cgf, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it must be considered how well the grain flow in that shaft piece is representative for the crank fillets.

10.3.5 Correlation of test results

The fatigue strength achieved by specimen testing shall be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).

When using the bending fatigue properties from tests mentioned in this section, it should be kept in mind that successful continuous grain flow (cgf) forging leading to elevated values compared to other (non cgf) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.

In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength, e.g. by using no credit for cgf. This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognized when using the von Mises or a multi-axial criterion such as Findley.

If the found ratio between bending and torsion fatigue differs significantly from $3^{1/2}$, one should consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it must be kept in mind that cgf makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.

Any addition of influence factors must be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a K-factor for cgf. Direct testing of samples from a clean and cgf forged crank is preferred.

10.4 Full size testing

10.4.1 Hydraulic pulsation

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any R-ratio.

Although the applied load should be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains.

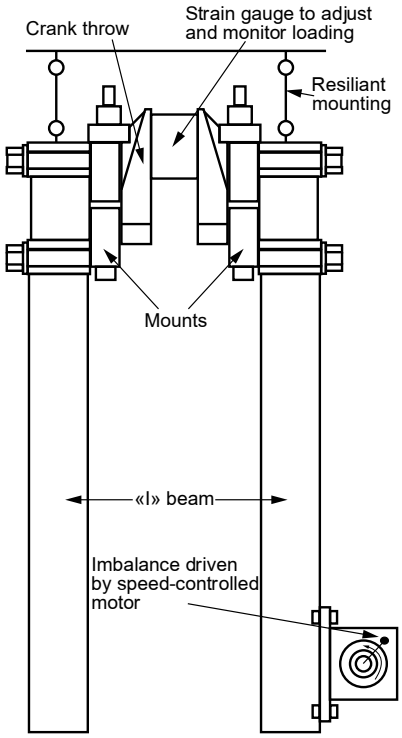
Furthermore, it is important that the test rig provides boundary conditions as defined in [9.3.2] to [9.3.4]).

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

10.4.2 Resonance tester

A rig for bending fatigue normally works with an R-ratio of -1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 10^7 cycles can be reached within some days. Fig 14 shows a layout of the testing arrangement.

Figure 14 : An example of testing arrangement of the resonance tester for bending loading



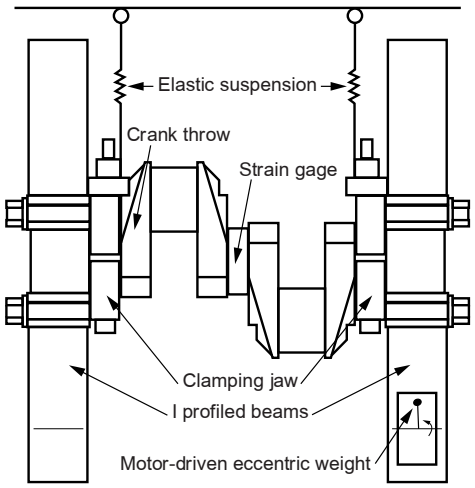
The applied load should be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.

In an engine, the crankpin fillets normally operate with an R-ratio slightly above –1 and the journal fillets slightly below –1. If found necessary, it is possible to introduce a mean load (deviate from R = –1) by means of a spring preload.

A rig for torsion fatigue can also be arranged as shown in Fig 15. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.

Figure 15 : An example of testing arrangement of the resonance tester for torsion loading with double crank throw section



This sideway movement of the clamped-on weights can be reduced by having two crank throws, especially if the cranks are almost in the same direction. However, the journal in the middle will move more.

Since sideway movements can cause some bending stresses, the plain portions of the crankpins should also be provided with strain gauge arranged to measure any possible bending that could have an influence on the test results.

Similarly, to the bending case the applied load shall be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

10.4.3 Use of results and crankshaft acceptability

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability, (see Article [7]), the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

- At the crankpin fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}}\right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}}\right)^2}\right)^{-1}$$

where:

σ_{DWCT} : Fatigue strength by bending testing

τ_{DWCT} : Fatigue strength by torsion testing

σ_{BH} : as defined in [2.1.3]

τ_H : as defined in [2.2.3]

σ_{add} : as defined in [4].

- Related to the crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_v}$$

$$\sigma_v = \frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right]$$

σ_{DWOT} : Fatigue strength by means of largest principal strength from torsion testing.

- At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$

σ_{DWJT} : Fatigue strength by bending testing

τ_{DWJT} : Fatigue strength by torsion testing.

σ_{BG} : as defined in [2.1.3]

τ_G : as defined in [2.2.3]

σ_{add} : as defined in [4].

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

10.5 Use of existing results for similar crankshafts

10.5.1 For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

- Material:
  - Similar material type
  - Cleanliness on the same or better level
  - The same mechanical properties can be granted (size versus hardenability)
- Geometry:
  - Difference in the size effect of stress gradient is insignificant or it is considered
  - Principal stress direction is equivalent. See [10.3].
- Manufacturing:
  - Similar manufacturing process.

Induction hardened or gas nitrited crankshafts will suffer fatigue either at the surface or at thetransition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately ± 30% of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

Note 1: The fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point. In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 10^7. Based on a publication by Yukitaka Murakami “Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions” the reduction is suggested to be 5% per decade especially when the hydrogen content is considered to be high.

11 Guidance for calculation of surface treated fillets and oil bore outlets

11.1 Introduction

11.1.1 This Article deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formula are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint.

Note 1: Measurements or more specific knowledge should be used if available. However, in the case of a wide scatter (e.g. for residual stresses) the values should be chosen from the end of the range that would be on the safe side for calculation purposes.

11.2 Definition of surface treatment

11.2.1 “Surface treatment” is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties such as hardness, chemistry or residual stresses from the surface to the core.

11.2.2 Surface treatment methods

Tab 3 covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this document. In addition, die quenching can be considered in the same way as induction hardening.

Table 3 : Surface treatment methods and the characteristics they affect.

Treatment method	Affecting		
	chemistry	hardness	residual stresses
Induction hardening	-	X	X
Nitriding	X	X	X
Case hardening	X	X	X
Die quenching (no temper)	-	X	X
Cold rolling	-	-	X
Stroke peening	-	-	X
Shot peening	-	-	X
Laser peening	-	-	X
Ball coining	-	-	X

11.3 Calculation principles

11.3.1 The basic principle is that the alternating working stresses shall be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also [11.6.2] for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment-affected zone i.e. to cover the depth all the way to the core.

Consideration of the local fatigue strength shall include the influence of the local hardness, residual stress and mean working stress. The influence of the 'giga-cycle effect', especially for initiation of subsurface cracks, should be covered by the choice of safety margin.

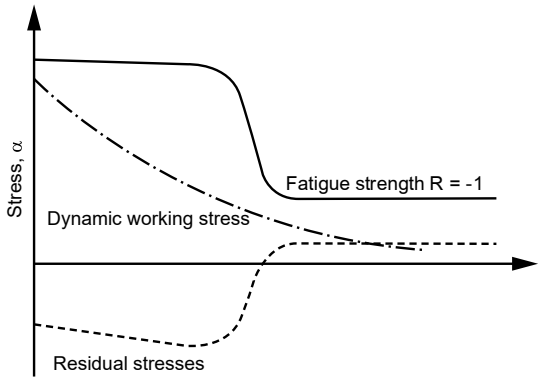
It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses.

This forms a 'weak spot' and is important if it coincides with an area of high stresses.

Alternating and mean working stresses must be known for the entire area of the stress concentration as well as to a depth of about 1,2 times the depth of the treatment. Fig 16 indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour.

The acceptability criterion should be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

Figure 16 : Stresses as functions of depth, general principles



11.3.2 Evaluation of local fillet stresses

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally this will be found via FEA as described in Article [9]. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer. If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in Article [3] if within its validity range, and a relative stress gradient inversely proportional to the fillet radius. Bending and torsional stresses must be addressed separately. The combination of these is addressed by the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B\text{-local}}$ and $\alpha_{T\text{-local}}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B\text{-local}}$ and $\alpha_{T\text{-local}}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin fillets they can be simplified to $2/R_H$ in bending and $1/R_H$ in

torsion. The journal fillets are handled analogously by using R_G and D_G. The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs are then functions of depth t:

- for bending (see Fig 17):

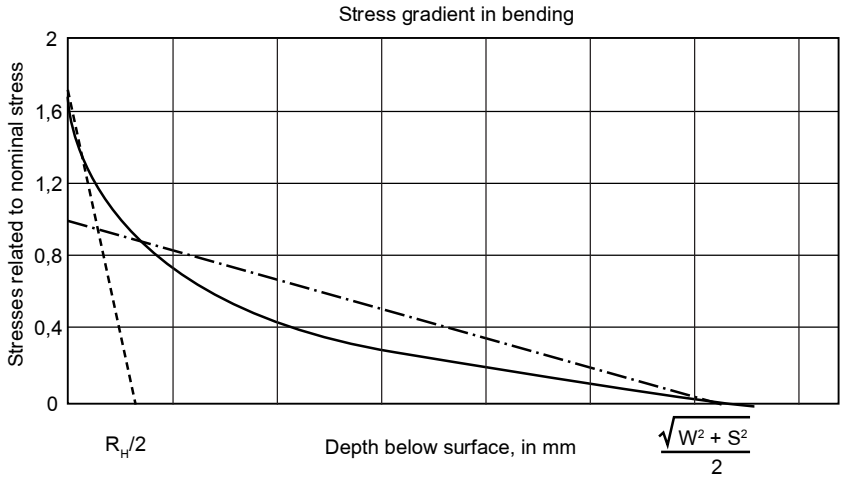
$$\alpha_{B-local} = (\alpha_B - 1)e^{\frac{-2t}{R_H}} + 1 - \left(\frac{2t}{\sqrt{W^2 + S^2}}\right)^{\frac{0,6}{\sqrt{\alpha_B}}}$$

- for torsion (see Fig 18):

$$\alpha_{T-local} = (\alpha_T - 1)e^{\frac{-t}{R_H}} + 1 - \left(\frac{2t}{D}\right)^{\frac{1}{\sqrt{\alpha_T}}}$$

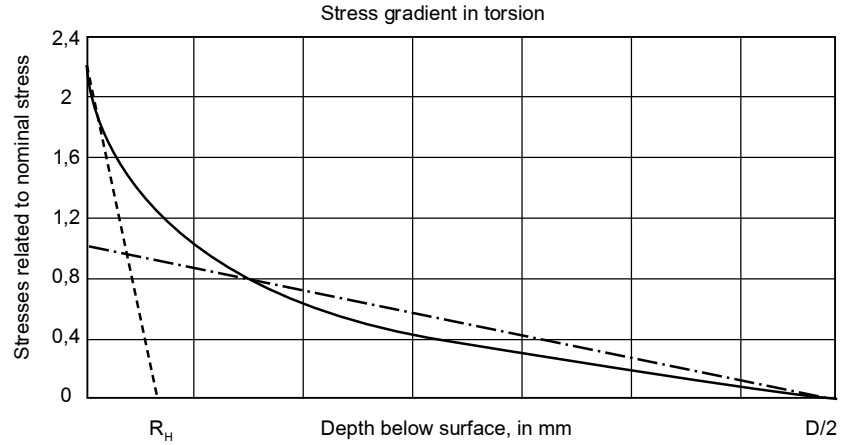
If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA should be used to determine the actual stresses in the transition zone.

Figure 17 : Bending SCF in the crankpin fillet as a function of depth.



The corresponding SCF for the journal fillet can be found by replacing R_H with R_G.

Figure 18 : Torsional SCF in the crankpin fillet as a function of depth.



The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G.

11.3.3 Evaluation of oil bore stresses

Stresses in the oil bores can be determined also by FEA. The element size should be less than 1/8 of the oil bore diameter D_0 and the element mesh quality criteria should be followed as prescribed in Article [9]. The fine element mesh should continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque, see [9.3.2] and the bending moment, with four-point bending as in [9.3.3].

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from Article [3] if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in Article [5].

Fig 19 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.

The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the centre of the pin. As can be seen from Fig 19, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion (1-2tH/D) of the peak stresses where tH is the hardening depth.

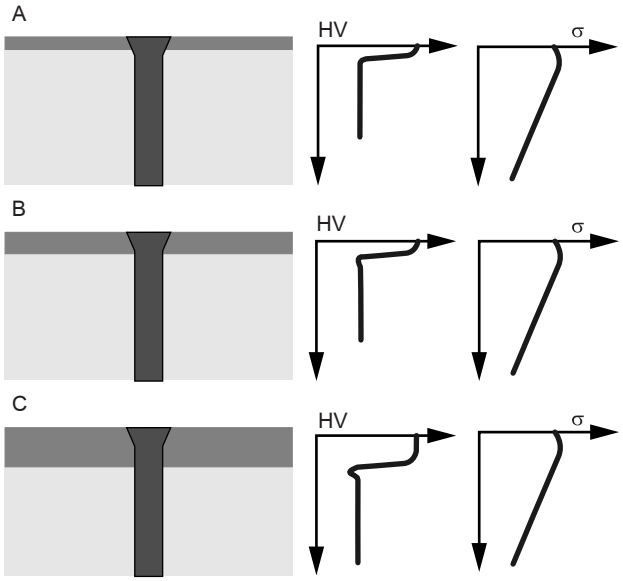
The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B\text{-local}}$ and $\gamma_{T\text{-local}}$ have different shapes, because of the different stress gradients.

The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B\text{-local}}$ and $\gamma_{T\text{-local}}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth t:

$$\gamma_{B-local} = (\gamma_B - 1)e^{\frac{-4t}{D_o}} + 1$$

$$\gamma_{T-local} = (\gamma_T - 1)e^{\frac{-2t}{D_o}} + 1$$

Figure 19 : Stresses and hardness in induction hardened oil holes



11.3.4 Acceptability criteria

Acceptance of crankshafts is based on fatigue considerations; This Appendix compares the equivalent alternating stress and the fatigue strength ratio to an acceptability factor of Q ≥ 1,15 for oil bore outlets, crankpin fillets and journal fillets. This shall be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

11.4 Introduction hardening

11.4.1 Generally, the hardness specification shall specify the surface hardness range i.e. minimum and maximum values, the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be HV0,5...HV5.

The induction hardening depth is defined as the depth where the hardness is 80% of the minimum specified surface hardness.

In the case of crankpin or journal hardening only, the minimum distance to the fillet shall be specified due to the tensile stress at the heat-affected zone as shown in Fig 20.

If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:

- the hardness profile consists of two layers (see Fig 21):
  - constant hardness from the surface to the transition zone
  - constant hardness from the transition zone to the core material
- residual stresses in the hard zone of 200 MPa (compression)
- transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided
- transition-zone maximum residual stresses (von Mises) of 300 MPa tension.

If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

Figure 20 : Residual stresses along the surface of a pin and fillet

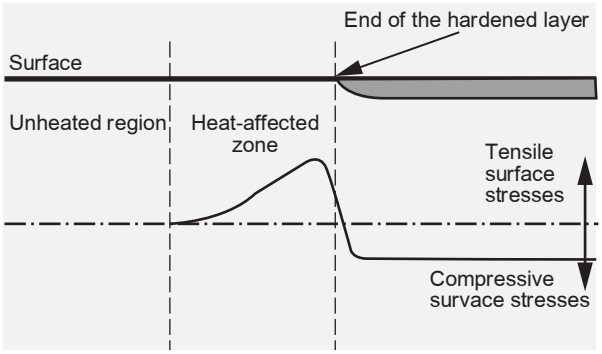
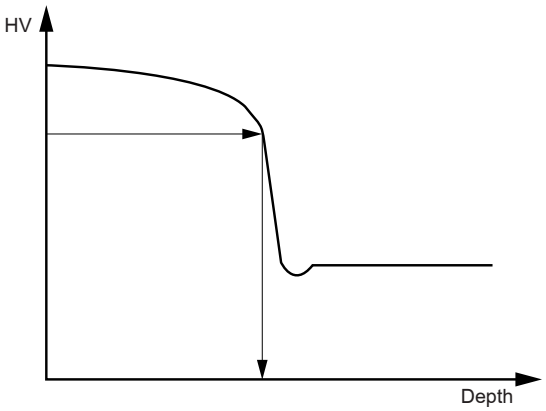


Figure 21 : Typical hardness as a function of depth.



The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur.

11.4.2 Local fatigue strength

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in Article [10]. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends. Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.

Alternatively, the surface fatigue strength can be determined empirically as follows where HV is the surface Vickers hardness. The following formula provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of R = –1:

$\sigma_{Fsurface} = 400 + 0,5\ (HV - 400)$

Note 1: It has to be noted also that the mean stress influence of induction-hardened steels may be significantly higher than that for QT steels.

The fatigue strength in the transition zone, without taking into account any possible local hardness drop, shall be determined by the equation introduced in Article [6].

For journal and respectively to crankpin fillet applies:

$$\sigma_{Ftransition,\ cpin} = \pm K(0,42R_m + 39,3)$$
$$\left[0,264 + 1,073Y^{-0,2} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{X}}\right]$$

where:

- for journal fillet: $Y = D_G$ and $X = R_G$
- for crankpin fillet: $Y = D$ and $X = R_H$
- for oil bore outlet: $Y = D$ and $X = Do/2$

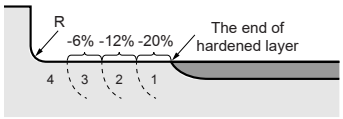
The influence of the residual stress is not included in the above formula.

For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.

When the residual stresses are known to be lower, also smaller value of subtraction shall be used. For low-strength steels the percentage chosen should be higher.

For the purpose of considering surface fatigue near the end of the hardened zone (i.e. in the heat-affected zone shown in the Fig 20) the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with Tab 4, from the value determined by the above formula.

Table 4 : The influence of tensile residual stresses at a given distance from the end of the hardening towards the fillet

Maximum hardening depth			%
	1	0 to 1,0	20
	2	1,0 to 2,0	12
	3	2,0 to 3,0	6
	4	3,0 or more	0

11.5 Nitriding

11.5.1 The hardness specification shall include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be HV0,5.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth tN as the depth to a hardness of 50 HV above the core hardness.

The hardening profile should be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core})\left(\frac{50}{HV_{surface} - HV_{core}}\right)^{\left(\frac{t}{t_N}\right)^2}$$

where:

t : Local depth

HV(t) : Hardness at depth t

HV_{core} : Core hardness (minimum)

$HV_{surface}$: Surface hardness (minimum)

tN : Nitriding depth as defined above (minimum).

11.5.2 Local fatigue strength

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in Article [10].

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$\sigma_{Fsurface}$ = 450 Mpa

Note 1: This fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of R = –1.

The fatigue strength in the transition zone can be determined by the equation introduced in Article [6]. For crankpin and respectively to journal applies:

$$\sigma_{Ftransition,\ cpin} = \pm K(0,42R_m + 39,3)$$

$$\left[0,264 + 1,073Y^{-0,2} + \frac{785 - R_m}{4900} + \frac{196}{R_m}\sqrt{\frac{1}{X}}\right]$$

where:

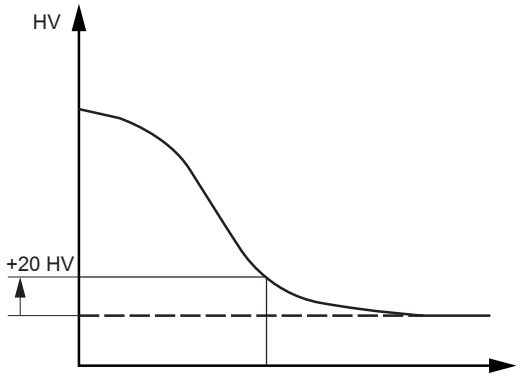
- for journal fillet: $Y = D_G$ and $X = R_G$
- for crankpin fillet: $Y = D$ and $X = R_H$
- for oil bore outlet: $Y = D$ and $X = Do/2$

Note 2: This fatigue strength is not assumed to include the influence of the residual stresses.

In contrast to induction-hardening the nitrited components have no such distinct transition to the core. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation should be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material should be used. This means that the stresses at the transition to the core can be found by using the local SCF formula mentioned earlier when inserting t = 1,2tN.

Figure 22 : Sketch of the location for the artificial transition point in the depth direction



11.6 Cold forming

11.6.1 The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formula are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also Article [10]. Such testing is normally carried out as four-point bending, with a working stress ratio of R = –1. From these results, the bending fatigue strength, surface or subsurface-initiated depending on the manner of failure can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio (utilized by the von Mises criterion) $3^{1/2}$. The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q + T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming must be proportional to the fillet radius.

11.6.2 Stroke peening by means of a ball

The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio $3^{1/2}$, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-peened material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual stresses below the surface ‘arrest’ small surface cracks.

This is illustrated in Fig 23 as gradient load 2.

In fatigue testing with full-size crankshafts these small “hairline cracks” should not be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, should be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts’ fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the base material. The effect on the fatigue strength of induction hardening and stroke peening the fillets shall be determined by a full-size crankshaft test.

11.6.3 Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved by applying stroke peening (see [11.6.2]), may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- ball size relative to fillet radius within ±10% in comparison to the tested crankshaft
- at least the same circumferential extension of the stroke peening
- angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- similar base material, e.g. alloyed quenched and tempered
- forward feed of ball of the same proportion of the radius
- force applied to ball proportional to base material hardness (if different)
- force applied to ball proportional to square of ball radius.

11.6.4 Cold rolling

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio $3^{1/2}$, the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-rolled material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-rolled material.

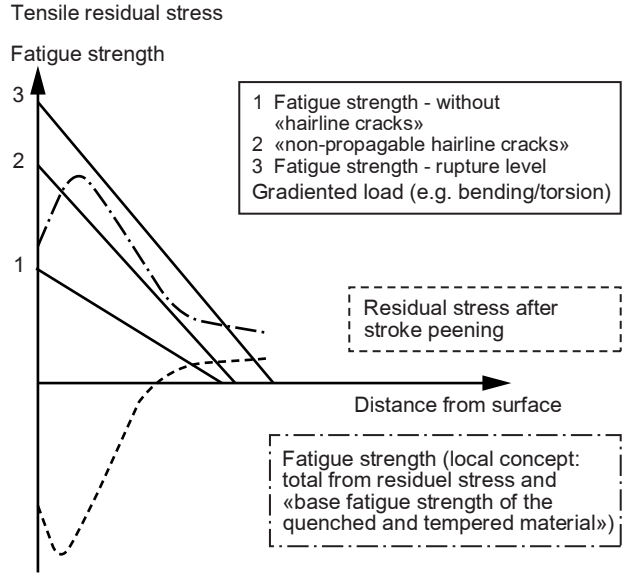
11.6.5 Use of existing results for similar crankshhafts

The increase in fatigue strength, which is achieved applying cold rolling (see [11.6.4]), may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- at least the same circumferential extension of cold rolling
- angular extension of the fillet contour relative to fillet radius within ±15% in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- similar base material, e.g. alloyed quenched and tempered
- roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment.

Figure 23 : Working and residual stresses below the stroke-peened surface

Straight lines 1 to 3 represent different possible load stress gradients.



12 Calculation of stress concentration factors in the oil bore outlets of crankshafts through utilization of the finite element method

12.1 General

12.1.1 The objective of the analysis described in this Article is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method is based on empirical formula developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formula beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in this Appendix, principal stresses shall be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is advisable to check the element accuracy of the FE solver in use, e.g. by modeling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

A boundary element method (BEM) approach may be used instead of FEM.

12.2 Model requirements

12.2.1 The basic recommendations and assumptions for building of the FE-model are presented in [12.2.2]. The final FE-model must meet one of the criteria in [12.2.4].

12.2.2 Element mesh recommendations

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

a) the model consists of one complete crank, from the main bearing centre line to the opposite side's main bearing centre line.

b) the following element types are used in the vicinity of the outlets:
   - 10 node tetrahedral elements
   - 8 node hexahedral elements
   - 20 node hexahedral elements

c) the following mesh properties for the oil bore outlet are used:
   - maximum element size a = r / 4 through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are required for meeting of the quality criterion)
   - recommended manner for element size in the fillet depth direction
     - first layer's thickness equal to element size of a
     - second layer's thickness equal to element size of 2a
     - third -layer thickness equal to element size of 3a

d) in general, the rest of the crank should be suitable for numeric stability of the solver

e) drillings and holes for weight reduction have to be modeled.

Submodeling may be used as long as the software requirements are fulfilled.

12.2.3 Material

This Appendix does not consider material properties such as Young's modulus (E) and Poisson's ratio (υ). In the FE analysis, these material parameters are required, as primarily strain is calculated and stress is derived from strain through the use of Young's modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in the literature or measured from representative material samples.

For steel the following is advised:

$E = 2{,}05\ 10^5$ MPa and $\upsilon = 0{,}3$

12.2.4 Element mesh quality criteria

If the actual element mesh does not fulfill any of the following criteria in the area examined for SCF evaluation, a second calculation, with a finer mesh is to be performed.

a) Principal stresses criterion

   The quality of the mesh should be assured through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1, σ_2 and σ_3 the following criterion must be met:

   $$\min(|\sigma_1||\sigma_2||\sigma_3|) < 0,03 \max(|\sigma_1||\sigma_2||\sigma_3|)$$

b) Averaged/unaveraged stresses criterion

   The averaged/unaveraged –stresses criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF:

   Unaveraged nodal stress results calculated from each element connected to a node i should differ less than 5% from the 100% averaged nodal stress results at this node i at the location examined.

12.3 Load cases and assessment of stress

12.3.1 For substitution of the analytically determined SCF in this Appendix, calculation shall be performed for the following load cases.

12.3.2 Torsion

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed.

Torque is applied to the central node, on the crankshaft axis. This node acts as the master node with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines.

For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max(|\sigma_1||\sigma_2||\sigma_3|)}{\tau_N}$$

where the nominal torsion stress τ_N referred to the crankpin is evaluated per [2.2.2] with torque T:

$$\tau_N = \frac{T}{w_P}$$

12.3.3 Bending

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines.

For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max(|\sigma_1||\sigma_2||\sigma_3|)}{\sigma_N}$$

where the nominal bending stress σ_N referred to the crankpin is calculated per [2.1.2], item d) with bending moment M:

$$\sigma_N = \frac{M}{w_e}$$

Appendix 2 Reciprocating Internal Combustion Engines Fuelled by Natural Gas

1 General

1.1 Scope

1.1.1 Type of engines

This appendix addresses the requirements for marine reciprocating internal combustion engines supplied with natural gas as fuel.

The scope of this Appendix is intended for natural gas fuelled engines. It may also be referred for engines using similar fuels with main component methane such as bio-methane or synthetic methane.

It is to be ensured by the gas supply system that the gas supplied to the engine is always in gaseous state. This appendix does not cover requirements for liquid or cryogenic gas.

The engines can be dual fuel engines (hereinafter referred to as DF engines), gas fuel only engines (hereinafter referred to as GF engines), or any variations thereof including fuel sharing capability.

DF engines and GF engines may not be permitted for emergency applications.

1.1.2 Application

This Appendix is to be applied in association with other relevant requirements of Ch 1, Sec 2, as far as found applicable to the specific engine design.

1.2 Definitions

1.2.1 Certified safe

Certified safe equipment is equipment certified by an independent national test institution or competent body to be in accordance with a recognised standard for electrical apparatus in hazardous areas.

Note 1: Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

1.2.2 Double block and bleed valves

Double block and bleed valves means the set of valves referred to in:

- Pt D, Ch 9, Sec 16, [4.5.1]
- NR529, 2.2.9 and NR529, 9.4.4 to 9.4.6.

1.2.3 Dual fuel engine (“DF engine”)

Dual fuel engine (“DF engine”) means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

1.2.4 Explosion relief device

Explosion relief device means a device to protect personnel and component against a determined overpressure in the event of a gas explosion. The device may be a valve, a rupture disc or other, as applicable.

1.2.5 Gas

Gas means natural gas used as fuel consisting primarily of methane.

Note 1: Gas may also be bio-methane or synthetic methane etc. with methane as main component.

1.2.6 Gas admission valve

Gas admission valve is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the engine’s gas demand.

1.2.7 Gas engine

Gas engine means a DF engine, a GF engine, or any variations thereof.

1.2.8 Gas fuel only engine (“GF engine”)

Gas fuel only engine (“GF engine”) means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

1.2.9 Gas piping

Gas piping means piping containing gas or air / gas mixtures.

1.2.10 High pressure gas

High pressure gas means gas with a maximum working pressure greater than 10 bar gauge.

1.2.11 Low pressure gas

Low pressure gas means gas with a maximum working pressure lower or equal to 10 bar gauge.

1.2.12 Lower heating value (LHV)

Lower heating value (LHV) means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.

1.2.13 Methane number

Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.

Note 1: Pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0.

1.2.14 Pilot fuel

Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.

1.2.15 Pre-mixed engine

Pre-mixed engine means an engine where gas is supplied in a mixture with air through a common manifold for all cylinders, e.g. mixed before or after the turbocharger.

1.2.16 Safety Concept

Safety concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures. The results of the risk analysis, see [1.4], are to be reflected in the safety concept.

Note 1: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Documents to be submitted

1.3.1 In addition to those required in Ch 1, Sec 2, Tab 1, Ch 1, Sec 2, Tab 2 and Ch 1, Sec 2, Tab 3, the documents and drawing listed in Tab 1 are to be submitted for approval of DF or GF engines.

Where considered necessary, the Society may request further documents to be submitted.

Table 1 : Documents and drawings to be submitted

No.	A/I **(1)**	Item
Documents to be submitted for both DF and GF engines		
1	A	Schematic layout or other equivalent documents of gas system on the engine
2	A	Gas piping system (including double-walled arrangement where applicable) **(4)**
3	A	Parts for gas admission system **(4)**
4	A	Arrangement of explosion relief valves (crankcase **(2)**, charge air manifold **(5)**, exhaust gas manifold **(5)** and exhaust gas system) as applicable
5	A	List of certified safe equipment and relevant certification
6	A	Hazardous area plan
7	I	Safety concept
8	I	Report of the risk analysis **(3)**
9	I	Gas used as fuel specification
Documents to be submitted for DF engines only		
10	A	Schematic layout or other equivalent documents of pilot fuel system
11	A	Shielding of high pressure fuel pipes for pilot fuel system, assembly
12	A	High pressure parts for pilot fuel oil injection system **(4)**
Documents to be submitted for GF engines only		
13	A	Schematic layout or other equivalent documents of the ignition system

(1) A: To be submitted for approval ; I: To be submitted for information
(2) If required by Ch 1, Sec 2, see also [2.2.4], item a)
(3) See [1.4]
(4) The documentation is to contain specification of design pressures, working pressure, pipe dimensions and materials
(5) See Ch 1, App 8 for the type approval of such equipment.

1.4 Risk analysis

1.4.1 Scope of the risk analysis

The risk analysis is to address:

- a failure or malfunction of any system or component involved in the gas operation of the engine
- a gas leakage downstream of the double block and bleed valves
- the safety of the engine in case of emergency shutdown or blackout, when running on gas
- the interactions between the gas fuel system and the engine.

Note 1: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis required by this appendix.

1.4.2 Form of the risk analysis

The risk analysis is to be carried out in accordance with international standard IEC 31010:2019: Risk management - Risk assessment techniques, or other recognized standards.

The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 Procedure for the risk analysis

The risk analysis is to:

a) Identify all the possible failures in the concerned equipment and systems which could lead:
   - to the presence of gas in components or locations not designed for such purpose, and/or
   - to ignition, fire or explosion.

b) Evaluate the consequences (see also [2.1.2])

c) Where necessary, identify the failure detection method

d) Where the risk cannot be eliminated, identify the corrective measures:
   1) in the system design, such as:
      - redundancies
      - safety devices, monitoring or alarm provisions which permit restricted operation of the system
   2) in the system operation, such as:
      - initiation of the redundancy
      - activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 Equipment and systems to be analysed

The risk analysis required for engines is to cover at least the following aspects:

a) failure of the gas-related systems or components, in particular:
   - gas piping and its enclosure, where provided
   - gas admission valves

Note 1: Failures of the gas supply components not located directly on the engine, such as block-and-bleed valves and other components of the gas supply system, are not to be considered in the analysis.

b) failure of the ignition system (oil fuel pilot injection, sparking plugs, glow plugs)

c) failure of the air to fuel ratio control system (charge air bypass, gas pressure control valve, etc.)

d) for engines where gas is supplied upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots)

e) failure of the gas combustion or abnormal combustion (misfiring, knocking)

f) failure of the engine monitoring, control and safety systems

Note 2: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with Ch 1, Sec 2, Tab 1, Footnote **(5)**.

g) presence of gas in engine components (e.g. air inlet manifold or scavenge space and exhaust manifold) and in the external systems connected to the engines (e.g. exhaust duct, cooling water system, hydraulic oil system).

h) changes of operating modes for DF engines

i) hazard potential for crankcase fuel gas accumulation, for trunk-piston engines, refer to NR529, 10.3.1.2 and Ch 1, Sec 2, [2.3.4]

j) risk of crankcase explosion in connection with active crankcase ventilation which produces a flow of external air into the crankcase, (see Ch 1, Sec 2, [2.3.4]).

2 Design Requirements

2.1 General Principles

2.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.

2.1.2 Components containing or likely to contain gas are to be designed to:

- minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
- mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) or the fitting of suitable explosion relief devices of an approved type, see Ch 1, App 4 and Ch 1, App 8.

  The strength of the component(s) of arrangement of explosion relief devices is be documented (e.g., as part of risk analysis) or otherwise demonstrated to be sufficient for a worst-case explosion.

Also refer to NR529, 10.2 and NR529, 10.3.

2.1.3 Discharge from explosion relief devices are to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.

2.1.4 Explosion relief devices are to be fitted with a flame arrester.

2.2 Gas piping

2.2.1 General

The requirements of this section apply to engine-mounted gas piping. The piping is to be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details etc.) as given in NR529, Part A-1, 7; Pt D, Ch 9, Sec 5, [1] and Pt D, Ch 9, Sec 5, [9] and Pt D, Ch 9, Sec 16, as applicable. Tab 2 details these requirements.

Other connections as mentioned in NR 529, 7.3.6.4.4 may be accepted subject to type approval in accordance with the relevant requirements of Ch 1, Sec 10.

All single walled or high-pressure gas pipes are to be considered as Class I.

Low pressure double walled gas pipes are to be considered as Class II.

All secondary enclosures for gas pipes are to be considered as Class II.

Single walled gas vent pipes, if permitted, are to be considered as Class I, except it is justified that the maximum built up pressure is less than 5 bar gauge, in which case it should be considered as Class II.

Gas vent pipes protected by a secondary enclosure are to be considered as Class II.

Secondary enclosure for vent pipes are to be considered as Class III.

Flexible bellows used in the fuel gas system on the engine are to be approved based on the requirements of NR 529 16.7.2, and Pt D, Ch 9, Sec 5, [13.4], as applicable.

The number of cycles, pressure, temperature, axial movement, rotational movement and transverse movement which the bellow will encounter in actual service on the engine are to be specified by the engine designer.

Endurance against high cycle fatigue due to vibration loads is to be verified by testing or alternatively be documented by the Expansion Joint Manufacturers Association, Inc. (EJMA) calculation or equivalent (i.e., more than 10^7 cycles).

Note 1: The fatigue test due to ship deformations in NR 529, 16.7.2.4 is considered not relevant for bellows which are an integral part of the engine.

Table 2 : Design pressure for gas pipes

	Design pressure	
Gas pipe, low pressure	see NR 529, 7.3.3.1	see Pt D, Ch 9, Sec 5, [4.1.1]
Gas pipe, high pressure	see NR 529, 7.3.3.1	see Pt D, Ch 9, Sec 5, [4.1.1]
outer pipe, low pressure	see NR 529, 9.8.1	see Pt D, Ch 9, Sec 5, [4.1.4]
outer pipe, high pressure	see NR 529, 9.8.2	see Pt D, Ch 9, Sec 5, [4.1.4]
Open ended pipes	see NR 529, 7.3.3.2	see Pt D, Ch 9, Sec 5, [4.1.1]

2.2.2 Arrangement of the gas piping system on the engine

Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to NR529, 12.5.1).

The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to NR529, 12.5.2.6).

a) Normal "double wall" arrangement

The gas piping system on the engine is to be arranged according to the principles and requirements of NR529, 9.6. For ships having the service notation **liquefied gas carrier**, Pt D, Ch 9, Sec 16, [4.3.1] applies.

The design criteria for the double pipe or duct are given in NR529, 9.8 and NR529, 7.4.1.4.

In case of a ventilated double wall, the ventilation inlet is to be located in accordance with the provisions of NR529, 13.8.3. For ships having the service notation **liquefied gas carrier**, Pt D, Ch 9, Sec 16, [4.3.1], item b) applies.

The pipe or duct is to be pressure tested at 1,5 x design pressure, to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

b) Alternative arrangement

Single walled gas piping is only acceptable:

- for engines supplied with low pressure gas and installed in ESD protected machinery spaces, as defined in NR529, 5.4.1.2 and in compliance with other relevant parts of NR529 (e.g. NR529, 5.6)
- in the case as per NR529, 9.6.2, Note 18.

For ships having the service notation **liquefied gas carrier**, Part D, Chapter 9 applies.

In case of gas leakage in an ESD-protected machinery space, which would result in the shut-down of the engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained.

Therefore the safety concept of the engine is to clearly indicate application of the "double wall" or "alternative" arrangement.

Note 1: The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

2.2.3 Charge air system and exhaust gas system on the engine

a) The charge air system and the exhaust gas system on the engine are to be designed in accordance with [2.1.2].

b) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

c) Load reduction is to be considered on a case-by-case basis, depending on engine configuration (single or multiple) and charge air relief mechanism (self-closing valve or rupture disc).

d) Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

e) Suitable explosion relief system for air inlet manifolds, scavenge spaces and exhaust system should be provided unless designed to accommodate the worst-case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation regarding the hazard potential of overpressure in air inlet manifolds, scavenge spaces and exhaust system should be carried out and reflected in the safety concept of the engine.

f) Explosion relief devices for air inlet and exhaust manifold are to be type approved according to Ch 1, App 8.

g) The necessary total relief area and the arrangement of the explosion relief devices are be determined taking into account:

- the worst-case explosion pressure depending on initial pressure and gas concentration,
- the volume and geometry of the component, and
- the strength of the component.

The arrangement is to be determined in the risk analysis (see [1.4.4], item g) and reflected in the safety concept.

2.2.4 Engine crankcase

a) Crankcase explosion relief valves

Crankcase explosion relief valves are to be installed in accordance with Ch 1, Sec 2, [2.3.4]. Refer also to NR529, 10.3.1.2.

For engines not covered by Ch 1, Sec 2, [2.3.4], the detailed evaluation as required in [1.4.4], item i, is to determine if crankcase explosion relief valves are necessary.

b) Inerting

For maintenance purposes, a connection, or other means, is to be provided for crankcase inerting and ventilating and gas concentration measuring.

c) Crankcase ventilation

Ventilation of crankcase (either supply or extraction), if arranged, is to comply with Ch 1, Sec 2, [2.3.2]. Relevant evidence is to be documented in Safety Concept.

The ventilation systems for crankcase, sump and other similar engine spaces are to be independent from the systems on the other engines

2.2.5 Gas ignition in the cylinder

The requirements of NR529, 10.3 apply. For ships having the service notation **liquefied gas carrier**, Pt D, Ch 9, Sec 16, [7.1.1] applies.

2.2.6 Control, monitoring, alarm and safety systems

The engine control system is to be independent and separate from the safety system.

The gas admission valves are to be controlled by the engine control system or by the engine gas demand.

Combustion is to be monitored on an individual cylinder basis.

In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in NR529, 10.3.1.6.

If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

Unless the risk analysis required by [1.4] proves otherwise, the monitoring and safety system functions for DF or GF engines are to be provided in accordance with Tab 3 in addition to the general monitoring and safety system functions required by the Rules.

Note 1: For DF engines, Tab 3 applies only to the gas mode.

2.2.7 Gas admission valves

Electrically operated gas admission valves are to be certified safe as follows:

- The inside of the valve contains gas and is therefore to be certified for Zone 0.
- When the valve is located within a pipe or duct in accordance with the provisions of [2.2.2], item a), the outside of the valve is to be certified for Zone 1.
- When the valve is arranged without enclosure in accordance with the "ESD-protected machinery space" concept (see [2.2.2], item b)), no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.

However, if they are not rated for the zone they are intended for, it is to be documented that they are suitable for that zone. Documentation and analysis are to be based on IEC 60079-10-1:2015 or IEC 60092-502:1999.

Gas admission valves operated by hydraulic oil system are to be provided with sealing arrangement to prevent gas from entering the hydraulic oil system.

Table 3 : Monitoring and safety system functions for DF and GF engines

Parameter	Alarm	Automatic activation of the double block-and-bleed valves	Automatic switching over to oil fuel mode **(1)**	Engine shutdown
Abnormal pressures in the gas fuel supply line	X	X	X	X **(5)**
Gas fuel supply systems - malfunction	X	X	X	X **(5)**
Pilot fuel injection or spark ignition systems - malfunction	X	X **(2)**	X	X **(2) (5)**
Exhaust gas temperature after each cylinder - high	X	X **(2)**	X	X **(2) (5)**
Exhaust gas temperature after each cylinder, deviation from average – low **(3)**	X	X **(2)**	X	X **(2) (5)**
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	X	X **(2) (4)**	X **(4)**	X **(2) (4) (5)**
Oil mist concentration in crankcase or bearing temperature **(6)** - high	X	X		X **(9)**
Pressure in the crankcase – high **(8)**	X	X	X	
Engine stops - any cause	X	X		
Failure of the control-actuating medium of the block and bleed valves	X	X	X	
Failure of crankcase ventilation system, if applicable	X	X **(7)**	X **(7)**	

(1) DF engine only, when running in gas mode

(2) For GF engines, the double block-and-bleed valves and the engine shut-down may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shut-off and the safe operation of the engine in such conditions is demonstrated by the risk analysis

(3) Required only if necessary for the detection of misfiring

(4) In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated

(5) GF engine only

(6) Where required by Ch 1, Sec 2, [2.3.5]

(7) Automatic safety actions to be activated as specified by the engine manufacturer, see Ch 1, Sec 2, [2.3.5]

(8) Only for trunk piston engines. This pressure sensor cannot replace or substitute a gas detector

(9) Only for trunk piston engines. For crosshead engines slow down applies (see Ch 1, Sec 2, Tab 4

3 Specific design requirements

3.1 DF Engines

3.1.1 General

The maximum continuous power that a DF engine can develop in gas mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas composition and its quality or the engine design.

This maximum continuous power available in gas mode and the corresponding conditions are to be stated by the engine manufacturer.

3.1.2 Starting, changeover and stopping

DF engines are to be arranged to started using either oil fuel or gas fuel with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to gas operation is to be automatic but manual interruption is to be possible in all cases.

If the power level or other conditions do not allow safe and reliable gas operation, changeover to oil fuel mode is to be automatically performed.

In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Pilot injection

Gas supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note 1: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.2 GF engines

3.2.1 Spark ignition system

In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.3 Pre-mixed engines

3.3.1 Charge air system

Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system. Failures of those components likely to result in a gas leakage are to be considered in the risk analysis (see [1.4]).

Flame arresters are to be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

3.4 Two-stroke engines

3.4.1 Scavenge air system

The risk analysis required in [1.4] is to cover the possible gas accumulation in a scavenge space.

3.4.2 Crankcase

The risk analysis required in [1.4] is to cover the possible failure of a piston rod stuffing box.

4 Type testing, factory acceptance tests and shipboard trials

4.1 Type Testing

4.1.1 General

Type approval of DF and GF engines is to be carried out in accordance with the provisions of Ch 1, Sec 2, [4], taking into account the requirements of this sub-article.

4.1.2 Type of engine

In addition to the criteria given in Ch 1, Sec 2, [4.1.2], item c), the type of engine is defined by the following:

- gas admission method (cylinder injection after compression stroke, cylinder-individual injection before compression stroke or pre-mixed)
- gas admission valve operation (mechanical or electronically controlled)
- ignition system (pilot injection, spark ignition, glow plug or gas self-ignition)
- ignition system (mechanical or electronically controlled)

Note 1: Cylinder-individual injection before compression stroke may be port injection into the air inlet channel before the cylinder inlet valve, injection into the cylinder before or during compression stroke, or similar arrangements.

4.1.3 Safety precautions

In addition to the safety precautions mentioned in Ch 1, Sec 2, [4.1.3], measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.1.4 Test programme

The type testing of the engine is to be carried out in accordance with Ch 1, Sec 2, [4.1.4] taking into account the additional requirements of this Appendix.

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It is however to be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

4.1.5 Measurements and records

In addition to the measurements and records required in Ch 1, Sec 2, [4.1.5], the following engine data are to be measured and recorded:

- each fuel index for gas and diesel as applicable (or equivalent reading)
- gas pressure and temperature at the inlet of the gas manifold
- Pilot fuel temperature and pressure (supply or common rail as appropriate)
- gas concentration in the crankcase

Note 1: The gas concentration in the crankcase should normally be measured inside the crankcase or at the crankcase outlet (crankcase vent pipe).

Gas concentration measurements may be carried out as part of Stage A if the method and the results are properly documented.

Additional measurements may be required in connection with the design assessment.

4.1.6 Stage A - internal tests

In addition to tests required in Ch 1, Sec 2, [4.1.6], the following conditions are to be tested:

- DF engines are to run the load points defined in Ch 1, Sec 2, [4.1.6], in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type.
- For DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.
- For DF engines, switch over between gas and diesel modes are to be tested at different loads.
- The influence of the methane number and LHV of the fuel gas on the engine's maximum continuous power available in gas mode is to be verified

4.1.7 Stage B - witnessed tests

a) General

Gas engines are to undergo the different tests required in Ch 1, Sec 2, [4.1.7].

In case of DF engine:

- all load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer

  This independent overspeed protective device has to be tested both in gas and diesel mode (see Ch 1, Sec 2, [4.1.7]), item b).
- For engines with variable liquid / gas ratio, selected load tests are to be carried out at different ratios between the minimum and the maximum allowable values (most relevant and critical loads and ratios should be selected for the test).
- The maximum continuous power available in gas mode (see [3.1.1]) is to be demonstrated.
- Overload testing is not required in gas mode for DF engines, provided that changeover to oil fuel mode is automatically performed in case of overload.
- The load tests are to be carried out in diesel mode and in gas mode at the different percentages of the engine's MCR.

b) Functional tests

In addition to the functional tests required in Ch 1, Sec 2, [4.1.7], item c), the following tests are to be carried out:

- for DF engines, the lowest specified speed is to be verified in diesel mode and gas mode
- for DF engines, switch over between gas and diesel modes are to be tested at different loads
- for DF engines, verification of automatic changeover to diesel mode when the load demand exceeds the maximum continuous power available in gas mode (see [3.1.1]and [3.1.2])
- the efficiency of the ventilation arrangement or other approved principal of the double walled gas piping system is to be verified.

Engines intended to produce electrical power are to be tested as follows:

- capability to take sudden load and loss of load in accordance with the provisions of Ch 1, Sec 2, [2.7.6]
- for GF and premixed engines, the influences of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to the limitations as specified in [2.1.1], the margin for satisfying dynamic load response is to be determined.

Note 1: For DF engines, switchover to oil fuel during the test is acceptable.

Note 2: Application of electrical load in more than 2 load steps can be permitted in the conditions stated in Ch 1, Sec 2, [2.7.5], item d).

c) Integration tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the risk analysis required in [1.4], and is to include at least the following incidents:

- failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure
- failure of a gas admission valve
- failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- abnormal gas pressure
- abnormal gas temperature

Note 3: This test may be carried out using a simulation signal of the temperature.

4.1.8 Stage C - Component inspection

Component inspection is to be carried out in accordance with the provisions of Ch 1, Sec 2, [4.1.8]. The components to be inspected after the test run are to include also:

- gas admission valve including pre-chamber as found applicable
- spark igniter (for GF engines)
- pilot fuel injection valve (for DF engines)

4.1.9 Engine type approval certificate

For DF engines, the maximum continuous power available in gas mode is to be specified on the type approval certificate in addition to the maximum continuous rating in diesel mode if differing.

4.2 Factory acceptance test

4.2.1 General

Factory acceptance tests of DF and GF engines are to be carried out in accordance with Ch 1, Sec 2, [4.3], taking into account [4.2.2] to [4.2.5].

For DF engines, the load tests referred to in Ch 1, Sec 2, [4.3.3], item c), are to be carried out in diesel mode and in gas mode at the different percentages of the engine's MCR.

Maximum continuous power available in gas mode is to be demontrated (see [3.1.1]).

4.2.2 Safety precautions

In addition to the safety precautions mentioned in Ch 1, Sec 2, [4.3.1], measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.2.3 Records

In addition to the records required in Ch 1, Sec 2, [4.3.3], item b), the following engine data are to be recorded:

- fuel index, both gas and diesel as applicable (or equivalent reading)
- gas pressure and temperature
- Pilot fuel temperature and pressure (supply or common rail as appropriate).

4.2.4 Test loads

Test loads for various engine applications are given in Ch 1, Sec 2, [4.3.3], item c). DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Integration tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with the Society for selected cases based on the risk analysis required in [1.4] and is to include at least the following incidents:

- failure of ignition (spark ignition or pilot injection systems), for one cylinder unit
- failure of gas admission valve
- failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- abnormal gas pressure
- abnormal gas temperature

The above tests may be carried out using simulation or other alternative methods, subject to special consideration by the Society.

4.3 Shipboard trials

4.3.1 A leak test is to be carried out for the gas piping system (see NR529 16.7.3.3) after assembly on board.

Shipboard trials are to be carried out in accordance with the provisions of Ch 1, Sec 18, [3.5] considering the additional requirements below.

For DF engines, the test loads required in Ch 1, Sec 18, [3.5.4] are to be carried out in all operating modes (gas mode, diesel mode, etc.) as applicable (see [3.1.1]). The maximum continuous power available in gas mode is to be demonstrated.

Note 1: If a test load is performed in all applicable operation modes without interruption (direct changeover at same power and speed), the duration as required in Ch 1, Sec 18, [3.5.4] may be considered as the total duration demonstrated in all fuel modes. However, demonstration at each mode is not to not be less than one hour

The starting maneuvers required in Ch 1, Sec 18, [3.5.2] are to be carried out in diesel mode and gas mode, if applicable.

For DF engines, automatic switching over to oil fuel mode is to be tested.

Further, manual change over from diesel to gas mode and vice versa is to be tested.

The efficiency of the ventilation arrangement, or other approved principle, of the double walled gas piping system is to be verified.

5 Certification of Engine Components

5.1 General

5.1.1 The principles, definitions, and general requirements of Ch 1, Sec 2, [4.2] apply.

5.2 Additional requirements for DF and GF engines

5.2.1 In addition to those components specified in Ch 1, Sec 2, [4.2], the engine components of DF and GF engines listed in Tab 4 are to be documented as listed in the table

Table 4 : Required documentation for DF and GF engine components

Part	Material properties	Non-destructive examination	Pressure testing	Visual inspection of welds	Component certificate
Gas pipe Low-pressure double walled	W(C+M)	W **(2) (6)**	W **(4)**	X	
Single walled Gas pipes	W(C+M)	W **(1)**	W **(4)**	X	SC
High-pressure gas pipes	W(C+M)	W **(1)**	W **(4)**	X	SC
Secondary enclosure for gas pipes	W(C+M)	W **(2)**	W **(3)**	X	
Gas pipe Low-pressure, Flanges **(8)**	W(C+M)	W **(2) (6)**		X	
Gas pipe High-pressure, Flanges **(8)**	W(C+M)	W **(1)**		X	SC

(1) 100 % radiographic or ultrasonic inspection of all butt-welded joints (NR529, 16.6.3.1)
(2) 10 % radiographic or ultrasonic inspection of butt-welded joints (NR529 16.6.3.4)
(3) Pressure test at 1,5 x design pressure to ensure gas tight integrity, not less than the expected maximum pressure at gas pipe rupture (as per NR529 16.7.3.4, and 9.8.4)
(4) Pressure test at 1,5 x design pressure
(5) Leak test
(6) If inside diameter > 75 mm or wall thickness > 10 mm: 100% radiographic or ultrasonic inspection of all butt-welded joints (NR529 16.6.3.1)
(7) If nominal diameter > 25 mm
(8) “Flanges” limited to the final connection to the engine

Part	Material properties	Non-destructive examination	Pressure testing	Visual inspection of welds	Component certificate
Gas pipe Low-pressure, Fittings and other components	W(C+M)		W **(4)**	X	
Gas pipe High-pressure, Fittings and other components	W(C+M)		W **(4)**	X	SC
Gas pipe Low-pressure Bodies of valves **(7)**	W(C+M)		W **(4)**		
Gas pipe High-pressure Bodies of valves	W(C+M)		W **(4)**		SC
Gas venting pipes and flanges, build up pressure less than 5,0 bar **(8)**	TR(C+M)	W **(2)**	W **(4)**	X	
Gas venting pipes and flanges, build up pressure at 5,0 bar or more with secondary enclosure **(8)**	TR(C+M)	W **(2)**	W **(4)**	X	
Gas venting pipes and flanges, build up pressure at 5,0 bar or more **(8)**	W(C+M)	W **(1)**	W **(4)**	X	SC
Gas venting pipes Secondary enclosure			W **(5)**	X	

(1) 100 % radiographic or ultrasonic inspection of all butt-welded joints (NR529, 16.6.3.1)

(2) 10 % radiographic or ultrasonic inspection of butt-welded joints (NR529 16.6.3.4)

(3) Pressure test at 1,5 x design pressure to ensure gas tight integrity, not less than the expected maximum pressure at gas pipe rupture (as per NR529 16.7.3.4, and 9.8.4)

(4) Pressure test at 1,5 x design pressure

(5) Leak test

(6) If inside diameter > 75 mm or wall thickness > 10 mm: 100% radiographic or ultrasonic inspection of all butt-welded joints (NR529 16.6.3.1)

(7) If nominal diameter > 25 mm

(8) "Flanges" limited to the final connection to the engine

Appendix 3 Plastic Pipes

1 General

1.1 Application

1.1.1 These requirements are applicable to pipes / piping systems made of plastic or made predominantly of other material than metal.

1.1.2 The use of mechanical joints approved for the use in metallic piping systems only is not permitted.

1.1.3 Piping systems intended for non-essential services are only required to meet the requirements of recognized standards and [2.1.3], item b), [2.5.2], [3.1.2], [3.1.3], [3.1.4], [3.1.5], [3.1.6], [3.1.7] and Article [4].

1.2 Use of plastic pipes

1.2.1 Plastic may be used in piping systems in accordance with the provisions of Ch 1, Sec 10, [2.1.3], provided the following requirements are complied with.

1.2.2 Plastic pipes are to be type approved by the Society.

1.3 Specifications

1.3.1 The specification of the plastic piping is to be submitted in accordance with the provisions of Ch 1, Sec 10, [1.2.2]. It is to comply with a recognised national or international standard approved by the Society. In addition, the requirements stated below are to be complied with.

1.4 Terms and conditions

1.4.1 Plastic(s)

Plastic(s) includes both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastic (FRP). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties.

1.4.2 Pipes / piping systems

Pipes / piping systems means those made of plastic(s) and include the pipes, fittings, system joints, method of joining and any internal or external liners, coverings and coatings required to comply with the performance criteria. Non-metallic flexible hoses are not covered by this Appendix. Requirements for non-metallic flexible hoses pipes are provided by Ch 1, Sec 10, [2.6].

1.4.3 Joint

Joint means the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints according to Ch 1, Sec 10, Fig 2.

1.4.4 Fitting

Fittings means bends, elbows, fabricated branch pieces etc. of plastic materials.

1.4.5 Nominal pressure

Nominal pressure means the maximum permissible working pressure which should be determined in accordance with the requirements in [2.1.3].

1.4.6 Design pressure

Design pressure means the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

1.4.7 Fire endurance

Fire endurance means the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

1.4.8 Essential to the safety of ships

Essential to the safety of ships means all piping systems that in the event of failure will pose a threat to personnel and the ship.

1.4.9 Essential services

Essential services are those services essential to propulsion and steering and safety of the ship as specified in Ch 2, Sec 1, [3.11].

Note 1: Examples for piping systems essential to the safety are provided by Tab 1.

2 General requirements

2.1 Strength

2.1.1 The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 100 kPa, relative humidity 30%, environmental and carried fluid temperature 298 kPa (25°C).

2.1.2 The strength of fittings and joints is to be not less than that of the pipes.

2.1.3 The nominal pressure P_N is to be determined from the following conditions:

a) Internal pressure

For an internal pressure $P_{N\,int}$, the following is to be taken whichever is smaller:

- $P_{N\,int} \leq P_{sth} / 4$
- $P_{N\,int} \leq P_{lth} / 2,5$

where:

P_{sth} : Short-term hydrostatic test pipe failure pressure

P_{lth} : Long-term hydrostatic test pipe failure pressure (>100 000 hours)

b) External pressure $P_{N\,ext}$, (for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe; and for any pipe installation required to remain operational in case of flooding damage, as per SOLAS Chapter II-1, Regulation 8-1, as amended, or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments)

$P_{N\,ext} \leq P_{col} / 3$

where P_{col} is the collapse pressure.

In no case is the pipe collapse pressure to be less than 0,3 MPa

The maximum working external pressure is the sum of the vacuum inside the pipe and the static pressure head outside the pipe.

2.1.4 Notwithstanding the requirements of items a) or b) as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of item a) above are to be met.

2.1.5 The maximum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with Manufacturer's recommendations.

2.2 Axial strength

2.2.1 The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

2.2.2 In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition (see [2.1.3]).

2.3 Impact resistance

2.3.1 Plastic pipes and joints are to have a minimum resistance to impact in accordance with a recognised national or international standard.

After the test the specimen is to be subjected to hydrostatic pressure equal to 2,5 times the design pressure for at least 1 hour.

2.4 Temperature

2.4.1 The permissible working temperature depending on the working pressure is to be in accordance with Manufacturer's recommendations, but in each case it is to be at least 20ºC lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75-2:2013 method A, or equivalent e.g. ASTM D648-18.

The minimum heat distortion/deflection temperature is to be not less than 80ºC.

2.5 Requirements depending on service and/or location

2.5.1 Fire endurance

Pipes and their associated joints and fittings whose integrity is essential to the safety of ships, including plastic piping required by SOLAS Chapter II-2, regulation 21.4, as amended, to remain operational after a fire casualty, are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO Resolution A.753(18), as amended.

Unless instructed otherwise by the Flag Administration, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings:

a) Pipes:
   - for sizes with outer diameter < 200 mm: the minimum outer diameter and wall thickness
   - for sizes with outer diameter ≥ 200 mm: one test specimen for each category of t/D, with:
     D = outer diameter
     t = structural wall thickness.

   A scattering of ±10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

b) Joints:

   Each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen.

Note 1: A test specimen incorporating several components of a piping system may be tested in a single test.

Note 2: Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested.

If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, are to be qualified by the fire test.

Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1 or Appendix 2 of the IMO Res.A.753(18), as amended. During the test it is not permitted to replace media drained by fresh water or nitrogen.

Depending on the capability of a piping system to maintain its strength and integrity, there exist three different levels of fire endurance for piping systems:

a) Level 1. Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution A.753(18), as amended, for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1).

   Level 1W - Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W).

b) Level 2. Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution A.753(18), as amended, for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard (L2).

   Level 2W - Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W).

c) Level 3. Piping having passed the fire endurance test specified in Appendix 2 of IMO Resolution A.753(18) for a duration of a minimum of 30 minutes in the wet condition is considered to meet level 3 fire endurance standard (L3).

Permitted use of piping depending on fire endurance, location and piping system is given in Tab 1.

For Safe Return to Port purposes (SOLAS Chapter II-2, Regulation 21.4), plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

2.5.2 Flame spread

a) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels, and ducts if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead are to have low surface flame spread characteristics not exceeding average values listed in Appendix 3 of IMO Resolution A.753(18), as amended.

b) Surface flame spread characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as also listed in Appendix 3 of IMO Resolution A.753(18), as amended.

c) Surface flame spread characteristics may also be determined using the test procedures given in ASTM D635-18, or in other national equivalent standards. Under the procedure of ASTM D635-18 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

2.5.3 Fire protection coating

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

- The pipes are generally to be delivered from the manufacturer with the protective coating on.
- The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.
- In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations and elasticity are to be taken into account.
- The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

2.5.4 Electrical conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed $1 \cdot 10^5$ Ohm/m.

Table 1 : Fire endurance of piping systems

PIPING SYSTEM	LOCATION **(13)**										
	Machinery spaces of category A **(14)**	Other machinery spaces and pump rooms **(15)**	Cargo pump rooms **(16)**	Ro-Ro cargo holds **(17)**	Other dry cargo holds **(18)**	Cargo tanks **(19)**	Fuel oil tanks **(20)**	Ballast water tanks **(21)**	Cofferdams, void spaces, pipe tunnels **(22)**	Accommodation, service and control spaces **(23)**	Open decks **(24)**
CARGO (FLAMMABLE CARGOES WITH FLASH POINT ≤ 60°C)											
Cargo lines	NA	NA	L1	NA	NA	0	NA	0 **(10)**	0	NA	L1 **(2)**
Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0 **(10)**	0	NA	L1 **(2)**
Vent lines	NA	NA	NA	NA	NA	0	NA	0 **(10)**	0	NA	X
INERT GAS											
Water seal effluent line	NA	NA	0 **(1)**	NA	NA	0 **(1)**	0 **(1)**	0 **(1)**	0 **(1)**	NA	0
Scrubber effluent line	0 **(1)**	0 **(1)**	NA	NA	NA	NA	NA	0 **(1)**	0 **(1)**	NA	0
Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1 **(6)**
Distribution line	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1 **(2)**
FLAMMABLE LIQUIDS (FLASH POINT > 60°C)											
Cargo lines	X	X	L1	X	X	NA **(3)**	0	0 **(10)**	0	NA	L1
Fuel oil	X	X	L1	X	X	NA **(3)**	0	0	0	L1	L1
Lubricating oil	X	X	L1	X	X	NA	NA	NA	0	L1	L1
Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEA WATER **(1)**											
Bilge main and branches	L1 **(7)**	L1 **(7)**	L1	X	X	NA	0	0	0	NA	L1
Fire main and water-spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
Foam system	L1W	L1W	L1W	NA	NA	NA	NA	NA	0	L1W	L1W
Sprinkler system	L1W	L1W	L3	X	NA	NA	NA	0	0	L3	L3
Ballast	L3	L3	L3	L3	X	0 **(10)**	0	0	0	L2W	L2W
Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2W
Tank cleaning services, fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3 **(2)**
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER											
Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY, DRAINS, SCUPPERS											
Deck drains (internal)	L1W **(4)**	L1W **(4)**	NA	L1W **(4)**	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
Scuppers and discharges (over-board)	0 **(1) (8)**	0 **(1) (8)**	0 **(1) (8)**	0 **(1) (8)**	0 **(1) (8)**	0	0	0	0	0 **(1) (8)**	0
SOUNDING, AIR											
Water tanks, dry spaces	0	0	0	0	0	0 **(10)**	0	0	0	0	0
Oil tanks (flash point > 60°C)	X	X	X	X	X	X **(3)**	0	0 **(10)**	0	X	X

MISCELLANEOUS											
Control air	L1 **(5)**	L1 **(5)**	L1 **(5)**	L1 **(5)**	L1 **(5)**	NA	0	0	0	L1 **(5)**	L1 **(5)**
Service air (non-essential)	0	0	0	0	0	NA	0	0	0	0	0
Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
Auxiliary low steam pressure (≤ 0,7 MPa)	L2W	L2W	0 **(9)**	0 **(9)**	0 **(9)**	0	0	0	0	0 **(9)**	0 **(9)**
Central vacuum cleaners	NA	NA	NA	0	NA	NA	NA	NA	0	0	0
Exhaust gas cleaning system effluent line	L3 **(1)**	L3 **(1)**	NA	NA	NA	NA	NA	NA	0	L3 **(1) (11)** NA	0
Urea transfer / supply system (SCR installations)	L1 **(12)**	L1 **(12)**	NA	NA	NA	NA	NA	NA	0	L3 **(1) (11)** NA	0

Note 1:

- L1 : Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended) in dry conditions, 60 min
- L1W : Fire endurance test (see [2.5.1])
- L2 : Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended) in dry conditions, 30 min
- L2W : Fire endurance test (see [2.5.1])
- L3 : Fire endurance test (appendix 2 of IMO Resolution A.753(18), as amended) in wet conditions, 30 min
- 0 : No fire endurance test required
- NA : Not applicable
- X : Metallic materials having a melting point greater than 925°C

(1) Where non-metallic piping is used, remote controlled valves to be provided at ship side (valve is to be controlled from outside space).

(2) Remote closing valves to be provided at the cargo tanks.

(3) When cargo tanks contain flammable liquids with flash point > 60 °C, "0" may replace "NA" or "X".

(4) For drains serving only the space concerned, "0" may replace "L1W".

(5) When controlling functions are not required by the Rules, "0" may replace "L1".

(6) For pipes between machinery space and deck water seal, "0" may replace "L1".

(7) For passenger vessels, "X" is to replace "L1".

(8) Scuppers serving open decks in positions 1 and 2, as defined in Pt B, Ch 1, Sec 3, are to be "X" throughout unless fitted at the upper end with a means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.

(9) For essential services, such as fuel oil tank heating and ship's whistle, "X" is to replace "0".

(10) For tankers required to comply with Pt D, Ch 7, Sec 4, [2.1.3], "NA" is to replace "0".

(11) L3 in service spaces, NA in accommodation and control spaces.

(12) Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.

(13) For passenger Ships subject to SOLAS Chapter II-2, Regulation 21.4 (Safe return to Port), plastic pipes for services required to remain operational in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with IMO Circular MSC.1/Circ.1369, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

(14) Machinery spaces of category A are defined in Ch 4, Sec 1, [2.30.1].

(15) Spaces, other than category A machinery spaces and cargo pumps rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.

(16) Spaces containing cargo pumps, and entrances and trunks to such spaces.

(17) Ro-ro cargo spaces and special category spaces are defined in Ch 4, Sec 1, [2].

(18) All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.

(19) All spaces used for liquid cargo and trunks to such spaces.

(20) All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.

(21) All spaces used for ballast water and trunks to such spaces.

(22) Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.

(23) Accommodation spaces, service spaces and control stations are defined in Ch 4, Sec 1, [2].

(24) Open decks are defined in Ch 4, Sec 5, [1.3.3], item b), 2).

3 Material approval and quality control during manufacture

3.1 General

3.1.1 Except as required in [1.1.3], prototypes of pipes and fittings are to be tested to determine short-term and long-term design strength, fire endurance and low surface flame spread characteristics (if applicable), electrical resistance (for electrically conductive pipes), impact resistance in accordance with the requirements of this Appendix.

3.1.2 For prototype testing representative samples of pipes and fittings are to be selected to the satisfaction of the Society.

3.1.3 The Manufacturer is to have quality system that meets ISO 9001:2015 standards or equivalent. The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

3.1.4 Each pipe and fitting is to be tested by the Manufacturer at a hydrostatic pressure not less than 1,5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognised national or international standard to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

3.1.5 Piping and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

3.1.6 In case the Manufacturer does not have an approved quality system complying with ISO 9001:2015 or equivalent, pipes and fittings are to be tested in accordance with this Appendix to the satisfaction of the Surveyors for every batch of pipes.

3.1.7 Depending upon the intended application a Society may require the pressure testing of each pipe and/or fitting.

4 Arrangement and installation of plastic pipes

4.1 Supports

4.1.1 Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe Manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, length of the piping, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected.

Combination of loads is to be considered.

4.1.2 Each support is to evenly distribute the load of the pipe and its content over the full width of the support. Measures are to be taken to minimise wear of the pipes where they are in contact with the supports.

4.1.3 Heavy components in the piping system such as valves and expansion joints are to be independently supported.

4.2 Expansion

4.2.1 Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

- the high difference in the coefficients of thermal expansion
- deformations of the ship’s structure.

4.2.2 Calculations of the thermal expansions are to take into account the system working temperature and the temperature at which the assembly is performed.

4.3 External loads

4.3.1 When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowance is to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter.

4.3.2 Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with [2.1], may be increased taking into account the conditions encountered during service on board ships.

4.3.3 Pipes are to be protected from mechanical damage where necessary.

4.4 Strength of connections

4.4.1 General

a) The strength of connections is not to be less than that of the piping system in which they are installed.

b) Pipes and fittings may be assembled using adhesive-bonded, welded, flanged or other joints.

c) When used for joint assembly, adhesives are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

d) Tightening of joints, where required, is to be performed in accordance with the manufacturer's instructions.

4.5 Installation of conductive pipes

4.5.1 In piping systems for fluids with conductivity less than 1000 pico siemens per metre (pS/m) such as refined products and distillates use is to be made of conductive pipes.

Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed 1×10^6 Ohm. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.

After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection

4.6 Application of fire protection coatings

4.6.1 Where necessary for the required fire endurance as stated in [2.5.3], fire protection coatings are to be applied on the joints, after performing hydrostatic pressure tests of the piping system.

4.6.2 The fire protection coatings are to be applied in accordance with the manufacturer's recommendations, using a procedure approved in each case.

4.7 Penetration of fire divisions and watertight bulkheads or decks

4.7.1 Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that fire endurance is not impaired. These arrangements are to be tested in accordance with 'Recommendations for Fire Test Procedures for "A", "B" and "F" Bulkheads' 2010 FTP Code, annex 1, part 3, as amended.

4.7.2 When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in [2.1.3] item b), a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

4.7.3 If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.

4.8 Control during installation

4.8.1 General

a) Installation is to be in accordance with the Manufacturer's guidelines.

b) Prior to commencing the work, joining techniques are to be approved by the Society.

c) The tests and explanations specified in the present Appendix are to be completed before shipboard piping installation commences.

d) The personnel performing this work are to be properly qualified and certified to the satisfaction of the Society.

e) The procedure for making bonds is to be submitted to the Society for qualification. It is to include the following:

- materials used
- tools and fixtures
- joint preparation requirements
- cure temperature
- dimensional requirements and tolerances
- acceptance criteria for the test of the completed assembly

f) Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be requalified.

4.8.2 Bonding qualification test

a) A test assembly is to be fabricated in accordance with the procedure to be qualified. It is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.

b) When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor of 2,5 times the design pressure of the test assembly, for not less than one hour. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.

c) Selection of the pipes used for the test assembly is to be in accordance with the following:

- when the largest size to be joined is 200 mm nominal outside diameter or smaller, the test assembly is to be the largest piping size to be joined.
- when the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is the greater.

d) When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies, the size and number of which are to be as required above.

4.9 Testing after installation on board

4.9.1 Piping systems for essential services are to be subjected to a test pressure not less than 1,5 times the design pressure or 4 bar whichever is greater. Notwithstanding the requirement above, the requirement in [4.9.2] may be applied to open ended pipes (drains, effluent, etc.).

4.9.2 Piping systems for non-essential services are to be checked for leakage under operational conditions.

4.9.3 For piping required to be electrically conductive, earthing is to be checked, and random resistance testing is to be conducted.

5 Test specification for plastic pipes

5.1 Scope

5.1.1 This Article contains requirements for the type approval of plastic pipes. It is applicable to piping systems, including pipe joints and fittings, made predominately of other material than metal.

5.2 Documentation

5.2.1 The following information for the plastic pipes, fittings and joints is to be submitted for consideration and approval:

a) General information

- pipe and fitting dimensions
- maximum internal and external working pressure
- working temperature range
- intended services and installation locations
- the level of fire endurance
- electrically conductive
- intended fluids
- limits on flow rates
- serviceable life
- installation instructions
- details of marking.

b) Drawings and supporting documentation

- certificates and reports for relevant tests previously carried out
- details of relevant standards
- all relevant design drawings, catalogues, data sheets, calculations and functional descriptions
- fully detailed sectional assembly drawings showing pipe, fittings and pipe connections.

c) Materials (as applicable)

- the resin type
- catalyst and accelerator types, and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed
- a statement of all reinforcements employed where the reference number does not identify the mass per unit area or the tex number of a roving used in a filament winding process, these are to be detailed
- full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate
- cure/post-cure conditions. The cure and post-cure temperatures and times employ resin/reinforcement ratio
- winding angle and orientation
- Joint bonding procedures and qualification tests results, see [4.8.1], item e).

5.3 Testing

5.3.1 Testing is to demonstrate compliance of the pipes, fittings and joints for which type approval is sought with the present Appendix.

Pipes, joints and fittings are to be tested for compliance with the requirements of recognized standards acceptable to the Society. In that order, recommended standards are given in Tab 2 and Tab 3.

Table 2 : Typical requirements for all systems

No.	Test	Typical standard	Notes
1	Internal pressure **(1)**	• the present [2.1.3], item a) • ASTM D 1599-18 • ASTM D 2992-18 • ISO 15493:2003 or equivalent	Top, middle, bottom (of range) Tests are to be carried out on pipe spools made of different pipe sizes, fittings and pipe connections
2	External pressure **(1)**	• the present [2.1.3], item b) • ISO 15493:2003 or equivalent	As above, for straight pipes only
3	Axial strength	the present [2.2]	As above
4	Load deformation	ASTM D 2412-21 or equivalent	Top, middle, bottom (of each pressure range)
5	Temperature limitations	• ISO 75-2:2013 method A GRP piping system: HDT test on each type of resin according to ISO 75-2:2013 method A • Thermoplastic piping systems: - ISO75-1:2020 and ISO 75:2-2013 method A - ISO 306:2022 - Thermoplastic materials - Determination of Vicat softening temperature (VST) - VICAT test according to ISO 2507:1995 • Polyesters with an HDT below 80°C should not be used	Each type of resin
6	Impact resistance	• ISO 9854:1994 • ISO 9653:1998 • ISO 15493:2003 • ASTM D 2444-21 or equivalent	Representative samples of each type of construction
7	Ageing	• Manufacturer's standard • ISO 9142:2003	Each type of construction
8	Fatigue	Manufacturer's standard or service experience	Each type of construction
9	Fluid absorption	ISO 8361:1991	
10	Material compatibility **(2)**	• ASTM C581-20 • Manufacturer's standard	

(1) Test to be witnessed by a Surveyor of the Society.
(2) If applicable.

Table 3 : Typical additional requirements depending on service and/or locations of piping

No	Test	Typical standard	Notes
1	Fire endurance **(1) (2) (3)**	IMO Resolution A.753(18), as amended, Appendix 1, 2	Representative samples of each type of construction and type of pipe connection
2	Flame spread **(1) (2) (3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
3	Smoke generation **(2) (3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
4	Toxicity **(2) (3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
5	Electrical conductivity **(1) (2) (3)**	ASTM F1173-95 or ASTM D 257, NS 6126 section 11.2 or equivalent	Representative samples of each type of construction

(1) Test to be witnessed by a Surveyor of the Society.
(2) If applicable
(3) Optional. However, if the test is not carried out, the range of approved applications for the pipes is to be limited accordingly

Appendix 4 Type Testing Procedure for Crankcase Explosion Relief Valves

1 General

1.1 Scope

1.1.1 This appendix specifies type tests and identifies standard test conditions using methane gas and air mixture to demonstrate the Society requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

1.1.2 This test procedure is only applicable to explosion relief valves fitted with flame arresters.

Note 1: Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with this appendix may be proposed by the manufacturer. The alternative testing arrangements are to be agreed by the Society.

1.2 Recognised standards

1.2.1 The following standards are considered as recognised standards:

- ISO 16852:2016
- ISO/IEC 17025:2017
- ISO 12100:2010
- VDI 3673-1:2002
- IMO MSC/Circ.677 as amended by MSC/Circ.1009 and MSC.1/Circ.1324.

1.3 Purpose

1.3.1 The purpose of type testing crankcase explosion relief valves is fourfold:

- To verify the effectiveness of the flame arrester
- To verify that the valve closes after an explosion
- To verify that the valve is gas/air tight after an explosion
- To establish the level of over pressure protection provided by the valve.

1.4 Approval

1.4.1 The approval of explosion relief valves is at the discretion of the Society based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

2 Type testing procedure

2.1 Test facilities

2.1.1 Test houses carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

a) The test houses where testing is carried out are to be accredited to a National or International Standard, e.g. ISO/IEC 17025:2017, and are to be acceptable to the Society.

b) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure

c) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0.1%

d) The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture

e) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera

f) The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not "pipe like" with the distance between dished ends being not more than 2.5 times its diameter. The internal volume of the test vessel is to include any standpipe arrangements

g) The test vessel is to be provided with a flange, located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve.

The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane

h) A circular plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:

1) Outside diameter of 2 times the outer diameter of the valve top cover

2) Internal bore having the same internal diameter as the valve to be tested

i) The test vessel is to have connections for measuring the methane in air mixture at the top and bottom

j) The test vessel is to be provided with a means of fitting an ignition source at a position specified in [2.2.3].

k) The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in Ch 1, Sec 2, [2.3.4], d) for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume.

Note 1: This means that the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10 m^3.

Note 2: Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.

Note 3: In no case is the volume of the test vessel to vary by more than +15% to –15% from the design cm^2/m^3 volume ratio.

2.2 Explosion test process

2.2.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ±0.5%. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

2.2.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0.5%.

2.2.3 The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

2.2.4 The ignition is to be made using a maximum 100 joule explosive charge.

2.3 Valves to be tested

2.3.1 The valves used for type testing (including testing specified in [2.3.3] are to be selected from the manufacturer's normal production line for such valves by the classification society witnessing the tests.

2.3.2 For approval of a specific valve size, three valves are to be tested in accordance with [2.3.3] and [2.4]. For a series of valves see [2.6].

2.3.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ± 20% and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds.

Note 1: This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

2.3.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

2.4 Method

2.4.1 The following requirements are to be satisfied at explosion testing:

a) The explosion testing is to be witnessed by a classification society surveyor

b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted

c) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions

d) The pressure rise and decay during all explosion testing is to be recorded

e) The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera

2.4.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

a) Stage 1:

Two explosion tests are to be carried out in the test vessel with the circular plate described in [2.1.1] h) fitted and the opening in the plate covered by a 0.05 mm thick polythene film

Note 1: These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, see [2.5.1] f).

b) Stage 2:

1) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought i.e., in the vertical or horizontal position with the circular plate described in [2.1.1] h) located between the valve and pressure vessel mounting flange

2) The first of the two tests on each valve is to be carried out with a 0.05mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30% of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in [1.2]

Note 2: During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

3) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no visible signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion

4) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test

c) Stage 3:

Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

2.5 Assessment and records

2.5.1 For the purposes of verifying compliance with the requirements of this Section, the assessment and records of the valves used for explosion testing is to address the following:

a) The valves to be tested are to have evidence of design appraisal/approval by the classification society witnessing tests

b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0.2bar

c) The test vessel volume is to be determined and recorded

d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test. This should be confirmed by the test laboratory taking into account measurements from the heat sensitive camera

e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady underpressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel

f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer

g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an underpressure of at least 0.3bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion

h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve

i) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

2.6 Design series qualification

2.6.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

2.6.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, depth of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters satisfying:

$$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

and

$$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where:

n_1 : total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 : total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2

A_1 : free area of quenching device for a valve with a relief area equal to S_1

A_2 : free area of quenching device for a valve with a relief area equal to S_2

2.6.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with [2.4] and [2.5] can be evaluated where valves are of identical type and have identical features of construction subject to the following:

a) The free area of a larger valve does not exceed three times + 5% that of the valve that has been satisfactorily tested

b) One valve of the largest size, see a), requiring qualification is subject to satisfactory testing required by [2.3.3] and [2.4.2], b) except that a single valve will be accepted in [2.4.2], b), 1) and the volume of the test vessel is not to be less than one third of the volume required by [2.1.1], k)

c) The assessment and records are to be in accordance with [2.5]noting that [2.5.1], f) will only be applicable to Stage 2 (see [2.4.2]for a single valve.

2.6.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with [2.4] and [2.5] can be evaluated where valves are of identical type and have identical features of construction subject to the following:

a) The free area of a smaller valve is not less than one third of the valve that has been satisfactorily tested

b) One valve of the smallest size, subject to a), requiring qualification is subject to satisfactory testing required by [2.3.3] and [2.4.2], b) except that a single valve will be accepted in [2.4.2], b), 1) and the volume of the test vessel is not to be more than the volume required by [2.1.1], k)

c) The assessment and records are to be in accordance with article [2.5] noting that [2.5.1], f) will only be applicable to Stage 2 for a single valve.

2.7 Report

2.7.1 The test facility is to deliver a full report that includes the following information and documents:

- Test specification
- Details of test pressure vessel and valves tested
- The orientation in which the valve was tested, (vertical or horizontal position).
- Methane in air concentration for each test
- Ignition source
- Pressure curves for each test
- Video recordings of each valve test
- The assessment and records stated in [2.5].

Appendix 5 Type Approval of Mechanical Joints

1 General

1.1 Scope

1.1.1 This specification describes the type testing condition for type approval of mechanical joints intended for use in marine piping systems. Conditions outlined in these requirements are to be fulfilled before Type Approval Certificates are issued.

1.1.2 The Society may accept alternative testing in accordance with national or international standards where applicable to the intended use and application.

1.1.3 This specification is applicable to mechanical joints defined in Ch 1, Sec 10, [2.4.5] including compression couplings and slip-on joints of different types for marine use.

1.2 Documentation

1.2.1 Following documents and information are to be submitted by Manufacturer for assessment and/or approval:

- product quality assurance system implemented
- complete description of the product
- typical sectional drawings with all dimensions necessary for evaluation of joint design
- complete specification of materials used for all components of the assembly
- proposed test procedure as required in [2] and corresponding test reports or other previous relevant tests
- initial information:
  - maximum design pressures (pressure and vacuum)
  - maximum and minimum design temperatures
  - conveyed media
  - intended services
  - maximum axial, lateral and angular deviation, allowed by manufacturer
  - installation details.

1.3 Materials

1.3.1 The materials used for mechanical joints are to comply with the requirements of Ch 1, Sec 10, [2.4.5].

The manufacturer has to submit evidence to substantiate that all components are adequately resistant to working the media at design pressure and temperature specified.

2 Testing, procedures and requirements

2.1 Aim of the tests

2.1.1 The aim of tests is to demonstrate ability of the pipe joints to operate satisfactory under intended service conditions. The scope and type of tests to be conducted e.g. applicable tests, sequence of testing, and the number of specimen, is subject to approval and will depend on joint design and its intended service in accordance with the requirements of Ch 1, Sec 10.

2.2 Test fluid

2.2.1 Unless otherwise specified, the water or oil as test fluid is to be used.

2.3 Test program

2.3.1 Testing requirements for mechanical joints are to be as indicated in Tab 1.

2.4 Selection of test specimen

2.4.1 Test specimens are to be selected from production line or at random from stock.

Where there is a variety of size of joints requiring approval, a minimum of three separate sizes, representative of the range, from each type of joint to be tested in accordance with in Tab 1.

2.5 Mechanical joint assembly

2.5.1 Assembly of mechanical joints is to consist of components selected in accordance with [2.4.1] and the pipe sizes appropriate to the design of the joints.

2.5.2 Where pipe material would affect the performance of mechanical joints, the selection of joints for testing is to take the pipe material into consideration.

2.5.3 Where not specified, the length of pipes to be connected by means of the joint to be tested is to be at least five times the pipe diameter. Before assembling the joint, conformity of components to the design requirements is to be verified. In all cases the assembly of the joint is to be carried out only according to the manufacturer's instructions. No adjustment operations on the joint assembly, other than that specified by the manufacturer, are permitted during the test.

2.6 Test results acceptance criteria

2.6.1 Where a mechanical joint assembly does not pass all or any part of the tests in Tab 1, two assemblies of the same size and type that failed are to be tested and only those tests which the mechanical joint assembly failed in the first instance, are to be repeated. In the event where one of the assemblies fails the second test, that size and type of assembly is to be considered unacceptable.

2.6.2 The methods and results of each test are to be recorded and reproduced as and when required.

Table 1 : Tests for mechanical joints

Tests		Type of mechanical joint			Notes and references
		Compression couplings and pipes unions	Slip on joints		
			Grid type and machine grooved type	Slip type	
1	Tightness test	+	+	+	[2.7.1]
2	Vibration (fatigue) test	+	+	–	[2.7.2]
3	Pressure pulsation test **(1)**	+	+	–	[2.7.3]
4	Burst pressure test	+	+	+	[2.7.4]
5	Pull-out test	+	+	–	[2.7.5]
6	Fire endurance test	+ **(3)**	+	+	[2.7.6] if required by Ch 1, Sec 10, Tab 17
7	Vacuum test	+ **(3)**	+	+	[2.7.7] for suction line only
8	Repeated assembly test	+ **(2)**	+	–	[2.7.8]

\+ : test is required
– : test is not required
(1) for use in all class I and II systems and those class III systems where pressure pulsation other than water hammer is expected
(2) except permanent joint type (e.g. press type and swage type)
(3) except joints with metal-to-metal tightening surfaces

2.7 Methods of tests

2.7.1 Tightness test

In order to ensure correct assembly and tightness of the joints, all mechanical joints are to be subjected to a tightness test, as follows:

a) The mechanical joint assembly test specimen is to be connected to the pipe or tubing in accordance with the requirements of [2.5] and the manufacturers instructions, filled with test fluid and de-aerated.

Mechanical joints assemblies intended for use in rigid connections of pipe lengths, are not to be longitudinally restrained.

The pressure inside the joint assembly is to be slowly increased to 1,5 times of design pressure. This test pressure is to be retained for a minimum period of 5 minutes.

In the event of a drop in pressure or visible leakage, the test (including fire test) is to be repeated for two further specimens.

If during the repeat test one test piece fails, the coupling is regarded as having failed.

Other alternative tightness test procedure, such as pneumatic test, may be accepted.

b) For compression couplings a static gas pressure test is to be carried out to demonstrate the integrity of the mechanical joints assembly for tightness under the influence of gaseous media. The pressure is to be raised to maximum pressure or 70 bar whichever is less.

c) Where the tightness test is carried out using gaseous media as permitted in a) above, then the static pressure test mentioned in b) above need not be carried out.

2.7.2 Vibration (fatigue) test

In order to establish the capability of the mechanical joint assembly to withstand fatigue, which is likely to occur due to vibrations under service conditions, mechanical joints assemblies are to be subject to the following vibration test.

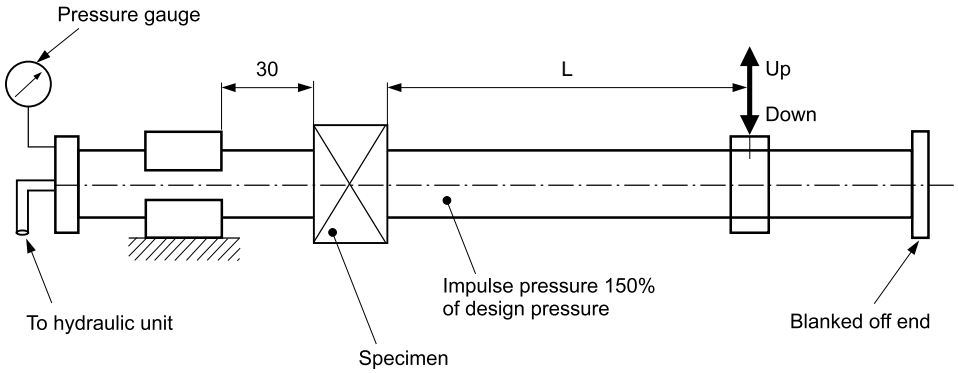
Conclusions of the vibration tests should show no leakage or damage.

a) Testing of compression couplings and pipe unions

Compression couplings and pipe unions intended for use in rigid pipe connections are to be tested as follows. Rigid connections are joints, connecting pipe length without free angular or axial movement.

Two lengths of pipe are to be connected by means of the joint to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibration rig. The test rig and the joint assembly specimen being tested are to be arranged as shown in Fig 1.

Figure 1 : Testing of compression couplings and pipe unions



The joint assembly is to be filled with test fluid, de-aerated and pressurised to the design pressure of the joint.

Pressure during the test is to be monitored. In the event of a drop in the pressure and visible leakage, the test is to be repeated as described in [2.6].

Visual examination of the joint assembly is to be carried out.

Re-tightening may be accepted once during the first 1000 cycles.

Vibration amplitude is to be within 5% of the value calculated from the following formula:

$$A = \frac{2SL^2}{3ED}$$

where:

A : Single amplitude, in mm

L : Length of the pipe, in mm

S : Allowable bending stress, in N/mm^2, based on 0,25 of the yield stress

E : Modulus of elasticity of tube material (for mild steel, E = 210 kN/mm^2)

D : Outside diameter of tube, in mm.

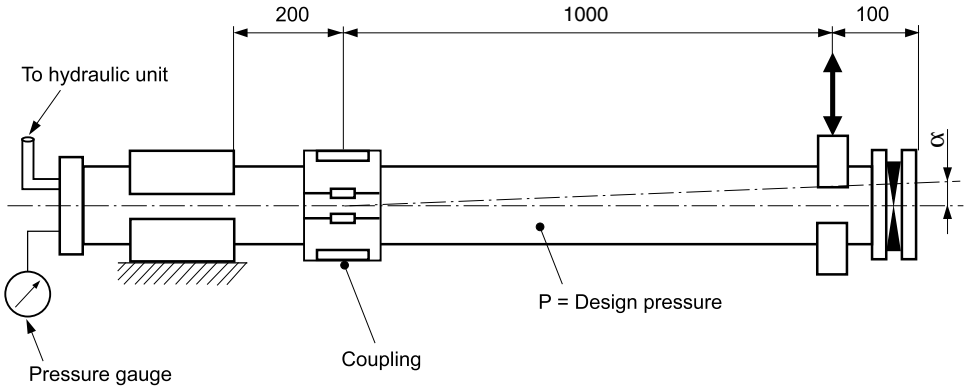
Test specimen is to withstand not less than 10^7 cycles with frequency 20 - 50 Hz without leakage or damage.

b) Grip type and machine grooved type joints

Grip type joints and other similar joints containing elastic elements are to be tested in accordance with the following method.

A test rig of cantilever type used for testing fatigue strength of components may be used. The test specimen being tested is to be arranged in the test rig as shown in Fig 2.

Figure 2 : Grip type and machine grooved type joints



Two lengths of pipes are to be connected by means of joint assembly specimen to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibrating element on the rig. The length of pipe connected to the fixed end should be kept as short as possible and in no case exceed 200 mm.

Mechanical joint assemblies are not to be longitudinally restrained.

The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint. Preliminary angle of deflection of pipe axis is to be equal to the maximum angle of deflection, recommended by the manufacturer. The amplitude is to be measured at 1m distance from the center line of the joint assembly at free pipe end connected to the rotating element of the rig (see Fig 2).

Parameters of testing are to be as indicated as per Tab 2 and to be carried out on the same assembly.

Pressure during the test is to be monitored. In the event of a drop in the pressure and visual signs of leakage the test is to be repeated as described in [2.6]. Visual examination of the joint assembly is to be carried out for signs of damage which may eventually cause leakage.

Table 2 : Parameters of testing

Number of cycles	Amplitude, mm	Frequency, Hz
$3 \cdot 10^6$	± 0,06	100
$3 \cdot 10^6$	± 0,50	45
$3 \cdot 10^6$	± 1,50	10

2.7.3 Pressure pulsation test

In order to determine capability of mechanical joint assembly to withstand pressure pulsation likely to occur during working conditions, joint assemblies intended for use in rigid connections of pipe lengths, are to be tested in accordance with the following method.

The mechanical joint test specimen for carrying out this test may be the same as that used in the test in [2.7.1], item a), provided it passed that test.

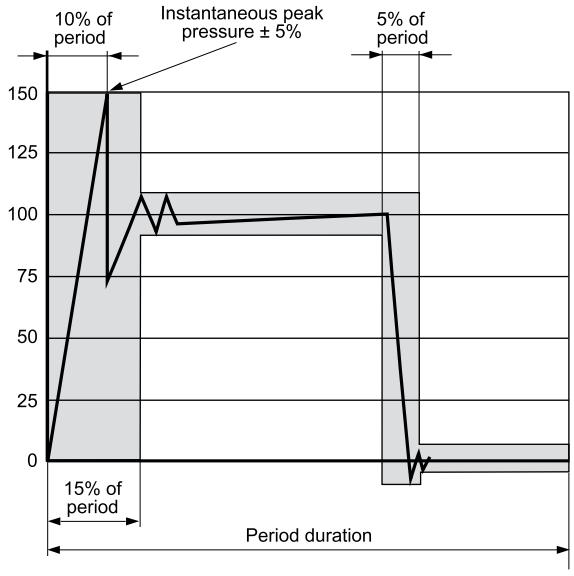
The vibration test in [2.7.2] and the pressure pulsation test are to be carried out simultaneously for compression couplings and pipe unions.

The mechanical joint test specimen is to be connected to a pressure source capable of generating pressure pulses of magnitude as shown in Fig 3.

Impulse pressure is to be raised from 0 to 1,5 times the design pressure of the joint with a frequency equal to 30-100 cycles per minute. The number of cycles is not to be less than 5×10^5.

The mechanical joint is to be examined visually for sign of leakage or damage during the test.

Figure 3 : Impulse pressure diagram



2.7.4 Burst pressure test

In order to determine the capability of the mechanical joint assembly to withstand a pressure as stated by Ch 1, Sec 10, [2.4.5], item d), the following burst test is to be carried out.

Mechanical joint test specimen is to be connected to the pipe or tubing in accordance with the requirements of [2.5] filled with test fluid, de-aerated and pressurized to test pressure with an increasing rate of 10% per minute of test pressure. The mechanical joint assembly intended for use in rigid connections of pipe lengths is not to be longitudinally restrained.

Duration of this test is not to be less than 5 minutes at the maximum pressure.

Where considered convenient, the mechanical joint test specimen used in the tightness test in [2.7.1], may be used for the burst test provided it passed the tightness test.

The specimen may exhibit a small deformation whilst under test pressure, but no leakage or visible cracks are permitted.

2.7.5 Pull-out test

In order to determine the ability of a mechanical joint assembly to withstand the axial loading likely to be encountered in service without the connecting pipe becoming detached, following pullout test is to be carried out.

Pipes of suitable length are to be fitted to each end of the mechanical joints assembly test specimen. The test specimen is to be pressurized to design pressure. When pressure is attained, an external axial load is to be imposed with a value calculated using the following formula:

$$L = \frac{\pi}{4} D^2 p$$

where:

D : Pipe outside diameter, in mm

p : Design pressure, in N/mm^2

L : Applied axial load, in N.

The pressure and axial load are to be maintained for a period of 5 minutes.

During the test, pressure is to be monitored and relative movement between the joint assembly and the pipe measured.

The mechanical joint assembly is to be visually examined for drop in pressure and signs of leakage or damage.

There is to be no movement between the mechanical joint assembly and the connecting pipes.

2.7.6 Fire endurance test

In order to establish capability of the mechanical joints to withstand effects of fire which may be encountered in service, mechanical joints are to be subjected to a fire endurance test. The fire endurance test is to be conducted on the selected test specimens as per the following standards.

- ISO19921:2005 - Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods
- ISO19922:2005 - Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

Clarifications to the standard requirements in ISO19921:2005, paragraphs 7.2, 7.4, 7.6 and 7.7:

a) If the fire test is conducted with circulating water at a pressure different from the design pressure of the joint (however of at least 5 bar) the subsequent pressure test is to be carried out to 1,5 times the design pressure.

b) If the fire test is required in Ch 1, Sec 10, Tab 17 to be “8 min dry + 22 min wet” or “30 min dry”, i.e. conducted for a period of time without circulating of water, the following test conditions apply:

   - Test condition “8 min dry + 22 min wet”: The test piece is not required to be rinsed with the test medium (water) in preparation for the test as required in Paragraph 7.2 of ISO19921:2005. The exposure to fire is to be started and continued for 8 minutes with the sample dry; after 8 minutes of dry test condition the piping system is to be filled with water and test pressure is to be increased up to at least 5 bar within 2 minutes, then maintained to at least 5 bar. After further 22 minutes (i.e. 30 minutes from initial exposure to fire) the exposure to fire is to be stopped and a hydrostatic pressure test as specified in item a) is to be carried out.
   - Test condition “30 min dry”: The exposure to fire is to be started and continued for 30 minutes with the sample dry. After 30 minutes the exposure to fire is to be stopped and a hydrostatic pressure test as specified in item a) is to be carried out.

   For fire tests in dry condition the pressure inside the test specimen is to be monitored for a rise due to heating of the enclosed air. Means of pressure relief are to be provided where deemed necessary.

   High pressures created during this test can result in failure of the test specimen. Precautions are to be taken to protect personnel and facilities.

   Paragraph 7.5 of ISO 19921:2005 does not apply to the dry tests and no forced air circulation is to be arranged.

   For fire endurance test requiring exposure time greater than 30 minutes test conditions are adjusted to meet the extended required total exposure time. In all cases for dry-wet test the minimum dry test exposure time is 8 minutes.

c) A selection of representative nominal bores may be tested in order to evaluate the fire resistance of a series or range of mechanical joints of the same design. When a mechanical joint of a given nominal bore (D_n) is so tested then other mechanical joints falling in the range D_n to $2 \cdot D_n$ (both inclusive) are considered accepted.

d) Alternative test methods and/or test procedures considered to be at least equivalent may be accepted at the discretion of the Society in cases where the test pieces are too large for the test bench and cannot be completely enclosed by the flames.

e) Where thermal insulation is acceptable as a means of providing fire resistance, the following requirements apply:

- Thermal insulation materials applied on couplings are to be non-combustible according to ISO1182:2010 as required by the Fire Test Procedures Code as defined in Ch 4, Sec 1, [2.22]. Precautions are to be taken to protect the insulation from being impregnated with flammable oils.
- At least the fire endurance and the vibration testing in Tab 1 are to be carried out with thermal insulation in place.
- A service restriction is to be stated on the type approval certificate that the mechanical joints are to be fitted with thermal insulation during the installation in cases where the mechanical joints are used where fire resistance is required, unless mechanical joints are delivered already fitted with thermal insulation before installation.

2.7.7 Vacuum test

In order to establish the capability of the mechanical joint assembly to withstand internal pressures below atmospheric, similar to the conditions likely to be encountered under service conditions, the following vacuum test is to be carried out.

The mechanical joint assembly is to be connected to a vacuum pump and subjected to a pressure of 170 mbar absolute. Once this pressure is stabilized, the specimen under test is to be isolated from the vacuum pump and the pressure is to be maintained for a period of 5 minutes.

No internal pressure rise is permitted.

2.7.8 Repeated assembly test

The mechanical joint test specimen is to be dismantled and reassembled 10 times in accordance with manufacturers instructions and then subjected to a tightness test as defined in [2.7.1].

Appendix 6 Special Approval of Alloy Steel used for Intermediate Shaft Material

1 General

1.1 Application

1.1.1 This Appendix applies to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm^2, but less than 950 N/mm^2 intended for use as intermediate shaft material.

1.2 Torsional fatigue test

1.2.1 A torsional fatigue test is to be performed to verify that the material exhibits similar fatigue life as conventional steels. The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress τ_C given by the formula of τ_1 in Ch 1, Sec 9, [3.4.2], item b).

The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration in the design criteria.

Note 1: The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{t(hole)} + 0,8\,\frac{(l-e)/d}{\sqrt{\left(1-\frac{d_i}{d}\right)\frac{e}{d}}}$$

This formula applies to:

- slots at 120 or 180 or 360 degrees apart
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

where:

l : Slot length

e : Slot width

d : Shaft outside diameter

d_i : Shaft inside diameter

$\alpha_{t(hole)}$: Stress concentration of radial holes (in this context e = hole diameter) and can be determined as:

$$\alpha_{t(hole)} = 2,3 - 3\frac{e}{d} + 15\left(\frac{e}{d}\right)^2 + 10\left(\frac{e}{d}\right)^2\left(\frac{d_i}{d}\right)^2$$

or simplified to $\alpha_{t(hole)} = 2,3$

For unnotched specimen, scf = 1

1.2.2 Test conditions

Test conditions are to be in accordance with Tab 1. Mean surface roughness, in µm, is to be less than 0,2 Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352:2011.

Test procedures are to be in accordance with Section 10 of ISO 1352:2011.

Table 1 : Test condition

Loading type	Torsion
Stress ratio	R = –1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1 x 10^7 cycles

1.2.3 Acceptance criteria

Measured high-cycle torsional fatigue strength τ_{C1} and low-cycle torsional fatigue strength τ_{C2} are to be equal to or greater than the values given by the following formulae:

$$\tau_{C1} \geq \tau_{C,\lambda=0} = \frac{\sigma_B + 160}{6} C_K C_D$$

$$\tau_{C2} \geq 1,7 \frac{1}{\sqrt{C_K}} \tau_{C1}$$

where:

C_K : Factor for the particular shaft design features, see Ch 1, Sec 9, Tab 1

C_D : Size factor, see Ch 1, Sec 9, [3.2.2]

σ_B : Specified minimum tensile strength in N/mm^2 of the shaft material.

1.3 Cleanliness requirements

1.3.1 The steels are to have a degree of cleanliness as shown in Tab 2 when tested according to ISO 4967:2013 method A. Representative samples are to be obtained from each heat of forged or rolled products.

The steels are generally to comply with the minimum requirements of NR216, Ch 5, Sec 3, Tab 1, with particular attention given to minimising the concentrations of sulphur, phosphorus and oxygen in order to achieve the cleanliness requirements. The specific steel composition is required to be approved by the Society.

1.4 Inspection

1.4.1 The ultrasonic testing required by NR216, Ch 5, Sec 1, [10.3.1] is to be carried out prior to acceptance. The acceptance criteria are to be in accordance with IACS Recommendation No. 68 or a recognized national or international standard.

Table 2 : Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index I
Type A	Fine	1,0
	Thick	1,0
Type B	Fine	1,5
	Thick	1,0
Type C	Fine	1,0
	Thick	1,0
Type D	Fine	1,0
	Thick	1,0
Type DS	–	1,0

Appendix 7 Exhaust Gas Back Pressure Analysis

1 General

1.1 Scope

1.1.1 This Appendix provides guidance regarding the exhaust gas back pressure analysis to be submitted to justify exhaust systems connections without forced ventilation as per Ch 1, Sec 11, [2.4.1], when an exhaust gas pollution prevention system is installed.

1.2 Required analysis

1.2.1 Calculation cases

A dedicated exhaust gas back pressure analysis is to be submitted for each exhaust gas pollution prevention system installation on-board.

1.2.2 Conclusion of the back pressure assessment

The back pressure created by the exhaust gas pollution prevention system is to be determined for each case, with a view to ensure that the specific equipment is compatible with an interconnected exhaust gas piping system without forced ventilation (spray, packing, etc.).

The back pressure calculation is to demonstrate that the diesel engines associated with the exhaust gas pollution prevention system are capable of being operated within the limits specified by the engine manufacturer.

Note 1: Particular attention is to be paid to the part of the piping system between isolating valves and exhaust gas pollution prevention system line outlet due to the fact that there is a reduction of flow circulation and altered temperature conditions. Moisture issues are to be taken into account during material selection of the exhaust piping, in order to avoid any premature corrosion.

1.3 Input data

1.3.1 The particulars of each engine type are to be documented and explained:

- Engine type
- Number of turbochargers
- Exhaust gas temperature at turbocharger outlet
- Exhaust gas temperature after boiler / SCR / silencer and/or any equipment in the exhaust gas line (as applicable)
- Total exhaust gas quantity
- Engine manufacturer maximum permissible pressure drop
- Exhaust gas pipe diameter and length after turbocharger
- Exhaust gas pipe diameter and length at manifold
- Exhaust gas pipe diameter and length after manifold
- Exhaust gas pipe diameter and length before boiler / SCR / silencer and/or any equipment in the exhaust gas line (as applicable)
- Exhaust gas pipe diameter and length after Boiler / SCR / silencer and/or any equipment in the exhaust gas line (as applicable)
- Exhaust gas pipe diameter and length after exhaust gas pollution prevention system

1.3.2 Ambient conditions

Ambient conditions corresponding to the ship operation, in particular summer and winter conditions as well as area of navigation are to be taken into consideration for the back pressure calculation.

1.3.3 A general description of the exhaust gas piping and exhaust gas pollution prevention system with the applicable limitations and ambient conditions is to be detailed in each case.

1.4 Exhaust gas back pressure assessment

1.4.1 General

The analysis is to detail the pressure losses along the exhaust lines.The total pressure loss is to be calculated for each possible exhaust line configuration depending on the number of engines connected to the exhaust gas pollution prevention system.

In addition, the following pressure losses are to be detailed individually:

- pressure losses along the exhaust gas pollution prevention system line
- pressure losses along lines with components other than exhaust gas pollution prevention system such as silencer, exhaust gas boiler, SCR etc

1.4.2 The calculation methodology is to be described with detailed formulas and related assumptions and/or approximations.

1.4.3 CFD simulation

The Society reserves the right to require a CFD simulation for each case near the limit of engine manufacturer maximum permissible pressure drop to validate the installation of such design on board.

Appendix 8 Type Testing Procedure of Explosion Relief Devices for Combustion Air Inlet and Exhaust Gas Manifolds of I.C. Engines Using Gas as Fuel

1 General

1.1 Scope

1.1.1 The purpose of this appendix is to specify testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

1.1.2 This appendix is dealing with engines using natural gas as only fuel or dual fuel engines using diesel oil and natural gas as fuel.

1.2 Definitions

1.2.1 Definitions addressing gas as fuel as given in Ch 1, App 2, apply.

1.2.2 Explosion relief device (ERD)

Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

1.3 Documentation to be submitted

1.3.1 List of documents to be provided for approval before testing related to ERD

- Drawings (sectional drawings, details, assembly etc.)
- Specification data sheet including operating conditions and design limits such as:
  - maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure
  - maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature
  - static opening pressure, resulting from maximum charging air or exhaust gas back pressure
  - maximum explosion pressure, i.e. maximum pressure that the device can withstand
  - geometric relief area
- Product marking
- Installation and operation manual
- Test program
- Specification of test vessel
- Type range and operating conditions encompassed for the type approval (see [2.1.3]).

1.3.2 List of documents to be provided for approval after testing related to ERD

A complete test report has to be submitted to the Society for:

- The demonstration of opening pressure (see [2.2]) and
- The explosion test (see [2.3]).

The reports shall include respective information according to the requirements in Article [2], as applicable:

- Test specimens
- Test facility, including measuring equipment and test vessel
- Measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.)
- Video documentation of explosion tests
- Photo documentation of ERD components.

2 Tests

2.1 Test specimens of ERD

2.1.1 The ERD used for the explosion test is to be selected from the manufacturer's production line by a representative of the Society:

- As a finished certified component itself, or
- On samples taken from earlier stages in the production of the component, when applicable.

2.1.2 If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.

2.1.3 If applicable, the selected ERD shall be representative for the type range and operating conditions, for example:

- Kind of ERD (valve, rupture disc, etc.)
- Mounting orientation (vertical, horizontal)
- Design of ERD (e.g., spring design, sealing)
- Design of flame arrester
- ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in [2.3.2].

The selection of the representative ERD is subject to approval by the Society.

2.2 Test for Demonstration of opening pressure

2.2.1 The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

2.3 Explosion test

2.3.1 Test facility

a) The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025:2017, and are to be acceptable to the Society.

b) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

c) The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of ± 0.1%.

d) The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

e) The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

f) The explosion test (see [2.3.5]) is to be documented by high speed (250 frames/s or above) video recording. The video recording shall be provided with a time stamp.

2.3.2 Test vessel

a) The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

The test vessel shall comply with the following requirements:

- The shape of the test vessel is to correspond to a pipe with L/D ≥ 10.
- The test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc shall be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure shall be ± 10% of the static opening pressure of the ERD.
- The volume of the test vessel is to comply with the specific relief area of the ERD of 700 cm^2/m^3 ± 15%.
- The test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment.
- The ignition is to be made at the middle of the test vessel.
- The test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel.
- The test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center.
- The test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in [2.3.6].
- The test vessel configuration is subject to approval by the Society.

b) Typical test vessels configurations:

- All test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end.
- The ignition is in the centre of the test vessel.
- The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2).
- The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).

See Fig 1, Fig 2, and Fig 3.

2.3.3 Explosion test process

The explosion testing is to be performed in two stages according to [2.3.4] and [2.3.5] for each ERD that is required to be approved as type tested.

The explosion testing is to be witnessed by a Society surveyor.

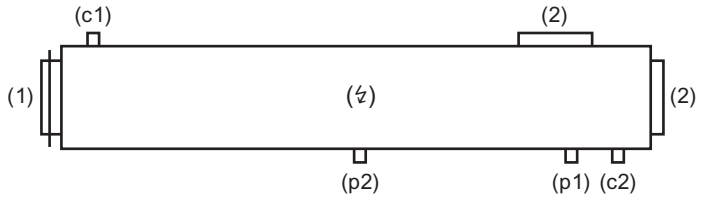
Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

2.3.4 Reference test - Explosion test without ERD

Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Fig 1.

The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

Figure 1 : Configuration without ERD (flanges for ERD closed (2))



2.3.5 ERD test - Explosion test with ERD

a) Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc shall be replaced.

a) If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted.

The test vessel configuration is shown in Fig 2 or Fig 3.

Figure 2 : Configuration with ERD (3) mounted at the front end of the test vessel

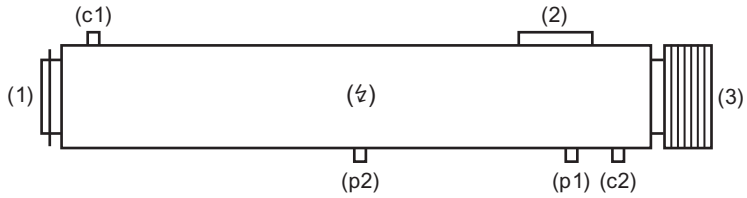
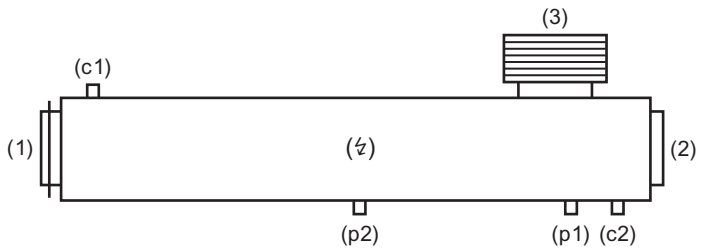


Figure 3 : Configuration with ERD (3) mounted on top of the test vessel



2.3.6 Explosion test method

a) The test conditions shall comply with the intended use of the ERD, such as:
   - Pipe diameter
   - Operating pressure
   - Operating temperature
   - Installation orientation.

b) All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ± 0.5%. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane shall not differ by more than 0.5%.

c) The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

   The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

d) If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer shall prove the acceptability of this deviation either using standards or generally applicable calculation methods.

e) The ignition is to be made using an explosive charge of 50 - 100 Joule.

f) Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

g) The pressure rise and decay during all explosion testing is to be recorded.

h) The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (see [2.3.4]) and the average of the two explosions of the ERD test (see [2.3.5]).

i) For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (see [2.3.5]). This is to be monitored by a high-speed video camera (see [2.3.1], item f)), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.

j) After each ERD test (see [2.3.5]), the external condition of the flame arrester to be examined for signs of damage and/or deformation that may affect the operation of the ERD.

2.4 Check of ERD components

2.4.1 After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

3 Assessment and approval

3.1 Assessment

3.1.1 To verify compliance with this requirement the assessment has to address the following:

a) Function and mechanical integrity of the ERD.
   - After dismantling of the ERD, the flame arrester shall not show signs of damage or any deformation that may affect the operation of the ERD.
   - If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
   - The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in [2.3.5].

b) The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

3.2 Approval

3.2.1

a) The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in [2.3.2] for the test vessel rupture disc in terms of free area.

b) ERD are to be type approved

c) Raw material certificates are to be Class Certificates

d) Product certificates are to be class certificates.

CHAPTER 2
ELECTRICAL INSTALLATIONS

Section 1 General
Section 2 General Design Requirements
Section 3 System Design
Section 4 Rotating Machines
Section 5 Transformers
Section 6 Semiconductor Converters
Section 7 Battery Energy Storage Systems and Chargers
Section 8 Switchgear and Controlgear Assemblies
Section 9 Cables
Section 10 Miscellaneous Equipment
Section 11 Location
Section 12 Installation
Section 13 High-voltage Installations
Section 14 Electric Propulsion Plant
Section 15 Testing
Appendix 1 Indirect Test Method for Synchronous Machines
Appendix 2 Indirect Test Method for Induction Machines (Static Torque Method)

Section 1 General

1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to electrical installations on ships. In particular, they apply to the components of electrical installations for:

- primary essential services
- secondary essential services
- essential services for special purposes connected with ships specifically intended for such purposes (e.g. cargo pumps on tankers, cargo refrigerating systems, air conditioning systems on passenger ships)
- services for habitability.

The other parts of the installation are to be so designed as not to introduce any risks or malfunctions to the above services.

1.1.2 The Society may consider modified requirements for installations not exceeding either 50 V or 50 kW total generator capacity (and for ships assigned with a restricted navigation notation).

1.2 References to other regulations and standards

1.2.1 The Society may refer to other regulations and standards when deemed necessary. These include the IEC publications, notably the IEC 60092 series.

It is to be noted however that, where the prescriptive requirements in the present Rules and such standards are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.2.2 When referred to by the Society, the versions (including revisions) of the publications by the International Electrotechnical Commission (IEC) or other internationally recognized standards defined in this Chapter are the ones to be normally applied.

Note 1: Later versions (including revisions) of the international standards specified in this Chapter may be found acceptable for use by the Society on a case-by-case basis.

2 Documentation to be submitted

2.1

2.1.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents to be submitted
1	A	General arrangement of electrical installation
2	A	Single line diagram of main and emergency power and lighting systems
3	I	Electrical power balance (main and emergency supply)
4	A	Calculation of short-circuit currents for each installation in which the sum of rated power of the energy sources which may be connected contemporaneously to the network is greater than 500 kVA (kW)
5	A	Where the maximum short-circuit current on the main bus-bar is expected to exceed 50 kVA for the main and emergency switchboards, justification of the main bus-bar and bracket strength related to induced electro-magnetic forces (except junction bars to the interrupting and protective devices)
6	A	List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, nominal and setting values of the protective and control devices
7	A	Single line diagram and detailed diagram of the main switchboard
8	A	Single line diagram and detailed diagram of the emergency switchboard
9	A	Diagram of the most important section boards or motor control centers (above 100 kW)
10	A	Diagram of the supply for monitoring and control systems of propulsion motors and generator prime movers
11	A	Diagram of the supply, monitoring and control systems of the rudder propellers

(1) A : To be submitted for approval ; I : To be submitted for information
(2) For high-voltage installations
(3) For electric propulsion installations
(4) If such standard is not available, the Manufacturer's specification is to be submitted

No.	I/A **(1)**	Documents to be submitted
12	A	Diagram of the supply, monitoring and control systems of controllable pitch propellers.
13	A	Diagram of the general emergency alarm system, of the public address system and other intercommunication systems
14	A	Detailed diagram of the navigation-light switchboard
15	A	Diagram of the remote stop system (ventilation, fuel pump, fuel valves, etc.)
16	A	List of batteries including type and manufacturer, voltage and capacity, location and equipment and/or system(s) served, maintenance and replacement schedule (when used for essential and emergency services)
17	A **(2)**	Selectivity and coordination of the electrical protection
18	A **(3)**	Single line diagram
19	A **(3)**	Principles of control system and its power supply
20	A **(3)**	Alarm and monitoring system including: • list of alarms and monitoring points • power supply diagram
21	A **(3)**	Safety system including: • list of monitored parameters for safety system • power supply diagram
22	I **(3)**	Arrangements and details of the propulsion control consoles and panels
23	I **(3)**	Arrangements and details of electrical coupling
24	I **(3)**	Arrangements and details of the frequency converters together with the justification of their characteristics
25	I **(3)**	Arrangements of the cooling system provided for the frequency converter and motor enclosure
26	A **(3)**	Test program for converters and rotating machines having rated power > 3 MW, dock and sea trials
27	I	Risk analysis for battery energy storage systems (See Ch 2, Sec 7 and Ch 2, Sec 12)
28	I	Information about toxic products present or likely to be produced in the battery system (See Ch 2, Sec 11, [6.9])
29	I	Justification for choice of Li Ion battery fire-extinguishing system
30	A	Test programs related to battery system type approval, factory test and onboard tests
31	I	Reports related to battery system test programs for type approval, gas analysis, factory test and onboard tests
32	I	List of standards used for battery system design and testing procedures **(4)**
33	A	List of alarms and defaults directly connected to the Li Ion battery system and interfaces with other ship systems, if any
34	I	Operation manual of Li Ion battery and battery management system (BMS)

(1) A : To be submitted for approval ; I : To be submitted for information
(2) For high-voltage installations
(3) For electric propulsion installations
(4) If such standard is not available, the Manufacturer's specification is to be submitted

3 Definitions

3.1 General

3.1.1 Unless otherwise stated, the terms used in this Chapter have the definitions laid down by the IEC standards.

The definitions given in the following requirements also apply.

3.2 Black out situation

3.2.1 A “blackout situation” means that the main and auxiliary machinery installations, including the main power supply, are out of operation but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.

3.3 Certified safe-type equipment

3.3.1 Certified safe-type equipment is electrical equipment of a type for which a national or other appropriate authority has carried out the type verifications and tests necessary to certify the safety of the equipment with regard to explosion hazard when used in an explosive gas atmosphere.

3.4 Dead ship condition

3.4.1 *The condition under which the main propulsion plant, boilers and auxiliaries are not in operation due to the absence of power.*

Note 1: Dead ship condition is a condition in which the entire machinery installation, including the power supply, is out of operation and the auxiliary services such as compressed air, starting current from batteries etc., for bringing the main propulsion into operation and for the restoration of the main power supply are not available.

3.5 Distribution board

3.5.1 A switchgear and controlgear assembly arranged for the distribution of electrical energy to final sub-circuits.

3.6 Earthing

3.6.1 Electrical connections between conductive parts and local earth (in this case, the local earth, ship's hull, or metallic structure) in such a manner as to ensure an immediate discharge of electrical energy without danger at all times.

3.7 Emergency condition

3.7.1 *A condition under which any services needed for normal operational and habitable conditions are not in working order due to failure of the main source of electrical power.*

3.8 Emergency source of electrical power

3.8.1 *A source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.*

3.9 Emergency switchboard

3.9.1 *A switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency and is intended to distribute electrical energy to the emergency services.*

3.10 Environmental categories

3.10.1 Electrical equipment is classified into environmental categories according to the temperature range, vibration levels, and resistance to chemically active substances, to humidity, and to EMC required for installation in bridge and deck zone.

The designation of the environmental categories is indicated by the EC Code in Tab 2.

The first characteristic numeral indicates the temperature range in which the electrical equipment operates satisfactorily, as specified in Tab 3.

The second characteristic numeral indicates the vibration level in which the electrical equipment operates satisfactorily, as specified in Tab 4.

3.10.2 The tests for verifying the additional letters and the characteristic numeral of the environmental categories are defined in Ch 3, Sec 6.

Table 2 : EC Code

Code letter	First characteristic numeral	Second characteristic numeral	Additional letter
EC	(numerals 1 to 4)	(numerals 1 to 3)	S **(1)** C **(2)** B **(3)**

(1) The additional letter S indicates the resistance to salt mist (exposed decks, masts) of the electrical equipment

(2) The supplementary letter C indicates the relative humidity up to 80% (air conditioned areas) in which the electrical equipment operates satisfactorily

(3) The additional letter B indicates the compliance for installing on the bridge and deck zone or in the vicinity of the bridge, with regards to EMC requirements specified in IEC 60533

Table 3 : First characteristic numeral

First characteristic numeral	Brief description of location	Temperature range, in °C	
1	Air conditioned areas	+ 5	+ 40
2	Enclosed spaces	+ 5	+ 45
3	Inside consoles or close to combustion engines and similar	+ 5	+ 55
4	Exposed decks, masts	– 25	+ 45

Table 4 : Second characteristic numeral

Second characteristic numeral	Brief description of location	Frequency range	Displacement amplitude, in mm	Acceleration amplitude g
1	Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 Hz	1,0	–
		from 13,2 to 100 Hz	–	0,7
2	Masts	from 2,0 to 13,2 Hz	3,0	–
		from 13,2 to 50 Hz	–	2,1
3	On air compressors, on diesel engines and similar	from 2,0 to 25,0 Hz	1,6	–
		from 25,0 to 100 Hz	–	4,0

3.11 Essential services

3.11.1 Essential services are defined in Pt A, Ch 1, Sec 1, [1.2.1]. They are subdivided in primary and secondary essential services.

3.11.2 Primary essential services

Primary essential services are those which need to be maintained in continuous operation.

Examples of equipment for primary essential services are the following:

- steering gear
- actuating systems of controllable pitch propellers
- scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for the propulsion
- forced draught fans, feed water pumps, water circulating pumps, condensate pumps, oil burning installations, for steam plants or steam turbines ship, and also for auxiliary boilers on ship where steam is used for equipment supplying primary essential services
- azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps
- electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
- electric generators and associated power sources supplying the above equipment
- hydraulic pumps supplying the above equipment
- viscosity control equipment for heavy fuel oil
- control, monitoring and safety devices/systems for equipment for primary essential services
- speed regulators dependent on electrical energy for main or auxiliary engines necessary for propulsion
- starting equipment of diesel engines and gas turbines.

The main lighting system for those parts of the ship normally accessible to and used by personnel and passengers is also considered as a primary essential service.

3.11.3 Secondary essential services

Secondary essential services are those services which need not necessarily be in continuous operation.

Examples of equipment for secondary essential services are the following:

- windlasses
- thrusters
- fuel oil transfer pumps and fuel oil treatment equipment
- lubrication oil transfer pumps and lubrication oil treatment equipment
- preheaters for heavy fuel oil
- sea water pumps
- starting air and control air compressors
- bilge, ballast and heeling pumps
- fire pumps and other fire-extinguishing medium pumps
- ventilation fans for engine and boiler rooms
- services considered necessary to maintain dangerous cargo in a safe condition
- navigation lights, aids and signals
- internal safety communication equipment
- fire detection and alarm systems
- electrical equipment for watertight closing appliances

- electric generators and associated power supplying the above equipment
- hydraulic pumps supplying the above mentioned equipment
- control, monitoring and safety for cargo containment systems
- control, monitoring and safety devices/systems for equipment for secondary essential services.
- cooling system of environmentally controlled spaces.

3.12 Final sub-circuit

3.12.1 That portion of a wiring system extending beyond the final required overcurrent protective device of a board.

3.13 Hazardous areas

3.13.1 Areas in which an explosive atmosphere is or may be expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Note 1: An explosive gas atmosphere is a mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour or mist, in which, after ignition, combustion spreads throughout the unconsumed mixture.

3.13.2 Hazardous areas are classified in zones based upon the frequency and the duration of the occurrence of explosive atmosphere.

3.13.3 Hazardous areas for explosive gas/dust atmosphere are classified in the following zones:

- Zone 0/20: an area in which an explosive gas/dust atmosphere is present continuously or is present for long periods
- Zone 1/21: an area in which an explosive gas/dust atmosphere is likely to occur in normal operation
- Zone 2/22: an area in which an explosive gas/dust atmosphere is not likely to occur in normal operation and if it does occur, is likely to do only infrequently and will exist for a short period only.

3.14 High fire risk areas

3.14.1 The high fire risk areas are defined as follows:

a) machinery spaces as defined in Ch 4, Sec 1, [2.30], except spaces having little or no fire risk as defined by category (10) of Ch 4, Sec 5, [1.3.3], item b) 2)

b) spaces containing fuel treatment equipment and other highly flammable substances

c) galleys and pantries containing cooking appliances

d) laundry with drying equipment

e) spaces as defined in Ch 4, Sec 5, [1.3.3] for ships carrying more than 36 passengers, as:
   - (8) accommodation spaces of greater fire risk
   - (12) machinery spaces and main galleys
   - (14) other spaces in which flammable liquids are stowed

3.15 High-voltage systems

3.15.1 Alternating current systems with rated voltages greater than 1000 V r.m.s. and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 1500 V.

3.16 Insulation

3.16.1 Basic insulation

Insulation applied to live parts to provide basic protection against electric shock.

Note 1: Basic insulation does not necessarily include insulation used exclusively for functional purposes.

3.16.2 Supplementary insulation

Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

3.16.3 Double insulation

Insulation comprising both basic insulation and supplementary insulation.

3.16.4 Reinforced insulation

A single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation.

Note 1: The term "insulation system" does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

3.17 Low-voltage systems

3.17.1 Alternating current systems with rated voltages greater than 50 V r.m.s. up to 1000 V r.m.s. inclusive and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 50 V up to 1500 V inclusive.

3.18 Main generating station

3.18.1 *The space in which the main source of electrical power is situated.*

3.19 Main source of electrical power

3.19.1 *A source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.*

3.20 Main switchboard

3.20.1 *A switchboard which is directly supplied by the main source of electrical power and is intended to distribute electrical energy to the ship's services.*

3.21 Normal operational and habitable condition

3.21.1 *A condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, fire and flooding safety, internal and external communications and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally.*

3.22 Safety voltage

3.22.1 A voltage which does not exceed 50 V a.c. r.m.s. between conductors, or between any conductor and earth, in a circuit isolated from the supply by means such as a safety isolating transformer.

3.22.2 A voltage which does not exceed 50 V d.c. between conductors or between any conductor and earth in a circuit isolated from higher voltage circuits.

3.23 Section boards

3.23.1 A switchgear and controlgear assembly which is supplied by another assembly and arranged for the distribution of electrical energy to other section boards or distribution boards.

3.24 Services for habitability

3.24.1 Services for habitability are those intended for minimum comfort conditions for people on board.

Examples of equipment for maintaining conditions of habitability:

- cooking
- heating
- domestic refrigeration
- mechanical ventilation
- sanitary and fresh water
- electric generators and associated power sources supplying the above equipment.

3.25 Voltage and frequency transient

3.25.1 Voltage transient

Sudden change in voltage (excluding spikes) which goes outside the nominal voltage tolerance limits and returns to and remains inside these limits within a specified recovery time after the initiation of the disturbance (time range: seconds).

3.25.2 Frequency transient

Sudden change in frequency which goes outside the frequency tolerance limits and returns to and remains inside these limits within a specified recovery time after initiation of the disturbance (time range: seconds).

4 Type approved components

4.1 General

4.1.1 The following components are to be type approved or in accordance with [4.1.2]:

- electrical cables
- transformers
- rotating machines
- electrical converters for primary essential services
- switching devices (circuit-breakers, contactors, disconnectors, etc.) and overcurrent protective devices
- sensors, alarm panels, electronic protective devices, automatic and remote control equipment, actuators, safety devices for installations intended for essential services (steering, controllable pitch propellers, propulsion machinery, etc.), electronic speed regulators for main or auxiliary engines
- computers used for tasks essential to safety
- cable trays or protective casings made of plastics materials (thermoplastic or thermosetting plastic materials)
- batteries.

4.1.2 Case by case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

Section 2 General Design Requirements

1 Environmental conditions

1.1 General

1.1.1 The electrical components of installations are to be designed and constructed to operate satisfactorily under the environmental conditions on board.

In particular, the conditions shown in the tables in this Article are to be taken into account.

Note 1: The environmental conditions are characterised by:

- one set of variables including climatic conditions (e.g. ambient air temperature and humidity), conditions dependent upon chemically active substances (e.g. salt mist) or mechanically active substances (e.g. dust or oil), mechanical conditions (e.g. vibrations or inclinations) and conditions dependent upon electromagnetic noise and interference, and
- another set of variables dependent mainly upon location on vessels, operational patterns and transient conditions.

1.2 Ambient air temperatures

1.2.1 For ships classed for unrestricted navigation, the ambient air temperature ranges shown in Tab 1 are applicable in relation to the various locations of installation.

Table 1 : Ambient air temperature

Location	Temperature range, in °C	
Enclosed spaces	+ 5	+ 45
Inside consoles or fitted on combustion engines and similar	+ 5	+ 55
Air conditioned areas	+ 5	+ 40
Exposed decks	– 25	+ 45

1.2.2 For ships classed for service in specific zones, the Society may accept different ranges for the ambient air temperature (e.g. for ships operating outside the tropical belt, the maximum ambient air temperature may be assumed as equal to + 40°C instead of + 45°C).

1.2.3 Reduced ambient air temperature ranges may be considered for enclosed spaces and air conditioned areas, provided the ambient air temperature range, equipment and temperature control comply with Ch 2, Sec 11, [1.3]. Cooling systems of these environmentally controlled spaces are to be classified as secondary essential service, in accordance with Ch 2, Sec 1, [3.11.3].

1.3 Humidity

1.3.1 For ships classed for unrestricted service, the humidity ranges shown in Tab 2 are applicable in relation to the various locations of installation.

Table 2 : Humidity

Location	Humidity
General	95% up to 45°C 70% above 45°C
Air conditioned areas	Different values may be considered on a case-by-case basis

1.4 Sea water temperatures

1.4.1 The temperatures shown in Tab 3 are applicable to ships classed for unrestricted service.

1.4.2 For ships classed for service in specific zones, the Society may accept different values for the sea water temperature (e.g. for ships operating outside the tropical belt, the maximum sea water temperature may be assumed as equal to + 25°C instead of + 32°C).

Table 3 : Water temperature

Coolant	Temperature range, in °C	
Sea water	0	+ 32

1.5 Salt mist

1.5.1 The applicable salt mist content in the air is to be 1mg/m^3.

1.6 Inclinations

1.6.1 The inclinations applicable are those shown in Tab 4.

The Society may consider deviations from these angles of inclination taking into consideration the type, size and service conditions of the ships.

Table 4 : Inclination of ship

Type of machinery, equipment or component	Angles of inclination, in degrees **(1)**			
	Athwartship		Fore-and-aft	
	static	dynamic **(4)**	static	dynamic **(5)**
Machinery and equipment relative to main electrical power installation	15	22,5	5	7,5
Machinery and equipment relative to the emergency power installation and crew and passenger safety systems of the ship (e.g. emergency source of power, emergency fire pumps, etc.)	22,5 **(2)**	22,5 **(2)**	10	10
Switchgear and associated electrical and electronic components and remote control systems **(3)**	22,5	22,5	10	10

(1) Athwartship and fore-and-aft angles may occur simultaneously in their most unfavourable combination.
(2) In the case of gas carriers or chemical tankers, the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°.
(3) No undesired switching operations or functional changes may occur up to an angle of inclination of 45°.
(4) The period of dynamic inclination may be assumed equal to 10 s.
(5) The period of dynamic inclination may be assumed equal to 5 s.

1.7 Vibrations

1.7.1 In relation to the location of the electrical components, the vibration levels given in Tab 5 are to be assumed.

1.7.2 The natural frequencies of the equipment, their suspensions and their supports are to be outside the frequency ranges specified.

Where this is not possible using a suitable constructional technique, the equipment vibrations are to be dumped so as to avoid unacceptable amplifications.

Table 5 : Vibration levels

Location	Frequency range, in Hz	Displacement amplitude, in mm	Acceleration amplitude g
Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2	1,0	–
	from 13,2 to 100	–	0,7
On air compressors, on diesel engines and similar	from 2,0 to 25,0	1,6	–
	from 25,0 to 100	–	4,0
Masts	from 2,0 to 13,2	3,0	–
	from 13,2 to 50	–	2,1

2 Quality of power supply

2.1 General

2.1.1 All electrical components supplied from the main and emergency systems are to be so designed and manufactured that they are capable of operating satisfactorily under the normally occuring variations in voltage and frequency specified from [2.2] to [2.4].

2.2 a.c. distribution systems

2.2.1 For alternating current components the voltage and frequency variations of power supply shown in Tab 6 are to be assumed.

Table 6 : Voltage and frequency variations of power supply in a.c.

Parameter	Variations	
	Continuous	Transient
Voltage	+ 6% – 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)
Note 1: For alternating current components supplied by emergency generating sets, different variations may be considered.		

2.3 d.c. distribution systems

2.3.1 For direct current components the power supply variations shown in Tab 7 are to be assumed.

Table 7 : Voltage variations in d.c.

Parameters	Variations
Voltage tolerance (continuous)	± 10%
Voltage cyclic variation	5%
Voltage ripple (a.c. r.m.s. over steady d.c. voltage)	10%

2.3.2 For direct current components supplied by electrical battery the following voltage variations are to be assumed:

- +30% to –25% for components connected to the battery during charging (see Note 1)
- +20% to –25% for components not connected to the battery during charging.

Note 1: Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered.

2.3.3 Any special system, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in the tables should not be supplied directly from the system but by alternative means, e.g. through stabilized supply.

2.4 Harmonic distortions

2.4.1 For components intended for systems without substantially static converter loads and supplied by synchronous generators, it is assumed that the total voltage harmonic distortion does not exceed 5%, and the single harmonic does not exceed 3% of the nominal voltage.

2.4.2 For components intended for systems fed by static converters, and/or systems in which the static converter load predominates, it is assumed that:

- the single harmonics distorsion does not exceed the values specified in IEC 61000-2-4:2002 for Class 2 systems. A maximum of 5% for single order harmonic can be accepted.
- the total harmonic distortion does not exceed the value in Ch 2, Sec 3, [3.22].

2.4.3 Higher values for the harmonic content (e.g. in electric propulsion plant systems) may be accepted where all installed equipment and systems have been designed for a higher specified limit. This relaxation on limits is to be documented (harmonic distortion calculation report).

3 Electromagnetic susceptibility

3.1

3.1.1 For electronic type components such as sensors, alarm panels, automatic and remote control equipment, protective devices and speed regulators, the conducted and radiated disturbance levels to be assumed are those given in Part C, Chapter 3.

Note 1: See also IEC Publication 60533 - "Electromagnetic Compatibility of Electrical and Electronic Installations in Ships and of Mobile and Fixed Offshore Units".

3.1.2 Electrical and electronic equipment on the bridge and in the vicinity of the bridge, not required neither by classification rules nor by International Conventions and liable to cause electromagnetic disturbance, shall be of type which fulfil the test requirements of test specification Ch 3, Sec 6, Tab 1, tests 19 and 20.

Note 1: Bridge and vicinity of the bridge covers deck and bridge zone, such as:

- the wheelhouse including bridge wings
- control rooms, characterized by equipment for inter-communication, signal processing, radio communication and navigation, auxiliary equipment
- area in close proximity (within a 5 meters distance) to receiving and/or transmitting antennas and large openings in the metallic structure.

4 Materials

4.1 General

4.1.1 In general, and unless it is adequately protected, all electrical equipment is to be constructed of durable, flame-retardant, moisture-resistant materials which are not subject to deterioration in the atmosphere and at the temperatures to which they are likely to be exposed. Particular consideration is to be given to sea air and oil vapour contamination.

Note 1: The flame-retardant and moisture-resistant characteristics may be verified by means of the tests cited in IEC Publication 60092-101:2018 or in other recognised standards.

4.1.2 Where the use of incombustible materials or lining with such materials is required, the incombustibility characteristics may be verified by means of the test cited in IEC Publication 60092-101:2018 or in other recognised standards.

4.2 Insulating materials for windings

4.2.1 Insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect insulants against such agents.

4.2.2 The insulation classes given in Tab 8 may be used in accordance with IEC Publication 60085.

Table 8 : Insulation Classes

Class	Maximum continuous operating temperature, in °C
A	105
E	120
B	130
F	155
H	180

4.3 Insulating materials for cables

4.3.1 See Ch 2, Sec 9, [2.3].

5 Construction

5.1 General

5.1.1 All electrical apparatus is to be so constructed as not to cause injury when handled or touched in the normal manner.

5.1.2 The design of electrical equipment is to allow accessibility to each part that needs inspection or adjustment, also taking into account its arrangement on board.

5.1.3 Enclosures are to be of adequate mechanical strength and rigidity.

5.1.4 Enclosures for electrical equipment are generally to be of metal; other materials may be accepted for accessories such as connection boxes, socket-outlets, switches and luminaires. Other exemptions for enclosures or parts of enclosures not made of metal will be specially considered by the Society.

5.1.5 Cable entrance are not to impair the degree of protection of the relevant enclosure (see Ch 2, Sec 3, Tab 2).

5.1.6 All nuts and screws used in connection with current-carrying parts and working parts are to be effectively locked.

5.1.7 All equipment is generally to be provided with suitable, fixed terminal connectors in an accessible position for convenient connection of the external cables.

5.2 Degree of protection of enclosures

5.2.1 Electrical equipment is to be protected against the ingress of foreign bodies and water.

The minimum required degree of protection, in relation to the place of installation, is generally that specified in Ch 2, Sec 3, Tab 2.

5.2.2 The degrees of protection are to be in accordance with:

- IEC Publication No. 60529:2019 for equipment in general
- IEC Publication No. 60034-5:2006 for rotating machines.

5.2.3 For cable entries see [5.1.5].

6 Protection against explosion hazard

6.1 Protection against explosive gas or vapour atmosphere hazard

6.1.1 Electrical equipment intended for use in areas where explosive gas or vapour atmospheres may occur (e.g. oil tankers, liquefied gas carriers, chemical tankers, ro-ro spaces, paint stores, ballast water management systems etc.), is to be of a "safe type" suitable for the relevant flammable atmosphere and for shipboard use.

6.1.2 For certified safe type equipment, see Ch 2, Sec 3, Tab 14.

6.2 Protection against combustible dust hazard

6.2.1 Electrical appliances intended for use in areas where a combustible dust hazard may be present are to be arranged with enclosures having a degree of protection and maximum surface temperature suitable for the dust to which they may be exposed.

Note 1: Where the characteristics of the dust are unknown, the appliances are to have a degree of protection IP6X. For most dusts a maximum surface temperature of 200°C is considered adequate.

Section 3 System Design

1 Supply systems and characteristics of the supply

1.1 Supply systems

1.1.1 The following distribution systems may be used:

a) on d.c. installations:
- two-wire insulated
- two-wire with one pole earthed

b) on a.c. installations:
- three-phase three-wire with neutral insulated
- three-phase three-wire with neutral directly earthed or earthed through an impedance
- three-phase four-wire with neutral directly earthed or earthed through an impedance
- single-phase two-wire insulated
- single-phase two-wire with one phase earthed.

1.1.2 Distribution systems other than those listed in [1.1.1] will be considered by the Society on a case by case basis.

1.1.3 The hull return system of distribution is not to be used for power, heating or lighting in any ship of 1600 gross tonnage and upwards.

1.1.4 The requirement of [1.1.3] does not preclude under conditions approved by the Society the use of:

a) impressed current cathodic protective systems

b) limited and locally earthed systems, or

c) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable conditions.

Note 1: Limited and locally earthed systems such as starting and ignition systems of internal combustion engines are accepted provided that any possible resulting current does not flow directly through any dangerous spaces.

1.1.5 For the supply systems of ships carrying liquid developing combustible gases or vapours, see Pt D, Ch 7, Sec 5, Pt D, Ch 8, Sec 10 or Pt D, Ch 9, Sec 10.

1.1.6 For the supply systems in HV Installations, see Ch 2, Sec 13.

1.2 Maximum voltages

1.2.1 The maximum voltages for both alternating current and direct current low-voltage systems of supply for the ship's services are given in Tab 1.

1.2.2 Voltages exceeding those shown will be specially considered in the case of specific systems.

1.2.3 For high-voltage systems, see Ch 2, Sec 13.

Table 1 : Maximum voltages for various ship services

Use		Maximum voltage V
For permanently installed and connected to fixed wiring	Power equipment	1000
	Heating equipment (except in accommodation spaces)	500
	Cooking equipment	500
	Lighting	250
	Space heaters in accommodation spaces	250
	Control **(1)**, communication (including signal lamps) and instrumentation equipment	250

(1) For control equipment which is part of a power and heating installation (e.g. pressure or temperature switches for start/stop motors), the same maximum voltage as allowed for the power and heating equipment may be used provided that all components are constructed for such voltage. However, the control voltage to external equipment is not to exceed 500 V.

(2) Both conductors in such systems are to be insulated from earth.

Use		Maximum voltage V
For permanently installed and connected by flexible cable	Power and heating equipment, where such connection is necessary because of the application (e.g. for moveable cranes or other hoisting gear)	1000
For socket-outlets supplying	Portable appliances which are not hand-held during operation (e.g. refrigerated containers) by flexible cables	1000
	Portable appliances and other consumers by flexible cables	250
	Equipment requiring extra precaution against electric shock where a isolating transformer is used to supply one appliance **(2)**	250
	Equipment requiring extra precaution against electric shock with or without a safety transformer **(2)**	50

(1) For control equipment which is part of a power and heating installation (e.g. pressure or temperature switches for start/stop motors), the same maximum voltage as allowed for the power and heating equipment may be used provided that all components are constructed for such voltage. However, the control voltage to external equipment is not to exceed 500 V.

(2) Both conductors in such systems are to be insulated from earth.

2 Sources of electrical power

2.1 General

2.1.1 *Electrical installations are to be such that:*

a) *All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions* and for the preservation of the cargo *will be assured without recourse to the emergency source of electrical power.*

b) *Electrical services essential for safety will be assured under various emergency conditions.*

c) When a.c. generators are involved, attention is to be given to the starting of motors connected to the system, specially squirrel-cage motors, particularly with regard to the effect of the magnitude and duration of the transient voltage change produced due to the maximum starting current and the power factor. The voltage drop due to such starting current is not to cause any motor already operating to stall or have any adverse effect on other equipment in use.

2.2 Main source of electrical power

2.2.1 *A main source of electrical power is to be provided, of sufficient capability to supply all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions* and for the preservation of the cargo *without recourse to the emergency source of electrical power.*

2.2.2 For vessels propelled by electrical power and having two or more constant voltage propulsion generating sets which constitute the source of electrical energy for the ship's auxiliary services, see Ch 2, Sec 14.

2.2.3 *The main source of electrical power is to consist of at least two generating sets.*

The capacity of these generating sets is to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide:

a) *normal operational conditions of propulsion and safety* (see [2.2.4])

b) *minimum comfortable conditions of habitability* (see Ch 2, Sec 1, [3.24])

c) preservation of the cargo, i. e. all the equipment which are needed for refrigerated cargo or operation of any safety device, such as inert gas generator.

Such capacity is, in addition, to be sufficient to start the largest motor without causing any other motor to stop or having any adverse effect on other equipment in operation.

2.2.4 Those services necessary to provide normal operational conditions of propulsion and safety include primary and secondary essential services.

For the purpose of calculating the capacity necessary for such services, it is essential to consider which of them can be expected to be in use simultaneously.

For a duplicated service, one being supplied electrically and the other non-electrically (e.g. driven by the main engine), the electrical capacity is not included in the above calculation.

2.2.5 The services in [2.2.4] do not include:

- thrusters not forming part of the main propulsion (except in manoeuvring conditions)
- cargo handling gear
- cargo pumps
- refrigerators for air conditioning.

2.2.6 *Further to the provisions above, the generating sets shall be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a "dead ship" condition.*

2.2.7 Where the electrical power is normally supplied by more than one generator set simultaneously in parallel operation, provision of protection, including automatic disconnection of sufficient non-essential services and, if necessary, secondary essential services and those provided for habitability, should be made to ensure that, in case of loss of any of these generating sets, the remaining ones are kept in operation to permit propulsion and steering and to ensure safety.

2.2.8 Where the electrical power is normally supplied by one generator, provision is to be made, upon loss of power, for automatic starting and connecting to the main switchboard of stand-by generator(s) of sufficient capacity to supply the primary essential services and to ensure the safety of the ship, with automatic restarting of the essential auxiliaries, in sequential operation if required. Starting and connection to the main switchboard of the stand-by generator is to be preferably within 30 seconds, but in any case not more than 45 seconds after loss of power.

Where prime movers with longer starting time are used, this starting and connection time may be exceeded upon approval from the Society

2.2.9 Load shedding or other equivalent arrangements should be provided to protect the generators required in the present Article against sustained overload.

The load shedding should be automatic.

The non-essential services, services for habitability and, if necessary, the secondary essential services may be shed in order to make sure that the connected generator set(s) is/are not overloaded.

2.2.10 *The emergency source of electrical power may be used for the purpose of starting from a "dead ship" condition if its capability either alone or combined with that of any other source of electrical power is sufficient to provide at the same time those services required to be supplied in accordance with the provisions of* [3.6.3], items a), b), c) and d), or Pt D, Ch 11, Sec 5 *for passenger ships.*

2.2.11 *The arrangement of the ship's main source of electrical power shall be such that essential services can be maintained regardless of the speed and direction of rotation of the main propulsion machinery or shafting.*

2.2.12 Generators driven by the propulsion plant (shaft generators) which are intended to operate at constant speed (e.g. a system where vessel speed and direction are controlled by varying propeller pitch) may be accepted as forming part of the main source of electrical power if, in all sailing and manoeuvring conditions including the propeller being stopped, the capacity of these generators is sufficient to provide the electrical power to comply with [2.2.3] and all further requirements, especially those of [2.2.6]. They are to be not less effective and reliable than the independent generating sets.

2.2.13 Shaft generator installations which do not comply with the provisions of [2.2.12] may be used as additional sources of electrical power with respect to the power balance provided that:

a) in the event of a loss of power from the shaft generator(s), e.g. due to a sudden stopping of the propulsion plant, or upon frequency variations exceeding ± 10%, a standby generating set is started automatically

b) the capacity of the standby set is sufficient for the loads necessary for propulsion and safety of the vessel

c) the time required to restore these services is not longer than 45 s.

2.2.14 *Where transformers,* converters or similar appliances *constitute an essential part of the electrical supply system, the system is to be so arranged as to ensure the same continuity of supply as stated in this sub-article.*

This may be achieved by arranging at least two three-phase or three single-phase transformers supplied, protected and installed as indicated in Fig 1, so that with any one transformer not in operation, the remaining transformer(s) is (are) sufficient to ensure the supply to the services stated in [2.2.3].

Each transformer required is to be located as a separate unit with separate enclosure or equivalent, and is to be served by separate circuits on the primary and secondary sides.

Each primary circuit is to be provided with switchgear and protection devices in each phase.

Each of the secondary circuits is to be provided with a multipole isolating switch.

Suitable interlocks or a warning label are to be provided in order to prevent maintenance or repair of one single-phase transformer unless both switchgears are opened on their primary and secondary sides.

2.2.15 For ships intended for operation with periodically unattended machinery spaces, see Part F, Chapter 3.

2.2.16 For starting arrangements for main generating sets, see Ch 1, Sec 2, [3.1].

2.2.17 Where single phase transformers are used, only one spare element is required if special precautions are taken to rapidly replace the faulty one.

2.2.18 Generators and generator systems, having the ship propulsion machinery as their prime mover but not forming part of the ship main source of electrical power, may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that:

a) there are sufficient and adequately rated additional generators fitted, which constitute the main source of electrical power required by [2.2.1]

b) arrangements are fitted to automatically start one or more of the generators, constituting the main source of electrical power required by [2.2.1], upon the frequency variations exceeding ± 10% of the limits specified below

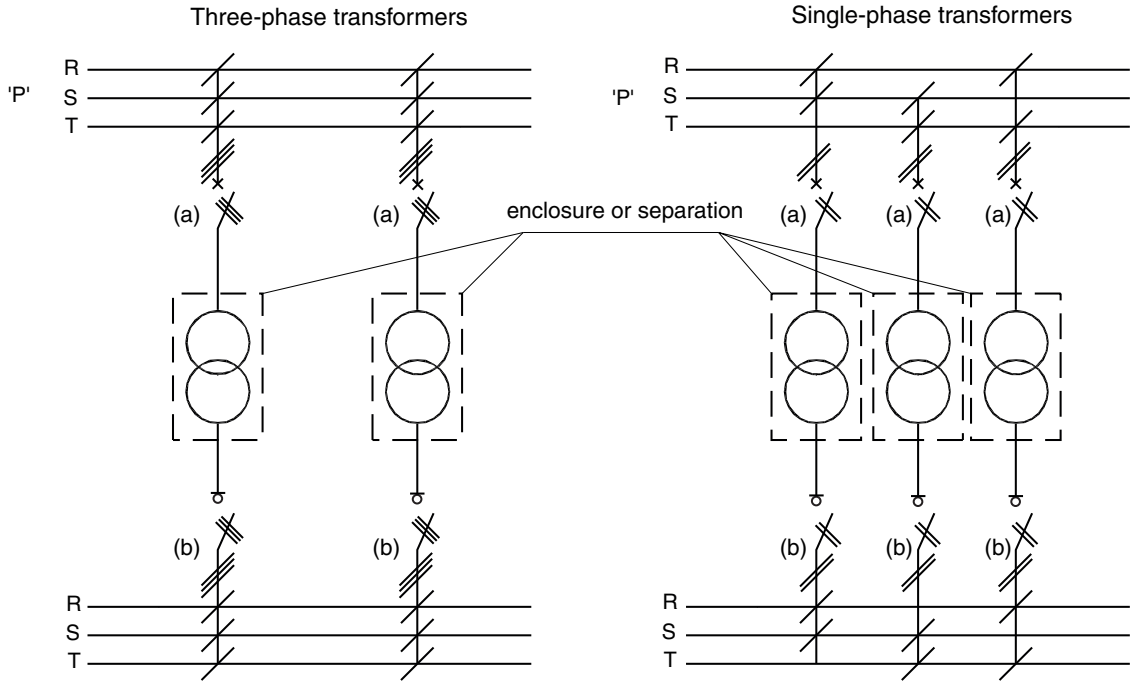
c) within the declared operating range of the generators and/or generator systems the specified limits for the voltage variations and the frequency variations in Ch 2, Sec 2 can be met

d) the short circuit current of the generator and/or generator system is sufficient to trip the generator/generator system circuit-breaker taking into account the selectivity of the protective devices for the distribution system

e) where considered appropriate, load shedding arrangements are to be fitted

f) on ships having remote control of the ship's propulsion machinery from the navigation bridge, means are provided, or procedures be in place, so as to ensure that supplies to essential services are maintained during manoeuvring conditions in order to avoid a blackout situation.

Figure 1 :



(a) switchgear and protection devices

(b) multipole isolating switch

2.3 Emergency source of electrical power

2.3.1 *A self-contained emergency source of electrical power shall be provided.*

2.3.2 *Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.*

Exceptionally is understood to mean conditions, while the vessel is at sea, such as:

a) blackout situation

b) dead ship situation

c) routine use for testing

d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless otherwise instructed by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of [2.4] are complied with.

2.3.3 *The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.*

2.3.4 *The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in* [3.6.3] *for the period specified, if they depend upon an electrical source for their operation.*

2.3.5 *The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services stated in* [3.6.7] *for half an hour, if they depend upon an electrical source for their operation.*

2.3.6 *An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power referred to in* [2.3.15] *and* [2.3.16] *are being discharged.*

2.3.7 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor converters, means are to be provided for supplying such services also in the event of failure of the converter (e.g. providing a bypass feeder or a duplication of converter).

2.3.8 *Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.*

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries is to be assumed available. It is assumed that means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator stored starting energy is not to be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

For steam ships, the 30 minute time limit given in SOLAS can be interpreted as time from blackout/dead ship condition defined above to light-off the first boiler.

2.3.9 Where the emergency source of power is necessary to restore the main source of electrical power, provisions are to be made to allow a manual restart of a main generating set in case of failure of the emergency source.

2.3.10 *Provision shall be made for the periodic testing of the complete emergency system and shall include the testing of automatic starting arrangements,* where provided.

2.3.11 For starting arrangements for emergency generating sets, see Ch 1, Sec 2, [3.1].

2.3.12 *The emergency source of electrical power may be either a generator or an accumulator battery which shall comply with the requirements of* [2.3.13] *or* [2.3.15]*, respectively.*

2.3.13 *Where the emergency source of electrical power is a generator, it shall be:*

a) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43°C

b) started automatically upon failure of the main source of electrical power supply to the emergency switchboard *unless a transitional source of emergency electrical power in accordance with c) below is provided; where the emergency generator is automatically started, it shall be automatically connected to the emergency switchboard; those services referred to in* [3.6.7] *shall then be connected automatically to the emergency generator, and*

c) provided with a transitional source of emergency electrical power as specified in [2.3.16] *unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 s.*

2.3.14 It is accepted to apply the total consumer load in steps providing that:

- the total load is supplied within 45 seconds since power failure on the main switchboard
- the power distribution system is designed such that the declared maximum step loading is not exceeded
- the compliance of time delays and loading sequence with the above is demonstrated at ship's trials.

2.3.15 *Where the emergency source of electrical power is an accumulator battery it shall be capable of:*

a) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage

b) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power, and

c) immediately supplying at least those services specified in [3.6.7].

2.3.16 *The transitional source of emergency electrical power where required by* [2.3.13] item c), *shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the services in* [3.6.7] *if they depend upon an electrical source for their operation.*

2.3.17 Where the emergency and/or transitional source of power is an uninterruptible power system (UPS), it is to comply with the requirement of Ch 2, Sec 6, [3].

2.3.18 Where the emergency and/or transitional emergency loads are supplied from a battery via an electronic converter or inverter, the maximum permitted d.c. voltage variations are to be taken as those on the load side of the converter or inverter.

Where the d.c. is converted into a.c. the maximum variations are not exceed those given in Ch 2, Sec 2, Tab 6.

2.3.19 If the emergency generator is fitted with control, alarm and safety systems based on electronic equipment, these systems are to be so arranged that, when in failure, there is still a possibility to operate the emergency generator manually.

A failure of the electronic governor is not considered.

2.3.20 For the emergency source of electrical power in passenger ships, see Pt D, Ch 11, Sec 5.

2.3.21 Ships assigned the additional service feature **SPxxx**, **SPxxx-capable**, **IPxxx** or **IPxxx-capable** with xxx greater than 60 are to comply, in addition to the requirements of this article, with the provisions of Pt D, Ch 11, Sec 5, [2].

2.4 Use of emergency generator in port

2.4.1 To prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation.

2.4.2 The prime mover is to be arranged with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as requested for the prime mover for main power generation and for unattended operation.

Note 1: Pt F, Ch 3, Sec 1, Tab 28 applies.

2.4.3 The fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in [3.6].

2.4.4 The prime mover is to be designed and built for continuous operation and should be subjected to a planned maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea.

2.4.5 Fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed.

2.4.6 Means are to be provided to readily change over to emergency operation.

2.4.7 Control, monitoring and supply circuits for the purpose of the use of the emergency generator in port are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services.

When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits.

2.4.8 Instructions are to be provided on board to ensure that, even when the vessel is underway, all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard.

These instructions are also to contain information on the required fuel oil tank level, position of harbour/sea mode switch, if fitted, ventilation openings, etc.

3 Distribution

3.1 Earthed distribution systems

3.1.1 System earthing is to be effected by means independent of any earthing arrangements of the non-current-carrying parts.

3.1.2 Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance or insulation resistance measurements.

3.1.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage wave form of each generator does not exceed 5%.

3.1.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

3.1.5 Where for final sub-circuits it is necessary to locally connect a pole (or phase) of the sub-circuits to earth after the protective devices (e.g. in automation systems or to avoid electromagnetic disturbances), provision (e.g. d.c./d.c. converters or transformers) is to be made such that current unbalances do not occur in the individual poles or phases.

3.1.6 For high-voltage systems see Ch 2, Sec 13.

3.2 Insulated distribution systems

3.2.1 Every insulated distribution system*, whether primary or secondary* (see Note 1)*, for power, heating or lighting, shall be provided with a device capable of continuously monitoring the insulation level to earth* (i.e. the values of electrical insulation to earth) *and of giving an audible* and *visual indication of abnormally low insulation values* (see Ch 2, Sec 15).

Note 1: A primary system is one supplied directly by generators. Secondary systems are those supplied by transformers or converters.

3.2.2 For high-voltage systems see Ch 2, Sec 13.

3.3 Distribution systems with hull return

3.3.1 *Where the hull return system is used,* if permitted*, all final sub-circuits, i.e. all circuits fitted after the last protective device, shall be two-wire.*

The hull return is to be achieved by connecting to the hull one of the busbars of the distribution board from which the final sub-circuits originate.

3.4 General requirements for distribution systems

3.4.1 The distribution system is to be such that the failure of any single circuit will not endanger or impair primary essential services and will not render secondary essential services inoperative for longer periods.

3.4.2 No common switchgear (e.g. contactors for emergency stop) is to be used between the switchboard's busbars and two primary non duplicated essential services.

3.4.3 *Where the main source of electrical power is necessary for propulsion and steering of the ship, the system shall be so arranged that the electrical supply to equipment necessary for propulsion and steering and to ensure safety of the ship will be maintained or immediately restored in the case of loss of any one of the generators in service.*

3.4.4 Ships assigned the additional service feature **SPxxx**, **SPxxx-capable**, **IPxxx** or **IPxxx-capable** with xxx greater than 60 are to comply, in addition to the requirements of this article, with the provisions of Pt D, Ch 11, Sec 5, [1.2.1].

3.5 Main distribution of electrical power

3.5.1 Where the main source of electrical power is necessary for propulsion of the ship, the main busbar is to be divided into at least two parts which are normally to be connected by circuit breakers or other approved means such as circuit breakers without tripping mechanisms or disconnecting links or switches by means of which busbars can be split safely and easily.

Bolted links, for example bolted bus bar sections, are not accepted.

The connection of generating sets and associated auxiliaries and other duplicated equipment is to be equally divided between the parts as far as practicable, so that in the event of damage to one section of the switchboard the remaining parts are still supplied.

3.5.2 Two or more units serving the same consumer (e.g. main and standby lubricating oil pumps) are to be supplied by individual separate circuits without the use of common feeders, protective devices or control circuits.

This requirement is satisfied when such units are supplied by separate cables from the main switchboard or from two independent section boards.

3.5.3 *A main electric lighting system which shall provide illumination throughout those parts of the ship normally accessible to and used by (passengers or) crew shall be supplied from the main source of electrical power.*

3.6 Emergency distribution of electrical power

3.6.1 *The emergency switchboard shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.*

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.6.2 *In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.*

3.6.3 *The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:*

a) for a period of 3 hours, emergency lighting at every muster and embarkation station and over the sides

b) for a period of 18 hours, emergency lighting:

1) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks

2) in the machinery spaces and main generating stations including their control positions

3) in all control stations, machinery control rooms, and at each main and emergency switchboard

4) at all stowage positions for fire-fighter's outfits

5) at the steering gear, and

6) at the fire pump referred to in e) below, at the sprinkler pump, if any, at the emergency bilge pump, if any, and at the starting positions of their motors

c) for a period of 18 hours:

1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force

2) the VHF radio installation required by Regulation IV/7.1.1 and IV/7.1.2 of SOLAS 1974 as amended, and, if applicable:

- *the MF radio installation required by Regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3*
- *the ship earth station required by Regulation IV/10.1.1, and*
- *the MF/HF radio installation required by Regulations IV/11.1.1 and IV/11.1.2.*

d) for a period of 18 hours:

1) all internal communication equipment as required in an emergency [3.6.4]

2) the shipborne navigational equipment as required by Regulation V/19 where such provision is unreasonable or impracticable the Society may waive this requirement for ships of less than 5 000 gross tonnage

3) the fire detection and fire alarm systems, and

4) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals (see [3.6.5]*) that are required in an emergency unless such services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency*

e) for a period of 18 hours: one of the fire pumps required by the relevant provisions of Part C, Chapter 4*, if dependent upon the emergency generator for its source of power*

f) for the period of time required in Ch 1, Sec 14, [2]*, the steering gear where it is required to be so supplied.*

g) On ships *assigned* the additional service feature **SPxxx** or **SPxxx-capable**, **IPxxx** *or* **IPxxx-capable** with length greater than or equal to 50m, *for a period of half an hour, any watertight door required by* Pt D, Ch 11, Sec 2 *to be power-operated together with their indicators and warning signals.*

3.6.4 Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigation bridge and the steering gear compartment

b) the means of communication between the navigation bridge and the position in the machinery space or control room from which the engines are normally controlled

c) the means of communication which is provided between the bridge and the radio communication station, if any

d) the public address system.

3.6.5 Internal signals required in an emergency generally include:

a) general alarm

b) watertight door indication.

3.6.6 In a ship engaged regularly in voyages of short duration, i.e. voyages where the route is no greater than 20 nautical miles offshore or where the vessel has a class notation "Coastal Navigation", the Society may, if satisfied that an adequate standard of safety would be attained, accept a lesser period than the 18-hour period specified in [3.6.3], items b) to e), but not less than 12 hours.

Note 1: In ships for which Solas is not applicable, a reduced period of time may be accepted.

Note 2: For passenger ships see Pt D, Ch 11, Sec 5.

3.6.7 *The transitional source of emergency electrical power, where required, shall supply for half an hour at least the following services if they depend upon an electrical source for their operation:*

a) the lighting required by [3.6.3], items a), b) and c) 1) *for this transitional phase, the required emergency electric lighting, in respect of the machinery space and the accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and*

b) all services required by [3.6.3]*,* items d) 1), d) 3) and d) 4)*, unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.*

3.7 Shore supply

3.7.1 Where arrangements are made for supplying the electrical installation from a source on shore or elsewhere, a suitable connection box is to be installed on the ship in a convenient location to receive the flexible cable from the external source.

3.7.2 Permanently fixed cables of adequate rating are to be provided for connecting the box to the main switchboard.

3.7.3 Where necessary for systems with earthed neutrals, the box is to be provided with an earthed terminal for connection between the shore's and ship's neutrals or for connection of a protective conductor.

3.7.4 The connection box is to contain a circuit-breaker or a switch-disconnector and fuses.

The shore connection is to be protected against short-circuit and overload however, the overload protection may be omitted in the connection box if provided on the main switchboard.

3.7.5 Means are to be provided for checking the phase sequence of the incoming supply in relation to the ship's system.

3.7.6 The cable connection to the box is to be provided with at least one switch-disconnector on the main switchboard.

3.7.7 The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energised.

3.7.8 At the connection box a notice is to be provided giving full information on the nominal voltage and frequency of the installation.

3.7.9 The switch-disconnector on the main switchboard is to be interlocked with the main generator circuit-breakers in order to prevent its closure when any generator is supplying the main switchboard.

3.7.10 Adequate means are to be provided to equalise the potential between the hull and the shore when the electrical installation of the ship is supplied from shore.

3.8 Supply of motors

3.8.1 A separate final sub-circuit is to be provided for every motor required for an essential service (and for every motor rated at 1 kW or more).

3.8.2 Each motor is to be provided with controlgear ensuring its satisfactory starting.

Direct on line starters are accepted if the voltage drop does not exceed 15% of the network voltage.

3.8.3 Efficient means are to be provided for the isolation of the motor and its associated control gear from all live poles of the supply.

Where the control gear is mounted on or adjacent to a switchboard, a disconnecting switch in the switchboard may be used for this purpose.

Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.

3.8.4 Where the starter or any other apparatus for disconnecting the motor is remote from the motor itself, one of the following is to be arranged:

a) provision for locking the circuit disconnecting switch in the OFF position

b) an additional disconnecting switch fitted near the motor

c) provision such that the fuses in each live pole or phase can be readily removed and retained by persons authorised to have access to the motor.

3.8.5 Unless automatic restarting is required, motor control circuits are to be designed so as to prevent any motor from unintentional automatic restarting after a stoppage due to over-current tripping or a fall in or loss of voltage, if such starting is liable to cause danger. Where reverse-current braking of a motor is provided, provision is to be made for the avoidance of reversal of the direction of rotation at the end of braking, if such reversal may cause danger.

3.9 Specific requirements for special power services

3.9.1 For the supply and characteristics of the distribution of the following services see the requirements listed:

- steering gear: Ch 1, Sec 14, [2]
- fire-extinguishing and detecting systems: Ch 4, Sec 15
- permanently installed submersible bilge pump: Ch 1, Sec 10, [6.7.7]
- ventilation fans, fuel pumps: Ch 4, Sec 2, [2.1]
- pumps discharging overboard above the lightest waterline and in way of the area of lifeboat and liferaft launching: Ch 1, Sec 10, [5.2.4].

3.9.2 All power circuits terminating in a bunker or cargo space are to be provided with a multiple-pole switch outside the space for disconnecting such circuits.

3.10 Power supply to heaters

3.10.1 Each heater rated more than 16 A is to be connected to a separate final circuit.

3.11 Reefer containers

3.11.1 Where the ship is intended to carry refrigerated containers, provision of suitable means for preventing earth faults on containers from affecting the main distribution system is to be made (galvanic isolation, tripping of the faulty circuit).

3.12 Power supply to final sub-circuits: socket outlet and lighting

3.12.1 Final sub-circuits for lighting supplying more than one lighting point and for socket-outlets are to be fitted with protective devices having a current rating not exceeding 16 A.

3.12.2 In spaces such as:

- main and large machinery spaces
- large galleys
- passageways
- stairways leading to boat-decks
- public spaces

there is to be more than one final sub-circuit for lighting such that failure of any one circuit does not reduce the lighting to an insufficient level.

3.12.3 Where the emergency installation is required, one of the circuits in [3.12.2] may be supplied from the emergency source of power.

3.12.4 All lighting circuits terminating in a bunker or cargo space are to be provided with a multiple-pole switch outside the space for disconnecting such circuits.

3.12.5 The number of lighting points (lamps) supplied by a final sub-circuit having a current rating not exceeding 16 A is not to exceed the following maxima:

- 10 lamps for voltage up to 55 V
- 14 lamps for voltage from 56 V up to 120 V
- 24 lamps for voltage from 121 V to 250 V.

3.12.6 Final sub-circuits for lighting in accommodation spaces may include socket-outlets. In that case, each socket-outlet counts for two lighting points.

3.13 Navigation lights

3.13.1 Navigation lights are to be connected separately to a distribution board specially reserved for this purpose.

3.13.2 The distribution board in [3.13] is to be supplied from two alternative circuits, one from the main source of power and one from the emergency source of power (see also [3.6]).

The transfer of supply is to be practicable from the bridge, for example by means of a switch.

3.13.3 Each navigation light is to be controlled and protected in each insulated pole by a double-pole switch and a fuse or, alternatively, by a double-pole circuit-breaker, fitted on the distribution board referred to in [3.13].

3.13.4 Where there are double navigation lights, i.e. lights with two lamps or where for every navigation light a spare is also fitted, the connections to such lights may run in a single cable provided that means are foreseen in the distribution board to ensure that only one lamp or light may be supplied at any one time.

3.13.5 Each navigation light is to be provided with an automatic indicator giving audible and/or visual warning in the event of failure of the light. If an audible device alone is fitted, it is to be connected to a separate source of supply from that of the navigation lights, for example an accumulator (storage) battery.

If a visual signal is used connected in series with the navigation light, means are to be provided to prevent the extinction of the navigation light due to the failure of the visual signal.

A minimum level of visibility is to be assured in the case of use of dimmer devices.

3.14 General emergency alarm system

3.14.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal, is to comply with the requirements of this sub-article.

3.14.2 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in [3.15] or other suitable means of communication.

3.14.3 Entertainment sound system is to be automatically turned off when the general alarm system is activated.

3.14.4 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

3.14.5 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by [2.3] and [3.6].

3.14.6 The system is to be capable of operation from the navigation bridge and, except for the ship’s whistle, also from other strategic points.

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station should normally be regarded as strategic points.

3.14.7 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

3.14.8 The alarm system is to be audible throughout all the accommodation and normal crew working spaces.

3.14.9 The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB (A) and at least 10 dB (A) above ambient noise levels occurring during normal equipment operation with the ship underway in moderate weather.

3.14.10 In cabins without a loudspeaker installation, an electronic alarm transducer, e.g. a buzzer or similar, is to be installed.

3.14.11 The sound pressure level at the sleeping position in cabins and in cabin bathrooms is to be at least 75 dB (A) and at least 10 dB (A) above ambient noise levels.

3.14.12 For cables used for the general emergency alarm system, see [9.6.1].

3.15 Public address system

3.15.1 The public address system is to be a loudspeaker installation enabling the broadcast of messages into all spaces where people on board are normally present.

In spaces such as under deck passageways, bosun’s locker, hospital and pump rooms, the public address system may not be required.

3.15.2 Where the public address system is used to supplement the general emergency alarm system as per [3.14.2], it is to be continuously powered from the emergency source of electrical power required by [2.3] and [3.6].

3.15.3 The system is to allow for the broadcast of messages from the navigation bridge and from other places on board the ship as deemed necessary.

3.15.4 The system is to be protected against unauthorised use.

3.15.5 The system is to be installed with regard to acoustically marginal conditions and not require any action from the addressee.

3.15.6 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigation bridge, is to be in place.

3.15.7 With the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

a) in interior spaces, 75 dB (A) and at least 20 dB (A) above the speech interference level

b) in exterior spaces, 80 dB (A) and at least 15 dB (A) above the speech interference level.

With respect to cabin/state rooms, the sound pressure level is to be attained as required inside such spaces during sea trials.

3.16 Combined general emergency alarm-public address system

3.16.1 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [3.14] and [3.15], the following are to be satisfied:

- the system automatically overrides any other non emergency input system when an emergency alarm is required
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required
- the system is arranged to prevent feedback or other interference
- the system is arranged to minimise the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the case of failure of any one circuit or component, by means of the use of:
  - multiple amplifiers
  - segregated cable routes to public rooms, alleyways, stairways and control stations
  - more than one device for generating electronic sound signal
  - electrical protection for individual loudspeakers against short-circuits.

3.17 Control and indication circuits

3.17.1 For the supply of automation systems, comprising control, alarm and safety system, see the requirements of Part C, Chapter 3.

3.17.2 Control and indicating circuits relative to primary essential services are to be branched off from the main circuit in which the relevant equipment is installed. Equivalent arrangements may be accepted by the Society.

3.17.3 Control and indicating circuits relative to secondary essential services and to non-essential services may be supplied by distribution systems reserved for the purpose to the satisfaction of the Society.

3.18 Power supply to the speed control systems of main propulsion engines

3.18.1 Electrically operated speed control systems of main engines are to be fed from the main source of electrical power.

3.18.2 Where more than one main propulsion engine is foreseen, each speed control system is to be provided with an individual supply by means of separate wiring from the main switchboard or from two independent section boards.

Where the main busbars are divided into two sections, the governors are, as far as practicable, to be supplied equally from the two sections.

3.18.3 In the case of propulsion engines which do not depend for their operation on electrical power, i.e. pumps driven from the main engine, the speed control systems are to be fed both from the main source of electrical power and from an accumulator battery for at least 15 minutes or from a similar supply source.

Such battery may also be used for other services such as automation systems, where foreseen.

3.19 Power supply to the speed control systems of generator sets

3.19.1 Each electrically operated control and/or speed control system of generator sets is to be provided with a separate supply from the main source of electric power and from an accumulator battery for at least 15 minutes or from a similar supply source.

3.19.2 The speed control system of generator sets is to be supplied from the main switchboard or from independent section boards.

Where the main busbars are divided into two sections, the governors are, as far as practicable, to be supplied from the sections to which the relevant generators are connected.

3.20 Installation of water-based local application fire-fighting systems (FWBLAFFS)

3.20.1 The system is to be capable of manual release.

3.20.2 The activation of the fire-fighting system is not to result in loss of electrical power or reduction of the manoeuvrability of the ship.

3.20.3 The system and its components are to be designed to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in machinery spaces. Components within the protected spaces are to be designed to withstand the elevated temperatures which could occur during a fire.

3.20.4 Degrees of protection are to be in accordance with [4.2].

3.20.5 Systems requiring an external power source are to be supplied by the main power source.

3.20.6 In case of activation of the system, an alarm in accordance with Ch 4, Sec 6, [4.7.4] is to be activated.

3.21 Integrated cargo and ballast systems on tankers

3.21.1 Integrated electric systems used to drive both cargo and ballast pumps on tankers, including control and safety systems, are to comply with the provisions of Pt D, Ch 7, Sec 4, [3.6].

3.22 Harmonic distortion for ship electrical distribution system without harmonics filters

3.22.1 The total harmonic distortion (THD) of electrical distribution systems is not to exceed 8% except in the cases defined in Ch 2, Sec 2, [2.4].

3.23 Harmonic distortion for ship electrical distribution system including harmonics filters

3.23.1 Where harmonic filters are installed on main busbars of electrical distribution system, other than those installed for single application frequency drives such as pump motors, the ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar. The crew is to be alerted when the level of harmonic distortion exceed the acceptable limits.

3.23.2 Where the electrical distribution system on board a ship includes harmonic filters the system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced.

3.23.3 The system integrator of the distribution system is to provide the Society, for information, with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters

3.23.4 Arrangements are to be provided to alert the crew in the event of activation of the protection of a harmonic filter circuit.

3.23.5 A harmonic filter is to be arranged as a three phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter.

3.23.6 A current unbalance detection system, independent of the overcurrent protection, is to be provided in order to alert the crew in case of current unbalance.

3.23.7 Additional protection for the individual capacitor element as e.g. relief valve or overpressure disconnector in order to protect against damage from rupturing may be considered, depending on the type of capacitors used.

4 Degrees of protection of the enclosures

4.1 General

4.1.1 The minimum required degree of protection for electrical equipment, in relation to the place of installation, is generally that specified in Tab 2.

4.1.2 Equipment supplied at nominal voltages in excess of 500 V and accessible to non-authorised personnel (e.g. equipment not located in machinery spaces or in locked compartments under the responsibility of the ship's officers) is to have a degree of protection against touching live parts of at least IP 4X.

4.1.3 In addition to the requirements of this paragraph, equipment installed in spaces with an explosion hazard is also subject to the provisions of Ch 2, Sec 2, [6].

4.1.4 The enclosures of electrical equipment for the monitoring and control of watertight doors which are situated below the bulkhead deck are to provide suitable protection against the ingress of water.

In particular, the minimum required degree of protection is to be:

- IP X7 for electric motors, associated circuits and control components
- IP X8 for door position indicators and associated circuit components
- IP X6 for door movement warning signals.

Note 1: The water pressure testing of the enclosures protected to IP X8 is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.

4.1.5 This requirement applies to ships with service notation **bulk carrier**, **bulk carrier ESP**, **ore carrier ESP**, **combination carrier /OBO ESP**, **combination carrier /OOC ESP**, **self-unloading bulk carrier ESP**, as described in Pt A, Ch 1, Sec 2, [4.3] and provided with a dewatering system (see Ch 1, Sec 10, [6.6.7]). The enclosures of electrical equipment for the dewatering system installed in any of the forward dry spaces are to provide protection to IPX8 standard for a water head equal to the height of the space in which the electrical equipment is installed for a time duration of at least 24 hours.

Table 2 : Minimum required degrees of protection

Condition in location	Example of location	Switchboar, control gear, motorstarters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outlets	Accessories (e.g. switches, connection boxes)
Danger of touching live parts only	Dry accommodation spaces, dry control rooms	IP 20	X **(1)**	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20
Danger of dripping liquid and/or moderate mechanical damage	Control rooms, wheel-house, radio room	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22
	Engine and boiler rooms above floor	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Steering gear rooms	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Emergency machinery rooms	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	General storerooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 22	IP 44
	Pantries	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Provision rooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Ventilation ducts	X	X	IP 22	X	X	X	X	X	X
Increased danger of liquid and/or mechanical damage	Bathrooms and / or showers	X	X	X	X	IP 34	IP 44	X	IP 55	IP 55
	Engine and boiler rooms below floor	X	X	IP 44	X	IP 34	IP 44	X	X	IP 55
	Closed fuel oil separator rooms	IP 44	X	IP 44	IP 44	IP 34	IP 44	X	X	IP 55
	Closed lubricating oil separator rooms	IP 44	X	IP 44	IP 44	IP 34	IP 44	X	X	IP 55
Increased danger of liquid and mechanical damage	Ballast pump rooms	IP 44	X	IP 44 **(2)**	IP 44 **(2)**	IP 34	IP 44	X	IP 55	IP 55
	Refrigerated rooms	X	X	IP 44	X	IP 34	IP 44	X	IP 55	IP 55
	Galleys and laundries	IP 44	X	IP 44	IP 44	IP 34	IP 44	IP 44	IP 44	IP 44
	Public bathrooms and shower	X	X	IP 44	IP 44	IP 34	IP 44	X	IP 44	IP 44
Danger of liquid spraying, presence of cargo dust, serious mechanical damage, aggressive fumes	Shaft or pipe tunnels in double bottom	IP 55	X	IP 55	IP 55	IP 55	IP 55	X	IP 56	IP 56
	Holds for general cargo	X	X	IP 55	X	IP 55	IP 55	X	IP 56	IP 56
	Ventilation trunks	X	X	IP 55	X	X	X	X	X	X
Danger of liquid in massive quantities	Open decks	IP 56	X	IP 56	X	IP 55	IP 56	X	IP 56	IP 56

(1) The symbol "X" denotes equipment which it is not advised to install.

(2) Electric motors and starting transformers for lateral thrust propellers located in spaces similar to ballast pump rooms may have degree of protection IP 22.

4.2 Installation of electrical and electronic equipment in engine rooms protected by fixed water-based local application fire-fighting systems (FWBLAFFS)

4.2.1 Unless it is essential for safety or operational purposes, electrical and electronic equipment is not to be located within areas protected by FWBLAFFS and in adjacent areas where water may extend.

The electrical and electronic equipment located within areas protected by FWBLAFFS and those within adjacent exposed to direct spray are to have a degree of protection not less than IP44.

Electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, filters, baffles, etc. to prevent or restrict the ingress mist/spray into the equipment. The cooling airflow for the equipment is to be assured.

Note 1: Definitions (see Fig 2):

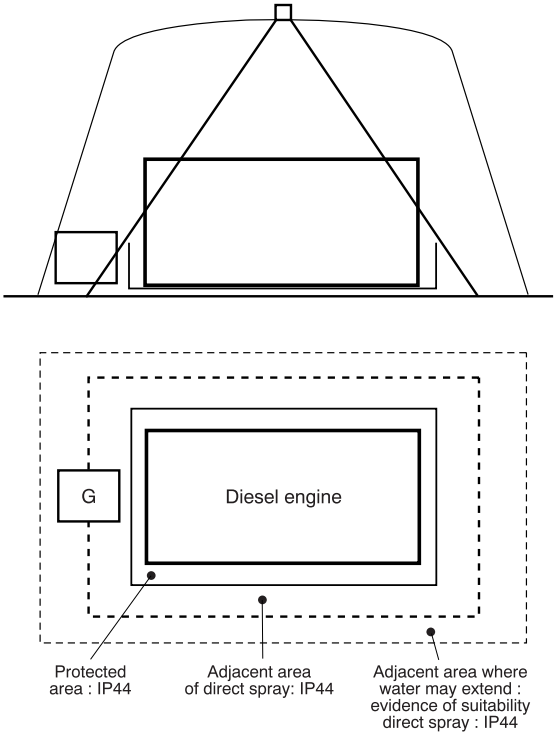
- protected space is a machinery space where a FWBLAFFS is installed
- protected areas: areas within a protected space which is required to be protected by FWBLAFFS
- adjacent areas:
  - areas other those protected areas, exposed
  - areas other those defined above, where water may extend.

Note 2: Additional precautions may be required to be taken in respect of:

- tracking as the result of water entering the equipment
- potential damage as the result of residual salts from sea water systems
- high-voltage installations
- personnel protection against electric shock

Equipment may require maintenance after being subjected to water mist/spray.

Figure 2 : Definitions of areas



5 Diversity (demand) factors

5.1 General

5.1.1 The cables and protective devices of final sub-circuits are to be rated in accordance with their connected load.

5.1.2 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justifiable, to the application of a diversity (demand) factor.

5.1.3 A diversity (demand) factor may be applied provided that the known or anticipated operating conditions in a particular part of an installation are suitable for the application of diversity.

6 Environmental categories of the equipment

6.1 Environmental categories

6.1.1 The environmental categories of the electrical equipment, in relation to the place of installation, are generally to be those specified in Tab 3.

6.1.2 For ships operating outside the tropical belt, the maximum ambient air temperature may be assumed as equal to + 40°C instead of + 45°C, so that the first characteristic numeral changes from 1 to 3.

Table 3 : Required environmental categories

Location within main area				
Main areas on board	General	Inside cubicles, desks, etc.	On machinery such as internal combustion engines, compressors	Masts
Machinery spaces, steering gear	EC21	EC31	EC23	X **(1)**
Control room, accommodation	EC21 EC11C	EC31	X	X
Bridge	EC21B EC11BC	EC31B	X	X
Pump room, holds, rooms without heating	EC41	X	X	X
Exposed decks	EC41S EC41BS	X	X	EC42S EC42BS
(1) The symbol "X" denotes locations which are generally not applicable.				

7 Electrical protection

7.1 General requirements for overcurrent protection

7.1.1 Electrical installations are to be protected against accidental overcurrents including short-circuit.

The choice, arrangement and performance of the various protective devices are to provide complete and coordinated automatic protection in order to ensure as far as possible:

- continuity of service in the event of a fault, through coordinated and discriminative action of the protective devices
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: An overcurrent is a current exceeding the nominal current.

Note 2: A short-circuit is the accidental connection by a relatively low resistance or impedance of two or more points in a circuit which are normally at different voltages.

7.1.2 Devices provided for overcurrent protection are to be chosen according to the requirements, especially with regard to overload and short-circuit.

Note 1: Overload is an operating condition in an electrically undamaged circuit which causes an overcurrent.

7.1.3 Systems are to be such as to withstand the thermal and electrodynamic stresses caused by the possible overcurrent, including short-circuit, for the admissible duration.

7.2 Short-circuit currents

7.2.1 In calculating the maximum prospective short-circuit current, the source of current is to include the most powerful configuration of generators which can be simultaneously connected (as far as permitted by any interlocking arrangements), and the maximum number of motors which are normally simultaneously connected in the system.

The maximum number of generators or transformers is to be evaluated without taking into consideration short-term parallel operation (e.g. for load transfer) provided that suitable interlock is foreseen.

7.2.2 Short-circuit current calculations are to be performed in accordance with a method recognised by the Society, such as that given in IEC Publication 61363-1.

7.2.3 In the absence of precise data concerning the characteristics of generators, accumulator batteries and motors, the maximum short-circuit currents on the main busbars may be calculated as follows:

- for alternating current systems:

  $I_{ac} = 10\ I_{TG} + 3,5\ I_{TM}$

  $I_{pk} = 2,4\ I_{ac}$
- for direct current systems supplied by batteries:

  $I_p = K\ C_{10} + 6\ I_{TM}$

where:

I_p : Maximum short-circuit current

I_{ac} : r.m.s. value of the symmetrical component (at the instant T/2)

I_{pk} : Maximum peak value

I_{TG} : Rated current of all generators which can be connected simultaneously

C_{10} : Battery capacity in Ah for a discharge duration of 10 hours

K : Ratio of the short-circuit current of the batteries to C_{10} (see Note 1)

I_{TM} : Rated current of all motors which are normally simultaneously connected in the system.

Note 1: For stationary batteries the following values may be assumed for guidance:

- vented lead-acid batteries: K = 8
- vented alkaline type batteries intended for discharge at low rates corresponding to a battery duration exceeding three hours: K = 15
- sealed lead-acid batteries having a capacity of 100 Ah or more or alkaline type batteries intended for discharge at high rates corresponding to a battery duration not exceeding three hours: K = 30.

7.2.4 Converters used for power supply are to supply a short-circuit current sufficient for selective tripping of downstream protective devices without sustaining any internal damage.

7.3 Selection of equipment

7.3.1 Circuit-breakers of withdrawable type are required where they are not suitable for isolation.

7.3.2 Equipment is to be chosen on the basis of its rated current and its making/breaking capacity.

7.3.3 In the selection of circuit-breakers with intentional short-time delay for short-circuit release, those of utilisation category B are to be used and they are to be selected also taking into account their rated short-time withstand current capacity (Icw).

For circuit-breakers without intentional short-time delay for short-circuit release, circuit breakers of utilisation category A may be used and they are to be selected according to their rated service short-circuit breaking capacity (Ics).

Note 1: For the purpose of these Rules, utilisation categories A and B are defined as follows:

- utilisation category A: circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without an intentional short-time delay provided for selectivity under short-circuit conditions
- utilisation category B: circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with an intentional short-time delay (which may be adjustable) provided for selectivity under short-circuit conditions.

7.3.4 For duplicated essential services and non-essential services, circuit-breakers may be selected according to their ultimate short-circuit breaking capacity (Icu).

7.3.5 For switches, the making/breaking capacity is to be in accordance with utilisation category AC-22 A or DC-22 A (in compliance with IEC Publication 60947-3).

7.3.6 For fuse-switch disconnectors or switch-disconnector fuse units, the making/breaking capacity is to be in accordance with utilisation categories AC-23 A or DC-23 A (in compliance with IEC Publication 60947-3).

7.4 Protection against short-circuit

7.4.1 Protection against short-circuit currents is to be provided by circuit- breakers or fuses.

7.4.2 The rated short-circuit breaking capacity of every protective device is to be not less than the maximum prospective value of the short-circuit current at the point of installation at the instant of contact separation.

7.4.3 The rated short-circuit making capacity of every mechanical switching device intended to be capable of being closed on short-circuit is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

7.4.4 Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current liable to occur at the point of installation having regard to the time required for the short-circuit to be removed.

7.4.5 The use of a protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point where it is installed is permitted, provided that it is backed up on the generator side by a fuse or by a circuit-breaker having at least the necessary short-circuit rating and not being the generator circuit-breaker.

7.4.6 The same fuse or circuit-breaker may back up more than one circuit-breaker where the circuits concerned do not involve essential services.

7.4.7 The short-circuit performance of the back-up arrangement is to be equal to the requirements of IEC Publication 60947-2 for a single circuit-breaker having the same short-circuit performance category as the backed-up circuit-breaker and rated for the maximum prospective short-circuit level at the supply terminals of the arrangement.

7.4.8 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuses and the circuit-breakers are of coordinated design, in order to ensure that the operation of the fuses takes place in due time so as to prevent arcing between poles or against metal parts of the circuit-breakers when they are submitted to overcurrents involving the operation of the fuse.

7.4.9 When determining the performance requirements for the above-mentioned back-up protection arrangement, it is permissible to take into account the impedance of the various circuit elements of the arrangement, such as the impedance of a cable connection when the backed-up circuit-breaker is located away from the back-up breaker or fuse.

7.5 Continuity of supply and continuity of service

7.5.1 The protection of circuits is to be such that a fault in one service does not cause the loss of any essential services.

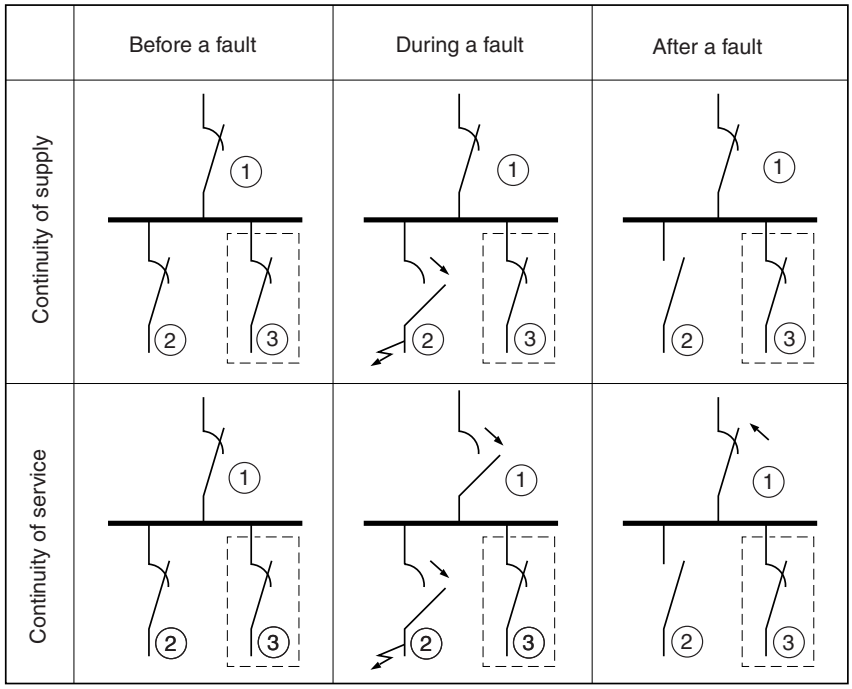
7.5.2 The protection of the emergency circuit is to be such that a failure in one circuit does not cause a loss of other emergency services.

Note 1: The continuity of supply for the primary essential services and the continuity of service for the secondary essential services are to be ensured.

The continuity of supply is the condition for which during and after a fault in a circuit, the supply to the healthy circuits (see circuit 3 in Fig 3) is permanently ensured.

The continuity of service is the condition for which after a fault in a circuit has been cleared, the supply to the healthy circuits (see circuit 3 in Fig 3) is re-established.

Figure 3 : Continuity of supply and continuity of service



7.6 Protection against overload

7.6.1 Devices provided for overload protection are to have a tripping characteristic (overcurrent-trip time) adequate for the overload ability of the elements of the system to be protected and for any discrimination requirements.

7.6.2 The use of fuses up to 320 A for overload protection is permitted.

7.7 Localisation of overcurrent protection

7.7.1 Short-circuit protection is to be provided for every non-earthed conductor.

7.7.2 Overload protection is to be provided for every non-earthed conductor nevertheless, in insulated single-phase circuits or insulated three-phase circuits having substantially balanced loads, the overload protection may be omitted on one conductor.

7.7.3 Short-circuit and overload protective devices are not to interrupt earthed conductors, except in the case of multiple disconnection devices which simultaneously interrupt all the conductors, whether earthed or not.

7.7.4 Electrical protection is to be located as close as possible to the origin of the protected circuit.

7.8 Protection of generators

7.8.1 Generators are to be protected against short-circuits and overloads by multipole circuit-breakers.

For generators not arranged to operate in parallel with a rated output equal to or less than 50 kVA, a multipole switch with a fuse in each insulated phase on the generator side may be accepted.

7.8.2 When multipole switch and fuses are used, the fuse rating is to be maximum 110% of the generator rated current.

7.8.3 Where a circuit-breaker is used:

a) The overload protection is to trip the generator circuit-breaker at an overload between 10% and 50%. For an overload of 50% of the rated current of the generator, the time delay is not to exceed 2 minutes. However, the figure of 50% or the time delay of 2 minutes may be exceeded if the construction of the generator permits this.

b) the setting of the short-circuit protection is to instantaneously trip the generator circuit-breaker at an overcurrent less than the steady short-circuit current of the generator. Short time delays (e.g. from 0,5 s to 1 s) may be introduced for discrimination requirements in "instantaneous" tripping devices.

7.8.4 For emergency generators the overload protection may, instead of disconnecting the generator automatically, give a visual and audible alarm in a permanently attended space.

7.8.5 After disconnection of a generator due to overload, the circuit-breaker is to be ready for immediate reclosure.

7.8.6 Generator circuit-breakers are to be provided with a reclosing inhibitor which prevents their automatic reclosure after tripping due to a short-circuit.

7.8.7 Generators having a capacity of 1500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit-breaker, will de-excite the generator and open the circuit-breaker (e.g. by means of differential protection).

7.8.8 *Where the main source of electrical power is necessary for the propulsion of the ship, load shedding or other equivalent arrangements are to be provided to protect the generators against sustained overload.*

7.8.9 Arrangements are to be made to disconnect or reduce automatically the excess load when the generators are overloaded in such a way as to prevent a sustained loss of speed and/or voltage (see Ch 2, Sec 2, Tab 6). The operation of such device is to activate a visual and audible alarm. A time delay of 5-20 s is considered acceptable.

7.8.10 When an overload is detected the load shedding system is to disconnect automatically, after an appropriate time delay, the circuits supplying the non-essential services and, if necessary, the secondary essential services in a second stage.

7.8.11 Alternating current generators arranged to operate in parallel are to be provided with reverse-power protection.

The protection is to be selected in accordance with the characteristics of the prime mover.

The following values are recommended:

- 2-6% of the rated power for turbogenerators
- 8-15% of the rated power for diesel generators.

The reverse-power protection may be replaced by other devices ensuring adequate protection of the prime movers.

7.8.12 Generators are to be provided with an undervoltage protection which trips the breaker if the voltage falls to 70%-35% of the rated voltage.

The undervoltage release also prevents the closing of the circuit-breaker if the generator voltage does not reach a minimum of 85% of the rated voltage.

The operation of the undervoltage release is to be instantaneous when preventing closure of the breaker, but it is to be delayed for selectivity purposes when tripping the breaker.

7.8.13 Generators are to be provided with overvoltage protection to avoid damage to the connected equipment.

7.9 Protection of circuits

7.9.1 *Each separate circuit shall be protected against short-circuit and against overload, unless otherwise specified in these Rules or where the Society may exceptionally otherwise permit.*

7.9.2 Each circuit is to be protected by a multipole circuit-breaker or switch and fuses against overloads and short-circuits.

7.9.3 Circuits for lighting are to be disconnected on both non-earthed conductors. Single-pole disconnection of final sub-circuits with both poles insulated is permitted only in accommodation spaces, when a differential protection is provided.

7.9.4 The protective devices of the circuits supplying motors are to allow excess current to pass during transient starting of motors.

7.9.5 Final sub-circuits which supply one consumer with its own overload protection (for example motors), or consumers which cannot be overloaded (for example permanently wired heating circuits and lighting circuits), may be provided with short-circuit protection only.

7.9.6 Steering gear circuits are to be provided with short-circuit protection only (see Ch 1, Sec 14, [2]).

7.10 Protection of motors

7.10.1 Motors of rating exceeding 1 kW and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection may be provided by the same protective device for the motor and its supply cable (see [7.9.5]).

7.10.2 For motors intended for essential services, the overload protection may be replaced by an overload alarm (for steering gear motors see Ch 1, Sec 14, [2]).

7.10.3 The protective devices are to be designed so as to allow excess current to pass during the normal accelerating period of motors according to the conditions corresponding to normal use.

If the current/time characteristic of the overload protection device does not correspond to the starting conditions of a motor (e.g. for motors with extra-long starting period), provision may be made to suppress operation of the device during the acceleration period on condition that the short-circuit protection remains operational and the suppression of overload protection is only temporary.

7.10.4 For continuous duty motors the protective gear is to have a time delay characteristic which ensures reliable thermal protection against overload.

7.10.5 The protective devices are to be adjusted so as to limit the maximum continuous current to a value within the range 105% - 120% of the motor's rated full load current.

7.10.6 For intermittent duty motors the current setting and the delay (as a function of time) of the protective devices are to be chosen in relation to the actual service conditions of the motor.

7.10.7 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

7.10.8 Motors rated above 1 kW are to be provided with:

- undervoltage protection, operating on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted or
- undervoltage release, operating on the reduction or failure of voltage, so arranged that the motor restarts automatically when power is restored after a power failure.

7.10.9 The automatic restart of a motor is not to produce a starting current such as to cause excessive voltage drop.

In the case of several motors required to restart automatically, the total starting current is not to cause an excessive voltage drop or sudden surge current to this end, it may be necessary to achieve a sequence start.

7.10.10 The undervoltage protective devices are to allow the motor to be started when the voltage exceeds 85% of the rated voltage and are to intervene without fail when the voltage drops to less than approximately 20% of the rated voltage, at the rated frequency and with a time delay as necessary.

7.11 Protection of storage batteries

7.11.1 Batteries are to be protected against overload and short-circuit by means of fuses or multipole circuit-breakers at a position adjacent to the battery room.

Note 1: Overcurrent protection may be omitted for the circuit to the starter motors when the current drawn is so large that is impracticable to obtain short-circuit protection.

Note 2: When conductors from the batteries are not protected against short-circuiting and overload, they are to be installed so as to be adequately protected against short-circuits and earth faults and as short as possible, e.g., starting batteries for emergency generator or fire pumps engines in the same skid or very near.

7.11.2 Emergency batteries supplying essential services are to have short-circuit protection only.

7.12 Protection of shore power connection

7.12.1 Permanently fixed cables connecting the shore connection box to the main switchboard are to be protected by fuses or circuit-breakers (see [3.7.4]).

7.13 Protection of measuring instruments, pilot lamps and control circuits

7.13.1 Measuring circuits and devices (voltage transformers, voltmeters, voltage coils of measuring instruments, insulation monitoring devices etc.) and pilot lamps are to be protected against short-circuit by means of multipole circuit-breakers or fuses.

The protective devices are to be placed as near as possible to the tapping from the supply.

The secondary side of current transformers is not to be protected.

7.13.2 Control circuits and control transformers are to be protected against overload and short-circuit by means of multipole circuit-breakers or fuses on each pole not connected to earth.

Overload protection may be omitted for transformers with a rated current of less than 2 A on the secondary side.

The short-circuit protection on the secondary side may be omitted if the transformer is designed to sustain permanent short-circuit current.

7.13.3 Where a fault in a pilot lamp would impair the operation of essential services, such lamps are to be protected separately from other circuits such as control circuits.

Note 1: Pilot lamps connected via short-circuit-proof transformers may be protected in common with control circuits.

7.13.4 Circuits whose failure could endanger operation, such as steering gear control feeder circuits, are to be protected only against short-circuit.

7.13.5 The protection is to be adequate for the minimum cross-section of the protected circuits.

7.14 Protection of transformers

7.14.1 The primary winding side of power transformers is to be protected against short-circuit and overload by means of multipole circuit-breakers or switches and fuses.

Overload protection on the primary side may be dispensed with where it is provided on the secondary side or when the total possible load cannot reach the rated power of the transformer.

7.14.2 The protection against short-circuit is to be such as to ensure the selectivity between the circuits supplied by the secondary side of the transformer and the feeder circuit of the transformer.

7.14.3 When transformers are arranged to operate in parallel, means are to be provided so as to trip the switch on the secondary winding side when the corresponding switch on the primary side is open.

7.15 Lightning protection

7.15.1 For ships fitted with non-metallic masts or non metallic superstructures, a lightning conductor is to be provided. The lower end of the lightning conductor is to be earthed to the hull.

8 System components

8.1 General

8.1.1 The components of the electrical system are to be dimensioned such as to withstand the currents that can pass through them during normal service without their rating being exceeded.

8.1.2 The components of the electrical system are to be designed and constructed so as to withstand for the admissible duration the thermal and electrodynamic stresses caused by possible overcurrents, including short-circuit.

9 Electrical cables

9.1 General

9.1.1 *All electrical cables and wiring external to equipment shall be at least of a flame-retardant type,* in accordance with Ch 2, Sec 9, [2.1.6].

9.1.2 When cables are laid in bunches, cable types are to be chosen in compliance with Ch 2, Sec 9, [2.1.7].

9.1.3 Cables which are required to have fire-resisting characteristics are to comply with the requirements stipulated in Ch 2, Sec 9, [2.1.9].

9.1.4 Cables and insulated wiring are generally to be chosen and installed in accordance with IEC Publications 60092-352, as well with the provisions of this Chapter.

9.2 Choice of insulation

9.2.1 The maximum rated operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to occur or to be produced in the space where the cable is installed.

9.2.2 The maximum rated conductor temperature for normal and short-circuit operation, for the type of insulating compounds normally used for shipboard cables, is not to exceed the values stated in Tab 4. Special consideration will be given to other insulating materials.

9.2.3 PVC-ST2 insulated cables are not to be used either in refrigerated spaces, or on decks exposed to the weather of ships classed for unrestricted service.

9.2.4 Mineral insulated cables will be considered on a case by case basis.

Table 4 : Maximum rated conductor temperature

Type of insulating compound	Abbreviated designation	Maximum rated conductor temperature, in °C	
		Normal operation	Short-circuit
a) Thermoplastic:			
- based upon polyvinyl chloride or copolymer of vinyl chloride and vinyl acetate	PVC	70	150
b) Elastomeric or thermoset:			
- based upon ethylene-propylene rubber or similar (EPM or EPDM)	EPR	90	250
- based upon high modulus or hard grade ethylene propylene rubber	HEPR	90	250
- based upon cross-linked polyethylene	XLPE	90	250
- based upon silicone rubber	S 95	95	350 **(1)**
- based upon ethylene-propylene rubber or similar (EPM or EPDM) halogen-free	HF EPR	90	250
- based upon high modulus or hard grade halogen-free ethylene propylene rubber	HF HEPR	90	250
- based upon halogen-free cross-linked polyethylene	HF XLPE	90	250
- based upon halogen-free silicone rubber	HF S 95	95	350 **(1)**
- based upon cross-linked polyolefin material for halogen-free cables	HF 90	90	250
(1) This temperature is applicable only to power cables and not appropriate for tinned copper conductors.			

9.3 Choice of protective covering

9.3.1 The conductor insulating materials are to be enclosed in an impervious sheath of material appropriate to the expected ambient conditions where cables are installed in the following locations:

- on decks exposed to the weather
- in damp or wet spaces (e.g. in bathrooms)
- in refrigerated spaces
- in machinery spaces and, in general
- where condensation water or harmful vapour may be present.

9.3.2 Where cables are provided with armour or metallic braid (e.g. for cables installed in hazardous areas), an overall impervious sheath or other means to protect the metallic elements against corrosion is to be provided (see Ch 2, Sec 9, [2.5]).

9.3.3 An impervious sheath is not required for single-core cables installed in tubes or ducts inside accommodation spaces, in circuits with maximum system voltage 250 V.

9.3.4 In choosing different types of protective coverings, due consideration is to be given to the mechanical action to which each cable may be subjected during installation and in service.

If the mechanical strength of the protective covering is considered insufficient, the cables are to be mechanically protected (e.g. by an armour or by installation inside pipes or conduits).

9.3.5 Single-core cables for a.c. circuits with rated current exceeding 20 A are to be either non-armoured or armoured with non-magnetic material.

9.4 Cables in refrigerated spaces

9.4.1 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armour is applied on the sheath, the armour is to be protected against corrosion by a further moisture-resisting covering.

9.5 Cables in areas with a risk of explosion

9.5.1 For cables in areas with a risk of explosion, see [10.5].

9.6 Cables in circuits required to be operable under fire condition

9.6.1 Electrical services required to be operable under fire conditions are as follows:

- control and power systems to power-operated fire doors and status indication for all fire doors
- control and power systems to power-operated watertight doors and their status indication
- emergency fire pump
- emergency lighting
- fire and general alarms
- fire detection systems
- fire-extinguishing systems and fire-extinguishing media release alarms
- low location lighting
- public address systems
- remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion.

9.6.2 Where cables for services specified in [9.6.1] including their power supplies pass through high fire risk areas, and, in addition for passenger ships, through main vertical fire zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

a) Cables being of a fire resistant type complying with Ch 2, Sec 9, [2.1.9] are installed and run continuous to keep the fire integrity within the high fire risk area (see Fig 4)

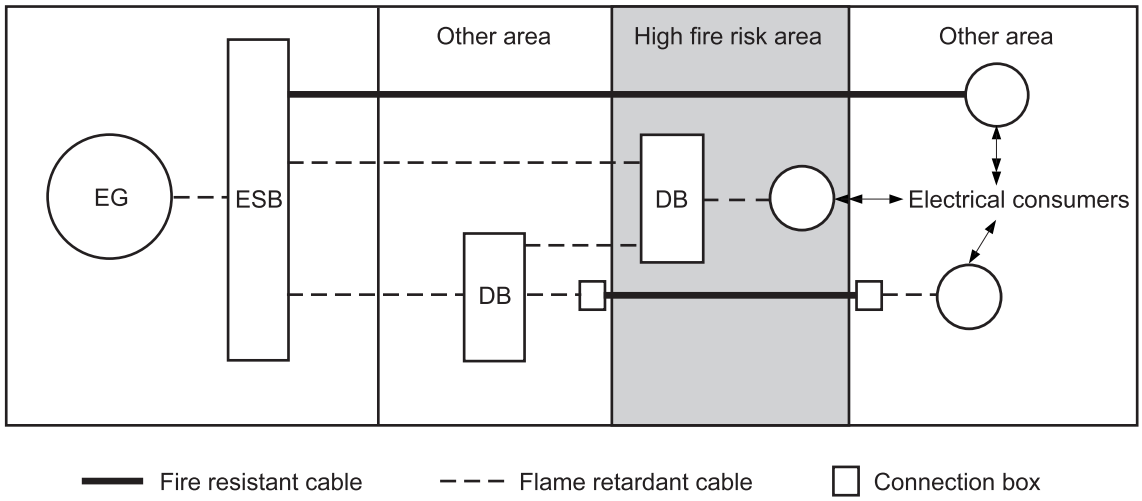
Note 1: The application of this requirement for public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m² or more will be considered on the case by case basis.

b) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

9.6.3 *Cables connecting fire pumps to the emergency switchboard shall be of a fire-resistant type where they pass through high fire risk areas.*

Figure 4 : Routing of cables in high fire risk area



9.7 Cables for submerged bilge pumps

9.7.1 Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cable is to be impervious-sheathed and armoured, is to be installed in continuous lengths from above the bulkhead to the motor terminals and is to enter the air bell from the bottom.

9.8 Internal wiring of switchboards and other enclosures for equipment

9.8.1 For installation in switchboards and other enclosures for equipment, single-core cables may be used without further protection (sheath).

Other types of flame-retardant switchboard wiring may be accepted at the discretion of the Society.

9.9 Current carrying capacity of cables

9.9.1 The current carrying capacity for continuous service of cables given in Tab 5 to Tab 9 is based on the maximum permissible service temperature of the conductor also indicated therein and on an ambient temperature of 45°C.

9.9.2 The current carrying capacity cited in [9.9.1] is applicable, with rough approximation, to all types of protective covering (e.g. both armoured and non-armoured cables).

9.9.3 Values other than those shown in Tab 5 to Tab 9 may be accepted provided they are determined on the basis of calculation methods or experimental values approved by the Society.

9.9.4 When the actual ambient temperature obviously differs from 45°C, the correction factors shown in Tab 10 may be applied to the current carrying capacity in Tab 5 to Tab 9.

9.9.5 Where more than six cables are bunched together in such a way that there is an absence of free air circulating around them, and the cables can be expected to be under full load simultaneously, a correction factor of 0,85 is to be applied.

9.9.6 Where a cable is intended to supply a short-time load for 1/2-hour or 1-hour service (e.g. mooring winches or bow thruster propellers), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the corresponding correction factors given in Tab 11.

In no case is a period shorter than 1/2-hour to be used, whatever the effective period of operation.

9.9.7 For supply cables to single services for intermittent loads (e.g. cargo winches or machinery space cranes), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the correction factors given in Tab 12.

The correction factors are calculated with rough approximation for periods of 10 minutes, of which 4 minutes with a constant load and 6 minutes without load.

9.9.8 The current carrying capacity of cables connected in parallel is the sum of the current ratings of all parallel conductors but the cables must have equal impedance, equal cross-section, equal maximum permissible conductor temperatures and follow substantially identical routing or be installed in close proximity. Connections in parallel are only permitted for cross-sections of 10 mm^2 or above. When equal impedance can not be assumed, a correction factor of 0,9 is to be applied to the current carrying capacity.

Table 5 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 60°C (ambient temperature 45°C)

Nominal section, in mm^2	Number of conductors		
	1	2	3 or 4
1,5	10	9	7
2,5	17	14	12
4	23	20	16
6	29	25	20
10	40	34	28
16	54	46	38
25	71	60	50
35	88	75	62
50	110	94	77
70	135	115	95
95	164	139	115
120	189	161	132
150	218	185	153
185	248	211	174
240	292	248	204
300	336	286	235
400	dc: 390 ac: 380	dc: 332 ac: 323	dc: 273 ac: 266
500	dc: 450 ac: 430	dc: 383 ac: 366	dc: 315 ac: 301
630	dc: 520 ac: 470	dc: 442 ac: 400	dc: 364 ac: 329

Table 6 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 85°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	21	18	15
2,5	28	24	20
4	38	32	27
6	49	42	34
10	67	57	47
16	91	77	64
25	120	102	84
35	148	126	104
50	184	156	129
70	228	194	160
95	276	235	193
120	319	271	223
150	367	312	257
185	418	355	293
240	492	418	344
300	565	480	396
400	dc: 650 ac: 630	dc: 553 ac: 536	dc: 455 ac: 441
500	dc: 740 ac: 680	dc: 629 ac: 578	dc: 518 ac: 476
630	dc: 840 ac: 740	dc: 714 ac: 629	dc: 588 ac: 518

Table 7 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 70°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	15	13	11
2,5	21	18	15
4	29	25	20
6	37	31	26
10	51	43	36
16	68	58	48
25	90	77	63
35	111	94	78
50	138	117	97
70	171	145	120
95	207	176	145
120	239	203	167
150	275	234	193
185	313	266	219
240	369	314	258
300	424	360	297
400	dc: 500 ac: 490	dc: 425 ac: 417	dc: 350 ac: 343
500	dc: 580 ac: 550	dc: 493 ac: 468	dc: 406 ac: 385
630	dc: 670 ac: 610	dc: 570 ac: 519	dc: 469 ac: 427

Table 8 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 90°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,5	23	20	16
2,5	30	26	21
4	40	34	28
6	52	44	36
10	72	61	50
16	96	82	67
25	127	108	89
35	157	133	110
50	196	167	137
70	242	206	169
95	293	249	205
120	339	288	237
150	389	331	272
185	444	377	311
240	522	444	365
300	601	511	421
400	dc: 690 ac: 670	dc: 587 ac: 570	dc: 483 ac: 469
500	dc: 780 ac: 720	dc: 663 ac: 612	dc: 546 ac: 504
630	dc: 890 ac: 780	dc: 757 ac: 663	dc: 623 ac: 546

Table 9 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 95°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,5	26	22	18
2,5	32	27	22
4	43	37	30
6	55	47	39
10	76	65	53
16	102	87	71
25	135	115	95
35	166	141	116
50	208	177	146
70	256	218	179
95	310	264	217
120	359	305	251
150	412	350	288
185	470	400	329
240	553	470	387
300	636	541	445
400	dc: 760 ac: 725	dc: 646 ac: 616	dc: 532 ac: 508
500	dc: 875 ac: 810	dc: 744 ac: 689	dc: 612 ac: 567
630	dc: 1010 ac: 900	dc: 859 ac: 765	dc: 707 ac: 630

Table 10 : Correction factors for various ambient air temperatures

Maximum conductor temperature, in °C	Correction factors for ambient air temperature of:										
	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C
60	1,29	1,15	1,00	0,82	–	–	–	–	–	–	–
65	1,22	1,12	1,00	0,87	0,71	–	–	–	–	–	–
70	1,18	1,10	1,00	0,89	0,77	0,63	–	–	–	–	–
75	1,15	1,08	1,00	0,91	0,82	0,71	0,58	–	–	–	–
80	1,13	1,07	1,00	0,93	0,85	0,76	0,65	0,53	–	–	–
85	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	–	–
90	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	–
95	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 11 : Correction factors for short-time loads

1/2-hour service		1-hour service		Correction factor
Sum of nominal cross-sectional areas of all conductors, in mm²		Sum of nominal cross-sectional areas of all conductors, in mm²		
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
up to 20	up to 75	up to 80	up to 230	1,06
21 - 41	76 - 125	81 - 170	231 - 400	1,10
41 - 65	126 - 180	171 - 250	401 - 600	1,15
66 - 95	181 - 250	251 - 430	601 - 800	1,20
96 - 135	251 - 320	431 - 600	–	1,25
136 - 180	321 - 400	601 - 800	–	1,30
181 - 235	401 - 500	–	–	1,35
236 - 285	501 - 600	–	–	1,40
286 - 350	–	–	–	1,45

Table 12 : Correction factors for intermittent service

Sum of nominal cross-sectional areas of all conductors, in mm²		Correction factor
Cables with metallic sheath and armoured cables	Cables without metallic sheath and non-armoured cables	
	$S \leq 5$	1,10
	$5 < S \leq 8$	1,15
	$8 < S \leq 16$	1,20
$S \leq 4$	$16 < S \leq 25$	1,25
$4 < S \leq 7$	$25 < S \leq 42$	1,30
$7 < S \leq 17$	$42 < S \leq 72$	1,35
$17 < S \leq 42$	$72 < S \leq 140$	1,40
$42 < S \leq 110$	$140 < S$	1,45
$110 < S$	–	1,50

9.10 Minimum nominal cross-sectional area of conductors

9.10.1 In general the minimum allowable conductor cross-sectional areas are those given in Tab 13.

9.10.2 The nominal cross-sectional area of the neutral conductor in three-phase distribution systems is to be equal to at least 50% of the cross-sectional area of the phases, unless the latter is less than or equal to 16 mm^2. In such case the cross-sectional area of the neutral conductor is to be equal to that of the phase.

9.10.3 For the nominal cross-sectional area of:

- earthing conductors, see Ch 2, Sec 12, [2.3]
- earthing connections for distribution systems, see Ch 2, Sec 12, [2.5]
- neutral connections for three-phase systems, see Ch 2, Sec 8, [1.3.4].

Table 13 : Minimum nominal cross-sectional areas

Service	Nominal cross-sectional area, in mm^2	
	External wiring	Internal wiring
Power, heating and lighting systems	1,0	1,0
Control circuits for power plant	1,0	1,0
Control circuits other than those for power plant	0,75	0,5
Control circuits for telecommunications, measurement, alarms	0,5	0,2
Telephone and bell equipment, not required for the safety of the ship or crew calls	0,2	0,1
Bus and data cables	0,2	0,1

9.11 Choice of cables

9.11.1 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

9.11.2 The nominal cross-sectional area of each cable is to be sufficient to satisfy the following conditions with reference to the maximum anticipated ambient temperature:

- the current carrying capacity is to be not less than the highest continuous load carried by the cable
- the voltage drop in the circuit, by full load on this circuit, is not to exceed the specified limits
- the cross-sectional area calculated on the basis of the above is to be such that the temperature increases which may be caused by overcurrents or starting transients do not damage the insulation.

9.11.3 The highest continuous load carried by a cable is to be calculated on the basis of the power requirements and of the diversity factor of the loads and machines supplied through that cable.

9.11.4 When the conductors are carrying the maximum nominal service current, the voltage drop from the main or emergency switchboard busbars to any point in the installation is not to exceed 6% of the nominal voltage.

For battery circuits with supply voltage less than 55 V, this value may be increased to 10%.

For the circuits of navigation lights, the voltage drop is not to exceed 5% of the rated voltage under normal conditions.

10 Electrical installations in hazardous areas

10.1 General

10.1.1 Hazardous area classification

For the classification of hazardous areas for explosive gas/dust atmospheres, see Ch 2, Sec 1, [3.13].

10.2 Electrical equipment

10.2.1 No electrical equipment is to be installed in hazardous areas unless the Society is satisfied that such equipment is:

- essential for operational purposes
- certified safe as per the types presented in Tab 14, in accordance with IEC 60079 series

Table 14 : The main types of electrical protection

Protection method	Symbol	Zones gas (dust)	EPL	IEC Standard
Intrinsically safe	Ex ia	0,1,2 (20,21,22)	Ga / Da	IEC 60079-11: 2011
	Ex ib	1,2 (21,22)	Gb / Db	
	Ex ic	2 (22)	Gc / Dc	
Increased safety	Ex eb	1,2 (21,22)	Gb	IEC 60079-7:2017
	Ex ec	2 (22)	Gc	
Flameproof enclosure	Ex da	0,1,2	Ga	IEC 60079-1:2014
	Ex db	1,2	Gb	
	Ex dc	2	Gc	
Powder filled	Ex q	1,2	Gb	IEC 60079-5:2015
Non sparking	Ex nA	2	Gc	IEC 60079-15: 2017
Protected sparking	Ex nC	2	Gc	
Restricted breathing	Ex nR	2	Gc	
Pressurization	Ex pxb	1,2	Gb	IEC60079-2: 2014
	Ex pyb	1,2 (21,22)	Gb / Db	
	Ex pzb	2 (22)	Gc / Dc	
Pressurized room	Ex pb	1,2		IEC60079-13:2017
	Ex pc	2		
Artificially ventilated	Ex vc	2		
Encapsulation	Ex ma	0,1,2 (20,21,22)	Ga	IEC 60079-18: 2017
	Ex mb	1,2 (21,22)	Gb	
	Ex mc	2 (22)	Gc	
Liquid immersion	Ex ob	1,2	Gb	IEC 60079-6: 2015
	Ex oc	2	Gc	
Optical radiation	Ex op pr	1,2 (21,22)	Gb (Zone 1) Gc (Zone 2)	IEC 60079-28: 2015
	Ex op is	0,1,2 (20,21,22)	Ga (Zone 0) Gb (Zone 1) Gc (Zone 2)	
	Ex op sh	0,1,2 (20,21,22)	Gb (Zone 1) Gc (Zone 2)	
Protection by enclosure	Ex ta	20,21,22	Da	IEC 60079-31: 2022
	Ex tb	21,22	Db	
	Ex tc	22	Dc	
Special protection	sa		Ga / Da	IEC 60079-33: 2015
	sb		Gb / Db	
	sc		Gc / Dc	

10.2.2 Certified safe electrical equipment is to be selected with due consideration to the following:

a) risk of explosive dust concentration (see Ch 2, Sec 2, [6.2]):
   - degree of protection of the enclosure
   - maximum surface temperature

b) risk of explosive gas atmosphere (see Ch 2, Sec 2, [6.1]):
   - explosion group, according to Tab 15
   - temperature class, according to Tab 16.

c) equipment protection level (EPL) according to Tab 17.

10.2.3 All switches and protective devices are to interrupt all poles or phases and, where practicable, to be located in a non-hazardous area unless specifically permitted otherwise.

Such switches and equipment located in hazardous areas are to be suitably labelled for identification purposes.

10.2.4 Electrical installations in hazardous areas are to be inspected by skilled personnel at their initial installation.

This verification is to be in accordance with IEC 60079-17:2023, IEC 60079-14:2016 or other recognized standard accepted by the Society.

Table 15 : Gas / Dust group

Explosive Atmosphere	Typical combustible material	Group	Temperature class
Gas or vapour	Methane	IIA	T1
	Octane	IIA	T3
	LPG (propane, butane)	IIA	T2
	Hydrogen	IIC / IIB+H2	T1
	Methanol (Methyl alcohol)	IIA	T2
	Ethanol / Ethylene	IIB	T2
	Ammonia	IIA	T1
	Acetylene	IIC	T2
Dust	Metal	IIIC	_
	Coal	IIIB	_
	Grain	IIIB	_
	Paper or wood	IIIA	_

Table 16 : Relationship between gas or vapour ignition temperature and temperature class of equipment

Temperature class required by the area classification	Ignition temperature of gas or vapour in °C	Allowable temperature classes of equipment
T1	> 450	T1 – T6
T2	> 300	T2 – T6
T3	> 200	T3 – T6
T4	> 135	T4 – T6
T5	> 100	T5 – T6
T6	> 85	T6

Table 17 : Equipment protection level (EPL)

Zone	EPL	Protection Level
0	Ga	Very high
1	Ga or Gb	High
2	Ga, Gb or Gc	Increased
20	Da	Very high
21	Da or Db	High
22	Da, Db or Dc	Increase

10.2.5 For electrical equipment installed in Zone 0 hazardous areas, only the following types are permitted:

- apparatus designed for zone 0 as per Tab 14
- certified intrinsically-safe apparatus Ex(ia) and their associated cables
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ia" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and accepted by the appropriate authority.

10.2.6 For electrical equipment installed in Zone 1 hazardous areas, only the following types are permitted:

- any apparatus that may be considered for Zone 0 as per [10.2.5]
- apparatus designed for Zone 1 as per Tab 14
- category 'Ex ib' intrinsically safe type electrical equipment and their associated cables
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ib" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and accepted by the appropriate authority.

10.2.7 For electrical equipment installed in Zone 2 hazardous areas, only the following types are permitted:

- any apparatus type that may be considered for Zone 1as per [10.2.6]
- apparatus designed for Zone 2 as per Tab 14.

10.2.8 When apparatus incorporates a number of types of protection, it is to be ensured that all are suitable for use in the zone in which it is located.

10.2.9 Ventilation

The electrical supply for ventilation systems in hazardous areas must be separate from that of non-hazardous areas.

10.3 Certified safe type documentation

10.3.1 Safe type certificates or equivalent documentation issued by an accredited or recognized certification body and established on a basis at least equivalent to the IEC 60079 series publication are to be submitted for each electrical equipment located in hazardous areas.

10.3.2 For intrinsically safe circuits, a document describing the system is to be submitted to the Society, specifying the items of electrical equipment and the electrical parameters of the system, including those of inter-connecting wiring. This document is not required in case a certificate defining the parameters for the complete intrinsically safe system is available.

The requirements of IEC 60079-14:2016 apply.

10.4 Marking

10.4.1 The Ex equipment is to be clearly marked on a main part of the equipment, in accordance with IEC 60079-0:2018, ensuring the marking is easily visible. List of the information to be presented on the marking plate:

- the name of the manufacturer or his registered trade mark
- the product code or model number
- an Ex certificate indicates that the Ex Equipment corresponds to one or more of the types of protection specified in the relevant standards. The certificate must contain the following information:
  - certificate number
  - equipment group
  - temperature class
  - equipment protection level (EPL)
  - explosive atmosphere (gas, vapour or dust)
  - type of protection.

10.5 Electrical cables

10.5.1 Electrical cables are not to be installed in hazardous areas except as specifically permitted or when associated with intrinsically safe circuits.

10.5.2 All cables installed in Zone 0 or in Zone 1 are to be sheathed with at least one of the following:

a) a non-metallic impervious sheath in combination with braiding or other metallic covering

b) a copper or stainless steel sheath (for mineral insulated cables only).

10.5.3 All cables installed in non-weather exposed Zone 2 areas are to be provided with at least a non-metallic external impervious sheath.

10.5.4 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

10.5.5 The circuits of a category “ib” intrinsically safe system are not to be contained in a cable associated with a category “ia” intrinsically safe system required for a hazardous area in which only category “ia” systems are permitted.

10.5.6 All metallic covering of power and lighting cables run though hazardous areas or connected to equipment Installed in these areas, are to be at least earthed at their ends.

10.5.7 Intrinsically safe circuit cables should be clearly marked as a part of an intrinsically safe circuit, if the sheaths or coverings are color-coded, the color for cables containing intrinsically safe circuits must be light blue.

Except if either all intrinsically safe cables or all non-intrinsically safe cables are equipped with armor, metal sheathing, or screening, then labeling the intrinsically safe cables is not necessary.

10.5.8 Penetration of bulkheads or decks separating areas with a risk of explosion are to comply with Ch 2, Sec 12, [7.5.4].

10.6 Electrical installations in battery rooms

10.6.1 Only lighting fittings may be installed in rooms assigned solely to large vented storage batteries (see Ch 2, Sec 11, [6.2.1]).

The associated switches are to be installed outside such spaces.

Overcurrent protective devices are to be installed as close as possible to, but outside of, battery rooms.

Electrical cables other than those pertaining to the equipment arranged in battery rooms are not permitted.

10.6.2 Standard marine electrical equipment may be installed in rooms assigned solely to valve-regulated sealed storage batteries.

10.6.3 Hazardous area classification

a) Hazardous area Zone 1

Hazardous area Zone 1 includes but is not limited to:

Battery rooms containing vented batteries. For NiCD and lead acid batteries, electrical equipment are to be minimum explosion group IIC and temperature class T1.

b) Hazardous area zone 2

Hazardous area Zone 2 includes but is not limited to:

Ducts and areas on open deck within 1,5 m of inlet or exhaust openings of battery rooms containing vented or Li-ion batteries.

For battery room containing Li-ion batteries, equipment installed at locations 450 mm or closer to the ceilings is to be suitable for Zone 2, with a minimum explosion group of IIB+H2 and a temperature class of T2.

10.6.4 Equipment (including fan motors) are to be suitable for the use in the corresponding hazardous area.

10.6.5 Additionally, when hazardous areas may be created regarding criteria of IEC 60079-10-1:2021 , the battery room and its neighborhood is to be considered accordingly.

10.7 Electrical installations in paint stores or enclosed spaces leading to paint stores

10.7.1 Hazardous area classification

a) The paint stores and supply and exhaust ventilation ducts serving such spaces are to be classified as Zone 1, as defined in Ch 2, Sec 1, [3.13].

b) Areas on open deck within 1 m of inlet and exhaust ventilation openings of paint stores or within 3 m of exhaust mechanical ventilation outlets of such spaces are to be classified as Zone 2, as defined in Ch 2, Sec 1, [3.13].

c) Enclosed spaces giving access to paint stores may be considered as non-hazardous, provided that:

- the door to the paint store is a gastight door with self-closing devices without holding back arrangements. A watertight door may be considered as being gastight
- the paint store is provided with an acceptable, independent, natural ventilation system ventilated from a safe area, and
- warning notices are fitted adjacent to the paint store entrance stating that the store contains flammable liquids

10.7.2 Type of equipment

In hazardous area zone 1, electrical equipment is to be only when it is essential for operational services. The following electrical equipment may be installed:

- certified intrinsically safe apparatus Ex(ib)
- certified flameproof Ex(db)
- certified pressurised Ex(pb)
- certified increased safety Ex(eb)
- certified specially Ex(s).

Cables (through runs or termination cables) of armoured type or installed in metallic conduits are to be used.

10.7.3 In hazardous area Zone 2, the following electrical equipment may be installed:

- electrical equipment with the type of protection as permitted in paint stores
- equipment of protection class Ex(n)
- appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature
- appliances with simplified pressurised enclosures or vapour-proof enclosures (minimum class of protection IP55) whose surface does not reach unacceptably high temperature; or
- cables as specified in [10.6] and [10.8.2].

10.7.4 Minimum requirements

The minimum requirements for the certified safe type equipment are as follows:

- explosion group II B
- temperature class T3.

10.7.5 Switches, protective devices and motor control gear of electrical equipment installed in a paint store are to interrupt all poles or phases and are preferably to be located in a non hazardous space.

10.8 Electrical installations in stores for welding gas (acetylene) bottles

10.8.1 The following equipment may be installed in stores for welding gas bottles provided that it is of a safe type appropriate for Zone 1 area installation:

- lighting fittings
- ventilator motors where provided.

10.8.2 Electrical cables other than those pertaining to the equipment arranged in stores for welding gas bottles are not permitted.

10.8.3 Electrical equipment for use in stores for welding gas bottles is to have minimum explosion group IIC and temperature class T2.

10.9 Specific ships or installations

10.9.1 For installations in hazardous areas in:

- oil tankers, chemical tankers and liquefied gas carriers, see Pt D, Ch 7, Sec 5, Pt D, Ch 8, Sec 10 or Pt D, Ch 9, Sec 10
- ships arranged with spaces for the carriage of vehicles, see Pt D, Ch 1, Sec 4 or Pt D, Ch 12, Sec 4
- ships arranged with fuel storage and refuelling facilities for auxiliary vehicles, see Ch 4, Sec 11, [4]
- ships intended for the carriage of dangerous goods, see Ch 4, Sec 12, [2.3]
- ships arranged with tanks used for the storage and use of chemical treatment fluids for exhaust gas pollution prevention system, see Ch 1, Sec 11, [5.2.2]
- ships arranged with ballast water management systems, see Ch 1, Sec 13, [2.6].

Section 4 Rotating Machines

1 Constructional requirements for generators and motors

1.1 Mechanical construction

1.1.1 Materials and construction of electrical machines are to conform to the relevant requirements of Ch 2, Sec 2, [4] and Ch 2, Sec 2, [5].

1.1.2 Shafts are to be made of material complying with the provisions of NR216 Materials and Welding, Chapter 5 or, where rolled products are allowed in place of forgings, with those of NR216 Materials and Welding, Chapter 3.

1.1.3 Where welded parts are foreseen on shafts and rotors, the provisions of NR216 Materials and Welding, Chapter 12 are to apply.

1.1.4 Sleeve bearings are to be efficiently and automatically lubricated at all running speeds.

Provision is to be made for preventing the lubricant from gaining access to windings or other insulated or bare current carrying parts.

1.1.5 Means are to be provided to prevent bearings from being damaged by the flow of currents circulating between them and the shaft. According to the manufacturer's requirements, electrical insulation of at least one bearing is to be considered.

1.1.6 For surface-cooled machines with an external fan installed on the open deck, adequate protection of the fan against icing is to be provided.

1.1.7 When liquid cooling is used, the coolers are to be so arranged as to avoid entry of water into the machine, whether by leakage or condensation in the heat exchanger, and provision is to be made for the detection of leakage.

1.1.8 Rotating machines whose ventilation or lubrication system efficiency depends on the direction of rotation are to be provided with a warning plate.

1.2 Sliprings, commutators and brushes

1.2.1 Sliprings and commutators with their brushgear are to be so constructed that undue arcing is avoided under all normal load conditions.

1.2.2 The working position of brushgear is to be clearly and permanently marked.

1.2.3 Sliprings, commutators and brushgear are to be readily accessible for inspection, repairs and maintenance.

1.3 Terminal connectors

1.3.1 Suitable, fixed terminal connectors are to be provided in an accessible position for connection of the external cables.

1.3.2 All terminal connectors are to be clearly identified with reference to a diagram.

1.3.3 The degree of protection of terminal boxes is to be adequate to that of the machine.

1.4 Electrical insulation

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 2, Sec 2, [4.2] and Ch 2, Sec 2, [4.3].

2 Special requirements for generators

2.1 Prime movers, speed governors and overspeed protection

2.1.1 Prime movers for generators are to comply with the relevant requirements of Ch 1, Sec 2, [2.7].

2.1.2 When generators are to operate in parallel, the characteristics of speed governors are to comply with the provisions of [2.2].

2.2 A.c. generators

2.2.1 Alternators are to be so constructed that, when started up, they take up the voltage without the aid of an external electrical power source.

Where these provisions are not complied with, the external electrical power source is to be constituted by a battery installation in accordance with the requirements for electrical starting systems of auxiliary machinery (see Ch 1, Sec 2).

2.2.2 The voltage wave form is to be approximately sinusoidal, with a maximum deviation from the sinusoidal fundamental curve of 5% of the peak value.

2.2.3 Each alternator is to be provided with automatic means of voltage regulation.

2.2.4 For a.c. generating sets operating in parallel, the governing characteristics regarding the load are to comply with requirement of Ch 1, Sec 2, [2.7.6].

2.2.5 When a.c. generators are operated in parallel, the reactive loads of the individual generating sets are not to differ from their proportionate share of the total reactive load by more than 10% of the rated reactive power of the largest machine, or 25% of that of the smallest machine, whichever is the lesser.

2.3 Approval of generating sets

2.3.1 A generating set is considered as a whole system including:

- a prime mover engine and its auxiliaries (for fuel oil, turbo compressor, lubricating oil, cooling circuits...)
- an alternator, and its auxiliaries, if any (lubricating and cooling system...)
- engine control system, speed governor and associated sensors
- an automatic voltage regulator
- a coupling system
- cabling

2.3.2 Components are to be type approved. Case by case approvals may be admitted at the discretion of the Society.

2.3.3 Documentation for system assembly is to be provided:

- List of components
- General electrical diagram
- Coupling system
- Torsional Vibration Calculation, when required in Ch 1, Sec 9, [1.1]

2.3.4 The rated power of the generating set is to be appropriate for its actual use. See also Ch 1, Sec 2, [1.3.2].

2.3.5 The entity responsible of assembling the generating set is to install a rating plate marked with at least the following information:

a) the generating set manufacturer's name or mark

b) the set serial number

c) the set date of manufacture (month/year)

d) the rated power (both in kW and KVA) with one of the prefixes COP, PRP (or, only for emergency generating sets, LTP) as defined in ISO 8528-1:2018

e) the rated power factor

f) the set rated frequency, in Hz

g) the set rated voltage, in V

h) the set rated current, in A

i) the mass, in kg.

3 Testing of rotating machines

3.1 General

3.1.1 All machines are to be tested by the manufacturers.

3.1.2 All tests are to be carried out according to IEC 60092-301.

3.1.3 The manufacturer is to issue a test report giving, inter alia, information concerning the construction, type, serial number, insulation class and all other technical data relevant to the machine, as well as the results of the tests required.

3.1.4 All electric motors rated at or above 100 kW and alternators rated at or above 100 kVA intended for essential services are to be type approved or case-by-case approved and surveyed by the Society during testing and, if appropriate, during manufacturing. Tested machines are to be individually certified by the Society.

In addition for rotating machines intended for propulsion developing a power of more than 1 MW, requirements given in [5] apply.

Note 1: An alternative inspection scheme may be agreed by the Society with the manufacturer whereby the attendance of the Surveyor will not be required as indicated above.

3.1.5 All electric motors rated below 100 kW and alternators rated below 100 kVA intended for essential services are to be type approved or case-by-case approved. Individual works' certificate is to be issued by the manufacturer and detailed test report submitted to the Society.

3.1.6 For rotating machines intended for non essential services, individual works' certificate is to be issued by the manufacturer and detailed test report made available and submitted upon request.

3.1.7 Case-by-case approval, mentioned in [3.1.4] and [3.1.5], is to be in line with requirement given in Ch 2, Sec 1, [4.1.2].

3.2 Shaft material

3.2.1 Shaft material for electric propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by the Society.

3.2.2 Shaft material for other machines is to be in accordance with recognized international or national standard.

3.3 Tests

3.3.1 Type test are to be carried out on a prototype machine or on the first batch of machines, and routine tests carried out on subsequent machines in accordance with Tab 1.

3.3.2 Where the test procedure is not specified, the requirements of IEC 60034-1 apply.

Table 1 : Tests to be carried out on electrical rotating machines

No	Tests	a.c. Generators		Motors	
		Type test **(1)**	Routine test **(2)**	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation **(3)**, visual inspection in compliance with design drawings	X	X	X	X
2	Insulation resistance measurement (stator and rotor windings)	X	X	X	X
3	Winding resistance measurement (stator and rotor)	X	X	X	X
4	Verification of the voltage regulation system	X	X **(4)**		
5	Rated load test and temperature rise measurement	X		X	
6	Overcurrent test	X			
7	Overtorque test			X	
8	Verification of steady short-circuit conditions **(5)**	X			
9	Overspeed test	X	X	X	
10	Dielectric strength test (stator and rotor windings)	X	X	X	X
11	No load test	X	X	X	X
12	Verification of degree of protection	X		X	
13	Verification of bearings	X	X	X	X

(1) Type test on prototype machine or test on at least the first batch of machines.
(2) The reports of machines routine tested are to contain the manufacturer's serial number of the machine which has been type tested and the test result.
(3) For a.c. Generators, documentation showing the transient behavior of the short circuit current is to be submitted for information.
(4) Only functional test of the voltage regulator system.
(5) Verification of steady short-circuit condition applies to synchronous machines only.

3.3.3 Testing of generating sets

Generating sets are to be submitted to the following tests:

- Load impact tests on whole assembled system are to be performed, as described in Ch 1, Sec 2, [4.3.3] item c)3) and c)4)
- Test of alarms and safeties, as per applicable requirements
- Test of voltage regulation, as described in [4.4]

Assembled generating sets of an electrical power of 100 kVA and over are to be tested at manufacturer premises with BV attendance prior installation on board.

When the whole assembled generating set cannot be tested at the Manufacturer's premises, those tests are to be carried out after installation and assembly on board.

4 Description of test

4.1 Technical documentation and visual inspection

4.1.1 Technical documentation of machines rated at 100 kW (kVA) and over are to be available for examination by the Surveyor.

4.1.2 A visual inspection of the machine is to be made to ensure, as far as practicable, that it complies with the technical documentation.

4.2 Insulation resistance measurement

4.2.1 Immediately after the high-voltage tests the insulation resistances are to be measured using a direct current insulation tester between:

a) all current carrying parts connected together and earth

b) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Tab 2. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

Table 2 : Minimum insulation resistance

Rated voltage Un V	Minimum test voltage V	Minimum insulation resistance MΩ
Un = 250	2 Un	1
250 < Un ≤ 1000	500	1
1000 < Un ≤ 7200	1000	Un/1000 + 1
7200 < Un ≤ 15000	5000	Un/1000 + 1

4.3 Winding resistance measurement

4.3.1 The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

4.4 Verification of the voltage regulation

4.4.1 The alternating current generator, together with its voltage regulation system, is to be verified in such a way that, at all loads from no load running to full load, the rated voltage at the rated power factor is maintained under steady conditions within ± 2,5%. These limits may be increased to ± 3,5% for emergency sets.

4.4.2 When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage is not to fall below 85% nor exceed 120% of the rated voltage.

4.4.3 The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage for the main generator sets in not more than 1.5 s. For emergency sets, these values may be increased to plus or minus 4% in not more than 5 s, respectively.

4.4.4 In the absence of precise information concerning the maximum values of the sudden loads, the following conditions may be assumed: 60% of the rated current with a power factor of between 0,4 lagging and zero to be suddenly switched on with the generator running at no load, and then switched off after steady-state conditions have been reached.

Subject to the Society's agreement, such voltage regulation during transient conditions may be calculated values based on the previous type test records, and need not to be tested during factory testing of a generator.

4.5 Rated load test and temperature rise measurements

4.5.1 The temperature rises are to be measured at the rated out-put, voltage and frequency and for the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC 60034-1, or by means of a combination of other tests (see indirect methods in Ch 2, App 1 for synchronous machines and in Ch 2, App 2 for induction machines).

4.5.2 The limits of temperature rise above ambient air temperature of 45°C for air-cooled machines are those given in Tab 3.

Table 3 : Temperature rise limits for air-cooled machines based on an ambient temperature of 45°C

No	Part of machines	Method of measurement of temperature **(1)**	Temperature rise, in °C, by class of insulation				
			A	E	B	F	H
1	a) a.c. windings of machines having outputs of 5000 kW (or kVA) or more	R ETD	55 60	– –	75 80	95 100	120 125
	b) a.c. windings of machines having outputs of less than 5000 kW (or kVA)	R ETD	55 60	70 –	75 85	100 105	120 125
2	Windings of armatures with commutators	T R	45 55	60 70	65 75	80 100	100 120
3	Field windings of a.c. and d.c machines having d.c. excitation other than those in item 4	T R	45 55	60 70	65 75	80 100	100 120
4	a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	–	–	85	105	130
	b) Stationary field windings of d.c. machines having more than one layer	T R ETD	45 55 –	60 70 –	65 75 85	80 100 105	100 120 130
	c) Low resistance field windings of more than one layer, and compensating windings	T, R **(2)**	55	70	75	95	120
	d) Single-layer windings with exposed bare surfaces	T, R **(2)**	60	75	85	105	130
5	Permanently short-circuited, insulated windings	T	55	70	75	95	120
6	Permanently short-circuited uninsulated windings	The temperature rise of these parts is in no case to reach such a value that there is a risk of damage to any insulating or other material on adjacent parts					
7	Magnetic core and other parts not in contact with windings						
8	Magnetic core and other parts in contact with windings	T	55	70	75	95	120
9	Commutators and sliprings, open or enclosed **(3)**	T	55	65	75	85	95

(1) T : Measurement by the thermometer method
R : Measurement by the resistance method
ETD : Measurement by embedded temperature detectors.

(2) Temperature rise measurement is to use the resistance method R whenever practicable.

(3) If commutators and sliprings are adjacent to windings with a lower insulation class, the temperature rises for this class apply.

4.6 Overcurrent/overtorque test

4.6.1 Overcurrent test is to be carried out as a type test for generators, as required in IEC 60034-1. The overcurrent test is the proof of current capability of the windings, wires, connections etc. of each machine.

AC generators are to be capable of withstanding a current equal to 1,5 times the rated current for not less than 30 s.

Note 1: This test may be performed in conjunction with the short-circuit testing, provided the electrical input energy to the machine is not less than that required for the above overload capability.

4.6.2 Overtorque test is to be carried out as a type test for motors, as required in IEC 60034-1. The overtorque test is a proof of momentary excess torque capability of the machine.

General purpose rotating machines are to be designed to withstand the following excess torque:

- AC induction motors and DC motors: 60% in excess of the torque that corresponds to the rating, for 15 s, without stalling or abrupt change in speed (under gradual increase of torque), the voltage and frequency being maintained at their rated value
- AC synchronous motors with salient poles: 50% in excess of the torque that corresponds to the rating, for 15 s, without falling out of synchronism, the voltage, frequency and excitation current being maintained at their rated values

- AC synchronous motors with wound (induction) or cylindrical rotors: 35% in excess of the torque that corresponds to the rating, for 15 s, without losing synchronism, the voltage and frequency being maintained at their rated value.

Note 1: The overtorque test can be replaced at a routine test by an overcurrent test.

Note 2: The overtorque test may be omitted for electrical propulsion motor supplied by converter if an overload protection / limitation is provided inside the converter. Justifications are to be transmitted by the converter manufacturer.

4.6.3 In the case of machines for special uses (e.g. for wind-lasses), overload values other than the above may be considered.

4.7 Verification of the steady short circuit current

4.7.1 It is to be verified that under steady state short-circuit conditions, the generator with its voltage regulating system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of at least 2 s or, where precise data is available, for a duration of any time delay which may be fitted in a tripping device for discrimination purposes.

In order to provide sufficient information for determining the discrimination settings in the distribution system where the generator is going to be used, the generator manufacturer is to provide the Society, for information, with documentation showing the transient behavior of the short circuit current upon a sudden short-circuit occurring when excited, and running at nominal speed. The influence of the automatic voltage regulator is to be taken into account, and the setting parameters for the voltage regulator are to be noted together with the decrement curve. Such a decrement curve is to be available when the setting of the distribution system's short-circuit protection is calculated. The decrement curve need not be based on physical testing. The manufacturer's simulation model for the generator and the voltage regulator may be used where this has been validated through the previous type test on the same model.

4.8 Overspeed test

4.8.1 Machines are to withstand the overspeed test as specified in IEC 60034-1.

4.9 Dielectric strength test

4.9.1 New and completed rotating machines are to withstand a dielectric test as specified in IEC 60034-1.

4.9.2 For high-voltage machines an impulse test is to be carried out on the coils according to Ch 2, Sec 13.

4.9.3 When it is necessary to perform an additional high-voltage test, this is to be carried out after any further drying, with a test voltage of 80% of that specified in IEC 60034-1.

4.9.4 Completely rewound windings of used machines are to be tested with the full test voltage applied in the case of new machines.

4.9.5 Partially rewound windings are to be tested at 75% of the test voltage required for new machines. Prior to the test, the old part of the winding is to be carefully cleaned and dried.

4.9.6 Following cleaning and drying, overhauled machines are to be subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 500 V if the rated voltage is less than 100 V, and with a minimum of 1000 V if the rated voltage is equal to or greater than 100 V.

4.9.7 A repetition of the high-voltage test for groups of machines and apparatus is to be avoided if possible, but if a test on an assembled group of several pieces of new apparatus, each of which has previously passed its high-voltage test, is per-formed, the test voltage to be applied to such assembled group is 80% of the lowest test voltage appropriate for any part of the group.

Note 1: For windings of one or more machines connected together electrically, the voltage to be considered is the maximum voltage that occurs in relation to earth.

4.10 No load test

4.10.1 Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor while generators are to be driven by a suitable means and excited to give rated terminal voltage.

During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

4.11 Verification of degree of protection

4.11.1 As specified in IEC 60034-5.

4.12 Verification of bearings

4.12.1 Upon completion of the above tests, machines which have sleeve bearings are to be opened upon request for examination by the Surveyor, to establish that the shaft is correctly seated in the bearing shells.

5 Additional tests for rotating machines used as propulsion motor or thruster

5.1 General

5.1.1 In addition to the tests defined in Tab 1, rotating machines used as propulsion motor or thruster and developing a power of more than 1 MW are to be subjected to the following requirements and tests during their assembly:

a) Shaft line
- requirements of Ch 1, Sec 7 apply

b) Rotor winding assembly
- dynamic balancing

c) Stator winding assembly
- dielectric test (after impregnation)
- insulation resistance measurement (after impregnation)

d) Frame
- visual examination in compliance with design drawings
- liquid penetrant test of 10% of the structure welds and 100% of the handling points.

e) Watercooler
- visual examination in compliance with design drawings
- performance test (see temperature rise measurement test in Tab 1)

f) Hydrostatic jacking unit
- pressure test
- working test under nominal conditions.

Section 5 Transformers

1 Constructional requirements

1.1 Construction

1.1.1 Transformers, except those for motor starting, are to be double wound (two or more separate windings).

1.1.2 Transformers are normally to be of the dry, air-cooled type.

1.1.3 When a forced air cooling system is used, an alarm is to be activated in the event of its failure.

1.1.4 Liquid-cooled transformers may be used provided that:

- the liquid is non-toxic and of a type which does not readily support combustion
- the construction is such that the liquid is not spilled in inclined position
- temperature and pressure relief devices with an alarm are installed
- drip trays or other suitable arrangements for collecting the liquid from leakages are provided
- a liquid gauge indicating the normal liquid level range is fitted.

1.1.5 Transformers are to have enclosures with a degree of protection in accordance with Ch 2, Sec 3, Tab 2.

1.2 Terminals

1.2.1 Suitable fixed terminal connections are to be provided in an accessible position with sufficient space for convenient connection of the external cables.

1.2.2 Terminals are to be clearly identified.

1.3 Voltage variation, short-circuit conditions and parallel operation

1.3.1 Under resistive load ($\cos \Phi = 1$), the voltage drop from no load to full load is not to exceed 2,5%.

For transformers with a power lower than 5 kVA per phase, this voltage drop is not to exceed 5%.

An exception is made for special transformers, such as starting and instrument transformers, for which a different voltage variation may be considered.

1.3.2 In determining the voltage ratio and the impedance voltage of transformers, account is to be taken of the total permitted voltage drop from the main switchboard's busbars to the consumers (see Ch 2, Sec 3, [9.11.4]).

1.3.3 Transformers are to be constructed to withstand, without damage, the thermal and mechanical effects of a secondary terminal short-circuit for 2 s, with rated primary voltage and frequency.

For transformers of 1 MVA and over, this is to be justified with appropriate tests or documentation.

1.3.4 When transformers are so arranged that their secondary windings may be connected in parallel, their winding connections are to be compatible, their rated voltage ratios are to be equal (with tolerances allowed) and their short-circuit impedance values, expressed as a percentage, are to have a ratio within 0,9 to 1,1.

When transformers are intended for operation in parallel, the rated power of the smallest transformer in the group is to be not less than half of the rated power of the largest transformer in the group.

1.4 Electrical insulation and temperature rise

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 2, Sec 2.

1.4.2 All windings of air-cooled transformers are to be suitably treated to resist moisture, air salt mist and oil vapours.

1.4.3 The permissible limits of temperature rise with an ambient air temperature of 45°C for (natural or forced) air-cooled transformers are given in Tab 1. The temperature rises shown for windings refer to measurement by the resistance method while those for the core refer to the thermometer method.

1.4.4 For dry-type transformers cooled with an external liquid cooling system, the permissible limits of temperature rise with a sea water temperature of 32°C are 13°C higher than those specified in Tab 1.

1.4.5 For liquid-cooled transformers, the following temperature rises measured by the resistance method apply:

- 55°C where the fluid is cooled by air
- 68°C where the fluid is cooled by water.

Table 1 : Temperature rise limits for transformers

No	Part of machine	Temperature rise by class of insulation, in °C				
		A	E	B	F	H
1	Windings	55	70	75	95	120
2	Cores and other parts: a) in contact with the windings b) not in contact with the windings	a) the same values as for the windings b) in no case is the temperature to reach values such as to damage either the core itself or other adjacent parts or materials				

2 Testing

2.1 General

2.1.1 Transformers intended for essential services are to be subjected to the test stated in [2.2].

2.1.2 The manufacturer is to issue a test report giving, inter alia, information concerning the construction, type, serial number, insulation class and all other technical data relevant to the transformer, as well as the results of the tests required.

Such test reports are to be made available to the Society.

2.1.3 In the case of transformers which are completely identical in rating and in all other constructional details, it will be acceptable for the temperature rise test to be performed on only one transformer.

The results of this test and the serial number of the tested transformer are to be inserted in the test reports for the other transformers.

2.1.4 Where the test procedure is not specified, the requirements of IEC 60076 apply.

2.1.5 The tests and, if appropriate, manufacture of transformers of 100 kVA and over (60 kVA when single phase) intended for essential services are to be attended by a Surveyor of the Society.

Transformers of 5 kVA up to the limit specified above are approved on a case by case basis, at the discretion of the Society, subject to the submission of adequate documentation and routine tests.

2.2 Tests on transformers

2.2.1 Tests to be carried out on transformers are specified in Tab 2.

Table 2 : Tests to be carried out on transformers

No	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)**	X	X
2	Insulation resistance measurement	X	X
3	Measurement of winding resistance	X	X
4	Measurement of voltage ratio and check of phase displacement	X	X
5	Measurement of short-circuit impedance and load loss	X	X
6	Measurements of no-load loss and no load current	X	X
7	high-voltage test	X	X
8	Induced voltage test	X	X
9	Temperature-rise measurement	X **(4)**	

(1) Type test on prototype transformer or test on at least the first batch of transformers.

(2) The certificates of transformers routine tested are to contain the manufacturer's serial number of the transformer which has been type tested and the test result.

(3) A visual examination is to be made of the transformer to ensure, as far as practicable, that it complies with technical documentation; inspection of enclosure, terminations, instrumentation or protection.

(4) Temperature rise test may be omitted for starting transformer.

2.3 Insulation tests

2.3.1 Transformers are to be subjected to a high-voltage test in accordance with the procedure defined in IEC publication 60076-3.

2.3.2 The test voltage is to be applied between each winding under test and the other windings not under test, core and enclosure all connected together.

Single-phase transformers for use in a polyphase group are to be tested in accordance with the requirements applicable to that group.

2.3.3 The r.m.s. value of the test voltage is to be equal to 2 U + 1000 V, with a minimum of 2500 V, where U is the rated voltage of the winding. The full voltage is to be maintained for 1 minute.

2.3.4 Partially rewound windings are to be tested at 80% of the test voltage required for new machines.

2.3.5 The insulation resistance of a new, clean and dry transformer, measured after the temperature rise test has been carried out (at or near operating temperature) at a voltage equal to 500 V d.c., is to be not less than 5 MΩ.

2.3.6 Transformers are to be subjected to an induced voltage insulation test by applying to the terminals of the winding under test a voltage equal to twice the rated voltage. The duration of the test is to be 60 s for any test frequency fp up to and including twice the rated frequency fn.

If the test frequency exceeds twice the rated frequency, the test time in seconds will be 120 fn/fp with a minimum of 15s.

Section 6 Semiconductor Converters

1 Constructional requirements

1.1 Construction

1.1.1 Semiconductor converters are to comply with the relevant requirements for switchgear assemblies (see Ch 2, Sec 8).

1.1.2 The design of semi-conductor converters is to comply with the requirements of IEC 60146-1-1:2024 with applicable requirements modified to suit marine installations like e.g. environmental requirements stated in Ch 2, Sec 2.

1.1.3 The design of semi-conductor converters for power supply is to comply with the requirements of IEC 62040 series (see Article [2]).

1.1.4 The design of semi-conductor converters for motor drives is to comply with the requirements of IEC 61800 series.

1.1.5 The monitoring and control circuits are generally to comply with the requirements of Part C, Chapter 3.

1.1.6 For liquid-cooled converters the following provisions are to be satisfied:

- liquid is to be non-toxic and of low flammability
- drip trays or other suitable means are to be provided to contain any liquid leakages
- the resistivity of the cooling fluid in direct contact with semiconductor or other current carrying parts is to be monitored and an alarm initiated if the resistivity is outside the specified limits.

1.1.7 Where forced cooling is used, the temperature of the heated cooling medium is to be monitored.

If the temperature exceeds a preset value an alarm is to be given and the shutdown of the converter is to be activated.

1.1.8 Where forced (air or liquid) cooling is provided, it is to be so arranged that the converter cannot be or remain loaded unless effective cooling is maintained.

Alternatively, other effective means of protection against overtemperature may be provided.

1.1.9 Stacks of semiconductor elements, and other equipment such as fuses, or control and firing circuit boards etc., are to be so arranged that they can be removed from equipment without dismantling the complete unit.

1.1.10 Semiconductor converters are to be rated for the required duty having regard to the peak loads, system transient and overvoltage and to be dimensioned so as to withstand the maximum short-circuit currents foreseen at the point of installation for the time necessary to trip the protection of the circuits they supply.

1.2 Protection

1.2.1 Semiconductor elements are to be protected against short-circuit by means of devices suitable for the point of installation in the network.

1.2.2 Overcurrent or overvoltage protection is to be installed to protect the converter. When the semiconductor converter is designed to work as an inverter supplying the network in transient periods, precautions necessary to limit the current are to be taken.

1.2.3 Semiconductor converters are not to cause distortion in the voltage wave form of the power supply at levels exceeding the voltage wave form tolerances at the other user input terminals (see Ch 2, Sec 2, [2.4]).

1.2.4 An alarm is to be provided for tripping of protective devices against overvoltages and overcurrents in electric propulsion converters and for converters for the emergency source of power.

1.3 Parallel operation with other power sources

1.3.1 For converters arranged to operate in parallel with other power sources, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

1.4 Temperature rise

1.4.1 The permissible limit of temperature rise of the enclosure of the semiconductors is to be assessed on the basis of an ambient air temperature of 45°C or sea water temperature of 32°C for water-cooled elements, taking into account its specified maximum permissible temperature value.

1.4.2 The value of the maximum permissible temperature of the elements at the point where this can be measured (point of reference) is to be stated by the manufacturer.

1.4.3 The value of the mean rated current of the semiconductor element is to be stated by the manufacturer.

1.5 Creepage and clearance distances

1.5.1 Creepage and clearance distances are to comply with the requirements specified in IEC 61800-5-1:2023. An interpolation of the specified values is permitted for high-voltage semi-conductor converters.

2 Requirements for uninterruptible power system (UPS) units as alternative and/or transitional power

2.1 Application

2.1.1 These requirements apply to UPS units, for the following cases:

a) When providing an alternative power supply as an accumulator battery in terms of being an independent power supply for the emergency services defined in Pt D, Ch 11, Sec 5, [2.2.3], item c) or item d)

b) When providing an alternative power supply or transitional power supply to any other emergency services as defined in Pt D, Ch 11, Sec 5, [2] and Ch 2, Sec 3, [3.6]

c) Where required, constituting a means of continuous and uninterruptible power supply to essential services as defined in Ch 2, Sec 3, [2.1] and Ch 2, Sec 3, [2.2], or

d) When providing power supply in accordance with conditions specified in Ch 4, Sec 15, [8.2.2], items b) to d).

2.1.2 These requirements may be referenced to UPS units for other cases than above in [2.1.1], and the application of requirements is at the discretion of the Society.

2.2 Definitions

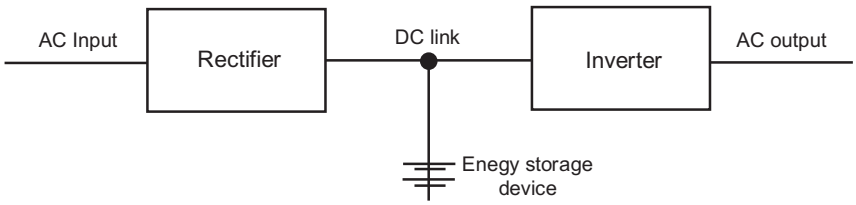
2.2.1 Uninterruptible Power System (UPS)

Combination of converters, switches and energy storage devices (such as batteries), constituting a power system for maintaining continuity of load power in case of AC input power failure (see IEC publication 62040-3:2021).

2.2.2 Double Conversion topology

A UPS topology comprises an AC to DC converter, generally a rectifier, and a DC to AC converter, generally an inverter. When the AC input power is out of UPS pre-set tolerances, the UPS enters stored energy mode (see Fig 1.

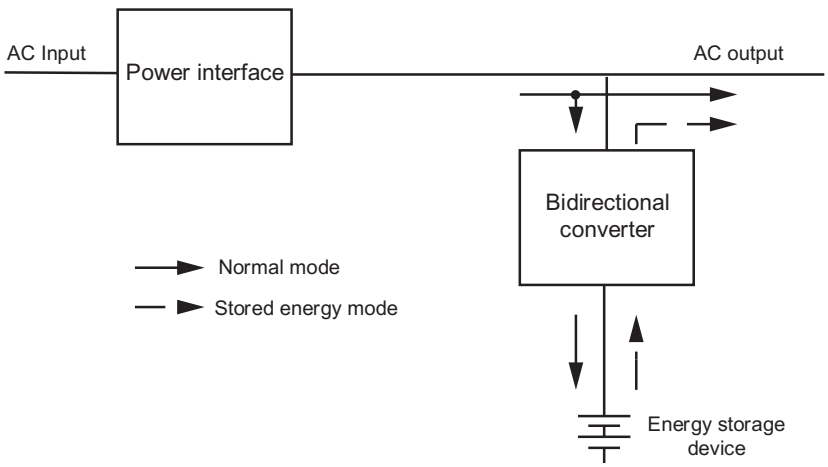
Figure 1 : Double conversion topology



2.2.3 Line interactive topology

A UPS topology comprises bidirectional AC to DC power conversion, generally through a bidirectional converter and an AC power interface. When AC input power voltage or frequency is out of UPS pre-set tolerances, the UPS runs in stored energy mode (see Fig 2.

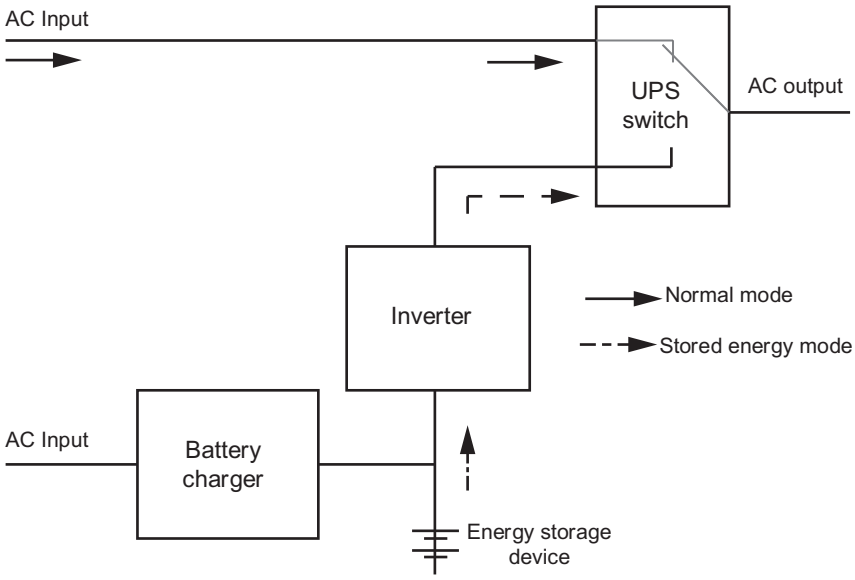
Figure 2 : Line-interactive topology



2.2.4 Standby topology

A UPS topology comprises a battery charger, a DC to AC converter, generally a unidirectional inverter and a UPS switch. When the AC input power is out of UPS pre-set tolerances, the UPS operates in stored energy mode (see Fig 3.

Figure 3 : Standby topology



2.2.5 Energy storage device

System consisting of a single or multiple devices designed to provide power to the UPS inverter/converter.

2.2.6 AC input power failure

Variation in the AC input power which could cause the UPS to operate in stored energy mode.

2.2.7 Bidirectional converter

Converter which has the functions of both a rectifier and an inverter, and which can reverse the flow of power from AC to DC and vice-versa.

2.3 Design and construction

2.3.1 UPS units are to be constructed in accordance with IEC 62040-1:2017+AMD1:2021+AMD2:2022, IEC 62040-2:2016, IEC 62040-3:2021, IEC 62040-4:2013 and/or IEC 62040-5-3:2016, as applicable, or an acceptable and relevant national or international standard.

2.3.2 The operation of the UPS is not to depend upon external services.

2.3.3 The configuration and topology of UPS unit employed is to be appropriate to the power supply requirements of the connected load equipment.

2.3.4 When external bypass is provided, bypass transfer switch is to be arranged to protect the load against power disturbances or interruption arising from inrush or fault current.

2.3.5 The UPS unit is to be monitored and audible and visual alarm is to be given in the continuously manned central control station for:

- power supply failure (voltage and frequency) to the connected load
- earth fault
- operation of battery protective device
- when the battery is being discharged
- when the bypass is in operation in case an external bypass is provided and
- any other fault and abnormal conditions of the UPS unit, as applicable.

2.4 Location

2.4.1 The UPS unit for emergency services in [2.1.1] items a) and b) is to be suitably located for use in an emergency.

2.4.2 UPS units utilising valve regulated sealed batteries may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040-1:2017+AMD1:2021+AMD2:2022, IEC 62040-2:2016, IEC 62040-3:2021, IEC 62040-4:2013 and/or IEC 62040-5-3:2016, as applicable, or an acceptable and relevant national or international standard.

2.5 Performance

2.5.1 The output power is to be maintained for the duration required for the connected equipment as stated in Ch 2, Sec 3, [3.6.3] and Pt D, Ch 11, Sec 5, [2.2.3].

2.5.2 No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity.

2.5.3 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in the regulations.

2.5.4 On restoration of the input power, the rating of the charge unit shall be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

3 Testing

3.1 General

3.1.1 Converters intended for essential services are to be subjected to the tests stated in [3.2].

3.1.2 The manufacturer is to issue a test report giving information on the construction, type, serial number and all technical data relevant to the converter, as well as the results of the tests required.

3.1.3 In the case of converters which are completely identical in rating and in all other constructional details, it will be acceptable for the rated current test and temperature rise measurement stipulated in [3.2] not to be repeated.

3.1.4 The tests and, if appropriate, manufacture of converters of 50 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

3.2 Tests on converters

3.2.1 Converters are to be subjected to tests in accordance with Tab 1.

Type tests are the tests to be carried out on a prototype converter or the first of a batch of converters, and routine tests are the tests to be carried out on subsequent converters of a particular type.

3.2.2 The tests listed in1 are to be performed in accordance with IEC 60146-1-1:2024. The relevant requirements of IEC 61800-5-1:2023 and of IEC 62040-3:2021 based on the equipment type also apply.

3.2.3 The electronic components of the converters are to be constructed to withstand the tests required in Ch 3, Sec 6.

3.2.4 Final approval of converters is to include complete function tests after installation on board, performed with all ship's systems in operation and in all characteristic load conditions.

Table 1 : Tests to be carried out on static converters

No	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Light load function test to verify all basic and auxiliary functions	X	X
3	Rated current test	X	
4	Temperature rise measurement	X	
5	Insulation test (dielectric strength test and insulation resistance measurement)	X	X
6	Protection of the converters in case of failure of forced cooling system	X	X

(1) Type test on prototype converter or test on at least the first batch of converters.

(2) The certificates of converters routine tested are to contain the manufacturer's serial number of the converter which has been type tested and the test result.

(3) A visual examination is to be made of the converter to ensure, as far as practicable, that it complies with technical documentation.

3.3 Additional testing and survey for uninterruptible power system (UPS) units as alternative and/or transitional power

3.3.1 UPS units of 50 kVA and over are to be surveyed by the Society during manufacturing and testing.

3.3.2 Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:

- functionality, including operation of alarms listed in [2.3.5]
- ventilation rate
- battery capacity
- temperature rise.

3.3.3 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical test.

3.4 Insulation test

3.4.1 The test procedure is that specified in IEC Publication 60146.

3.4.2 The effective value of the test voltage for the insulation test is to be as shown in Tab 2.

Table 2 : Test voltages for high-voltage test on static converters

$\frac{U_m}{\sqrt{2}} = U$ in V **(1)**	Test voltage, in V
$U \leq 60$	600
$60 < U \leq 90$	900
$90 < U$	2 U + 1000 (at least 2000)
(1) U_m: highest crest value to be expected between any pair of terminals.	

Section 7 Battery Energy Storage Systems and Chargers

1 Batteries

1.1 General

1.1.1 The requirements of this Section apply to battery energy storage systems permanently installed on board.

Specific requirements for Non Li-ion batteries are defined in Article [2].

Specific requirements for Li-ion batteries are defined in Article [3].

Additional requirements for ships assigned the notation **battery system** are defined in Article [5].

1.1.2 Battery energy storage systems may be of the lead-acid, nickel-alkaline or Li Ion type, due consideration being given to the suitability for any specific application.

Other types of storage batteries may be considered by the Society on a case-by-case basis.

1.1.3 Cells are to be assembled in suitable crates or trays equipped with handles for convenient lifting.

1.2 Definitions

1.2.1 Battery management system (BMS)

A battery management system is an electronic system associated with a battery pack which monitors and/or manages its electric and thermal state by controlling its environment, and which provides communication between the battery system and other macro-system controllers, such as a power management system (PMS).

1.2.2 Battery pack

Battery pack means one or more sub-packs that can work as a standalone unit.

1.2.3 Battery support system (BSS)

A battery support system is a group of interconnected and interactive parts that performs an essential task as a component of a battery system.

Such systems are, for example, electrolyte circulation pumps, cooling and heating devices.

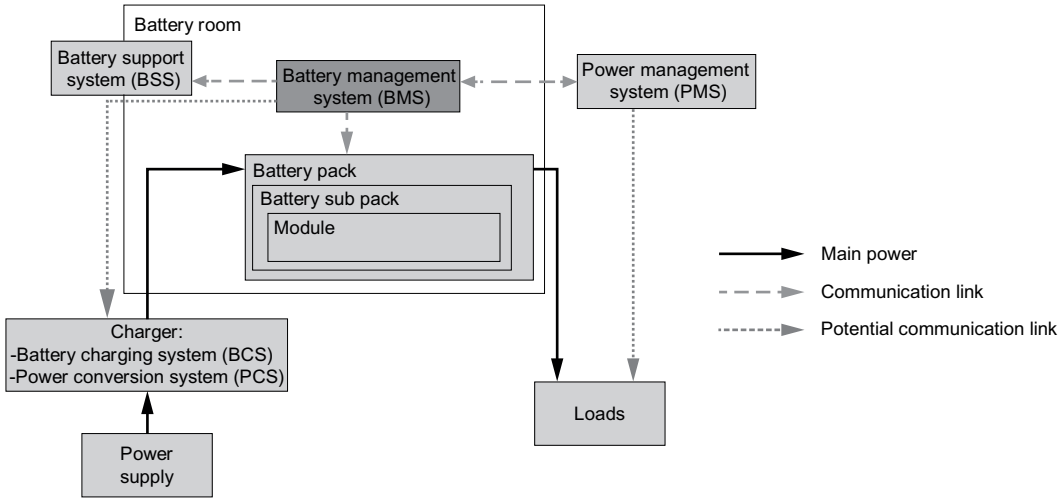
1.2.4 Battery system

A battery system is an energy storage device that includes cells, cell assemblies or battery pack(s), as well as electrical circuits and electronics. See Fig 1.

1.2.5 Cell

Cell means the smallest unit of a battery.

Figure 1 : Battery system components



This configuration shows only one battery pack. The battery pack may be duplicated inside the battery system.

1.2.6 Module

A module is an assembly of cells including some levels of electronic control.

1.2.7 Rated capacity

Rated capacity means Supplier's specification of the total amount of ampere hours that can be withdrawn from a fully charged battery pack or system for a specified set of test conditions, such as discharge rate, temperature and discharge cut-off voltage.

1.2.8 Shelf life

Shelf life is the duration of storage under specified conditions at the end of which a battery retains the ability to give a specified performance.

1.2.9 State of charge (SOC)

State of charge means the available capacity in a battery pack or system, used to estimate the current charge level of a battery in use. The state of charge is expressed as a percentage of the rated capacity.

1.2.10 State of health (SOH)

State of health means the maximum available capacity in a battery pack or system compared to initial maximum capacity as a function of the battery lifetime. The state of health is expressed as a percentage of the rated capacity.

1.2.11 Sub-pack

Sub-pack means the assembly of one or more modules. This is the smallest unit that can be electrically isolated

1.2.12 Valve-regulated battery

A valve-regulated battery is one in which cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value.

Note 1: The cells of batteries marketed as "sealed" or "maintenance free" and fitted with a pressure relief valve as a safety precaution to enable uncombined gas to be vented to the atmosphere should more properly be referred to as valve-regulated sealed batteries.

1.2.13 Vented battery

A vented battery is one in which the cells have a cover provided with an opening through which products of electrolysis and evaporation are allowed to escape freely from the cells to atmosphere.

1.3 Battery pack

1.3.1 Protection against ingress

Batteries are to have a degree of protection (IP) in relation with the location of the installation and the risk of ingress, according to Ch 2, Sec 3, [4]. In addition, the minimum required degree of protection for batteries is as follows:

- IP 4X for battery packs with nominal voltages in excess of 500 V DC
- Not less than IP 44 for battery packs located within areas protected by fixed water-based local application fire-fighting systems (FWBLAFFS).

1.4 Battery maintenance

1.4.1 Battery room and overhaul battery system elements are to be readily accessible for inspection, repairs and common maintenance

1.4.2 Where batteries are fitted for use for essential and emergency services, a schedule of such batteries is to be compiled and maintained. The schedule is to include at least the following information regarding the batteries:

- Type and manufacturer’s type designation
- Voltage and ampere-hour rating
- Location
- Equipment and/or system(s) served
- maintenance/replacement cycle dates
- date(s) of last maintenance and/or replacement
- for replacement batteries in storage, the date of manufacture and shelf life.

1.4.3 Procedures are to be put in place to ensure that, where batteries are replaced, they are of an equivalent performance type.

1.4.4 Where vented type batteries replace valve-regulated sealed types, it is to be ensured that there is adequate ventilation and that the Society's requirements relevant to the location and installation of vented types batteries are complied with.

1.4.5 Details of the schedule and of the procedures are to be included in the ship's safety management system and be integrated into the ship's operational maintenance routine, as appropriate, to be verified by the Society's surveyor.

1.5 Testing and certification process for batteries

1.5.1 Application

The requirements of [1.5] to [1.8] apply to:

- Li Ion batteries of capacity above 20kWh
- Li Ion batteries used as emergency source or transitional source
- Other batteries covered by the additional service feature **battery system**.

1.5.2 Certification

Pieces of equipment are to be certified as defined in Tab 1 where symbols have the following meaning:

C : A BV product certificate is required with invitation of the Surveyor to attend the tests unless otherwise agreed, in addition to the manufacturer's document stating the results of the tests performed and/or compliance with the approved type as applicable

TA : Type Approval is required

TA (HBV): Type Approval is required with work's recognition (HBV scheme as per NR320)

W : A manufacturer's document is required, stating the results of the tests performed and/or stating compliance with the approved type (as applicable)

X : Examinations and tests are required

Table 1 : Certification requirements

Item	Product certification			
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate
Battery cell	TA (HBV)		X **(1)**	W
Battery pack, including the associated BMS, if any	TA		X **(2)**	C
(1) See [1.6] **(2)** See [1.7]				

1.6 Battery cells

1.6.1 Type approval

Battery cells are to be tested in accordance with a recognized standard accepted by the Society. See [3.1.1] for Li Ion batteries.

The scope of tests is to include as least:

- External short circuit
- Impact / Crush
- Drop
- Thermal abuse / Thermal cycling
- Overcharge
- Forced discharge
- Internal short circuit
- Insulation tests (High-voltage test and insulation resistance test according to Ch 2, Sec 8, [3]).

1.6.2 Factory acceptance testing

The scope of tests is to include at least:

- Insulation tests (High-voltage test and insulation resistance test according to Ch 2, Sec 8, [3])

1.7 Battery packs and associated BMS

1.7.1 Type approval

Battery packs are to be tested in accordance with a recognized standard accepted by the Society. See [3.1.1] for Li Ion batteries.

The scope of tests is to include at least:

a) Propagation/internal thermal event

b) Overcharge control of voltage

c) Overcharge control of current

d) Overheating control

e) Insulation tests (High-voltage test and insulation resistance test according to Ch 2, Sec 8, [3])

f) IP characteristics

g) Safety function tests:
- Emergency stop function
- Alarms and shutdowns
- Temperature protection BMS
- Overvoltage protection BMS
- Undervoltage protection BMS
- Communication Failure

h) Discharge performance (rated capacity check)

i) Endurance

j) Charge retention and recovery (self discharge)

k) Additional tests based on FMEA (sensors failures)

l) Environmental tests according to Ch 3, Sec 6.

1.7.2 Gas analysis

The types and quantities of gases released by the cell when submitted to the propagation/internal test required in [1.7.1], item a) are to be measured and recorded. This gas analysis will be used as an input for the risk analysis required in [3.2.1], [5.4.2] or Ch 2, Sec 12, [5.2.1], as relevant, and the design of the battery room, see Ch 2, Sec 11, [6].

1.7.3 Factory acceptance testing

The scope of tests is to include at least:

a) ability to achieve safety functions

b) proper working of alarms and defaults and related functions and/or interfacing to the other ship systems

c) proper working of monitoring systems

d) temperature rise test

Note 1: When this test is impractical at the factory, the following alternative may be considered:
- a calculation based on a method validated by tests is to be submitted to the Society, and
- Proper working of the cooling circuit is to be checked after installation onboard, see Ch 2, Sec 15, [4.8.3].

Note 2: The test condition to be selected is the most unfavourable nominal operating conditions of the batteries (maximum charging or discharging current which will produce the maximum heating losses)

e) Insulation tests (High-voltage test and insulation resistance test according to Ch 2, Sec 8, [3]).

1.8 Equipment used in battery systems

1.8.1 Approval and testing of pieces of equipment, such as safety electrical equipment, fuses, over current protective devices, circuit breakers, contractors and cables, are to comply with the applicable requirements of Part C, Chapter 2.

Note 1: See also NR266, Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units.

2 Non Li-ion batteries

2.1 Vented batteries

2.1.1 Vented batteries are to be constructed to withstand the movement of the ship and the atmosphere (salt mist, oil) to which they may be exposed.

2.1.2 Battery cells are to be so constructed as to prevent spilling of electrolyte at any inclination of the battery up to 40° from the vertical.

2.1.3 It is to be possible to check the electrolyte level and the pH.

2.2 Valve-regulated batteries

2.2.1 Cell design is to minimise risks of release of gas under normal and abnormal conditions.

3 Li-ion batteries

3.1 Li Ion batteries above 20kWh

3.1.1 Battery cells are to be designed in accordance with IEC 62619:2022 and IEC 62281: 2023 or other recognized standard accepted by the Society. Battery pack are to be designed in accordance with IEC 62619:2022 and IEC 62620:2023 or other recognized standard accepted by the Society.

3.1.2 Li Ion battery pack charging and discharging are to be controlled with a BMS that is to be able to:

- monitor the battery pack state at the level at least of modules, sub-packs and packs regarding at least voltage, temperature, and, if necessary, to monitor current flow and detect leakage currents
- estimate the potential need for battery pack or sub-pack connection or disconnection by determining if the battery pack or sub-pack is in a critical state, if there is a need coming from the PMS (Power Management System) or any other connected control system
- control the proper connection and disconnection of the battery packs and sub-packs
- optimise battery lifetime and energy availability by monitoring and controlling battery pack SOC and SOH, managing cells, sub-packs and packs balancing, and monitoring and controlling BSS.

3.1.3 Battery pack cooling

Battery pack cooling is to be ensured either by the ventilation of the battery room or by direct cooling (dedicated cooling circuit).

When a direct cooling is installed, the following alarms are to be provided, where applicable:

- High temperature of the cooling air of battery pack provided with forced ventilation
- Reduced flow of primary and secondary coolants of battery packs having a closed cooling system with a heat exchanger.

As an alternative to monitoring the air temperature and the cooling flow, electrical supply to the fan may be monitored.

3.2 Li Ion batteries below 20kWh

3.2.1 a risk analysis is to be conducted and submitted to the Society for review.

3.3 Li Ion batteries used as emergency source or transitional source

3.3.1 Battery cells are to be designed in accordance with IEC 62619:2022 and IEC 62281:2023 or other recognized standard accepted by the Society. Battery pack are to be designed in accordance with IEC 62619:2022 and IEC 62620:2023 or other recognized standard accepted by the Society.

4 Chargers

4.1 General

4.1.1 Chargers are to be adequate for the batteries for which they are intended and provided with a voltage regulator.

4.1.2 In the absence of indications regarding its operation, the battery charger is to be such that the completely discharged battery can be recharged to 80% capacity within a period of 10 hours without exceeding the maximum permissible charging current. A charging rate other than the above (e.g. fully charged within 6 hours for batteries for starting of motors) may be required in relation to the use of the battery.

4.1.3 For floating service or for any other condition where the load is connected to the battery while it is on charge, the maximum battery voltage is not to exceed the safe value of any connected apparatus.

Note 1: Consideration is to be given to the temperature variation of the batteries.

4.1.4 The battery charger is to be designed so that the charging current is set within the maximum current allowed by the manufacturer when the battery is discharged and the floating current to keep the battery fully charged.

4.1.5 Trickle charging to neutralise internal losses is to be provided. An indication is to be provided to indicate a charging voltage being present at the charging unit.

4.1.6 Protection against reversal of the charging current is to be provided.

4.1.7 Battery chargers are to be constructed to simplify maintenance operation. Indications are to be provided to visualise the proper operation of the charger and for troubleshooting.

4.2 Testing

4.2.1 Battery chargers are to be subjected to tests in accordance with Tab 2.

Type tests are the tests to be carried out on a prototype charger or the first of a batch of chargers, and routine tests are the tests to be carried out on subsequent chargers of a particular type.

4.2.2 The electronic components of the battery chargers are to be constructed to withstand the tests required in Ch 3, Sec 6.

4.2.3 The tests of battery chargers of 5 kW and over intended for essential services are to be attended by a Surveyor of the Society.

Table 2 : Tests to be carried out on battery chargers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Functional tests (current and voltage regulation, quick, slow, floating charge, alarms)	X	X
3	Temperature rise measurement	X	
4	Insulation test (dielectric strength test and insulation resistance measurement)	X	X

(1) Type test on prototype battery charger or test on at least the first batch of battery chargers.
(2) The certificates of battery chargers routine tested are to contain the manufacturer's serial number of the battery charger which has been type tested and the test result.
(3) A visual examination is to be made of the battery charger to ensure, as far as practicable, that it complies with technical documentation.

5 Requirements for the additional service feature battery systems

5.1 Application

5.1.1 Where the battery is part of the main source of power and necessary to supply the services defined in Ch 2, Sec 3, [2.2.3] items a) to c), the ship is to be assigned the additional service feature **battery system**.

Note 1: Ships covered by SOLAS Convention are not normally allowed to rely only on batteries for electrical power supply. See Ch 2, Sec 3, [2.2.3].

5.2 Documents to be submitted

5.2.1 The documents to be submitted are listed in Tab 3.

5.3 System considered

5.3.1 The main components of a battery system in the scope of this Article are defined in Fig 1.

Table 3 : Documents to be submitted

No.	A/I **(1)**	Document
1	I	Power balance **(2)**
2	I	Risk analysis (see [5.4.2]) **(3)**
3	I	Failure analysis regarding availability of ship propulsion and energy
4	I	List of alarms and defaults **(4)**
5	I	Justification for choice of fire-extinguishing system
6	I	Operation manual of battery and BMS

(1) A = to be submitted for approval; I = to be submitted for information
(2) This document is to take into account the achievable configurations for energy production and distribution
(3) This document is to consider together battery and BMS if any
(4) This list is to describe alarms and defaults directly connected to the battery system and interfaces with other ship systems, if any

5.4 Qualification of the battery system

5.4.1 As a deviation from Ch 2, Sec 3, [2.2.3], a risk-based qualification of the battery system is to be performed to the satisfaction of the Society. See NI525 for guidance.

5.4.2 A risk analysis, whatever the type of batteries, is to be conducted and submitted to the Society.

An HAZID study is to be carried out for battery system installation. It is to cover at least the following spaces, zones and systems:

- Battery Room (Location and adjacent spaces)
- Battery system and auxiliaries
- An additional vibration analysis of the battery system may be required, taking into account the type of ship and its operational activity.

The risks identified by the HAZID study may be mitigated by operational procedures.

The following risks, at least, are to be covered:

- risk of thermal runaway
- risk of emission of combustion gases
- risk of internal short-circuit
- risk of external short-circuit
- risk of sensor failure (voltage, temperature, gas sensor)
- risk of high impedance (cell, connectors)
- risk of loss of cooling
- risk of leakage (electrolyte, cooling system)
- risk of failure of BMS (error on manoeuvring breakers, overloading, over discharge)
- risk for external ingress (fire, fluid leakage, fire-fighting water).

Adequation of fire-extinguishing system to battery type is to be documented.

Appropriate alarms and shutdown are to be described (for example, default on the cooling system when necessary to proper operation of the battery system).

5.5 General requirements

5.5.1 When an emergency source of power is required on board the ship, it is to remain independent from the battery source considered for propulsion and/or main source of power.

5.5.2 Batteries may be of the lead-acid type, nickel alkaline type or Li Ion type, due consideration being given to the suitability for any specific application. Other types of batteries may be considered.

5.5.3 These requirements are supplementary to those mentioned in [1], Ch 2, Sec 11, [6] and Ch 2, Sec 12, [5].

5.5.4 Ventilation

The power supplied to the ESS ventilation fans is to be provided from two alternative circuits; one of which is the main power source and the other is the emergency source. The supply circuits are to be managed through a change-over switch.

5.5.5 Fire protection

a) Battery rooms, except for Li-ion battery rooms, are to be regarded as:
   - auxiliary machinery spaces of moderate fire risk i.e. cat(11) on passenger ships carrying more than 36 passengers
   - other machinery spaces i.e. cat(7) on other ships

   The boundary between two battery rooms is to have at least A-0 fire integrity.

b) A fixed fire detection and fire alarm system complying with the requirements of Ch 4, Sec 15, [8] is to be provided in battery rooms.

c) Battery rooms are to be fitted with a fixed fire-extinguishing system according to Ch 4, Sec 6, [3.1]. This system is to be compatible with the technology of the battery employed, according to the battery manufacturer specification.

d) Requirements for battery rooms containing Li-ion batteries are given in Ch 2, Sec 11, [6.5].

5.6 Availability of power

5.6.1 When only batteries are installed for electrical power supply, the battery system is to be fitted with at least two independent battery systems which are to be installed in separate spaces to supply the main energy source.

5.6.2 A failure analysis taking into account single failure of the battery system and ability of the ship to reach a safe destination or to operate life-saving appliances and safety systems is to be provided.

5.6.3 It is to be possible to steer and manoeuvre the ship with one battery pack unavailable.

5.6.4 If the generator set, if any, or one battery pack is unavailable, the remaining battery packs are to be able to provide energy for 8-hour operations, as mentioned in Ch 1, Sec 10, [11] The duration may be reduced depending on the operational profile of the ship.

5.7 Test and certification process for batteries

5.7.1 Certification and production testing

Battery cells and the battery pack and the associated BMS if any are to be of a type approved by the Society. The requirements for certification and testing of the battery system are given in [1.5].

5.7.2 Onboard testing

The requirements for tests on board of the battery system are given in Ch 2, Sec 15, [4.8].

Section 8 Switchgear and Controlgear Assemblies

1 Constructional requirements for main and emergency switchboards

1.1 Construction

1.1.1 Construction is to be in accordance with IEC Publication 60092-302-2:2019.

1.1.2 Where the framework, panels and doors of the enclosure are of steel, suitable measures are to be taken to prevent overheating due to the possible circulation of eddy currents.

1.1.3 Insulating material for panels and other elements of the switchboard is at least to be moisture-resistant and flame-retardant.

1.1.4 Switchboards are to be of dead front type, with enclosure protection according to Ch 2, Sec 3, Tab 2.

1.1.5 Switchboards are to be provided with insulated handrails or handles fitted in an appropriate position at the front of the switchboard. Where access to the rear is necessary for operational or maintenance purposes, an insulated handrail or insulated handles are to be fitted.

1.1.6 Where the aggregate capacity of generators connected to the main busbars exceeds 100 kVA, a separate cubicle for each generator is to be arranged with flame-retardant partitions between the different cubicles. Similar partitions are to be provided between the generator cubicles and outgoing circuits.

1.1.7 Instruments, handles or push-buttons for switchgear operation are to be placed on the front of the switchboard. All other parts which require operation are to be accessible and so placed that the risk of accidental touching of live parts, or accidental making of short-circuits and earthings, is reduced as far as practicable.

1.1.8 Where it is necessary to make provision for the opening of the doors of the switchboard, this is to be in accordance with one of the following requirements:

a) Opening is to necessitate the use of a key or tool (e.g. when it is necessary to replace a lamp or a fuse-link)

b) All live parts which can be accidentally touched after the door has been opened are to be disconnected before the door can be opened

c) The switchboard is to include an internal barrier or shutter with a degree of protection not less than IP2X shielding all live parts such that they cannot accidentally be touched when the door is open. It is not to be possible to remove this barrier or shutter except by the use of a key or tool.

1.1.9 All parts of the switchboard are to be readily accessible for maintenance, repair or replacement. In particular, fuses are to be able to be safely inserted and withdrawn from their fuse-bases.

1.1.10 Hinged doors which are to be opened for operation of equipment on the door or inside are to be provided with fixing devices for keeping them in open position.

1.1.11 Means of isolation of the circuit-breakers of generators and other important parts of the installation are to be provided so as to permit safe maintenance while the main busbars are alive.

1.1.12 Where components with voltage exceeding the safety voltage are mounted on hinged doors, the latter are to be electrically connected to the switchboard by means of a separate, flexible protective conductor.

1.1.13 All measuring instruments and all monitoring and control devices are to be clearly identified with indelible labels of durable, flame-retardant material.

1.1.14 The rating of each circuit, together with the rating of the fuse or the appropriate setting of the overload protective device (circuit-breaker, thermal relay etc.) for each circuit is to be permanently indicated at the location of the fuse or protective device.

1.1.15 When Busbar Trunking systems are used outside switchboards, IACS Recommendation No.67: Test and Installation of busbar trunking systems may be taken as reference for design, installation and testing.

1.2 Documents to be submitted

1.2.1 Documents showing arrangements and details as indicated in Tab 1 are to be submitted for switchgear and controlgear assemblies.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents to be submitted
1	A	General arrangement drawings (DWGs) including the following details and information: Bill of Materials (BoM), external and internal layout (front view, top view, side elevation) and component placement
2	A	Type and sizes of wiring within the switchboards and controlgear assemblies
3	A	Protective device ratings and settings for internal components
4	A	Bus bar size, clearance, support structure, current rating, and short circuit rating for internal connections
(1) A : To be submitted for approval ; I : To be submitted for information		

1.3 Busbars and bare conductors

1.3.1 Busbars are to be of copper or of copper-surrounded aluminium alloy if suitable for use in the marine environment and if precautions are taken to avoid galvanic corrosion.

1.3.2 All connections are to be so made as to inhibit corrosion.

1.3.3 Busbars are to be dimensioned in accordance with IEC Publication 60092-302-2:2019.

The mean temperature rise of busbars is not to exceed 45°C under rated current condition with an ambient air temperature of 45°C (see Ch 2, Sec 2, [1.2.2]) and is not to have any harmful effect on adjacent components. Higher values of temperature rise may be accepted to the satisfaction of the Society.

1.3.4 The cross-section of neutral connection on an a.c. three-phase, four-wire system is to be at least 50% of the cross-section for the corresponding phases.

1.3.5 Bare main busbars, excluding the conductors between the main busbars and the supply side of outgoing units, are to have the minimum clearances and creepage distances given in Tab 2. The values shown apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

Note 1: Clearance is the distance between two conductive parts along a string stretched the shortest way between such parts. Creepage distance is the shortest distance along the surface of an insulating material between two conductive parts.

Table 2 : Clearance and creepage distances

Rated insulation voltage a.c. r.m.s. or d.c., in V	Minimum clearance, in mm	Minimum creepage distance, in mm
≤ 250	15	20
> 250 to ≤ 690	20	25
> 690	25	35

1.3.6 Reduced values as specified in IEC Publication 60092-302-2:2019 may be accepted for type tested and partially type tested assemblies

The reference values for the evaluation of the minimum clearances and creepage distances for these assemblies are based on the following:

- pollution degree 3 (conductive pollution occurs, or dry non-conductive pollution occurs which becomes conductive due to condensation which is expected)
- overvoltage category III (distribution circuit level)
- unhomogenous field conditions (case A)
- rated operational voltage 1000 V a.c., 1500 V d.c.
- group of insulating material IIIa.

Special consideration is to be given to equipment located in spaces where a pollution degree higher than 3 is applicable, e.g. in diesel engine rooms.

1.3.7 Busbars and other bare conductors with their supports are to be mechanically dimensioned and fixed such that they can withstand the stresses caused by short-circuits.

Where maximum symmetrical short-circuit currents are expected to exceed 50 kA, calculation is to be submitted to the Society.

1.3.8 Busbars and bare conductors are to be protected, where necessary, against falling objects (e.g. tools, fuses or other objects).

1.4 Internal wiring

1.4.1 Insulated conductors for internal wiring of auxiliary circuits of switchboards are to be constructed in accordance with Ch 2, Sec 9, [2.1.1].

1.4.2 All insulated conductors provided for in [1.4.1] are to be of flexible construction and of the stranded type.

1.4.3 Connections from busbars to protective devices are to be as short as possible. They are to be laid and secured in such a way to minimise the risk of a short-circuit.

1.4.4 All conductors are to be secured to prevent vibration and are to be kept away from sharp edges.

1.4.5 Connections leading to indicating and control instruments or apparatus mounted in doors are to be installed such that they cannot be mechanically damaged due to movement of the doors.

1.4.6 Non-metallic trays for internal wiring of switchboards are to be of flame-retardant material.

1.4.7 Control circuits are to be installed and protected such that they cannot be damaged by arcs from the protective devices.

1.4.8 Where foreseen, fixed terminal connectors for connection of the external cables are to be arranged in readily accessible positions.

1.5 Switchgear and controlgear

1.5.1 Switchgear and controlgear are to comply with IEC Publication 60947 series and to be chosen from among that type approved by the Society.

1.5.2 The characteristics of switchgear, controlgear and protective devices for the various consumers are to be in compliance with Ch 2, Sec 3, [7].

1.6 Auxiliary circuits

1.6.1 Auxiliary circuits are to be designed in such a manner that, as far as practicable, faults in such circuits do not impair the safety of the system. In particular, control circuits are to be designed so as to limit the dangers resulting from a fault between the control circuit and earth (e.g. inadvertent operation or malfunction of a component in the installation), also taking account of the earthing system of their supply.

1.6.2 Auxiliary circuits of essential systems are to be independent of other auxiliary circuits.

1.6.3 Common auxiliary circuits for groups of consumers are permitted only when the failure of one consumer jeopardises the operation of the entire system to which it belongs.

1.6.4 Auxiliary circuits are to be branched off from the main circuit in which the relevant switchgear is used.

1.6.5 The supply of auxiliary circuits by specifically arranged control distribution systems will be specially considered by the Society.

1.6.6 Means are to be provided for isolating the auxiliary circuits as well when the main circuit is isolated (e.g. for maintenance purposes).

1.6.7 For the protection of auxiliary circuits see Ch 2, Sec 3, [7.13].

1.7 Instruments

1.7.1 The upper limit of the scale of every voltmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.7.2 The upper limit of the scale of every ammeter is to be not less than 130% of the normal rating of the circuit in which it is installed.

1.7.3 The upper limit of the scale of every wattmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.7.4 Ammeters or wattmeters for use with a.c. generators which may be operated in parallel are to be capable of indicating 15% reverse-current or reverse power, respectively.

1.7.5 For wattmeters using one current circuit only, the measurement of the current of all generators is to be made in the same phase.

1.7.6 The rated value of the measure read, at full load, is to be clearly indicated on the scales of instruments.

1.7.7 Frequency meters are to have a scale at least ± 5% of the nominal frequency.

1.7.8 The secondary windings of instrument transformers are to be earthed.

1.7.9 Each a.c. generator not operated in parallel is to be provided with:

- 1 voltmeter
- 1 frequency meter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read
- 1 three-phase wattmeter in the case of generators rated more than 50 kVA.

1.7.10 Each a.c. generator operated in parallel is to be provided with:

- 1 three-phase wattmeter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read.

1.7.11 For paralleling purposes the following are to be provided:

- 2 voltmeters (voltage measurements of each alternator and busbar)
- 2 frequency meters (frequency measurements of each alternator and busbar).

Note 1: As an alternative, a switch may be provided to enable one voltmeter and one frequency meter to be connected to each generator before the latter is connected to the busbars.

The other voltmeter and frequency meter are to be permanently connected to the busbars.

Note 2: Voltmeter and frequencymeter with dual display may be considered.

1.7.12 Each secondary distribution system is to be provided with one voltmeter.

1.7.13 Switchboards are to be fitted with means for monitoring the insulation level of insulated distribution systems as stipulated in Ch 2, Sec 3, [3.2.1].

1.7.14 The main switchboard is to be fitted with a voltmeter or signal lamp indicating that the cable between the shore-connection box and the main switchboard is energised (see Ch 2, Sec 3, [3.7.7]).

1.7.15 For each d.c. power source (e.g. converters, rectifiers and batteries), one voltmeter and one ammeter are to be provided, except for d.c. power sources for starting devices (e.g. starting motor for emergency generator).

1.8 Synchronisation of generators

1.8.1 It is to be possible to synchronise each generator intended for parallel operation with two independent synchronizing devices. at least, one of these synchronizing devices is to be manual.

1.8.2 Provisions are to be made for manual speed control of the prime mover and manual voltage control of the generators at the place where the manual synchronization is carried out.

2 Constructional requirements for section boards and distribution boards

2.1 Construction

2.1.1 Section boards and distribution boards are to be constructed, insofar as applicable, as specified for main and emergency switchboards.

2.1.2 All parts which require operation in normal use are to be placed on the front.

2.1.3 Distribution switchboards which are provided with two or more supply circuits arranged for automatic standby connection are to be provided with positive indication of which of the circuits is feeding the switchboard.

2.1.4 Where switchboard supplying essential services is provided with a forced air cooling system, the air temperature is to be monitored. An alarm is to be activated when temperature exceeds a preset value.

3 Testing

3.1 General

3.1.1 Switchboards and controlgear assemblies are to be subjected to the tests specified from [3.2] to [3.5].

3.1.2 The manufacturer is to issue the relative test reports providing information concerning the construction, serial number and technical data relevant to the switchboard and controlgear assemblies, as well as the results of the tests required.

3.1.3 The tests are to be carried out prior to installation on board.

3.1.4 The test procedures are as specified in IEC Publication 60092-302-2:2019.

3.1.5 The tests of main switchboards, emergency switchboards or switchboards rated above 100 kW are to be attended by a surveyor of the Society.

3.2 Visual Inspection

3.2.1 It is to be verified that the switchboard and controlgear assemblies:

- complies with the approved drawings
- maintains the prescribed degree of protection
- is constructed in accordance with the relevant constructional requirements, in particular as regards creepage and clearance distances.

3.3 Functional Testing

3.3.1 Electrical functioning tests are to be conducted on switchboard and controlgear assemblies. These tests include, but are not limited to, the testing of control and protective devices, alarms, electrical interlocks, sequence control facilities, and other related components. In certain cases, it may be necessary to perform or repeat these tests following installation on board.

3.3.2 The connections, especially screwed or bolted connections, are to be checked for adequate contact, possibly by random tests.

3.4 High-voltage test

3.4.1 The test is to be performed with alternating voltage at the assembly's rated frequency with a ± 25% tolerance.

3.4.2 The test voltage is to be applied:

- between all live parts connected together and exposed conductive parts
- between each polarity and, all other polarities and exposed conductive parts connected together.

During the high-voltage test, measuring instruments, ancillary apparatus and electronic devices may be disconnected and tested separately in accordance with the appropriate requirements.

3.4.3 The test voltage is to have a substantially sinusoidal waveform, and is not to exceed half of the full test value at the moment of application. It is then to be increased gradually within a few seconds to this full value and maintained for 60 seconds.

3.4.4 The value of the test voltage for main and auxiliary circuits is given in Tab 3 and Tab 4.

3.5 Measurement of insulation resistance

3.5.1 Immediately after the high-voltage test, the insulation resistance is to be measured using a device with a direct current voltage of at least 500 V.

3.5.2 The insulation resistance between all cu.rrent carrying parts and earth (and between each polarity and the other polarities) is to be at least equal to 1 MΩ..

Table 3 : Test voltage for main circuits

Rated insulation voltage Ui, (line to line a.c. or d.c.), in V	Dielectric test voltage a.c. (r.m.s.), in V	Dielectric test voltage d.c., in V
Ui ≤ 60	1000	1415
60 < Ui ≤ 300	1500	2120
300 < Ui ≤ 690	1890	2670
690 < Ui ≤ 800	2000	2830
800 < Ui ≤ 1000	2200	3110
1000 < Ui ≤ 1500	–	3820

Table 4 : Test voltage for auxiliary circuits

Rated insulation voltage Ui, (line to line), in V	Dielectric test voltage a.c. (r.m.s.), in V	Dielectric test voltage d.c., in V
Ui ≤ 12	250	355
12 < Ui ≤ 60	500	710
Ui > 60	see Tab 3	see Tab 3

Section 9 Cables

1 General

1.1 Type approval

1.1.1 Cables are to be of a type approved by the Society.

2 Constructional requirements

2.1 Construction

2.1.1 Cables and insulated wiring are generally to be constructed in accordance with the relevant recommendations of IEC Publications 60092-350, 60092-352, 60092-353, 60092-354, 60092-360, 60092-370 and 60092-376, as well as with the provisions of this Chapter.

2.1.2 Mineral-insulated cables are to be constructed according to IEC Publication 60702.

2.1.3 Optical fibre cables are to be constructed in accordance with IEC Publication 60794.

2.1.4 Cables and insulated wires manufactured and tested in accordance to standards other than those specified in [2.1.1] will be accepted provided they are in accordance with an acceptable and relevant international or national standard and are of an equivalent or higher safety level than those listed in [2.1.1].

However, cables such as flexible cable, fibre-optic cable, etc. used for special purposes may be accepted provided they are manufactured and tested in accordance with the relevant standards accepted by the Society.

2.1.5 Insulated wiring for auxiliary circuits of switchboards may be constituted by cables with a single conductor of the stranded type for all sections, PVC-ST2 or rubber-insulated in accordance with the standards cited in [2.1.1] and without further protection.

2.1.6 The insulated wiring is to be at least of the flame-retardant type according to IEC 60332-1-2:2004 + AMD1:2015.

Switchboard wires, of an equivalent flame-retardant type, will be specially considered by the Society.

2.1.7 In addition to the provisions of Ch 2, Sec 3, [9.1.1], when cables are laid in bunches, cable types are to be chosen in compliance with IEC 60332-3-22:2018 Category A, or other means (see Ch 2, Sec 12, [7.1.4], item b)) are to be provided such as not to impair their original flame-retarding properties.

2.1.8 Where necessary for specific applications such as radio frequency or digital communication systems, which require the use of particular types of cables, the Society may permit the use of cables which do not comply with the provisions of Ch 2, Sec 3, [9.1.1] and with [2.1.7].

2.1.9 Fire resistant cables are to be designed and tested in accordance with the relevant IEC Publication 60092-series standards.

They are to comply with the requirements of:

- IEC Standard 60331-1 for cables with an overall diameter exceeding 20 mm, or
- IEC Standard 60331-2 for cables with an overall diameter not exceeding 20 mm,
- otherwise IEC 60331-21.

The minimum flame application time is to be at least 90 minutes.

Fire resistant type cables are to be easily distinguishable.

Note 1: For special cables, requirements in the following standards may be used:

- IEC 60331-23: Procedures and requirements - Electric data cables
- IEC 60331-25: Procedures and requirements - Optical fibre cables

2.2 Conductors

2.2.1 Conductors are to be of annealed electrolytic copper with a resistivity not exceeding 17,241 Ω mm^2/km at 20°C according to IEC 60228.

2.2.2 Individual conductor wires of rubber-insulated cables are to be tinned or coated with a suitable alloy.

2.2.3 All conductors are to be stranded, except for cables of nominal cross-sectional area 2,5 mm^2 and less (provided that adequate flexibility of the finished cable is assured).

2.2.4 For the minimum nominal cross-sectional areas permitted, see Ch 2, Sec 3, [9.10].

2.3 Insulating materials

2.3.1 The materials used for insulation are to comply with IEC Publication 60092-360 and to have the thicknesses specified for each type of cable in the relevant standard. The maximum permissible rated temperature is specified for the various materials.

2.3.2 Materials and thicknesses other than those in [2.3.1] will be specially considered by the Society.

2.4 Inner covering, fillers and binders

2.4.1 The cores of a multicore cable are to be laid up. The spaces between the cores are to be filled so as to obtain an assembly having an essentially circular cross-section. The filling may be omitted in multicore cables having a conductor cross-sectional area not exceeding 4 mm^2.

2.4.2 When a non-metallic sheath is applied directly over the inner covering or the fillers, it may substitute partially for the inner covering or fillers.

2.5 Protective coverings (armour and sheath)

2.5.1 Metallic armour, if not otherwise protected against corrosion, is to be protected by means of a coating of protective paint (see Ch 2, Sec 3, [9.3]).

2.5.2 The paint is to be non-flammable and of adequate viscosity. When dry, it is not to flake off.

2.5.3 The materials used for sheaths are to be in accordance with IEC Publication 60092-360 and are to have the thicknesses specified for each type of cable in the relevant standard.

The quality of the materials is to be adequate to the service temperature of the cable.

2.5.4 Materials other than those in [2.5.3] will be specially considered by the Society.

2.6 Identification

2.6.1 Each cable is to have clear means of identification so that the manufacturer can be determined.

2.6.2 Flame retardant and fire resistant cables are to be clearly labeled with the specific standards according to which their properties have been verified and approved.

2.6.3 An identification tag is to be fitted at both ends of the cable.

3 Testing

3.1 Type tests

3.1.1 Type tests are to be in accordance with the relevant IEC 60092-3 Series Publications and IEC 60332-1-2:2004 + AMD1:2015, IEC 60332-3-22:2018 Category A, IEC 60331-1, IEC 60331-2, and IEC 60331-21 where applicable.

3.2 Routine tests

3.2.1 Every length of finished cable is to be subjected to the tests specified in [3.2.2].

3.2.2 The following routine tests are to be carried out:

a) visual inspection

b) check of conductor cross-sectional area by measuring electrical resistance

c) high-voltage test

d) insulation resistance measurement

e) dimensional checks (as necessary).

3.2.3 The manufacturer is to issue a statement providing information on the type and characteristics of the cable, as well as the results of the tests required and the Type Approval Certificates.

3.2.4 The test procedure is as specified in IEC Publication 60092-350.

3.2.5 Where an alternative scheme, e.g. a certified quality assurance system, is recognised by the Society, attendance of the Surveyor may not be required.

Section 10 Miscellaneous Equipment

1 Switchgear and controlgear, protective devices

1.1 General

1.1.1 Switchgear and controlgear are to comply with IEC Publication 60947.

1.1.2 For materials and construction see Ch 2, Sec 2, [4] and Ch 2, Sec 2, [5].

1.2 Circuit-breakers

1.2.1 Power-driven circuit-breakers are to be equipped with an additional separate drive operated by hand.

1.2.2 Power circuit-breakers with a making capacity exceeding 10 kA are to be equipped with a drive which performs the make operation independently of the actuating force and speed.

1.2.3 Where the conditions for closing the circuit-breaker are not satisfied (e.g. if the undervoltage trip is not energised), the closing mechanism is not to cause the closing of the contacts.

1.2.4 All circuit-breakers rated more than 16 A are to be of the trip-free type, i.e. the breaking action initiated by overcurrent or undervoltage releases is to be fulfilled independently of the position of the manual handle or other closing devices.

1.3 Protection devices

1.3.1 Short-circuit releases are generally to be independent of energy supplied from circuits other than that to be protected. Tripping due to short-circuit is to be reliable even in the event of a total loss of voltage in the protected circuit.

1.3.2 Short-circuit releases for generators are to be equipped with reclosing inhibitors and are to be delayed for selective tripping.

1.3.3 Overload releases or relays are to operate reliably at any voltage variation of the supply voltage in the protected circuit.

1.3.4 Undervoltage relays or releases are to cause the circuit-breaker to open if the voltage drops to 70%-35% of the rated voltage.

1.3.5 Shunt releases are to ensure the disconnection of the circuit-breaker even when the supply voltage of the release drops to 85% of the rated supply voltage.

1.3.6 The reverse power protection device is to respond to the active power regardless of the power factor, and is to operate only in the event of reverse power.

1.3.7 Single-phase failure devices in three-phase circuits are to operate without a time lag.

1.3.8 Insulation monitoring devices are to continuously monitor the insulation resistance to earth and trigger an alarm should the insulation resistance fall below a predetermined value.

The measuring current of such devices is not to exceed 30 mA in the event of a total short to earth.

2 Electrical slip ring assemblies

2.1 General requirements

2.1.1 The purpose of the electrical slip ring is to form a continuous electrical connection between a fixed part and a rotating part. The electrical slip rings may transfer power or control/automation signals.

2.1.2 High-voltage electrical slip rings are to be segregated from slip rings operating at different voltage ratings.

2.1.3 Slip rings fitted with forced cooling system are to be capable of restricted operation in case of loss of the cooling system. The cooling system failure is to be alarmed.

2.1.4 Where data transmission is carried out via a bus system, transmission paths are to be duplicated. Failure of each single system is to be alarmed.

2.2 Construction

2.2.1 It is to be taken into account that the mechanical and electrical characteristics of the slip rings can be degraded by contamination or by oxidation.

2.2.2 Enclosures for slip ring assemblies is to ensure at least a degree of protection IP23.

2.2.3 The suitability of used materials at maximum permitted temperature values is to be proven. The permitted conductor temperature values of the connected cables is not to be exceeded.

2.2.4 The maximum temperature rise of external surface parts which can easily be touched in service is not to exceed 15°C.

2.2.5 The enclosure is to be protected against internal condensation.

2.2.6 Clearance and creepage distances between non-insulated parts of low-voltage slip rings are to be in accordance with Ch 2, Sec 8, [1.3.5] and Ch 2, Sec 8, [1.3.6]

2.2.7 Clearance and creepage distances between non-insulated parts of high-voltage slip rings are to be in accordance with Ch 2, Sec 13, [2.3].

2.2.8 Power slip rings are to be capable to withstand without damage the maximum prospective value of the short-circuit current which can occur at its terminals.

2.2.9 High-voltage slip rings are to be able to withstand an internal short circuit arcing failure with the maximum duration and magnitude which can occur at this particular point of the installation, without harmful effect to operators. They are to be internal arc classified (IAC). Where they are accessible by authorized personnel only, Accessibility Type A is sufficient (IEC 62271-200:2021/A1:2024 Annex A 2.2). Installation and location of the slip rings is to correspond with its internal arc classification and classified sides.

2.3 Testing

2.3.1 General

All slip rings are to be type approved or case-by-case approved and surveyed by the Society during testing and, if appropriate, during manufacturing. Tested slip rings are to be individually certified by the Society.

Electric slip ring assemblies are to be subjected to the tests stated in Tab 1. Where the test procedure is not specified, the requirements of IEC 61439-1 and IEC 61439-2 or IEC 62271-200 apply.

Tests procedure is to be submitted to the Society for approval.

Type tests are to be carried out, unless the manufacturer can produce evidence based on previous experience indicating the satisfactory performance of such equipment.

Table 1 : Tests to be carried out on electrical slip rings

No	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of protection index, clearances and creepage distances	X	X
2	Mechanical tests	X	X
3	Electric contact resistance test	X	X
4	Insulation resistance measurement	X	X
5	Dielectric strength test	X	X
6	Signal attenuation (for fibre optic swivel)	X	X
7	Functional test of auxiliaries (e.g. sensors, data transfer)	X	X
8	Endurance test	X	–
9	Temperature rise test	X	–
10	Impulse voltage withstand test	X	–
11	Short-circuit withstand test	X	–
12	Verification degree of protection	X	–
13	Environmental tests	X	–

(1) Type test on prototype slip ring or test on at least the first batch of slip rings

(2) The certificates of slip rings routine tested are to contain the manufacturer's serial number of the slip ring which has been type tested and the test result

(3) A visual examination is to be made of the slip ring, as far as practicable, that it complies with technical documentation.

2.4 Description of tests

2.4.1 Visual inspection

An inspection and checks are carried out with a view to establish that the electrical slip ring assembly:

- complies with approved technical documentation
- maintains the prescribed degree of protection
- is constructed in accordance with the relevant constructional requirements, in particular as regards to creepage and clearance distances

2.4.2 Mechanical tests

The electrical slip ring is to be subjected to the following mechanical tests:

- Free rotation test on the full 360° in both clockwise and counter-clockwise. No hard point is to be encountered.
- Free rotation test on the full 360° in clockwise and counter-clockwise to measure and record the breakout torque and the steady running torque.
- Free rotation test on the full 360° in clockwise and counter-clockwise when the slip ring is inclined at an angle of 22,5° (roll) to measure and record the breakout torque and the steady running torque.

Tests are to be carried out at the specified rotation speed and the measured values are not to exceed data given by Manufacturer.

2.4.3 Electric contact resistance test

The electrical slip ring is to be subjected to a resistance test to measure and record the contact resistance across all paths on the full 360° in clockwise and counter-clockwise. Test is to be carried out at the specified rotation speed. The measured values are not to exceed the values given by the Manufacturer.

2.4.4 Insulation resistance measurement

Immediately after the high-voltage test, the insulation resistance between all current carrying parts and earth (and between each polarity and the other polarities) is to be measured using a direct current insulation tester. The minimum values of test voltages and corresponding insulation resistances are as given in Ch 2, Sec 4, Tab 2.

2.4.5 Dielectric strength test

Low voltage slip ring assemblies are to be subjected to a high-voltage test as given in Ch 2, Sec 8, [3.3].

High-voltage slip ring assemblies are to be subjected to a high-voltage test:

- between all live parts connected together and exposed conductive parts
- between each polarity and, all other polarities and exposed conductive parts connected together

The test voltage is to be applied for at least 1 minute and is to be as given in Ch 2, Sec 13, Tab 2.

2.4.6 Signal attenuation test (for fibre optic swivel)

The fibre optic swivel is to be subjected to signal attenuation test to measure and record the signal attenuation across all paths on the full 360° in clockwise and counter-clockwise. Test is to be carried out at the specified rotation speed. The measured values are not to exceed the values given by the Manufacturer.

2.4.7 Endurance test

An endurance test at a rotation speed of 1 rpm is to be carried out as follows:

- 100 rotations with 10% rated current (In)
- 100 rotations with 90% rated current (In)
- 1 rotation with 150% rated current (In)
- 100 rotations without current.

After the test, the slip rings electric contact resistance measurement is to be repeated.

2.4.8 Temperature rise test

A temperature rise test is to be carried out to measure the temperature rise of the active parts and the slip ring enclosure when all paths are loaded at their rated current and with normal cooling capability. Test may be performed in static condition. The measured values are not to exceed the values given by the Manufacturer.

2.4.9 Short-circuit withstand test

A short-circuit withstand test is to be performed to demonstrate that active parts with their supports are mechanically dimensioned and fixed to withstand the stresses caused by sudden short-circuit current without damage. The test value is not to be lower than the maximum prospective value of the short-circuit current on the slip ring. A calculation note is admitted as alternative to the test.

2.4.10 Impulse voltage withstand test

An impulse voltage withstand test in accordance with requirements of IEC 61439-1 or IEC 62271-200 is to be carried out in case the air clearance does not satisfy the requirements of [2.2.6] and [2.2.7].

2.4.11 Verification of degree of protection

The degree of protection is to be as specified in IEC 60529.

2.4.12 Environmental tests

To validate that the slip rings assemblies are designed and constructed to operate satisfactorily under the environmental conditions expected on board they are to be subjected to the following environmental tests. During testing the slip rings are to be in normal operating conditions. For large slip rings, a case-by-case evaluation based on calculations and/or documented measures is admitted as an alternative to the vibration test.

a) Ambient temperature test in compliance with IEC 60068-2-2, at temperatures specified in Ch 2, Sec 2, [1.2.1]

b) Humidity resistance test in compliance with IEC 60068-2-30 Test Db, at a relative humidity specified in Ch 2, Sec 2, [1.3.1]

c) Inclination test at inclination angles specified in Ch 2, Sec 2, [1.6.1]

d) Vibration test in compliance with IEC 60068-2-6 Test Fc, at vibration levels specified in Ch 2, Sec 2, [1.7.1].

3 Lighting fittings

3.1 Applicable requirements

3.1.1 Lighting fittings are to comply with IEC Publications 60598 and 60092-306.

Lighting fittings complying with other standards will be specially considered by the Society.

3.2 Construction

3.2.1 The temperature of terminals for connection of supplying cables is not to exceed the maximum conductor temperature permitted for the cable (see Ch 2, Sec 3, [9.9]).

Where necessary, luminaires are to be fitted with terminal boxes which are thermally insulated from the light source.

3.2.2 Wires used for internal connections are to be of a temperature class which corresponds to the maximum temperature within the luminaire.

3.2.3 The temperature rise of parts of luminaires which are in contact with the support is not to exceed 50°C. The rise is not to exceed 40°C for parts in contact with flammable materials.

3.2.4 The temperature rise of surface parts which can easily be touched in service is not to exceed 15°C.

3.2.5 High-power lights with higher surface temperatures than those in [3.2.2] and [3.2.3] are to be adequately protected against accidental contact.

4 Accessories

4.1 Applicable requirements

4.1.1 Accessories are to be constructed in accordance with the relevant IEC Publications, and in particular with Publication 60092-306.

4.2 Construction

4.2.1 Enclosures of accessories are to be of metal having characteristics suitable for the intended use on board, or of flame-retardant insulating material.

4.2.2 Terminals are to be suitable for the connection of stranded conductors, except in the case of rigid conductors for mineral-insulated cables.

5 Plug-and-socket connections

5.1 Applicable requirements

5.1.1 Plug-and-socket connections are to comply with IEC Publication 60092-306 and with the following additional standards in relation to their use:

- in accommodation spaces, day rooms and service rooms (up to 16 A, 250 V a.c.): IEC Publication 60083 or 60320, as applicable
- for power circuits (up to 250 A, 690 V a.c.): IEC Publication 60309
- for electronic switchgear: IEC Publications, e.g. 60512 and 60603
- for refrigerated containers: ISO 1496-2:2018.

6 Heating and cooking appliances

6.1 Applicable requirements

6.1.1 Heating and cooking appliances are to comply with the relevant IEC Publications (e.g. those of series 60335), with particular attention to IEC 60092-307.

6.2 General

6.2.1 Heating elements are to be enclosed and protected with metal or refractory material.

6.2.2 The terminals of the power supply cable are not to be subjected to a higher temperature than that permitted for the conductor of the connection cable.

6.2.3 The temperature of parts which are to be handled in service (switch knobs, operating handles and the like) is not to exceed the following values:

- 55°C for metal parts
- 65°C for vitreous or moulded material.

6.3 Space heaters

6.3.1 The casing or enclosure of heaters is to be so designed that clothing or other flammable material cannot be placed on them.

6.3.2 The temperature of the external surface of space heaters is not to exceed 60°C.

6.3.3 Space heaters are to be provided with a temperature limiting device without automatic reconnection which automatically trips all poles or phases not connected to earth when the temperature exceeds the maximum permissible value.

6.4 Cooking appliances

6.4.1 Live parts of cooking appliances are to be protected such that any foods or liquids which boil over or spill do not cause short-circuits or loss of insulation.

6.5 Fuel oil and lube oil heaters

6.5.1 In continuous-flow fuel oil and lube oil heaters, the maximum temperature of the heating elements is to be below the boiling point of the oil.

6.5.2 Each oil heater is to be provided with a thermostat maintaining the oil temperature at the correct level.

6.5.3 In addition to the thermostat in [6.5.2], each oil heater is to be provided with a temperature limiting device without automatic reconnection, and with the sensing device installed as close as possible to the heating elements and permanently submerged in the liquid.

6.6 Water heaters

6.6.1 Water heaters are to be provided with a thermostat and safety temperature limiter.

Section 11 Location

1 General

1.1 Location

1.1.1 The degree of protection of the enclosures and the environmental categories of the equipment are to be appropriate to the spaces or areas in which they are located; see Ch 2, Sec 3, Tab 2, Ch 2, Sec 3, Tab 3 and Ch 2, Sec 2, [5.2.2].

1.2 Areas with a risk of explosion

1.2.1 Except where the installation of equipment for explosive gas atmosphere is provided for by the Rules, electrical equipment is not to be installed where flammable gases or vapours are liable to accumulate; see Ch 2, Sec 3, [10].

1.3 Electrical equipment in environmentally controlled spaces

1.3.1 Where electrical equipment is installed within environmentally controlled spaces the ambient temperature for which the equipment is to be suitable may be reduced from 45°C to a value not less than 35°C provided:

a) the equipment is not for use for emergency services

b) temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature

c) the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45°C ambient temperature

d) audible and visual alarms are provided, at a continuously manned control station, to indicate any malfunction of the cooling units.

1.3.2 In accepting a lesser ambient temperature than 45°C, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

2 Main electrical system

2.1 Location in relation to the emergency system

2.1.1 The arrangement of the emergency electrical system is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render inoperative the main electric lighting system and the other primary essential services.

2.2 Main switchboard

2.2.1 *The main switchboard shall be so placed relative to one main generating station that, as far as is practicable, the integrity of the normal electrical supply may be affected only by a fire or other casualty in one space.*

2.2.2 *An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating switchboards from generators.*

2.2.3 The main generating station is to be situated within the machinery space, i.e. within the extreme main transverse watertight bulkheads.

2.2.4 Any bulkhead between the extreme main transverse watertight bulkheads is not regarded as separating the equipment in the main generating station provided that there is access between the spaces.

2.2.5 The main switchboard is to be located as close as practicable to the main generating station, within the same machinery space and the same vertical and horizontal A60 fire boundaries.

2.2.6 Where essential services for steering and propulsion are supplied from section boards, these and any transformers, converters and similar appliances constituting an essential part of the electrical supply system are also to satisfy the above provisions.

2.2.7 A non-required subdivision bulkhead, with sufficient access, located between the switchboard and generators, or between two or more generators, is not to be considered as separating the equipment.

3 Emergency electrical system

3.1 Spaces for the emergency source

3.1.1 *The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard shall be located above the uppermost continuous deck and shall be readily accessible from the open deck.*

They shall not be located forward of the collision bulkhead.

3.1.2 *The spaces containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard are not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard.*

Where this is not practicable, the contiguous boundaries are to be Class A60.

3.2 Location in relation to the main electrical system

3.2.1 *The location of the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard shall be such as to ensure to the satisfaction of the Society that a fire or other casualty in the space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A will not interfere with the supply, control and distribution of emergency electrical power.*

3.2.2 The arrangement of the main electrical system is to be such that a fire or other casualty in spaces containing the main source of electrical power, associated converting equipment, if any, the main switchboard and the main lighting switchboard will not render inoperative the emergency electric lighting system and the other emergency services other than those located within the spaces where the fire or casualty has occurred.

3.3 Emergency switchboard

3.3.1 *The emergency switchboard shall be installed as near as is practicable to the emergency source of electrical power.*

3.3.2 *Where the emergency source of electrical power is a generator, the emergency switchboard shall be located in the same space unless the operation of the emergency switchboard would thereby be impaired.*

3.4 Emergency battery

3.4.1 *No accumulator battery fitted in accordance with the provisions of* Ch 2, Sec 3, [2.3] *shall be installed in the same space as the emergency switchboard.*

3.4.2 For ships not subject to Solas, accumulator batteries fitted in accordance with the provisions of Ch 2, Sec 3, [2.3] and connected to a charging device of power of 2 kW or less may be accepted in the same space as the emergency switchboard but outside the emergency switchboard to the satisfaction of the Society.

4 Distribution boards

4.1 Distribution boards for cargo spaces and similar spaces

4.1.1 Distribution boards containing multipole switches for the control of power and lighting circuits in bunkers and cargo spaces are to be situated outside such spaces.

4.2 Distribution board for navigation lights

4.2.1 The distribution board for navigation lights is to be placed in an accessible position on the bridge.

5 Cable runs

5.1 General

5.1.1 Cable runs are to be selected so as to be as far as practicable accessible, with the exception of single cables, situated behind walls or ceilings constructed of incombustible materials, supplying lighting fittings and socket-outlets in accommodation spaces, or cables enclosed in pipes or conduits for installation purposes.

5.1.2 Cable runs are to be selected so as to avoid action from condensed moisture and from dripping of liquids.

5.1.3 Connection and draw boxes are to be accessible.

5.1.4 Cables are generally not to be installed across expansion joints.

Where this is unavoidable, however, a loop of cable of length proportional to the expansion of the joint is to be provided (see Ch 2, Sec 12, [7.2.2]).

5.2 Location of cables in relation to the risk of fire and overheating

5.2.1 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are, so far as is practicable, to be routed clear of galleys, laundries, machinery spaces of Category A and their casings and other high fire risk areas, except for supplying equipment in those spaces.

5.2.2 When it is essential that a circuit functions for some time during a fire and it is unavoidable to carry the cable for such a circuit through a high fire risk area (e.g. cables connecting fire pumps to the emergency switchboard), the cable is to be of a fire-resistant type or adequately protected against direct exposure to fire.

5.2.3 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s).

They are to be of a fire resistant type, in accordance with Ch 2, Sec 9, [2.1.9], where they pass through other high fire risk areas.

5.2.4 Main cable runs (see Note 1) and cables for the supply and control of essential services are, as far as is practicable, to be kept away from machinery parts having an increased fire risk (see Note 2) unless:

- the cables have to be connected to the subject equipment
- the cables are protected by a steel bulkhead or deck, or
- the cables in that area are of the fire-resisting type.

Note 1: Main cable runs are for example:

- cable runs from generators and propulsion motors to main and emergency switchboards
- cable runs directly above or below main and emergency switchboards, centralised motor starter panels, section boards and centralised control panels for propulsion and essential auxiliaries.

Note 2: Machinery, machinery parts or equipment handling combustibles are considered to present an increased fire risk.

5.2.5 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are to be arranged, as far as practicable, in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

5.2.6 Cables are to be arranged as remote as possible from sources of heat such as hot pipes, resistors, etc. Where installation of cables near heat sources cannot be avoided, and where there is consequently a risk of damage to the cables by heat, suitable shields are to be installed, or other precautions to avoid overheating are to be taken, for example use of ventilation, heat insulation materials or special heat-resisting cables.

5.3 Location of cables in relation to electromagnetic interference

5.3.1 For the installation of cables in the vicinity of radio equipment or of cables belonging to electronic control and monitoring systems, steps are to be taken in order to limit the effects of unwanted electromagnetic interference (see Ch 3, Sec 5).

5.4 Services with a duplicate feeder

5.4.1 In the case of essential services requiring a duplicate supply (e.g. steering gear circuits), the supply and associated control cables are to follow different routes which are to be as far apart as practicable, separated both vertically and horizontally.

5.5 Emergency circuits

5.5.1 Cables supplying emergency circuits are not to run through spaces containing the main source of electrical power, associated transforming equipment, if any, the main switchboard and the main lighting switchboard, except for cables supplying emergency equipment located within such spaces (see [3.2.2]).

5.6 Electrical distribution in passenger ships

5.6.1 For the electrical distribution in passenger ships, see Pt D, Ch 11, Sec 5, [1.2].

6 Storage batteries

6.1 General requirements for arrangements

6.1.1 Batteries are to be located where they are not exposed to excessive heat, extreme cold, spray, steam or other conditions which would impair performance or accelerate deterioration. They are to be installed in such a way that no damage may be caused to surrounding appliances by the vapours generated.

6.1.2 Storage batteries are to be suitably housed, and rooms, lockers or boxes used primarily for their accommodation are to be properly constructed and efficiently ventilated so as to prevent accumulation of flammable gas.

6.1.3 Starter batteries are to be located as close as practicable to the engine or engines served.

6.1.4 *Accumulator batteries shall not be located in sleeping quarters except where hermetically sealed to the satisfaction of the Society.*

6.1.5 Lead-acid batteries and alkaline batteries are not to be installed in the same compartment (room, locker, box), unless of valve-regulated sealed type.

6.1.6 Protection against water entry in battery room

Means are to be provided to avoid sea water ingress in battery room under normal operating conditions.

6.1.7 Protection against liquid leakage in battery room

The piping systems not involved in battery operation are not to be located in the battery room. Departure from this requirement may be accepted by the Society, with the following minimum conditions

- efficient detection of fluid leakage is implemented in room
- pipes are provided with welded joints inside the battery room and are not to be installed above the battery packs
- no flammable fluid is conveyed
- only class III pipes are accepted.

6.1.8 Protection against falling objects

Access hatches to batteries are to prevent falling of objects directly on battery cells, connections, elements of BMS, and cooling system if any.

6.1.9 Protection against electrostatic hazard

When hazardous areas may be created regarding criteria of IEC 60079 series, the battery room is to be painted with antistatic paintings in the circulating area with the exception of battery rooms containing Li ion batteries provided it is confirmed by the risk analysis required in Ch 2, Sec 7, [3.2.1]; Ch 2, Sec 7, [5.4.2] or Ch 2, Sec 12, [5.2.1].

6.1.10 The charging device power mentioned in [6.2] to [6.4] is to be taken equal to the product from the maximum obtainable charging current and the nominal voltage of battery. When several charging devices are used in one location, the sum of each individual charging device power is to be considered to determine which provisions are applicable.

6.2 Arrangement of large vented batteries

6.2.1 Batteries connected to a charging device of power exceeding 2 kW (hereafter referred to as “large batteries”) are to be installed in a room assigned to batteries only. Where this is not possible, they may be arranged in a suitable locker on deck.

Where this is not possible, they may be arranged in a suitable locker on deck.

6.2.2 Rooms assigned to large batteries are to be provided with mechanical exhaust ventilation.

Natural ventilation may be employed for boxes located on open deck.

6.3 Arrangement of moderate vented batteries

6.3.1 Batteries connected to a charging device of power between 0,2 kW and 2 kW (hereafter referred to as “moderate batteries”) are to be placed in a box or locker in suitable locations such as machinery spaces, storerooms or similar spaces. In machinery spaces and similar well-ventilated compartments, these batteries may be installed without a box or locker provided they are protected from falling objects, dripping water and condensation where necessary. An arrangement complying with [6.2] is also acceptable

6.3.2 Rooms, lockers or boxes assigned to moderate batteries are to be provided with natural ventilation or mechanical exhaust ventilation, except for batteries installed without a box or locker (located open) in well-ventilated spaces.

6.4 Arrangement of small vented batteries

6.4.1 Batteries connected to a charging device of power less than 0,2 kW (hereafter referred to as “small batteries”) are to be arranged in a box in a ventilated area or without a box or locker, provided they are protected from falling objects.

6.4.2 Boxes for small batteries may be ventilated only by means of openings near the top to permit escape of gas.

6.5 Arrangement of Li-ion batteries above 20kWh

6.5.1 Batteries are to be installed in a dedicated space that is not located forward of the collision bulkhead.

6.5.2 Fire protection

a) For structural fire protection, see Ch 4, Sec 5, [1].

b) For detection and alarm, see Ch 4, Sec 3, [9].

c) For fire fighting, see Ch 4, Sec 6, [8].

6.6 General requirements for ventilation

6.6.1 The ventilation of battery rooms is to be independent of ventilation systems for other spaces.

6.6.2 Fans starters cabinet is to be located outside of the battery room.

6.6.3 In the event of failure of the remote or automatic control system, it is to be possible to start/stop the energy electric storage system (ESS) ventilation locally without entering the battery room.

6.6.4 Ventilation fans are not to produce a source of vapor ignition in either the ventilated space or the ventilation system associated with the space. A non-sparking exhaust fan is to be provided.

6.6.5 Ducts are to be made of a corrosion-resisting material or their interior surfaces are to be painted with corrosion-resistant paint.

6.6.6 The ventilation ducting system is to be gastight and able to withstand the off-gas temperature and over-pressure. The pipes to and from the battery room are to be made of steel.

6.6.7 Adequate air inlets (whether connected to ducts or not) are to be provided near the floor of battery rooms or the bottom of lockers or boxes (except for that of small batteries).

Air inlet may be from the open air or, when in lockers and boxes, from another space.

Ventilation air inlets are to be taken from areas which, in the absence of the considered inlet, would be non-hazardous.

6.6.8 The ventilation exhaust suction is to be located as close as practicable to the ceiling such that light gases are evacuated.

6.6.9 Exhaust ducts of natural ventilation systems:

a) are to be run directly from the top of the room to the open air above (they may terminate in the open or in well-ventilated spaces)

b) are to terminate not less than 90 cm above the top of the battery room

c) are to have no part more than 45° from the vertical

d) are not to contain appliances (for example for barring flames) which may impede the free passage of air or gas mixtures.

Where natural ventilation is impracticable or insufficient, mechanical exhaust ventilation is to be provided.

6.6.10 Mechanical exhaust ventilation systems

a) electric motors for ventilation fans are not to be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served

b) fans are to be so constructed and of a material such as to render sparking impossible in the event of the impeller touching the fan casing

c) steel or aluminium impellers are not to be used

d) the system is to be interlocked with the charging device so that the battery cannot be charged without ventilation (trickle charge may be maintained)

e) a temperature sensor is to be located in the battery room to monitor the correct behaviour of the battery in cases where the battery element is sensitive to temperature.

6.6.11 Natural ventilation systems for deck boxes

a) holes for air inlet are to be provided on at least two opposite sides of the box

b) the exhaust duct is to be of ample dimensions

c) the duct is to terminate at least 1,25 m above the box in a goose-neck or mushroom-head or the equivalent

d) the degree of protection is to be in accordance with Ch 2, Sec 3, Tab 2.

6.6.12 Battery room ventilators are to be fitted with a means of closing whenever:

a) The battery room does not open directly onto an exposed deck

b) The battery room is fitted with a fixed gas fire extinguishing system.

6.6.13 Where a battery room ventilator is fitted with a closing device, then a warning notice stating, for example "This closing device is to be kept open and only closed in the event of fire or other emergency – Explosive gas", is to be provided at the closing device to mitigate the possibility of inadvertent closing.

6.7 Additional requirement for vented batteries ventilation

6.7.1 The quantity of air expelled (by natural or forced ventilation) for compartments containing vented type batteries is to be at least equal to:

$Q = 110\ I\ n$

where:

Q : Quantity of air expelled, in litres per hour

I : Maximum current delivered by the charging equipment during gas formation, but not less than one quarter of the maximum obtainable charging current in amperes

n : Number of cells in series.

For natural ventilation, the available inlet and outlet duct free cross-sectional area S, in mm^2 is deemed sufficient provided it complies with following criteria:

$S \geq 2,8\ Q$

Otherwise, the dimensioning of the natural ventilation is to be considered on a case-by-case basis depending on the actual ducting arrangement. Detailed calculations may be required for this purpose.

6.8 Additional requirement for valve regulated batteries ventilation

6.8.1 The quantity of air expelled (by natural or forced ventilation) for rooms containing valve-regulated sealed batteries is to be at least 25% of that given in [6.7.1].

6.9 Additional requirement for Li-Ion batteries above 20kWh ventilation

6.9.1 The quantity of air expelled (by natural or forced ventilation) is to be at least equal to 6 air changes per hour.

6.9.2 The power supplied to the ESS ventilation fans is to be provided from two alternative circuits; one of which is the main power source and the other is the emergency source. The supply circuits are to be managed through a change-over switch.

6.9.3 When toxic products may be emitted in normal or abnormal conditions of operation, a specific analysis is to be undertaken (see Ch 2, Sec 7, [5.4.2]).

Note 1: The risk of release of toxic or explosive gases is to be assessed based on the gas analysis performed during the battery pack prototype testing, as required by Ch 2, Sec 7, [1.7.2].

6.9.4 For systems where potential off-gases are ventilated directly into the battery room:

- A non-sparking exhaust fan is to be provided, producing under-pressure in the battery room
- The exhaust fan is to be continuously running (or is to start automatically upon off-gas detection).

6.9.5 For systems equipped with an integrated duct for potential off-gas ventilation:

- An inlet fan is to be provided, producing over-pressure in the battery room
- The inlet fan is to be continuously running or is to start automatically upon off-gas detection.
- The integrated duct's inlets are to be equipped with non-return valves or flaps
- The integrated off-gas duct fan is to be continuously running or is to start automatically upon off-gas detection
- The integrated off-gas ventilation is not to be equipped with fire dampers

6.9.6 A specific detection should be implemented, in order to monitor:

- negative pressure of the room
- ventilation air flow
- explosive or inflammable gas concentration. Detectors are to be positioned regarding air streams repartition in the battery room or box, if any.
- position of ventilation circuit valves.

6.10 Hazardous area classification

6.10.1 Hazardous area classification is to be in accordance with Ch 2, Sec 3, [10.6].

Section 12 Installation

1 General

1.1 Protection against injury or damage caused by electrical equipment

1.1.1 All electrical equipment is to be so installed as not to cause injury when handled or touched in the normal manner.

1.1.2 All electrical equipment is to be installed in such a way that live parts cannot be inadvertently touched, unless supplied at a safety voltage.

1.1.3 For protective earthing as a precaution against indirect contact, see Article [2].

1.1.4 Equipment is to be installed so as not to cause, or at least so as to reduce to a minimum, electromagnetic interference.

1.2 Protection against damage to electrical equipment

1.2.1 Electrical equipment is to be so placed that as far as practicable it is not exposed to risk of damage from water, steam, oil or oil vapours.

1.2.2 The air supply for internal ventilation of electrical equipment is to be as clean and dry as practicable; cooling air for internal ventilation is not to be drawn from below the floor plates in engine and/or boiler rooms.

1.2.3 Equipment is to be so mounted that its enclosing arrangements and the functioning of the built-in equipment will not be affected by distortions, vibrations and movements of the ship's structure or by other damage liable to occur.

1.2.4 If electrical fittings, not of aluminium, are attached to aluminium, suitable provision is to be made to prevent galvanic corrosion.

1.3 Accessibility

1.3.1 Equipment is to be so installed that sufficient space is available for inspection and maintenance as required for all its parts (see [6.1.3]).

2 Earthing of non-current carrying parts

2.1 Parts which are to be earthed

2.1.1 Exposed metal parts of both fixed and portable electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live and similar metal parts inside non-metallic enclosures are to be permanently earthed through separate conductors of earthing straps, securely attached, and protected against damage unless the machines or equipment are:

a) supplied at a voltage not exceeding 50 V direct current or 50 V, root mean square between conductors, achieved without the use of auto-transformers (safety voltage); or

b) supplied at a voltage not exceeding 250 V by safety isolating transformers supplying one consuming device only; or

c) constructed in accordance with the principle of double insulation.

2.1.2 Special consideration is to be given to the earthing of the non-current- carrying parts which are not accessible but which under fault conditions might become live and hence constitute a fire hazard, such as a metal junction-box mounted on a wooden panel.

2.1.3 To minimise shock from high frequency voltage induced by the radio transmitter, handles, handrails and other metal elements on the bridge or upper decks are to be in electrical connection with the hull or superstructures.

2.2 Methods of earthing

2.2.1 Metal frames or enclosures of apparatus and electrical machinery may be fixed to, and in metallic contact with, the ship's structure, provided that the surfaces in contact are clean and free from rust, scale or paint when installed and are firmly bolted together.

2.2.2 For metal frames or enclosures which are not earthed as specified in [2.2.1], earthing connections complying with [2.3] and [2.4] are to be used.

2.2.3 For requirements regarding the earthing of coverings of cables and the mechanical protection of cables, see [7.11] and [7.12].

2.3 Earthing connections

2.3.1 Every earthing connection is to be of copper or other corrosion-resistant material and is to be securely installed and protected, where necessary, against damage and electrolytic corrosion.

2.3.2 The nominal cross-sectional area of each copper earthing connection is to be not less than that required in Tab 1. Earthing connections of other metals are to have conductance at least equal to that specified for a copper earthing connection.

2.3.3 Metal parts of portable appliances are to be earthed, where required (see [2.1.1]), by means of an earth-continuity conductor in the flexible supply cable or cord, which has the cross-sectional area specified in Tab 1 and which is earthed, for example, through the associated plug and socket.

2.3.4 In no circumstances is the lead sheathing or armour of cables to be relied upon as the sole means of earthing.

Table 1 : Cross-sectional area of earth-continuity conductors and earthing connections

<table>
<tr><th colspan="2">Type of earthing connection</th><th>Cross-sectional area of associated current carrying conductor</th><th colspan="2">Minimum cross-sectional area of copper earthing connection</th></tr>
<tr><td>1</td><td>Earth-continuity conductor in flexible cable or flexible cord</td><td>any</td><td colspan="2">Same as current carrying conductor up to and including 16 mm² and one half above 16 mm² but at least 16 mm²</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Earth-continuity conductor incorporated in fixed cable</td><td rowspan="4">any</td><td colspan="2">a) for cables having an insulated earth-continuity conductor
• a cross-section equal to the main conductors up to and including 16 mm², but minimum 1,5 mm²
• a cross-section not less than 50% of the cross-section of the main conductor when the latter is more than 16 mm², but at least 16 mm²
b) for cables with a bare earth wire in direct contact with the lead sheath</td></tr>
<tr><td>Cross-section of main conductor, in mm²</td><td>Earthing connection, in mm²</td></tr>
<tr><td>1 to 2,5
4 to 6</td><td>1
1,5</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Separate fixed earthing conductor</td><td>≤ 3 mm²</td><td colspan="2">Same as current carrying conductor subject to minimum of 3 mm² for stranded earthing connection or 2,5 mm² for unstranded earthing connection</td></tr>
<tr><td>> 3 mm² but ≤ 125 mm²</td><td colspan="2">One half the cross-sectional area of the current carrying conductor, subjected to a minimum of 3 mm²</td></tr>
<tr><td>> 125 mm²</td><td colspan="2">64 mm²</td></tr>
</table>

2.4 Connection to the ship's structure

2.4.1 Every connection of an earth-continuity conductor or earthing lead to the ship's structure is to be secured by means of a screw of brass or other corrosion-resistant material of diameter not less than 6 mm.

2.4.2 Such earthing connection is not to be used for other purposes.

2.4.3 The connection described in [2.4.1] is to be located in an accessible position where it may readily be checked.

2.5 Earthed distribution systems

2.5.1 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current carrying parts and is to be connected to the hull at one point only.

2.5.2 All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

2.5.3 In an earthed distribution system in which the earthing connection does not normally carry current, this connection is to conform with the requirements of [2.3], except that the lower limit of 70 mm² does not apply (see Tab 1).

2.5.4 In a distribution system with hull return, the system earthing connection is to have at least the same cross-sectional area as the feeder lines.

2.5.5 The earthing connection is to be in an accessible position where it may readily be inspected and disconnected for insulation testing.

2.6 Aluminium superstructures

2.6.1 When aluminium superstructures are insulated from the steel hull to prevent electrolytic corrosion, they are to be secured to the hull by means of a separate bonding connection.

2.6.2 The connections are to be adequately close together and are to have a resistance less than 0,1 Ω.

2.6.3 The connections are to be located where they may readily be inspected.

3 Rotating machines

3.1

3.1.1 Every rotating machine is preferably to be installed with the shaft in the fore-and-aft direction. Where a rotating machine of 100 kW (kVA) and over is installed athwartship, or vertically, it is to be ensured that the design of the bearings and the arrangements for lubrication are satisfactory to withstand the rolling specified in Ch 2, Sec 2, Tab 4.

4 Semiconductor converters

4.1 Semiconductor power converters

4.1.1 Naturally air-cooled semiconductor converters are to be installed such that the circulation of air to and from the stacks or enclosures is not impeded and that the temperature of the cooling inlet air to converter stacks does not exceed the ambient temperature for which the stacks are specified.

5 Batteries

5.1 Vented batteries

5.1.1 Batteries are to be arranged so that each cell or crate of cells is accessible from the top and at least one side to permit replacement and periodical maintenance.

5.1.2 Cells or crates are to be carried on insulating supports of material non-absorbent to the electrolyte (e.g. treated wood).

5.1.3 Cells are to be securely chocked by means of insulating material non-absorbent to the electrolyte, e.g. strips of treated wood. Special mechanical precautions are to be taken to prevent the emergency battery from being damaged by the shock due to a collision.

5.1.4 Provision is to be made for the free circulation of air.

5.1.5 Protection against corrosion

a) The battery boxes and interior of battery rooms including all metal parts subject to the electrolyte is to be protected against the deteriorating effect of the latter by electrolyte-resistant coating or other equivalent means, unless corrosion-resistant materials are used.

b) Interior surfaces of metal shelves for battery cells, whether or not grouped in crates or trays, are to be protected by a lining of electrolyte-resistant material, watertight and carried up to at least 75 mm on all sides. In particular, linings are to have a minimum thickness of 1,5 mm, if of lead sheet for lead-acid batteries, and of 0,8 mm, if of steel for alkaline batteries.

   Alternatively, the floor of the room or locker is to be lined as specified above to a height of at least 150 mm.

c) Battery boxes are to be lined in accordance with the requirements of item b) to a height of at least 75 mm.

5.2 Li Ion batteries above 20kWh

5.2.1 Risk analysis

A risk analysis is to be conducted and submitted to the Society.

An HAZID study is to be carried out for battery system installation. It is to cover at least the following spaces, zones and systems:

- Battery Room (Location and adjacent spaces)
- Battery system and auxiliaries
- An additional vibration analysis of the battery system may be required, taking into account the type of ship and its operational activity.

The risks identified by the HAZID study may be mitigated by operational procedures.

The following risks, at least, are to be covered:

- risk of thermal runaway
- risk of emission of combustion gases
- risk of internal short-circuit
- risk of external short-circuit
- risk of sensor failure (voltage, temperature, gas sensor)
- risk of high impedance (cell, connectors)
- risk of loss of cooling
- risk of leakage (electrolyte, cooling system)
- risk of failure of BMS (error on manoeuvring breakers, overloading, over discharge)
- risk for external ingress (fire, fluid leakage, fire-fighting water).

Adequation of fire-extinguishing system to battery type is to be documented.

Appropriate alarms and shutdown are to be described (for example, default on the cooling system when necessary to proper operation of the battery system).

6 Switchgear and controlgear assemblies

6.1 Main switchboard

6.1.1 The main switchboard is to be so arranged as to give easy access as may be needed to apparatus and equipment, without danger to personnel.

6.1.2 An unobstructed space is to be left in front of the switchboard wide enough to allow access for operation; such width is generally about 1 metre.

When withdrawable equipment is contained in the switchboard, the width of the space is to be not less than 0,5 m when the equipment is fully withdrawn.

Reduced widths may be considered for small ships.

6.1.3 Where necessary, an unobstructed space is to be provided at the rear of the switchboard ample to permit maintenance; in general, the width of this passage is to be not less than 0,6 m, except that this may be reduced to 0,5 m in way of stiffeners and frames, and the height sufficient for the operation foreseen.

6.1.4 Where the switchboard is open at the rear, the rear space in [6.1.3] is to form a locked space provided at each end with an access door. The required IP protection for the corresponding location is to be fulfilled.

6.1.5 If necessary, the clear height above the switchboard specified by the manufacturer is to be maintained for pressure relief in the event of a short-circuit.

6.1.6 When the voltage exceeds the safety voltage, non-conducting mats or gratings are to be provided at the front and rear of the switchboard as necessary.

6.1.7 Piping and conduits are not to be installed directly above or in the vicinity of switchboards.

Where this is unavoidable, pipes and conduits are to have welded joints only or to be provided with protection against spray from steam or pressurised liquids or dripping.

6.2 Emergency switchboard

6.2.1 For the installation of the emergency switchboard, the same requirements apply as given in [6.1] for the installation of the main switchboard.

6.3 Section boards and distribution boards

6.3.1 For the installation of section and distribution boards, the same requirements apply, as far as applicable, as given in [6.1] for the installation of the main switchboard.

7 Cables

7.1 General

7.1.1 Cables having insulating materials with different maximum permissible conductor temperatures are not to be bunched together.

Where this is not practicable, the cables are to be so installed that no cable reaches a temperature higher than its rating.

7.1.2 Cables having a protective covering which may damage the covering of more vulnerable cables are not to be bunched with the latter.

7.1.3 Cables having a bare metallic sheath (e.g. of copper) or braid or armour are to be installed in such a way that galvanic corrosion by contact with other metals is prevented.

7.1.4 All cables and wiring external to equipment are to be so installed as not to impair their original flame-retarding properties. To this end, the following methods may be used:

a) the use of cables in accordance with Ch 2, Sec 9, [2.1.7] or an equivalent standard for cables installed in bunches, or

b) the use of fire stops having at least B-0 penetrations fitted as follows (see Fig 1, Fig 2, Fig 3 and Fig 4):
   - cable entries at the main and emergency switchboard
   - where cables enter engine control rooms
   - cable entries at centralised control panels for propulsion machinery and essential auxiliaries
   - at each end of totally enclosed cable trunks
   - every second deck or approximately 6 metres for vertical runs and every 14 metres for horizontal runs in enclosed and semi-enclosed spaces
   - at the boundaries of the spaces in cargo areas.

The cable penetrations are to be installed in steel plates of at least 3 mm thickness extending all around to twice the largest dimension of the cable run for vertical runs and once for horizontal runs, but need not extend through ceilings, decks, bulkheads or solid sides of trunks. In addition, for cables installed in enclosed and semi-enclosed spaces, a fire protection coating is to be applied at least 1 metre in every 14 metres on horizontal cable runs and over the entire length of vertical cable runs.

These precautions apply in particular to bunches of 5 or more cables in areas with a high fire risk (such as Category A machinery spaces, galleys etc.) and to bunches of more than 10 cables in other areas.

Figure 1 : Totally enclosed trunks

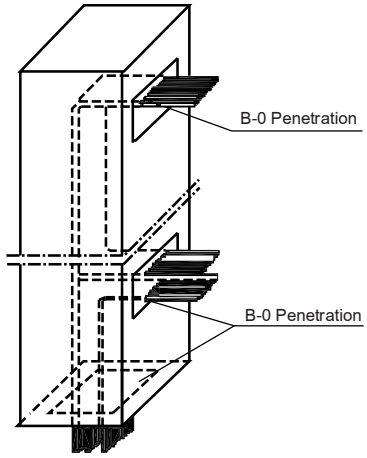


Figure 2 : Non-totally enclosed trunks, vertical

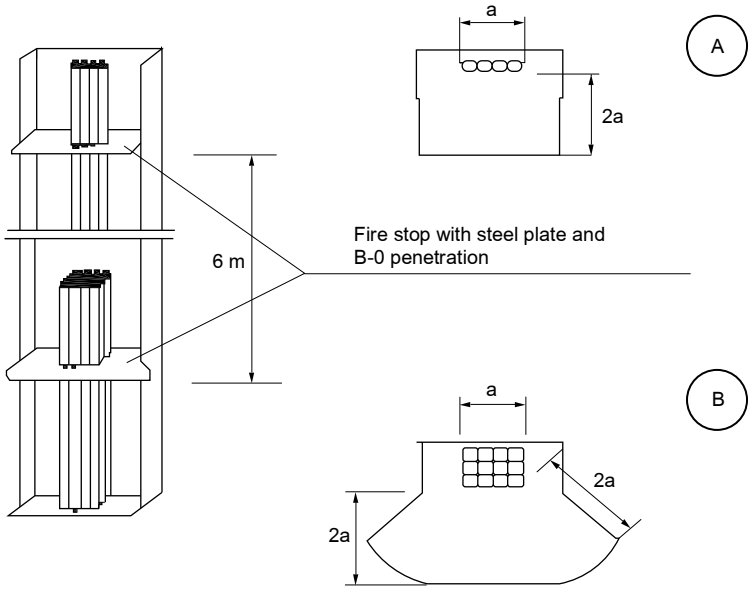


Figure 3 : Non-totally enclosed trunks, horizontal

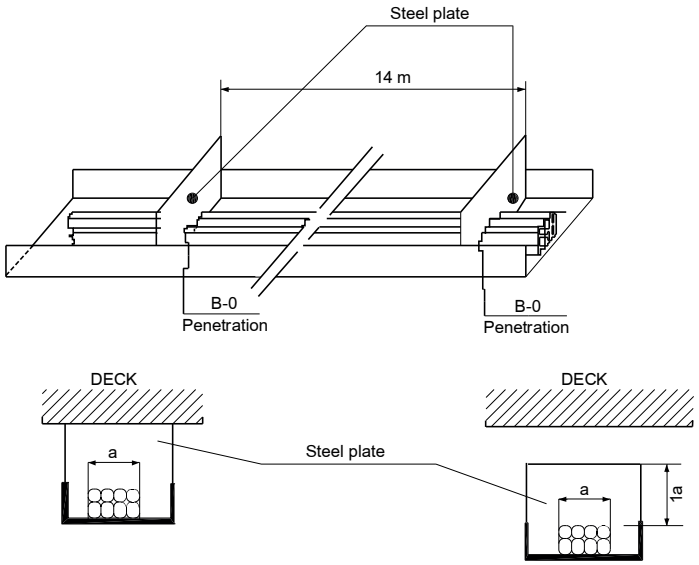
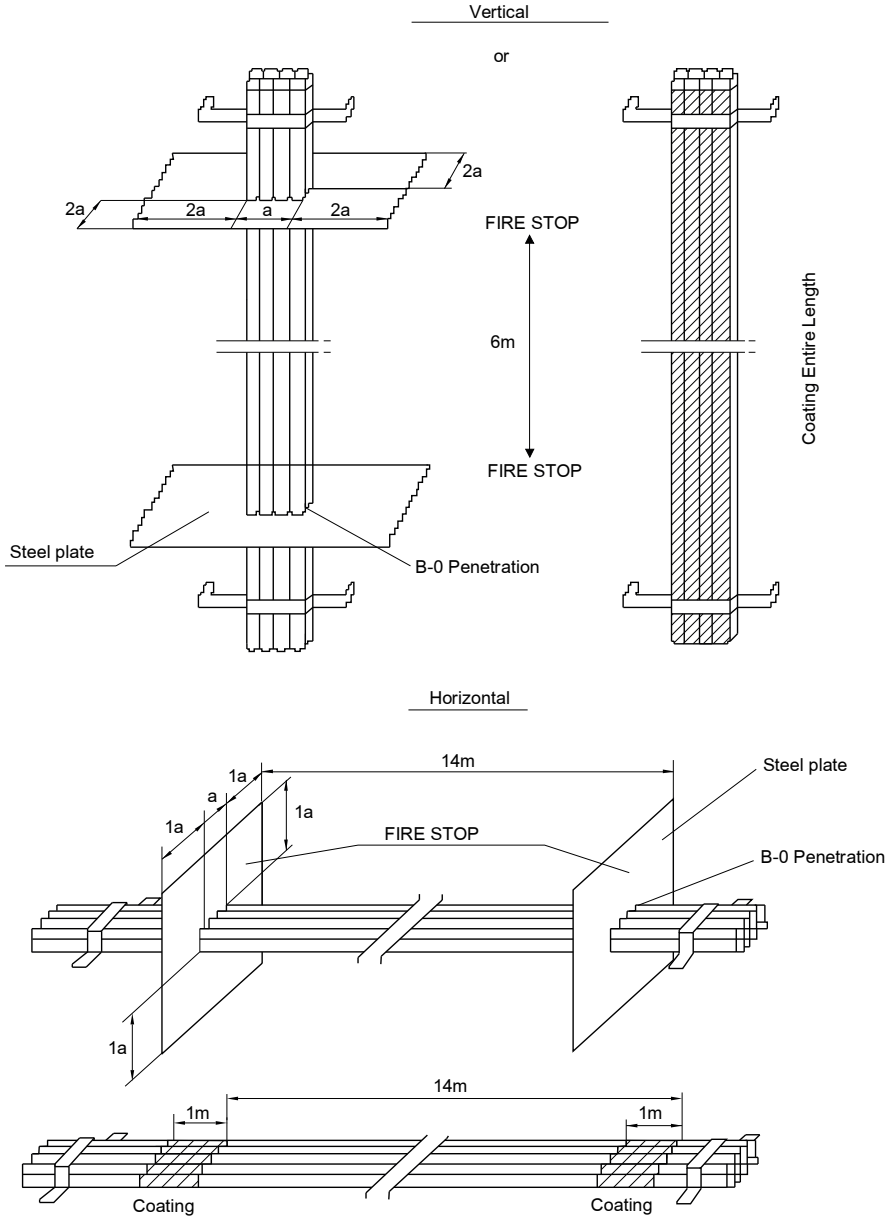


Figure 4 : Open cables runs



7.2 Radius of bend

7.2.1 The internal radius of bend for the installation of cables is to be chosen according to the type of cable as recommended by the manufacturer.

Its value is generally to be not less than the figure given in Tab 2.

7.2.2 Where the installation of cables across expansion joints is unavoidable, the minimum internal radius of the loop at the end of the travel of the expansion joint is to be not less than 12 times the external diameter of the cable.

Table 2 : Bending radii

Cable construction		Overall diameter of cable (D)	Minimum internal radius of bend
Insulation	Outer covering		
Thermoplastic or thermosetting with circular copper conductors	Unarmoured or unbraided	≤ 25 mm	4 D
		> 25 mm	6 D
	Metal braid screened or armoured	Any	6 D
	Metal wire armoured Metal tape armoured or metal-sheathed	Any	6 D
	Composite polyester/metal laminate tape screened units or collective tape screening	Any	8 D
Thermoplastic or thermosetting with shaped copper conductors	Any	Any	8 D

7.3 Fixing of cables

7.3.1 *Cables shall be installed and supported in such a manner as to avoid chafing or other damage.*

7.3.2 The supports (tray plates, separate support brackets or hanger ladders) and the corresponding accessories are to be of robust construction and of corrosion-resistant material or suitably treated before erection to resist corrosion.

When cables are installed directly on aluminium structures, fixing devices of aluminium or suitably treated steel are to be used.

For mineral-insulated cables with copper sheath, fixing devices in contact with the sheath are to be of copper alloy.

7.3.3 With the exception of cables installed in pipes, conduits, trunkings or special casings, cables are to be fixed by means of clips, saddles or straps of suitable material, in order to tighten the cables without their coverings being damaged.

7.3.4 Cable clips or straps made from a material other than metal are to be manufactured of a flame-retardant material.

7.3.5 The distances between fastenings and between supports are to be suitably chosen according to the type and number of cables and the probability of vibration.

7.3.6 When cables are fixed by means of clips or straps made from a material other than metal and these cables are not laid on top of horizontal cable supports (e.g. in the case of vertical installation or suspended cables), suitable metal clips or saddles spaced not more than 2 m apart are to be used in addition in order to prevent the release of cables during a fire.

7.4 Mechanical protection

7.4.1 Cables exposed to risk of mechanical damage are to be protected by metal casing, profiles or grids or enclosed in metal pipes or conduits, unless the cable covering (e.g. armour or sheath) provides adequate mechanical protection.

7.4.2 In situations where there would be an exceptional risk of mechanical damage, e.g. in holds, storage spaces, cargo spaces, etc., cables are to be protected by metal casing, trunkings or conduits, even when armoured, if the ship's structure or attached parts do not afford sufficient protection for the cables.

7.4.3 For the protection of cables passing through decks, see [7.5.3].

7.4.4 Metal casing used for mechanical protection of cables is to be effectively protected against corrosion.

7.5 Penetrations of bulkheads and decks

7.5.1 If cables have to pass without adequate support through non-watertight bulkheads and generally through holes drilled in sheets of structural steel, these holes are to be fitted with glands or bushings of suitable material.

7.5.2 If cables have to pass through a watertight bulkhead or deck, the penetration is to be effected in a watertight manner.

Either suitable individual watertight glands for single cables or boxes containing several cables and filled with a flame-retardant packing may be used for this purpose.

Whichever type of penetration is used, the watertight integrity of the bulkheads or deck is to be maintained.

7.5.3 Cables passing through decks and continuing vertically are to be protected against mechanical damage from deck penetration. All burrs and sharp edges are to be removed in way of the penetration.

Additional mechanical protection is to be provided to a suitable height above deck where the cables are exposed to the risk of mechanical damage.

7.5.4 Where cables pass through bulkheads or decks separating areas with a risk of explosion, arrangements are to be such that hazardous gas or dust cannot penetrate through openings for the passage of cables into other areas.

7.5.5 Where cables pass through a bulkhead or deck which is required to have some degree of fire integrity, penetration is to be so effected as to ensure that the required degree of fire integrity is not impaired.

7.6 Expansion joints

7.6.1 If there is reason to fear that a tray plate, pipe or conduit may break because of the motion of the ship, different load conditions and temperature variations, appropriate expansion joints are to be provided.

This may apply in particular in the case of cable runs on the weather deck.

7.7 Cables in closed pipes or conduits

7.7.1 Closed pipes or conduits are to have such internal dimensions and radius of bend as will permit the easy drawing in and out of the cables which they are to contain; the internal radius of bend is to be not less than that permitted for cables and, for pipes exceeding 63 mm external diameter, not less than twice the external diameter of the pipe where this value is greater.

7.7.2 Closed pipes and conduits are to be suitably smooth on the interior and are to have their ends shaped or bushed in such a way as not to damage the cable covering.

7.7.3 The space factor (ratio of the sum of the cross-sectional areas corresponding to the external diameters of the cables to the internal cross-sectional areas of the pipe or conduit) is to be not greater than 0,4.

7.7.4 If necessary, openings are to be provided at the highest and lowest points so as to permit air circulation and ensure that the heat from the cables can be dissipated, and to obviate the possibility of water accumulating at any part of the pipe or conduit.

7.7.5 Vertical trunking for electrical cables is to be so constructed as not to jeopardise the required passive fire protection between the spaces.

7.7.6 Metal pipes or conduits are to be protected against corrosion.

7.7.7 Non-metallic pipes or conduits are to be flame-retardant.

7.8 Cables in casings or trunking and conduits with removable covers

7.8.1 Covers are to be removable and when they are open, cables are to be accessible.

7.8.2 Materials used are to comply with [7.7.6] and [7.7.7].

7.8.3 If the fixing of covers is by means of screws, the latter are to be of non-rusting material and arranged so as not to damage the cables.

7.8.4 Means are to be provided to ensure that the heat from the cables can be dissipated and water accumulation is avoided (see [7.7.4]).

7.9 Cable ends

7.9.1 Terminations in all conductors are to be so made as to retain the original electrical, mechanical, flame-retarding properties of the cable.

7.9.2 Where mechanical clamps are not used, the ends of all conductors having a cross-sectional area greater than 4 mm^2 are to be fitted with soldering sockets or compression-type sockets of sufficient size to contain all the strands of the conductor.

7.9.3 Cables not having a moisture-resistant insulation (e.g. mineral-insulated) are to have their ends effectively sealed against ingress of moisture.

7.10 Joints and tappings (branch circuit)

7.10.1 Cable runs are normally not to include joints. Where absolutely necessary, cable joints are to be carried out by a junction method with rebuilding of the insulation and protective coverings.

7.10.2 Joints in all conductors are to be so made as to retain the original electrical (continuity and isolation), mechanical (strength and protection), flame-retarding and, where necessary, fire-resisting properties of the cable.

7.10.3 Tappings (branch circuits) are to be made via suitable connections or in suitable boxes of such design that the conductors remain adequately insulated and protected from atmospheric action and are fitted with terminals or busbars of dimensions appropriate to the current rating.

7.10.4 Cables for safety voltages are not to terminate in the same connection boxes as cable for higher voltages unless separated by suitable means.

7.11 Earthing and continuity of metal coverings of cables

7.11.1 All metal coverings of cables are to be electrically connected to the metal hull of the ship.

7.11.2 Metal coverings are generally to be earthed at both ends of the cable, except for [7.11.3] and [7.11.4].

7.11.3 Single-point earthing is admitted for final sub-circuits (at the supply end), except for those circuits located in areas with a risk of explosion.

7.11.4 Earthing is to be at one end only in those installations (mineral-insulated cables, intrinsically safe circuits, control circuits (see Ch 3, Sec 5), etc.) where it is required for technical or safety reasons.

7.11.5 Metal coverings of single-core a.c. cables and special d.c. cables with high "ripple" content (e.g. for thyristor equipment) are to be earthed at one point only (e.g. at the mid-point).

7.11.6 The electrical continuity of all metal coverings of cables throughout the length of the latter, particularly at joints and tappings, is to be ensured.

7.11.7 The metal covering of cables may be earthed by means of glands intended for the purpose and so designed as to ensure an effective earth connection.

The glands are to be firmly attached to, and in effective electrical contact with, a metal structure earthed in accordance with these requirements.

7.11.8 The metal covering of cables may also be earthed by means of clamps or clips of corrosion-resistant material making effective contact with the covering and earthed metal.

7.12 Earthing and continuity of metal pipes, conduits and trunking or casings

7.12.1 Metal casings, pipes, conduits and trunking are to be effectively earthed.

7.12.2 Pipes or conduits may be earthed by being screwed into a metal enclosure, or by nuts on both sides of the wall of a metallic enclosure, provided the surfaces in contact are clean and free from rust, scale or paint and that the enclosure is in accordance with these requirements on earthing.

The connection is to be painted immediately after assembly in order to inhibit corrosion.

7.12.3 Pipes and conduits may be earthed by means of clamps or clips of corrosion-resistant metal making effective contact with the earthed metal.

7.12.4 Pipes, conduits or trunking together with connection boxes of metallic material are to be electrically continuous.

7.12.5 All joints in metal pipes and conduits used for earth continuity are to be soundly made and protected, where necessary, against corrosion.

7.12.6 Individual short lengths of pipes or conduits need not be earthed.

7.12.7 The connections to earth are to have a resistance less than 0,1 Ω.

7.13 Precautions for single-core cables for a.c.

7.13.1 For the earthing of metal coverings see [7.11.5].

7.13.2 Single-core cables are to be firmly fixed, using supports of strength sufficient to withstand forces corresponding to the expected short-circuit currents at the point of installation.

7.13.3 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A, the requirements of [7.13.4] to [7.13.8] are to be complied with.

7.13.4 Conductors belonging to the same circuit are to be contained within the same pipe, conduit or trunking, unless this is of non-magnetic material.

7.13.5 Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

7.13.6 In the installation of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits, or three-phase and neutral circuits, the cables are to be in contact with one another, as far as possible. In any event, the distance between the external covering of two adjacent cables is to be not greater than one diameter.

7.13.7 When single-core cables having a current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.13.8 Magnetic material is not to be used between single-core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is to be no less than 75 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.14 Cables in refrigerated spaces

7.14.1 For the types of cables permitted in refrigerated spaces, see Ch 2, Sec 3, [9.4].

7.14.2 Power cables installed in refrigerated spaces are not to be covered by thermal insulation. Moreover, such cables are not to be placed directly on the face of the refrigerated space unless they have a thermoplastic or elastomeric extruded sheath.

7.14.3 Power cables entering a refrigerated space are to pass through the walls and thermal insulation at right angles, in tubes sealed at each end and protected against oxidation.

7.15 Cables in areas with a risk of explosion

7.15.1 For installation of cables permitted in areas with a risk of explosion, see Ch 2, Sec 3, [10.5].

7.15.2 For penetration of bulkheads or decks separating areas with a risk of explosion, see [7.5.4].

7.15.3 Terminals of intrinsically safe circuits are to be separated from terminals of non-intrinsically safe circuits by a physical distance of at least 50 mm, or by an earthed metallic partition.

7.15.4 In enclosures, unscreened wirings of intrinsically safe circuits are to be separated from non-intrinsically safe circuits by a physical distance of at least 50mm, or by an earthed metallic partition.

7.16 Cables and apparatus for services required to be operable under fire conditions

7.16.1 Cables and apparatus for services required to be operable under fire conditions including their power supplies are to be so arranged that the loss of these services is minimized due to a localized fire at any one area or zone listed in Ch 2, Sec 1, [3.14].

7.17 Cables in the vicinity of radio equipment

7.17.1 All cables between antennas and transmitters are not to be routed along with any other cable except when mitigation measures are taken in accordance with Annex B of IEC 60533:2015.

7.17.2 Where it is necessary to use single-core cables, the arrangement of conductors is to be such as to avoid complete or partial loops.

7.18 Cables for submerged bilge pumps

7.18.1 See Ch 2, Sec 3, [9.7].

7.19 Cable trays/protective casings made of plastics materials

7.19.1 Cable trays or protective casings made of plastics materials (thermoplastic or thermosetting plastic materials) are to be case-by-case approved or type-approved in accordance with IACS recommendation No. 73 rev.3.

7.19.2 Cable trays/protective casings are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing injury to personnel and/or an obstruction to any escape route.

When used on open deck, they are to be protected against U.V. light.

7.19.3 The load on the cable trays/ protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the manufacturer recommendations nor in excess of spacing at SWL test. In general, the spacing is not to exceed 2 meters.

7.19.4 The selection and spacing of cable tray/protective casing supports are to take into account:

- cable trays/protective casings' dimensions
- mechanical and physical properties of their material
- mass of cable trays/protective casings
- loads due weight of cables, external forces, thrust forces and vibrations
- maximum accelerations to which the system may be subjected
- combination of loads.

7.19.5 The sum of the cables total cross-sectional area, based on the cables external diameter is not to exceed 40% of the protective casing internal cross-sectional area. This does not apply to a single cable in a protective casing.

7.20 Cables in environmentally controlled spaces

7.20.1 Cables feeding electrical equipment located in environmentally controlled spaces are to comply with Ch 2, Sec 11, [1.3.2].

8 Various appliances

8.1 Lighting fittings

8.1.1 Lighting fittings are to be so arranged as to prevent temperature rises which could damage the cables and wiring.

Note 1: Where the temperature of terminals of lighting fittings exceeds the maximum conductor temperature permitted for the supplied cable (see Ch 2, Sec 3, [9.9]), special installation arrangements, such as terminal boxes thermally insulated from the light source, are to be provided.

8.1.2 Lighting fittings are to be so arranged as to prevent surrounding material from becoming excessively hot.

8.1.3 Lighting fittings are to be secured in place such that they cannot be displaced by the motion of the vessel.

8.1.4 Emergency lights are to be marked for easy identification.

8.2 Heating appliances

8.2.1 Space heaters are to be so installed that clothing, bedding and other flammable material cannot come in contact with them in such a manner as to cause risk of fire.

Note 1: To this end, for example, hooks or other devices for hanging garments are not to be fitted above space heaters or, where appropriate, a perforated plate of incombustible material is to be mounted above each heater, slanted to prevent hanging anything on the heater itself.

8.2.2 Space heaters are to be so installed that there is no risk of excessive heating of the bulkheads or decks on which or next to which they are mounted.

8.2.3 Combustible materials in the vicinity of space heaters are to be protected by suitable incombustible and thermal-insulating materials.

8.3 Heating cables and tapes or other heating elements

8.3.1 Heating cables and tapes or other heating elements are not to be installed in contact with combustible materials. Where they are installed close to such materials, they are to be separated by means of a non-flammable material.

Section 13 High-voltage Installations

1 General

1.1 Field of application

1.1.1 The following requirements apply to a.c. three-phase systems with nominal voltage exceeding 1kV, the nominal voltage being the voltage between phases.

If not otherwise stated herein, construction and installation applicable to low-voltage equipment stated in Part C, Chapter 2 generally apply to high-voltage equipment.

1.2 Nominal system voltage

1.2.1 The nominal system voltage is not to exceed 15 kV.

Note 1: Where necessary for special application, higher voltages may be accepted by the Society.

1.3 High-voltage, low-voltage segregation

1.3.1 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low-voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low-voltage equipment is obtained without danger.

2 System design

2.1 Distribution

2.1.1 It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Services which are duplicated are to be divided between the sections.

2.1.2 In the event of an earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.

It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energised mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.

2.1.3 Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.

2.1.4 In systems with neutral earthed, connection of the neutral to the hull is to be provided for each section.

2.1.5 Alternators running in parallel may have a common neutral connection to earth provided they are suitably designed to avoid excessive circulating currents.

This is particularly important if the alternators are of different size and make. Alternators in which the third harmonic content does not exceed 5% may be considered adequate.

Note 1: This would mostly occur with a neutral bus with a single grounding resistor with the associated neutral switching. Where individual resistors are used, circulation of the third harmonic currents between paralleled alternators is minimised.

2.1.6 In systems with earthed neutral, resistors or other current-limiting devices for the connection of the neutrals to the hull are to be provided for each section in which the systems are split [2.1.2].

2.2 Degrees of protection

2.2.1 Each part of the electrical installation is to be provided with a degree of protection appropriate to the location, as a minimum the requirements of IEC 60092-201.

2.2.2 The degree of protection of enclosures of rotating electrical machines is to be at least IP 23.

The degree of protection of terminals is to be at least IP 44.

For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP 4X is required.

2.2.3 The degree of protection of enclosures of transformers is to be at least IP 23.

For transformers installed in spaces accessible to unqualified personnel, a degree of protection of at least IP 4X is required.

For transformers not contained in enclosures, see [7.1].

2.2.4 The degree of protection of metal enclosed switchgear, controlgear assemblies and static converters is to be at least IP 32. For switchgear, control gear assemblies and static converters installed in spaces accessible to unqualified personnel, a degree of protection of at least IP 4X is required.

2.3 Insulation

2.3.1 In general, for non type tested equipment phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are to be not less than those specified in Tab 1.

Intermediate values may be accepted for nominal voltages, provided that the next higher air clearance is observed.

In the case of smaller distances, an appropriate voltage impulse test is to be applied.

Table 1 : Minimum clearances

Nominal voltage (kV)	Highest voltage for equipment (kV)	Minimum air clearance (mm)
3 - 3,3	3.6	55
6 - 6,6	7.2	90
10 - 11	12	120
15	17.5	160

2.3.2 Creepage distances between live parts and between live parts and earthed metal parts are to be in accordance with IEC 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.

2.4 Protection

2.4.1 Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and to automatically de-excite the generator.

In distribution systems with a neutral earthed, phase-to-earth faults are also to be treated as above.

2.4.2 Any earth fault in the system is to be indicated by means of a visual and audible alarm.

In low impedance or direct earthed systems provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems, where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase-to-phase voltage.

A system is defined effectively earthed (low impedance) when this factor is lower than 0,8. A system is defined non-effectively earthed (high impedance) when this factor is higher than 0,8.

Note 1: Earthing factor is defined as the ratio between the phase-to-earth voltage of the health phase and the phase-to-phase voltage. This factor may vary between $1/3^{1/2}$ and 1.

2.4.3 Power transformers are to be provided with overload and short circuit protection.

When transformers are connected in parallel, tripping of the protective devices on the primary side is to automatically trip the switch connected on the secondary side.

2.4.4 Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

2.4.5 Fuses are not to be used for overload protection.

2.4.6 Lower voltage systems supplied through transformers from high-voltage systems are to be protected against overvoltages. This may be achieved by:

a) direct earthing of the lower voltage system

b) appropriate neutral voltage limiters

c) earthed screen between the primary and secondary windings of transformers.

3 Rotating machinery

3.1 Stator windings of generators

3.1.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

3.2 Temperature detectors

3.2.1 Rotating machinery is to be provided with temperature detectors in its stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.

If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

3.3 Tests

3.3.1 In addition to the tests normally required for rotating machinery, a high-voltage test in accordance with IEC 60034-15 is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

4 Power transformers

4.1 General

4.1.1 Dry type transformers are to comply with IEC 60076-11.

Liquid cooled transformers are to comply with the applicable parts of the IEC 60076 series.

Oil immersed transformers are to be provided with the following alarms and protection:

- liquid level (Low) - alarm
- liquid temperature (High) - alarm
- liquid level (Low) - trip or load reduction
- liquid temperature (High) - trip or load reduction
- gas pressure relay (High) - trip.

5 Cables

5.1 General

5.1.1 Cables are to be constructed in accordance with IEC 60092-353 and 60092-354 or other equivalent Standard.

6 Switchgear and controlgear assemblies

6.1 General

6.1.1 Switchgear and controlgear assemblies are to be constructed in accordance with IEC 62271-200 and the following additional requirements.

6.2 Construction

6.2.1 Switchgear is to be of metal-enclosed type in accordance with IEC 62271-200 or of the insulation-enclosed type in accordance with IEC 62271-201.

6.2.2 Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

6.2.3 The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.

Shutters are to be clearly marked for incoming and outgoing circuits. This may be achieved with the used of colours or labels.

6.2.4 For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked on in safety.

6.2.5 Switchgear and controlgear assemblies are to be internal arc classified (IAC).

Where swichgear and controlgear are accessible by authorized personnel only, Accessibility Type A is sufficient (IEC 62271-200 Annex AA 2.2). Accessibility Type B is required if accessible by non-authorised personnel.

Installation and location of the switchgear and controlgear is to correspond with its internal arc classification and classified sides (F, L and R)

6.3 Auxiliary systems

6.3.1 If electrical energy and/or physical energy is required for the operation of circuit-breakers and switches, a store supply of such energy is to be provided for at least two operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

6.3.2 When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more than one generator set and/or a main switchboard section as described in [2.1.1] and/or set of essential services.

Where necessary one source of supply is to be from the emergency source of electrical power for the start up from dead ship condition.

6.4 High-voltage test

6.4.1 A power-frequency voltage test is to be carried out on any switchgear and controlgear assemblies. The test voltage is to be applied for at least 1 minute and is to be as given in Tab 2.

Table 2 : Test voltages for high-voltage assemblies

Nominal voltage (kV)	Highest voltage for equipment (kV)	Test voltage a.c. (r.m.s.) (kV)
3 - 3,3	3,6	10
6 - 6,6	7,2	20
10 - 11	12,0	28
15	17,5	38

7 Installation

7.1 Electrical equipment

7.1.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance to spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed indicating danger of high-voltage. As regards high-voltage electrical equipment installed outside the aforementioned spaces, similar marking is to be provided.

An adequate, unobstructed working space is to be left in the vicinity of high-voltage equipment for preventing potential severe injuries to personnel performing maintenance activities. In addition, the clearance between the switchboard and the ceiling / deckhead above is to meet the requirements of the Internal Arc Classification according to IEC 62271-200. See [6.2.5].

7.2 Cables

7.2.1 In accommodation spaces, high-voltage cables are to be run in enclosed cable transit systems.

7.2.2 High-voltage cables are to be segregated from cables operating at different voltage ratings; in particular, they are not to be run in the same cable bunch, in the same ducts or pipes, or in the same box.

Where high-voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in [2.3.1]. However, high-voltage cables are not to be installed on the same cable tray for cables operating at the nominal system voltage of 1 kV and less.

7.2.3 High-voltage cables are generally to be installed on cable trays when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise, they are to be installed for their entire length in metallic castings effectively bonded to earth.

7.2.4 Terminations in all conductors of high-voltage cables are, as far as practicable, to be effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials.

High-voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc.).

7.2.5 High-voltage cables are to be readily identifiable by suitable marking.

7.2.6 Before a new high-voltage cable installation, or an addition to an existing installation, is put into service, a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories.

The test is to be carried out after an insulation resistance test.

For cables with rated voltage (Uo/U) above 1,8/3 kV (Um = 3,6 kV) an a.c. voltage withstand test may be carried out upon advice from high-voltage cable manufacturer. One of the following test is to be used:

- test for 5 minutes with the phase to phase voltage of the system applied between the conductor and the metallic screan/sheath
- test for 24 hours with the normal operating voltage of the system. Alternatively, a d.c. test voltage equal to 4 Uo may be applied for 15 minutes.

For cables with rated voltage (Uo/U) up to 1,8/3 kV (Um = 3,6 kV) an d.c. voltage equal to 4 Uo is to be applied for 15 minutes.

7.2.7 After completion of the test, the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge.

An insulation resistance test is then repeated.

Section 14 Electric Propulsion Plant

1 General

1.1 Applicable requirements

1.1.1 The following requirements apply to ships for which the main propulsion plants are provided by at least one electric propulsion motor and its electrical supply. All electrical components of the propulsion plants are to comply with these requirements.

1.1.2 Prime movers are to comply with the requirements of Ch 1, Sec 2.

1.1.3 For the torsional vibration characteristics of the electric propulsion plant, the provisions of Ch 1, Sec 9 apply.

1.1.4 Cooling and lubricating oil systems are to comply with the requirements of Ch 1, Sec 10.

1.1.5 Monitoring and control systems are to comply with the requirements of Part C, Chapter 3.

1.1.6 Installations assigned an additional notation for automation are to comply with the requirements of Part F, Chapter 3 and Part F, Chapter 4.

1.2 Operating conditions

1.2.1 The normal torque available on the electric propulsion motors for manoeuvring is to be such as to enable the vessel to be stopped or reversed when sailing at its maximum service speed.

1.2.2 Adequate torque margin is to be provided for three-phase synchronous motors to avoid the motor pulling out of synchronism during rough weather and when turning.

1.2.3 Means are to be provided to limit the continuous input to the electric propulsion motor. This value is not to exceed the continuous full load torque for which motor and shafts are designed.

1.2.4 The plant as a whole is to have sufficient overload capacity to provide the torque, power and reactive power needed during starting and manoeuvring conditions.

Locked rotor torque which may be required in relation to the operation of the vessel (e.g. for navigation in ice) is to be considered.

1.2.5 The electric motors and shaftline are to be constructed and installed so that, at any speed reached in service, all the moving components are suitably balanced.

2 Design of the propulsion plant

2.1 General

2.1.1 The electrical power for the propulsion system may be supplied from generating sets, dedicated to the propulsion system, or from a central power generation plant, which supplies the ship's services and electric propulsion.

The minimum configuration of an electric propulsion plant consists of one prime mover, one generator and one electric motor. When the electrical production used for propulsion is independent of the shipboard production, the diesel engines driving the electric generators are to be considered as main engines.

Note 1: When the electric power plant is constituted with 2 generators, the corresponding prime movers are to be considered as main propulsion medium. For electrical propulsion plant fitted with more than 2 generators, they will be considered as auxiliary generators. The corresponding control and monitoring will be considered accordingly.

2.1.2 For plants having only one propulsion motor controlled via a static converter, a standby converter which it is easy to switch over to is to be provided. Double stator windings with one converter for each winding are considered as an alternative solution.

2.1.3 In electric propulsion plants having two or more constant voltage propulsion generating sets, the electrical power for the ship's auxiliary services may be derived from this source. Additional ship's generators for auxiliary services need not be fitted provided that effective propulsion and the services mentioned in Ch 2, Sec 3, [2.2.3] are maintained with any one generating set out of service.

Where transformers are used to supply the ship's auxiliary services, see Ch 2, Sec 5.

2.1.4 Plants having two or more propulsion generators, two or more static converters or two or more motors on one propeller shaft are to be so arranged that any unit may be taken out of service and disconnected electrically, without affecting the operation of the others.

2.2 Power supply

2.2.1 Where the plant is intended exclusively for electric propulsion, voltage variations and maximum voltage are to be maintained within the limits required in Ch 2, Sec 2.

2.2.2 When an energy storage system (ESS) is used to supply the electric propulsion and when this ESS is necessary to maintain the voltage and frequency variations of power supply between the limits of the rules defined in Ch 2, Sec 2 (for instance the peak power load during ice breaking of the pods), the requirements of Pt F, Ch 14, Sec 1 are to be complied with.

2.2.3 In special conditions (e.g. during crash-stop manoeuvres), frequency variations may exceed the limits stipulated in Ch 2, Sec 3 provided that other equipment operating on the same network is not unduly affected.

2.2.4 The electric plant is to be so designed as to prevent the harmful effects of electromagnetic interference generated by semiconductor converters, in accordance with Ch 2, Sec 3.

2.3 Auxiliary machinery

2.3.1 Propeller/thruster auxiliary plants are to be supplied directly from the main switchboard or from the main distribution board or from a distribution board reserved for such circuits, at the auxiliary rated voltage.

2.3.2 When the installation has one or more lubrication systems, devices are to be provided to ensure the monitoring of the lubricating oil return temperature.

2.3.3 Propelling machinery installations with a forced lubrication system are to be provided with alarm devices which will operate in the event of oil pressure loss.

2.4 Electrical Protection

2.4.1 Automatic disconnections of electric propulsion plants which adversely affect the manoeuvrability of the ship are to be restricted to faults liable to cause severe damage to the equipment.

2.4.2 The following protection of converters is to be provided:

- protection against overvoltage in the supply systems to which converters are connected
- protection against overcurrents in semiconductor elements during normal operation
- short-circuit protection.

2.4.3 Overcurrent protective devices in the main circuits are to be set sufficiently high so that there is no possibility of activation due to the overcurrents caused in the course of normal operation, e.g. during manoeuvring or in heavy seas.

2.4.4 Overcurrent protection may be replaced by automatic control systems ensuring that overcurrents do not reach values which may endanger the plant, e.g. by selective tripping or rapid reduction of the magnetic fluxes of the generators and motors.

2.4.5 In the case of propulsion plants supplied by generators in parallel, suitable controls are to ensure that, if one or more generators are disconnected, those remaining are not overloaded by the propulsion motors.

2.4.6 In three-phase systems, phase-balance protective devices are to be provided for the motor circuit which de-excite the generators and motors or disconnect the circuit concerned.

2.5 Excitation of synchronous electric propulsion motor

2.5.1 Each propulsion motor is to have its own exciter.

2.5.2 For plants where only one generator or only one motor is foreseen, each machine is to be provided with a standby exciter, which it is easy to switch over to.

2.5.3 In case of multi-propeller propulsion ships, standby exciter may be omitted, provided failure of one exciter on one electric motor doesn't impair the functionality of the remaining motor.

2.5.4 In excitation circuits, there is to be no overload protection causing the opening of the circuit, except for excitation circuits with semiconductor converters.

2.5.5 Each exciter is to be supplied by a separate feeder.

3 Contruction of rotating machines, semiconductor converters and braking resistors

3.1 Ventilation

3.1.1 Where electrical machines are fitted with an integrated fan and are to be operated at speeds below the rated speed with full load torque, full load current, full load excitation or the like, the design temperature rise is not to be exceeded.

3.1.2 Where electrical machines or converters are force-ventilated, at least two fans, or other suitable arrangements, are to be provided so that limited operation is possible in the event of one fan failing.

3.2 Protection against moisture and condensate

3.2.1 Machines and equipment which may be subject to the accumulation of moisture and condensate are to be provided with effective means of heating. The latter is to be provided for motors above 500 kW, in order to maintain the temperature inside the machine at about 3°C above the ambient temperature.

3.2.2 Provision is to be made to prevent the accumulation of bilge water, which is likely to enter inside the machine.

3.3 Rotating machines

3.3.1 Electrical machines are to be able to withstand the excess speed which may occur during operation of the ship.

3.3.2 The design of rotating machines supplied by static converters is to consider the effects of harmonics.

3.3.3 The winding insulation of electrical machines is to be capable of withstanding the overvoltage which may occur in manoeuvring conditions.

3.3.4 The design of a.c. machines is to be such that they can withstand without damage a sudden short-circuit at their terminals under rated operating conditions.

3.3.5 The obtainable current and voltage of exciters and their supply are to be suitable for the output required during manoeuvring and overcurrent conditions, including short-circuit in the transient period.

3.4 Semiconductor converters

3.4.1 The following limiting repetitive peak voltages U_{RM} are to be used as a base for each semiconductor valve:

- when connected to a supply specifically for propeller drives:
  $U_{RM} = 1,5\ U_P$
- when connected to a common main supply:
  $U_{RM} = 1,8\ U_P$

where

U_P : Peak value of the rated voltage at the input of the semiconductor converter.

3.4.2 For semiconductor converter elements connected in series, the values in [3.4.1] are to be increased by 10%. Equal voltage distribution is to be ensured.

3.4.3 For parallel-connected converter elements, an equal current distribution is to be ensured.

3.4.4 Means are to be provided, where necessary, to limit the effects of the rate of harmonics to the system and to other semiconductor converters. Suitable filters are to be installed to keep the current and voltage within the limits given in Ch 2, Sec 2.

3.4.5 The piping system of the cooling system is to be in accordance with Ch 1, Sec 10.

3.5 Braking resistors

3.5.1 Braking resistors may be provided to absorb excess amounts of regenerated energy and to reduce the speed of the propulsion motor. When provided, each braking resistor is to be tested according to [6.2].

4 Control and monitoring

4.1 General

4.1.1 The control and monitoring systems, including computer based systems, are to be type approved, according to Ch 3, Sec 6.

4.2 Power plant control systems

4.2.1 The power plant control systems are to ensure that adequate propulsion power is available, by means of automatic control systems and/or manual remote control systems.

4.2.2 The automatic control systems are to be such that, in the event of a fault, the propeller speed and direction of thrust do not undergo substantial variations.

4.2.3 Failure of the power plant control system is not to cause complete loss of generated power (i.e. blackout) or loss of propulsion.

4.2.4 The loss of power plant control systems is not to cause variations in the available power; i.e. starting or stopping of generating sets is not to occur as a result.

4.2.5 Where power-aided control (for example with electrical, pneumatic or hydraulic aid) is used for manual operation, failure of such aid is not to result in interruption of power to the propeller. Any such device is to be capable of purely manual local operation.

4.2.6 The control system is to include the following main functions:

- monitoring of the alarms: any event critical for the proper operation of an essential auxiliary or a main element of the installation requiring immediate action to avoid a breakdown is to activate an alarm
- speed or pitch control of the propeller
- shutdown or slow down when necessary.

4.2.7 Where the electric propulsion system is supplied by the main switchboard together with the ship's services, load shedding of the non-essential services and /or power limitation of the electric propulsion is to be provided. An alarm is to be triggered in the event of power limitation or load shedding.

4.2.8 The risk of blackout due to electric propulsion operation is to be eliminated. At the request of the Society, a failure mode and effects analysis is to be carried out to demonstrate the reliability of the system.

4.3 Indicating instruments

4.3.1 In addition to the provisions of Part C, Chapter 3 of the Rules, instruments indicating consumed power and power available for propulsion are to be provided at each propulsion remote control position.

4.3.2 The instruments specified in [4.3.3] and [4.3.4] in relation to the type of plant are to be provided in the main machinery control room.

4.3.3 The following instruments are required for each alternator:

- an ammeter on each phase, or with a selector switch to all phases
- a voltmeter with a selector switch to all phases
- a wattmeter
- a tachometer or frequency meter
- a power factor meter or a var-meter or a field ammeter for each alternator operating in parallel
- a temperature indicator for the stator windings, for each alternator rated above 500 kVA.

4.3.4 The following instruments are required for each a.c. propulsion motor:

- an ammeter on the main circuit
- an embedded temperature sensor for the stator windings of motors rated above 500 kW
- an ammeter on the excitation circuit for each synchronous motor
- a voltmeter for the measurement of the voltage between phases of each motor supplied through a semiconductor frequency converter.

4.3.5 Where a speed measuring system is used for control and indication, the system is to be duplicated with separate sensor circuits and separate power supply.

4.3.6 An ammeter is to be provided on the supply circuit for each propulsion semiconductor bridge.

4.4 Alarm system

4.4.1 An alarm system is to be provided, in accordance with the requirements of Part C, Chapter 3. The system is to give an indication at the control positions when the parameters specified in [4.4] assume abnormal values or any event occurs which can affect the electric propulsion.

4.4.2 Where an alarm system is provided for other essential equipment or installations, the alarms in [4.4.1] may be connected to such system.

4.4.3 Critical alarms for propulsion are to be indicated to the bridge separately.

4.4.4 The following alarms are to be provided, where applicable:

- high temperature of the cooling air of machines and semiconductor converters provided with forced ventilation (see Note 1)
- reduced flow of primary and secondary coolants of machines and semiconductor converters having a closed cooling system with a heat exchanger
- leakage of coolant inside the enclosure of machines and semiconductor converters with liquid-air heat exchangers
- high winding temperature of generators and propulsion motors, where required (see [4.3])
- low lubricating oil pressure of bearings for machines with forced oil lubrication
- tripping of protective devices against overvoltages in semiconductor converters (critical alarm)
- tripping of protection on filter circuits to limit the disturbances due to semiconductor converters
- tripping of protective devices against overcurrents up to and including short-circuit in semiconductor converters (critical alarm)
- voltage unbalance of three-phase a.c. systems supplied by semiconductor frequency converters
- earth fault for the main propulsion circuit (see Note 2)
- earth fault for excitation circuits of propulsion machines (see Note 3).

Note 1: As an alternative to the air temperature of converters or to the airflow, the supply of electrical energy to the ventilator or the temperature of the semiconductors may be monitored.

Note 2: In the case of star connected a.c. generators and motors with neutral points earthed, this device may not detect an earth fault in the entire winding of the machine.

Note 3: This may be omitted in brushless excitation systems and in the excitation circuits of machines rated up to 500 kW. In such cases, lamps, voltmeters or other means are to be provided to detect the insulation status under operating conditions.

4.5 Reduction of power

4.5.1 Power is to be automatically reduced in the following cases:

- low lubricating oil pressure of bearings of propulsion generators and motors
- high winding temperature of propulsion generators and motors
- fan failure in machines and converters provided with forced ventilation, or failure of cooling system
- lack of coolant in machines and semiconductor converters
- load limitation of generators or inadequate available power.

4.5.2 When power is reduced automatically, this is to be indicated at the propulsion control position (critical alarm).

4.5.3 Switching-off of the semiconductors in the event of abnormal service operation is to be provided in accordance with the manufacturer's specification.

5 Installation

5.1 Ventilation of spaces

5.1.1 Loss of ventilation to spaces with forced air cooling is not to cause loss of propulsion. To this end, two sets of ventilation fans are to be provided, one acting as a standby unit for the other. Equivalent arrangements using several independently supplied fans may be considered.

5.2 Cable runs

5.2.1 Instrumentation and control cables are to comply with the requirements of Ch 3, Sec 5 of the Rules.

5.2.2 Where there is more than one propulsion motor, all cables for any one machine are to be run as far as is practicable away from the cables of other machines.

5.2.3 Cables which are connected to the sliprings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manoeuvring.

6 Tests

6.1 Test of rotating machines

6.1.1 The test requirements are to comply with Ch 2, Sec 4.

6.1.2 For rotating machines, such as synchronous generators and synchronous electric motors, of a power of more than 1 MW, a quality plan detailing the different controls during the machine assembly is to be submitted to the Society for approval.

6.1.3 In relation to the evaluation of the temperature rise, it is necessary to consider the supplementary thermal losses induced by harmonic currents in the stator winding. To this end, two methods may be used:

- direct test method, when the electric propulsion motor is being supplied by its own frequency converter, and/or back to back arrangement according to the supplier's facility
- indirect test method as defined in Ch 2, App 1; in this case, a validation of the estimation of the temperature excess due to harmonics is to be documented. A justification based on a computer program calculation may be taken into consideration, provided that validation of such program is demonstrated by previous experience.

6.1.4 Rotating machines used for propulsion or manoeuvring are to be subjected to the tests stated in Ch 2, Sec 4, [5.1.1].

6.2 Test of braking resistors

6.2.1 Each braking resistor is to undergo the following tests after manufacturing:

- visual and mechanical inspection and dimensions check
- ohmic value measurement
- insulation resistance measurement
- dielectric test
- earth continuity check
- cabling verification
- function tests of leakage detector, space heater and thermostat.

7 Specific requirements for PODs

7.1 General

7.1.1 The requirements for the structural part of a POD are specified in Pt B, Ch 12, Sec 1, [11].

7.1.2 When used as steering manoeuvring system, the POD is to comply with the requirements of Ch 1, Sec 14.

7.2 Electrical slip ring assemblies

7.2.1 Electrical slip ring assemblies are to comply with Ch 2, Sec 10, [2.3] and Ch 2, Sec 10, [2.4].

7.3 Electric motor

7.3.1 The thermal losses are dissipated by the liquid cooling of the bulb and by the internal ventilation of the POD. The justification for the evaluation of the heating balance between the sea water and air cooling is to be submitted to the Society.

Note 1: The calculation method used for the evaluation of the cooling system (mainly based on computer programs) is to be documented. The calculation method is to be justified based on the experience of the designer of the system. The results of scale model tests or other methods may be taken into consideration.

7.3.2 Means to adjust the air cooler characteristics are to be provided on board, in order to obtain an acceptable temperature rise of the windings. Such means are to be set following the dock and sea trials.

7.3.3 Vibrations of the electric motor are to be monitored. The alarm set point is to be defined in accordance with the manufacturer recommendation.

7.4 Instrumentation and associated devices

7.4.1 Means are to be provided to transmit the low level signals connected to the sensors located in the POD.

7.5 Additional tests and tests on board

7.5.1 Tests of electric propulsion motors are to be carried out in accordance with Ch 2, Sec 4, and other tests in accordance with Ch 1, Sec 18.

7.5.2 Tests are to be performed to check the validation of the temperature rise calculation.

7.5.3 Tests on board are described in Ch 1, Sec 18, [3.9].

Section 15 Testing

1 General

1.1 Rule application

1.1.1 Before a new installation, or any alteration or addition to an existing installation, is put into service, the electrical equipment is to be tested in accordance with Articles [2], [3] and [4] to the satisfaction of the Surveyor in charge.

1.2 Insulation-testing instruments

1.2.1 Insulation resistance may be measured with an instrument applying a voltage of at least 500 V. The measurement will be taken when the deviation of the measuring device is stabilised.

Note 1: Any electronic devices present in the installation are to be disconnected prior to the test in order to prevent damage.

1.2.2 For high-voltage installation, the measurement is to be taken with an instrument applying a voltage adapted to the rated value and agreed with the Society.

2 Insulation resistance

2.1 Lighting and power circuits

2.1.1 The insulation resistance between all insulated poles (or phases) and earth and, where practicable, between poles (or phases), is to be at least 1 MΩ in ordinary conditions.

The installation may be subdivided to any desired extent and appliances may be disconnected if initial tests give results less than that indicated above.

2.2 Internal communication circuits

2.2.1 Circuits operating at a voltage of 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 MΩ.

2.2.2 Circuits operating at voltages below 50 V are to have an insulation resistance between conductors and between each conductor and earth of at least 0,33 MΩ.

2.2.3 If necessary, any or all appliances connected to the circuit may be disconnected while the test is being conducted.

2.3 Switchboards

2.3.1 The insulation resistance between each busbar and earth and between each insulated busbar and the busbar connected to the other poles (or phases) of each main switchboard, emergency switchboard, section board, etc. is to be not less than 1 MΩ.

2.3.2 The test is to be performed before the switchboard is put into service with all circuit-breakers and switches open, all fuse-links for pilot lamps, earth fault-indicating lamps, voltmeters, etc. removed and voltage coils temporarily disconnected where otherwise damage may result.

2.4 Generators and motors

2.4.1 The insulation resistance of generators and motors, in normal working condition and with all parts in place, is to be measured and recorded.

2.4.2 The test is to be carried out with the machine hot immediately after running with normal load.

2.4.3 The insulation resistance of generator and motor connection cables, field windings and starters is to be at least 1 MΩ.

3 Earth

3.1 Electrical constructions

3.1.1 Tests are to be carried out, by visual inspection or by means of a tester, to verify that all earth-continuity conductors and earthing leads are connected to the frames of apparatus and to the hull, and that in socket-outlets having earthing contacts, these are connected to earth.

3.2 Metal-sheathed cables, metal pipes or conduits

3.2.1 Tests are to be performed, by visual inspection or by means of a tester, to verify that the metal coverings of cables and associated metal pipes, conduits, trunking and casings are electrically continuous and effectively earthed.

4 Operational tests

4.1 Generating sets and their protective devices

4.1.1 Generating sets are to be run at full rated load to verify that the following are satisfactory:

- electrical characteristics
- commutation (if any)
- lubrication
- ventilation
- noise and vibration level.

4.1.2 Suitable load variations are to be applied to verify the satisfactory operation under steady state and transient conditions (see Ch 2, Sec 4, [2]) of:

- voltage regulators
- speed governors.

4.1.3 Generating sets intended to operate in parallel are to be tested over a range of loading up to full load to verify that the following are satisfactory:

- parallel operation
- sharing of the active load
- sharing of the reactive load (for a.c. generators).

Synchronising devices are also to be tested.

4.1.4 The satisfactory operation of the following protective devices is to be verified:

- overspeed protection
- overcurrent protection (see Note 1)
- load-shedding devices
- any other safety devices.

For sets intended to operate in parallel, the correct operation of the following is also to be verified:

- reverse-power protection for a.c. installations (or reverse-current protection for d.c. installations)
- minimum voltage protection.

Note 1: Simulated tests may be used to carry out this check where appropriate.

4.1.5 The satisfactory operation of the emergency source of power and of the transitional source of power, when required, is to be tested. In particular, the automatic starting and the automatic connection to the emergency switchboard, in case of failure of the main source of electrical power, are to be tested.

4.2 Switchgear

4.2.1 All switchgear is to be loaded and, when found necessary by the attending Surveyor, the operation of overcurrent protective devices is to be verified (see Note 1).

Note 1: The workshop test is generally considered sufficient to ensure that such apparatus will perform as required while in operation.

4.2.2 Short-circuit tests may also be required at the discretion of the Society in order to verify the selectivity characteristics of the installation.

4.3 Harmonic filters

4.3.1 The calculation results and the validity of the guidance required in Ch 2, Sec 3, [3.23.2] and Ch 2, Sec 3, [3.23.3] are to be verified by the Surveyor during sea trials.

4.4 Consuming devices

4.4.1 Electrical equipment is to be operated under normal service conditions (though not necessarily at full load or simultaneously) to verify that it is suitable and satisfactory for its purpose.

4.4.2 Motors and their starters are to be tested under normal operating conditions to verify that the following are satisfactory:

- power
- operating characteristics
- commutation (if any)
- speed
- direction of rotation
- alignment.

4.4.3 The remote stops foreseen are to be tested.

4.4.4 Lighting fittings, heating appliances etc. are to be tested under operating conditions to verify that they are suitable and satisfactory for their purposes (with particular regard to the operation of emergency lighting).

4.5 Communication systems

4.5.1 Communication systems, order transmitters and mechanical engine-order telegraphs are to be tested to verify their suitability.

4.6 Installations in areas with a risk of explosion

4.6.1 Installations and the relevant safety certification are to be examined to ensure that they are of a type permitted in the various areas and that the integrity of the protection concept has not been impaired.

4.7 Voltage drop

4.7.1 Where it is deemed necessary by the attending Surveyor, the voltage drop is to be measured to verify that the permissible limits are not exceeded (see Ch 2, Sec 3, [9.11.4]).

4.8 Batteries

4.8.1 The battery autonomy is to be verified on board in accordance with the operating conditions.

4.8.2 The requirements of [4.8.3]] to [4.8.4]apply to:

- Li Ion batteries of capacity above 20kWh
- Li Ion batteries used as emergency source or transitional source
- other batteries covered by the notation **battery system**.

4.8.3 The scope of tests for the battery pack and associated BMS is to include at least:

- proper working of alarms and defaults and related functions and/or interfacing to the other ship systems
- proper working of monitoring systems
- fitting of battery pack arrangement to battery room
- battery capacity and loading duration, at least for the cases mentioned in the ship availability failure analysis
- insulation resistance test
- IP characteristics
- temperature rise test, see Ch 2, Sec 7, [1.7.3].

4.8.4 The scope of tests for the battery room and fire-extinguishing system is to include at least:

- proper working of fire detection
- proper working of dangerous gas detection. This includes testing that detectors were properly positioned to detect dangerous gas concentration in any normal circumstance of operation of the ventilation system.
- proper working of fire-extinguishing system. Gas concentration after fire-extinguishing system operation is to be measured and found high enough to prevent an explosion or stop a fire. Other criteria may be defined or asked for, at the satisfaction of the Society.
- satisfactory accessibility for common maintenance and devices used for battery overhaul, if any.

Appendix 1 Indirect Test Method for Synchronous Machines

1 General

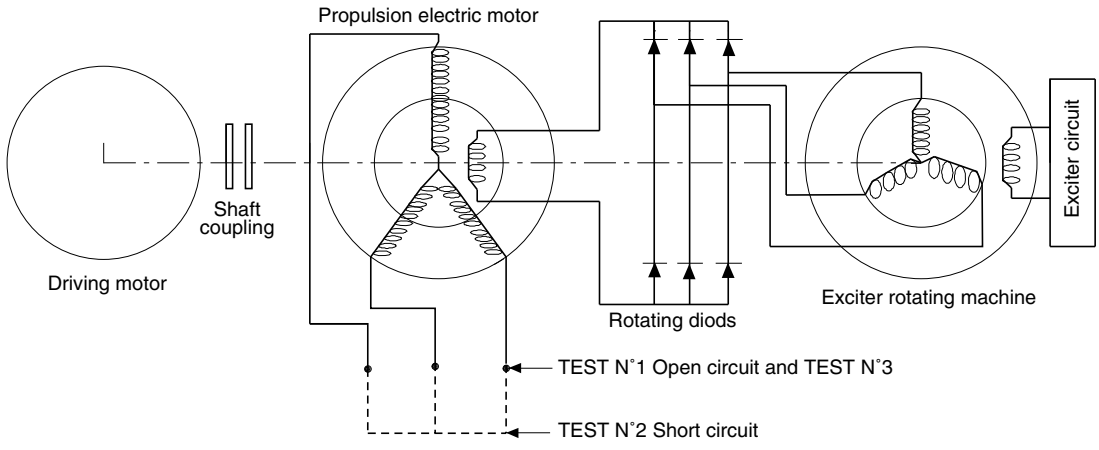
1.1 Test method

1.1.1 The machine is to be subject to the three separate running tests specified below (see Fig 1) when it is complete (with covers, heat exchangers, all control devices and sensors), the exciter circuit is connected to its normal supply or to a separate supply having the same characteristics, and the supply is fitted with the necessary measuring instruments:

- Test N° 1: No load test at rated voltage and current on rotor, stator winding in open circuit. The temperature rise of the stator winding depends, in such case, on the magnetic circuit losses and mechanical losses due to ventilation, where:
  - Δts1 is the stator temperature rise
  - Δtr1 is the rotor temperature rise.
- Test N° 2: Rated stator winding current with the terminals short-circuited. The temperature of the stator winding depends on the thermal Joule losses and mechanical losses, as above, where:
  - Δts2 is the stator temperature rise
  - Δtr2 is the rotor temperature rise, which for test N° 2 is negligible.
- Test N° 3: Zero excitation. The temperature of all windings depends on the mechanical losses due to friction and ventilation, where:
  - Δts3 is the stator temperature rise
  - Δtr3 is the rotor temperature rise.

Note 1: The synchronous electric motor is supplied at its rated speed by a driving motor. The temperature balance will be considered as being obtained, when the temperature rise does not vary by more than 2°C per hour.

Figure 1 : Schematic diagram used for the test



1.1.2 Temperature measurements of the stator winding can be based on the use of embedded temperature sensors or measurement of winding resistance. When using the resistance method for calculation of the temperature rise, the resistance measurement is to be carried out as soon as the machine is shut down.

The rotor temperature rise is obtained by calculation of rotor resistance, Rrotor = U/Ir , where U and I are the voltage and current in the magnetic field winding.

The following parameters are recorded, every 1/2 hour:

- temperature sensors as well as the stator current and voltage
- the main field voltage and current
- the bearing temperatures (embedded sensor or thermometer), and the condition of cooling of the bearings, which are to be compared to those expected on board.

1.1.3 The tests described above allow the determination of the final temperature rise of stator and rotor windings with an acceptable degree of accuracy.

- The temperature rise of the stator winding is estimated as follows:

  $\Delta t \text{ stator} = \Delta ts1 + \Delta ts2 - \Delta ts3$

  Δt stator winding is to be corrected by the supplementary temperature rise due to current harmonics evaluated by the manufacturer
- Considering that in test N° 1 the magnetic field winding current Irt is different from the manufacturer's estimated value Ir (due to the fact that the cos φ in operation is not equal to 1), the temperature rise of the rotor is to be corrected as follows:

  $\Delta t \text{ rotor} = (\Delta tr1 - \Delta tr3) \times (\text{rated loading conditions Ir} / \text{test loading conditions Irt})^2 + \Delta tr3$

1.1.4 In the indirect method, a possible mutual influence of the temperature rise between the stator and the rotor is not taken into consideration. The test results may be representative of the temperature rise on board ship, but a margin of 10 to 15°C is advisable compared with the permitted temperature of the Rules and the measure obtained during tests.

Appendix 2 Indirect Test Method for Induction Machines (Static Torque Method)

1 General

1.1 Test method

1.1.1 The induction machine is to be subject to the three separate tests specified in Tab 1 when it is completely assembled (with covers, heat exchangers, all control devices and sensors).

1.1.2 Temperature measurements of the stator winding is based on the use of embedded temperature sensors. The stator temperature taken into account for the temperature rise is the average of all sensors values.

The following parameters are recorded, every 1/2 hour:

- temperature sensors as well as the stator current and voltage
- bearing temperatures (embedded sensor or thermometer), and the condition of cooling of the bearings, which are to be compared to those expected on board.

1.1.3 The tests described in Tab 1 allow the determination of the final temperature rise of stator windings with an acceptable degree of accuracy.

The stator temperature rise Δt_{stator} is the average of embedded temperature sensors values minus cooling element temperature:

$\Delta t_{stator} = \Delta\theta_1 - \Delta\theta_2 + \Delta\theta_3$

where:

$\Delta\theta_1$: Stator temperature rise of Test 1 defined in Tab 1

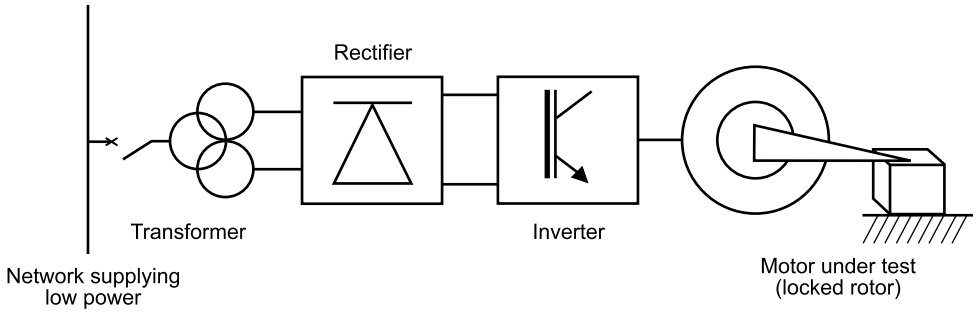
$\Delta\theta_2$: Stator temperature rise of Test 2 defined in Tab 1

$\Delta\theta_3$: Stator temperature rise of Test 3 defined in Tab 1.

Table 1 : Tests for induction machines

Test 1	Test 2	Test 3
Rotor locked (see Fig 1), machine ventilated in normal condition with stator supplied by rated current at reduced voltage and frequency	Rotor running at no-load with stator supplied at the same voltage and frequency as Test 1	Rotor running at no-load at rated speed with stator supplied at rated voltage and rated frequency

Figure 1 : Heating Test 1



CHAPTER 3
AUTOMATION

Section 1 General Requirements

Section 2 Design Requirements

Section 3 Computer Based Systems

Section 4 Constructional Requirements

Section 5 Installation Requirements

Section 6 Testing

Appendix 1 Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment

Section 1 General Requirements

1 General

1.1 Field of application

1.1.1 The following requirements apply to automation systems, installed on all ships, intended for essential services as defined in Ch 2, Sec 1. They also apply to systems required in Part C, Chapter 1 and Part C, Chapter 2, installed on all ships.

1.1.2 This Chapter is intended to avoid that failures or malfunctions of automation systems associated with essential and non-essential services cause danger to other essential services.

1.1.3 Requirements for unattended machinery spaces and for automation additional class notations are specified in Part F, Chapter 3.

1.2 Regulations and standards

1.2.1 The regulations and standards applicable are those defined in Ch 2, Sec 1.

1.3 Definitions

1.3.1 In addition to the following definitions, unless otherwise specified, the terms used in this chapter have the definitions laid down in Ch 2, Sec 1 or in the IEC standards.

1.3.2 Alarm system

Alarm system is a system intended to give a signal in the event of abnormal running condition.

1.3.3 Automatic control

Automatic control is the control of an operation without direct or indirect human intervention, in response to the occurrence of predetermined conditions.

1.3.4 Automation system

Automation systems are systems including control systems and monitoring systems.

1.3.5 Control station

Control station is a group of control and monitoring devices by means of which an operator can control and verify the performance of equipment.

1.3.6 Control system

Control system is a system by which an intentional action is exerted on an apparatus to attain given purposes.

1.3.7 Failure analysis (Fault tree analysis, risk analysis, FMEA or FMECA)

For safety related functions, failure analysis refers to the analysis carried out using appropriate methods, such as:

- fault tree analysis
- risk analysis
- FMEA or FMECA.

The purpose is to demonstrate that for single failures, systems will fail safe and that systems in operation will not be lost or degraded beyond acceptable performance criteria when specified by the Society.

1.3.8 Fail safe

Fail safe is a design property of an item in which the specified failure mode is predominantly in a safe direction with regard to the safety of the ship, as a primary concern.

1.3.9 Local control

Local control is control of an operation at a point on or adjacent to the controlled switching device.

1.3.10 Monitoring system

Monitoring system is a system designed to observe the correct operation of the equipment by detecting incorrect functioning (measure of variables compared with specified value).

1.3.11 Remote control

Remote control is the control from a distance of apparatus by means of an electrical or other link.

1.3.12 Safety system

Safety system is a system intended to limit the consequence of failure and is activated automatically when an abnormal condition appears.

1.3.13 Software

- Application software is a software performing tasks specific to the actual configuration of the computer based system and supported by the basic software
- Basic software is the minimum software, which includes firmware and middleware, required to support the application software.

1.4 General

1.4.1 The automation systems and components, as indicated in Ch 2, Sec 1, [4], are to be of a type approved by the Society according to the applicable requirements of these Rules and in particular those stated in this Chapter and in Ch 2, Sec 15.

Case-by-case approval may also be granted at the discretion of the Society, based on submission of adequate documentation and subject to the satisfactory outcome of any required tests.

1.4.2 *Main and auxiliary machinery essential for the propulsion, control and safety of the ship shall be provided with effective means for its operation and control.*

1.4.3 Control, alarm and safety systems are to be based on the fail safe principle.

1.4.4 Failure of automation systems is to generate an alarm.

1.4.5 Detailed indication, alarm and safety requirements regarding automation systems for individual machinery and installations are to be found in tables located in Part C, Chapter 1 and in Part F, Chapter 3.

Each row of these tables is to correspond to one independent sensor.

2 Documentation

2.1 Documents to be submitted

2.1.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documentation to be submitted

No	I/A **(1)**	Documentation
1	I	General specification for the automation of the ship
2	A	Detailed specification of the essential service systems
3	A	List of components used in the automation circuits, and references (Manufacturer, type, etc.)
4	I	Instruction manuals
5	I	Test procedures for control, alarm and safety systems
6	A	General diagram showing the monitoring and/or control positions for the various installations, with an indication of the means of access and the means of communication between the positions as well as with the engineers
7	A	Diagrams of the supply circuits of automation systems, identifying the power source
8	A	List of monitored parameters for alarm/monitoring and safety systems
9	A	Diagram of the engineers' alarm system
10	I	List of computerized systems as mentioned in Ch 3, Sec 3, [1.6.1]
11	A / I	Documentation as mentioned in Ch 3, Sec 3, Tab 3 and Ch 3, Sec 3, Tab 4
12	I	Change records as mentioned in Ch 3, Sec 3, [6.11]
(1) A = to be submitted for approval; I = to be submitted for information.		

2.2 Documents for type approval of equipment

2.2.1 Documents to be submitted for type approval of equipment are listed hereafter:

- a request for type approval from the manufacturer or his authorized representative
- the technical specification and drawings depicting the system, its components, characteristics, working principle, installation and conditions of use and, when there is a computer based system, the documents listed in Ch 3, Sec 3, Tab 3 and Ch 3, Sec 3, Tab 4.
- any test reports previously prepared by specialized laboratories.

2.2.2 Modifications

Modifications are to be documented by the manufacturer. Subsequent significant modifications to the software and hardware for systems of categories II and III are to be submitted for approval.

Note 1: A significant modification is a modification which influences the functionality and/or the safety of the system.

3 Environmental and supply conditions

3.1 General

3.1.1 General

The automation system is to operate correctly when the power supply is within the range specified in Ch 3, Sec 2.

3.1.2 Environmental conditions

The automation system is to be designed to operate satisfactorily in the environment in which it is located. The environmental conditions are described in Ch 2, Sec 2.

3.1.3 Failure behaviour

The automation system is to have non-critical behaviour in the event of power supply failure, faults or restoration of operating condition following a fault. If a redundant power supply is used, it must be taken from an independent source.

3.2 Power supply conditions

3.2.1 Electrical power supply

The conditions of power supply to be considered are defined in Ch 2, Sec 2.

3.2.2 Pneumatic power supply

For pneumatic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

3.2.3 Hydraulic power supply

For hydraulic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

4 Materials and construction

4.1 General

4.1.1 The choice of materials and components is to be made according to the environmental and operating conditions in order to maintain the proper function of the equipment.

4.1.2 The design and construction of the automation equipment is to take into account the environmental and operating conditions in order to maintain the proper function of the equipment.

Section 2 Design Requirements

1 General

1.1

1.1.1 *All control systems essential for the propulsion, control and safety of the ship shall be independent or designed such that failure of one system does not degrade the performance of another system.*

1.1.2 Controlled systems are to have manual operation.

Failure of any part of such systems shall not prevent the use of the manual override.

1.1.3 Automation systems are to have constant performance.

1.1.4 Safety functions are to be independent of control and monitoring functions.

1.1.5 Control, monitoring and safety systems are to have self-check facilities. In the event of failure, an alarm is to be activated. In particular, failure of the power supply of the automation system is to generate an alarm.

1.1.6 When a computer based system is used for control, alarm or safety systems, it is to comply with the requirements of Ch 3, Sec 3.

1.1.7 The automatic change-over switch is to operate independently of both systems. When change-over occurs, no stop of the installation is necessary and the latter is not to enter undefined or critical states.

1.1.8 Emergency stops are to be hardwired and independent of any computer based system.

Note 1: Computerized systems may be admitted if evidence is given demonstrating they provide a safety level equivalent to a hardwired system.

2 Power supply of automation systems

2.1

2.1.1 Automation systems are to be arranged with an automatic change-over to a continuously available stand-by power supply in case of loss of normal power source.

2.1.2 The capacity of the stand-by power supply is to be sufficient to allow the normal operation of the automation systems for at least half an hour.

2.1.3 Failure of any power supply to an automation system is to generate an audible and visual alarm.

2.1.4 Power supplies are to be protected against short circuit and overload for each independent automation system.

Power supplies are to be isolated.

3 Control systems

3.1 General

3.1.1 In the case of failure, the control systems used for essential services are to remain in the last position they had before the failure, unless otherwise specified by these Rules.

3.2 Local control

3.2.1 Each system is to be able to be operated manually from a position located so as to enable visual control of operation. For detailed instrumentation for each system, refer to Part C, Chapter 1and Part C, Chapter 2.

It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.

Note 1: For electrically driven units in auxiliary services, the local control is normally to be arranged at the motor starter in motor control centers and, if applicable, also near the equipment under control.

3.2.2 Local control systems is to be self-contained and not depend on other systems or external communication links for its intended operation.

3.2.3 When local control is selected, any control signal(s) from the remote control system is to be ignored.

3.3 Remote control systems

3.3.1 When several remote control stations are provided, control of machinery is to be possible at one station at a time. At each location, an indicator showing which location is in control is to be provided.

3.3.2 Remote control is to be provided with the necessary instrumentation, in each remote control station, to allow effective control (correct function of the system, indication of control station in operation, alarm display).

3.3.3 When transferring the control location, no significant alteration of the controlled equipment is to occur. Transfer of control is to be protected by an audible warning and acknowledged by the receiving remote control location. The main remote control location is to be able to take control without acknowledgment.

3.3.4 Failure in remote control systems is not to prevent local operation.

3.4 Automatic control systems

3.4.1 *Automatic starting, operational and control systems shall include provisions for manually overriding the automatic controls.*

3.4.2 Automatic control is to be stable in the range of the controller in normal working conditions.

3.4.3 Automatic control is to have instrumentation to verify the correct function of the system.

3.4.4 For machinery systems which due to their complexity requires continuous automatic control, manual control of the individual Equipment Under Control may not be feasible. In such cases, local means are to be provided to both monitor the concerned process- and to enable/disable any automatic functions / modes (a typical example is the gas supply system to a gas fuelled engine).

4 Control of propulsion machinery

4.1 Application

4.1.1 Ships with restricted navigation notations

The requirements of this article are applicable to all ships except non-propelled units. However, arrangements which are not in compliance with the provisions of this article may be considered for ships with restricted navigation notations.

4.2 Remote control

4.2.1 The requirements mentioned in [3] are to be applied for propulsion machinery.

4.2.2 *The design of the remote control system shall be such that in case of its failure an alarm will be given.*

4.2.3 Supply failure (voltage, fluid pressure, etc.) in propulsion plant remote control is to activate an alarm at the control position. In the event of remote control system failure and unless the Society considers it impracticable, the preset speed and direction of thrust are to be maintained until local control is in operation. This applies in particular in the case of loss of electric, pneumatic or hydraulic supply to the system.

4.2.4 *Propulsion machinery orders from the navigation bridge shall be indicated in the main machinery control room, and at the manoeuvring platform.*

4.2.5 *The control shall be performed by a single control device for each independent propeller, with automatic performance of all associated services, including, where necessary, means of preventing overload of the propulsion machinery. Where multiple propellers are designed to operate simultaneously, they must be controlled by one control device.*

4.2.6 *Indicators shall be fitted on the navigation bridge,* in *the main machinery control room and at the manoeuvring platform, for:*

- *propeller speed and direction of rotation in the case of fixed pitch propellers; and*
- *propeller speed and pitch position in the case of controllable pitch propellers.*

4.2.7 *The main propulsion machinery shall be provided with an emergency stopping device on the navigation bridge which shall be independent of the navigation bridge control system.*

In the event that there is no reaction to an order to stop, provision is to be made for an alternative emergency stop. This emergency stopping device may consist of a simple and clearly marked control device, for example a push-button. This fitting is to be capable of suppressing the propeller thrust, whatever the cause of the failure may be.

4.3 Remote control from navigation bridge

4.3.1 Where propulsion machinery is controlled from the navigation bridge, the remote control is to include an automatic device such that the number of operations to be carried out is reduced and their nature is simplified and such that control is possible in both the ahead and astern directions. Where necessary, means for preventing overload and running in critical speed ranges of the propulsion machinery is to be provided.

4.3.2 On board ships fitted with remote control, direct control of the propulsion machinery is to be provided locally. The local direct control is to be independent from the remote control circuits, and takes over any remote control when in use.

4.3.3 The local control of the propulsion machinery is to continue to operate in the case of failure of any parts of the remote control system or blackout.

4.3.4 *Remote control of the propulsion machinery shall be possible only from one location at a time; at such locations interconnected control positions are permitted. At each location there shall be an indicator showing which location is in control of the propulsion machinery.*

4.3.5 *The transfer of control between the navigation bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room. The system shall include means to prevent the propelling thrust from altering significantly, when transferring control from one location to another.*

4.3.6 At the navigation bridge, the control of the routine manoeuvres for one line of shafting is to be performed by a single control device: a lever, a handwheel or a push-button board. However each mechanism contributing directly to the propulsion, such as the engine, clutch, automatic brake or controllable pitch propeller, is to be able to be individually controlled, either locally or at a central monitoring and control position in the engine room.

4.3.7 Remote starting of the propulsion machinery is to be automatically inhibited if a condition exists which may damage the machinery, e.g. shaft turning gear engaged, drop of lubrication oil pressure or brake engaged.

4.3.8 As a general rule, the navigation bridge panels are not to be overloaded by alarms and indications which are not required.

4.3.9 *Automation systems shall be designed in a manner which ensures that threshold warning of impending or imminent slowdown or shutdown of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems shall control, monitor, report, alert and take safety action to slowdown or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example in the case of overspeed.*

4.4 Remote control from navigation bridge for gas fuelled ship

4.4.1 For ships assigned with additional service feature **LNGfuel**, **CNGfuel**, **LPGfuel** or, as relevant, other additional service features defined in Pt A, Ch 1, Sec 2, [4.16.4], the provisions of NR529, 9.4.3; NR529, 15.5(b); NR529, 15.11.4 and NR529, 15.7 are applicable.

4.5 Automatic control

4.5.1 The requirements in Article [3] are applicable. In addition, the following requirements are to be considered, if relevant.

4.5.2 *Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shutoff arrangements in the case of failures such as lubricating oil supply failure which could lead rapidly to complete breakdown, serious damage or explosion.*

4.5.3 The automatic control system is to be designed on a fail safe basis, and, in the event of failure, the system is to be adjusted automatically to a predetermined safe state.

4.5.4 Operations following any setting of the bridge control device (including reversing from the maximum ahead service speed in case of emergency) are to take place in an automatic sequence and with acceptable time intervals, as prescribed by the manufacturer.

4.5.5 For steam turbines, a slow turning device is to be provided which operates automatically if the turbine is stopped longer than admissible. Discontinuation of this automatic turning from the bridge is to be possible.

Note 1: For attended machinery spaces, the slow turning device may be arranged to be operated manually.

4.6 Automatic control of propulsion and manoeuvring units

4.6.1 When the power source actuating the automatic control of propelling units fails, an alarm is to be triggered. In such case, the preset direction of thrust is to be maintained long enough to allow the intervention of engineers. Failing this, minimum arrangements, such as stopping of the shaft line, are to be provided to prevent any unexpected reverse of the thrust. Such stopping may be automatic or ordered by the operator, following an appropriate indication.

4.7 Clutches

4.7.1 Where the clutch of a propulsion engine is operated electrically, pneumatically or hydraulically, an alarm is to be given at the control station in the event of loss of energy; as far as practicable, this alarm is to be triggered while it is still possible to operate the equipment.

4.7.2 When only one clutch is installed, its control is to be fail safe. Other arrangements may be considered in relation to the configuration of the propulsion machinery.

4.8 Brakes

4.8.1 Automatic or remote controlled braking is to be possible only if:

- propulsion power has been shut off
- the turning gear is disconnected
- the shaftline speed (r.p.m.) is below the threshold stated by the builder.

5 Communications

5.1 Communications between navigation bridge and machinery space

5.1.1 *At least two independent means are to be provided for communicating orders from the navigation bridge to the position in the machinery space or in the control room from which the speed and the direction of the thrust of the propellers are normally controlled; one of these is to be an engine room telegraph, which provides visual indication of the orders and responses both in the machinery space and on the navigation bridge,* with audible alarm mismatch between order and response.

5.1.2 The engine room telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of whether the engine room is attended. An alarm is to be given at the navigation bridge in the event of failure of power supply to the engine room telegraph.

5.1.3 Where the main propulsion system of the ship is controlled from the navigation bridge by a remote control system, the second means of communication may be the same bridge control system.

5.1.4 The second means for communicating orders is to be fed by an independent power supply and is to be independent of other means of communication.

5.1.5 *Appropriate means of communication*, providing for verification of both engine orders and responses, *shall be provided from the navigation bridge and the engine room to any other position from which the speed and direction of thrust of the propellers may be controlled.*

Note 1: This requirement also applies to each local partial control position of the propulsion (e.g. clutches).

5.1.6 For ships assigned with a restricted navigation notation, the requirements of this sub-article may be relaxed at the Society's discretion.

5.2 Engineers’ alarm

5.2.1 *An engineers' alarm shall be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and shall be clearly audible in the engineers' accommodation*

6 Remote control of valves

6.1

6.1.1 The following requirements are applicable to valves whose failure could impair essential services.

6.1.2 Failure of the power supply is not to permit a valve to move to an unsafe condition.

6.1.3 An indication is to be provided at the remote control station showing the actual position of the valve or whether the valve is fully open or fully closed. This indication may be omitted for quick-closing valves.

6.1.4 When valves are remote controlled, a secondary manual means of operating them is to be provided (see Ch 1, Sec 10, [2.7.3]).

7 Alarm system

7.1 General requirements

7.1.1 Alarms are to be visual and audible and are to be clearly distinguishable, in the ambient noise and lighting in the normal position of the personnel, from any other signals.

7.1.2 Sufficient information is to be provided for proper handling of alarms.

7.1.3 The alarm system is to be of the self-check type; failure within the alarm system, including the outside connection, is to activate an alarm. The alarm circuits are to be independent from each other. All alarm circuits are to be protected so as not to endanger each other.

7.2 Alarm functions

7.2.1 Alarm activation

Alarms are to be activated when abnormal conditions appear in the machinery, which need the intervention of personnel on duty, and on the automatic change-over, when standby machines are installed.

An existing alarm is not to prevent the indication of any further fault.

7.2.2 Acknowledgement of alarm

The acknowledgment of an alarm consists in manually silencing the audible signal and additional visual signals (e.g. rotating light signals) while leaving the visual signal on the active control station. Acknowledged alarms are to be clearly distinguishable from unacknowledged alarms. Acknowledgment should not prevent the audible signal to operate for new alarm.

Alarms shall be maintained until they are accepted and visual indications of individual alarms shall remain until the fault has been corrected, when the alarm system shall automatically reset to the normal operating condition.

Acknowledgment of alarms is only to be possible at the active control station.

Alarms, including the detection of transient faults, are to be maintained until acknowledgment of the visual indication.

Acknowledgment of visual signals is to be separate for each signal or common to a limited group of signals. Acknowledgment is only to be possible when the user has visual information on the alarm condition for the signal or all signals in a group.

7.2.3 Inhibition of alarms

Manual inhibition of separate alarms may be accepted when this is clearly indicated.

Inhibition of alarm and safety functions in certain operating modes (e.g. during start-up or trimming) is to be automatically disabled in other modes.

7.2.4 Time delay of alarms

It is to be possible to delay alarm activation in order to avoid false alarms due to normal transient conditions (e.g. during start-up or trimming).

7.2.5 Transfer of responsibility

Where several alarm control stations located in different spaces are provided, responsibility for alarms is not to be transferred before being acknowledged by the receiving location. Transfer of responsibility is to give an audible warning. At each control station it is to be indicated which location is in charge.

8 Safety system

8.1 Design

8.1.1 System failures

A safety system is to be designed so as to limit the consequence of failures. It is to be constructed on the fail safe principle.

The safety system is to be of the self-check type; as a rule, failure within the safety system, including the outside connection, is to activate an alarm.

8.2 Function

8.2.1 Safety activation

The safety system is to be activated automatically in the event of identified conditions which could lead to damage of associated machinery or systems, such that:

- normal operating conditions are restored (e.g. by the starting of the standby unit), or
- the operation of the machinery is temporarily adjusted to the prevailing abnormal conditions (e.g. by reducing the output of the associated machinery), or
- the machinery is protected, as far as possible, from critical conditions by shutting off the fuel or power supply, thereby stopping the machinery (shutdown), or appropriate shutdown.

8.2.2 Safety indication

When the safety system has been activated, it is to be possible to trace the cause of the safety action. This is to be accomplished by means of a central or local indication.

When a safety system is made inoperative by a manual override, this is to be clearly indicated at corresponding control stations.

Override of safety functions in certain operating modes (e;g; during start-up or trimming) is to be automatically disabled in other modes

Automatic safety actions are to activate an alarm at predefined control stations.

8.3 Shutdown

8.3.1 For shutdown systems of machinery, the following requirements are to be applied:

- when the system has stopped a machine, the latter is not to be restarted automatically before a manual reset of the safety system has been carried out
- the shutdown of the propulsion system is to be limited to those cases which could lead to serious damage, complete breakdown or explosion.

8.4 Standby systems

8.4.1 For the automatic starting system of the standby units, the following requirements are to be applied:

- faults in the electrical or mechanical system of the running machinery are not to prevent the standby machinery from being automatically started
- when a machine is on standby, ready to be automatically started, this is to be clearly indicated at its control position
- the change-over to the standby unit is to be indicated by a visual and audible alarm
- means are to be provided close to the machine, to prevent undesired automatic or remote starting (e.g. when the machine is being repaired)
- automatic starting is to be prevented when conditions are present which could endanger the standby machine.

8.5 Testing

8.5.1 The safety systems are to be tested in accordance with the requirements in Ch 3, Sec 6.

Section 3 Computer Based Systems

1 General requirements

1.1 Scope

1.1.1 This Section applies to design, construction, commissioning and maintenance of computer-based systems where they depend on software for the proper achievement of their functions.

The requirements of Articles [2] to [7] apply to systems which provide control, alarm, monitoring, safety, or internal ship communication functions that are subject to classification requirements.

1.1.2 The additional requirements of Article [8] are to be complied with for ships assigned the additional service feature **SW-Registry**.

1.2 Exclusion

1.2.1 Computer-based systems that are covered by statutory regulations are excluded from the requirements of this Section.

Note 1: Examples of such systems are navigation systems and radio communication system required by SOLAS chapter V and IV.

Note 2: For loading instrument/stability computer, see Pt B, Ch 1, Sec 5, [3].

1.3 References

1.3.1 Applicable Rules

For the purposes of this Section:

- Reference is made to Ch 3, Sec 6, [2] for test specification for type approval
- Reference is made to NR659 for cyber security assessment of ships, systems and equipment.

Note 1: NR659 Rules on Cyber Security for the Classification of Marine Units

1.3.2 Informative standards

For the purposes of this Section, the following standards are listed for information and may be used for the development of hardware/software of computer-based systems:

- IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems
- ISO/IEC 12207:2017 Systems and software engineering – Software life cycle processes
- ISO 9001:2015 Quality Management Systems – Requirements
- ISO/IEC 90003:2018 Software engineering - Guidelines for the application of ISO 9001:2015 to computer software
- IEC 60092-504:2016 Electrical installations in ships - Part 504: Special features - Control and instrumentation
- ISO/IEC 25000:2014 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE
- ISO/IEC 25041:2012 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators
- IEC 61511:2016 Functional safety - Safety instrumented systems for the process industry sector
- ISO/IEC 15288:2015 Systems and software engineering - System life cycle process
- ISO 90007:2017 Quality management – Guidelines for configuration management
- ISO 24060:2021 Ships and marine technology - Ship software logging system for operational technology.

Note 1: Other industry standards may also be considered.

1.4 Structure

1.4.1 The general certification requirements for computer-based systems and the relation to type approval is described in [2].

1.4.2 The requirements and extent of verification of a computer-based system depends on its categorization into one of three categories. The categories are described in [3].

1.4.3 The requirements of this Section cover the lifecycle of computer-based system from design through operations. The requirements are split into groups representing the different phases of the life cycle and the roles responsible for fulfilling the requirements.

1.4.4 The activities related to the development and delivery of a computer-based system are described in [4].

1.4.5 The activities related to the maintenance in the operational phase are described in [5].

1.4.6 Management of changes to software and systems is described in [6].

1.4.7 The technical requirements on computer-based systems have been gathered in [7].

1.4.8 Each activity contains a requirement part which describes the minimum requirements on the role in question, and a part which describes the Society's verification of the activity in question.

1.5 Definition of abbreviations and terminology

1.5.1 Abbreviations are given in Tab 1. Terminology is given in Tab 2.

Table 1 : Abbreviations

Abbreviation	Expansion
Cat I	Category one systems as defined in [3.1]
Cat II	Category two systems as defined in [3.1]
Cat III	Category three systems as defined in [3.1]
COTS	Commercial off-the-shelf
FAT	Factory acceptance test
FMEA	Failure mode and effect analysis

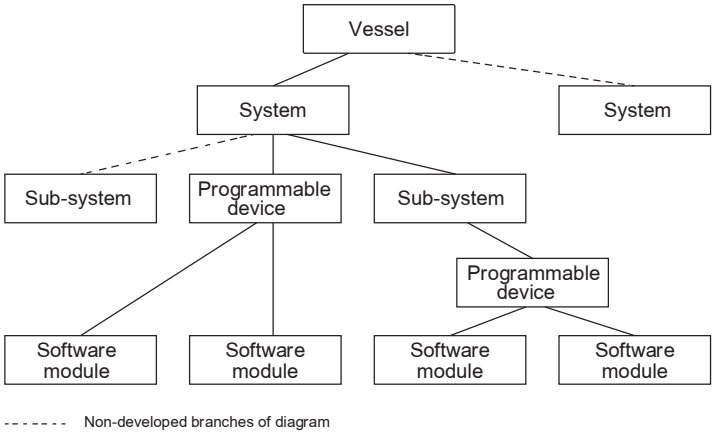
Abbreviation	Expansion
IT	Information technology
OT	Operational technology
PMS	Planned maintenance system
SAT	System acceptance test
SOST	System of systems test
SSLS	Ship software logging system

Table 2 : Terminology

Term	Definition
Black-box description	A description of a system's functionality and behaviour and performance as observed from outside the system in question
Black-box test methods	Verification of the functionality, performance, and robustness of a system, sub-system or component by only manipulating the inputs and observing the outputs. This does not require any knowledge of the system's inner workings and focuses only on the observable behaviour of the system or component under test in order to achieve the desired level of verification
Computer-based system (CBS)	A programmable electronic device, or interoperable set of programmable electronic devices, organised to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBSs on board include IT and OT systems. A CBS may be a combination of subsystems connected via network. Onboard CBSs may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other ships' CBSs and/or other facilities
Data communication link	Data communication link includes point to point links, instrument net and local area networks, normally used for inter-computer communication on board units. The software and hardware which support the data communication are also included
Failure mode description	A document describing the effects due to failures in the system, excluding the failures in the equipment supported by the system. The following aspects are to be covered: • list of failures which are subject to assessment • description of the system response to each of these failures • comments to the consequence of each of these failures
Local Area Network (LAN)	Physical or virtual computer network that interconnects devices within a limited area (e.g. machinery room, ship)
Media Access Control (MAC)	A media access control address of a device is a unique identifier assigned to network interfaces for communications at the data link layer of a network segment
Network communication device	A computer based equipment, ensuring service or function for the communication devices of the ship, who handles, manages and routes packets over the networks
Parameterisation	An action of configuring and tuning system and software functionality by changing parameters. It does not usually require computer programming and is normally done by the System Supplier or a Service Provider, not the operator or end-user.
Programmable device	Physical component where software is installed
Robustness	The ability to respond to abnormal inputs and conditions

Term	Definition
Service Supplier	A person or company, not employed by the Society, who at the request of an equipment manufacturer, shipyard, ship's owner or other client acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services
Simulation test	Monitoring, control, or safety system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools
Society Certificate	Compliance document issued by the Society stating: • conformity with applicable rules and requirements • that the tests and inspections have been carried out on the finished certified component itself, or on samples taken from earlier stages in the production of the component, when applicable • that the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements, i.e. Alternative Survey Scheme (BV Mode I) as per NR320, Sec 3.
Software component	A standalone piece of code that provides specific and closely coupled functionality
Software master files	The computer-files that constitute the original source of the software. For custom made software, this may be readable source- code files, and, for COTS software, it may be different forms of binary files
Software-structure	Overview of how the different software components interact and is commonly referred to as the Software Architecture, or Software Hierarchy. Fig 1 shows the hierarchy and relationships of a typical computer based system
Sub-system	Identifiable part of a system, which may perform a specific function or set of functions
Supplier	A generic term used for any organisation or person that is a contracted or a subcontracted provider of services, system components, or software
System	A combination of components, equipment and logic which has a defined purpose, functionality, and performance. In the context of this Section, a specific system is delivered by one System Supplier
System of systems	A system which is made up of several systems. In the context of this Section, the system of systems encompasses all monitoring, control and safety systems delivered from the Shipyard as a part of a ship
System Supplier	An organisation or person who is a contracted or a subcontracted provider of system components or software under the coordination of the Systems Integrator. In the context of this Section this is a defined role with specific responsibilities.
Systems Integrator	Single organisation or a person coordinating interaction between Suppliers of systems and sub-systems on all stages of life cycle of computer-based systems in order to integrate them into a verified ship-wide system of systems and to provide proper operation and maintenance of the computer-based systems. In the context of this Section this is a defined role with specific responsibilities. During the design and delivery phase the Shipyard is the default Systems Integrator, during operations phase the Owner is the default Systems Integrator
Type approval Certificate	Compliance document issued by the Society by which the Society declares that a product design meets a set of technical requirements
Virtual Local Area Network (VLAN)	A VLAN is a custom network created from one or more existing LANs. It enables groups of devices from multiple networks (both wired and wireless) to be combined into a single logical network. The result is a virtual LAN that can be administered like a physical LAN

Figure 1 : Illustrative system hierarchy



1.6 Documentation to be submitted

1.6.1 List of computerised systems covered by this Section as described in [1.1.1] are to be submitted to the Society as soon as possible during design stage of the ship. This list is to include:

- designation of system involved
- category of system according to [3.1]
- manufacturer of system (if available)
- supplier of control system (if available).

Tab 3 and Tab 4 summarise the documentation to be submitted to the Society.

1.6.2 The user interface description submitted as a part of the system description mentioned in Tab 3 is to contain:

- a description of the functions allocated to each operator interface (keyboard/screen or equivalent)
- a description of individual screen views (schematics, colour photos, etc.)
- a description of how menus are operated (tree presentation)
- an operator manual providing necessary information for installation and use.

Table 3 : Summary of documentation submittal by the System Supplier

Item		Responsible role	System category		
Reference	Document		Cat I	Cat II	Cat III
[4.2.1]	Quality plan	System Supplier		I **(1)**	I **(1)**
[4.2.3]	System description	System Supplier	I **(1)**	A	A
[4.2.4]	Environmental compliance	System Supplier	I **(1)**	I	I
[4.2.5]	Software test reports	System Supplier		I **(1)**	I **(1)**
[4.2.6]	System test report	System Supplier		I **(1)**	I **(1)**
[4.2.7]	Factory Acceptance Test (FAT) program	System Supplier		A	A
[4.2.7]	FAT report	System Supplier		I	I
[4.2.7]	Additional FAT docs. (e.g. user manual)	System Supplier		I **(1)**	I **(1)**
[4.2.8]	Management of change procedure	System Supplier		I **(1)**	I **(1)**

(1) Upon request
Note 1: A = to be submitted for approval, I = to be submitted for information

Table 4 : Summary of documentation submittal by the Systems Integrator

Item		Responsible role	System category		
Reference	Document		Cat I	Cat II	Cat III
[4.3.2]	Quality plan	Systems Integrator		I **(1)**	I **(1)**
[4.3.3]	List of system categorisations	Systems Integrator	A **(1)**	A **(1)**	A **(1)**
[4.3.4]	Risk assessment report	Systems Integrator	A **(1)**	A **(1)**	A **(1)**
[4.3.5]	Ship's system architecture	Systems Integrator	I **(1)**	I **(1)**	I **(1)**
[4.3.6]	System Acceptance Test (SAT) program	Systems Integrator		A	A
[4.3.6]	SAT report	Systems Integrator		I	I
[4.3.7]	System of System Test (SOST) program	Systems Integrator		A	A
[4.3.7]	SOST report	Systems Integrator		I	I
[4.3.8]	Change management procedure for software	Systems Integrator		I **(1)**	I **(1)**

(1) Upon request
Note 1: A = to be submitted for approval, I = to be submitted for information

1.7 Test witnessing and survey

1.7.1 Tab 5 summarises the activities that are to be witnessed or surveyed by the Society. The responsible role is to facilitate the activity.

Table 5 : Summary of test witnessing and survey

Item		Responsible role	System category		
Reference	Document		Cat I	Cat II	Cat III
[4.2.7]	FAT witnessing	System Supplier	–	X	X
[4.3.6]	SAT witnessing	Systems Integrator	–	X	X
[4.3.7]	SOST witnessing	Systems Integrator	–	X	X
[6.12]	Verification of changes	Systems Integrator	–	X	X
Note 1: x = witnessing required, - = witnessing not required.					

2 Approval of system and components

2.1 System certification

2.1.1 Computer-based systems that are necessary to accomplish ship-functions of Category II or Category III (as defined in [3.1]) are to be delivered with a ship-specific Society certificate. The objective of the ship-specific system certification is to confirm that design and manufacturing of the system has been completed and that the system complies with applicable rules of the Society.

2.1.2 Ship-specific system certification consist of two main verification activities:

- Assessment of ship-specific documentation (see [4.2] and [6])
- Survey and testing of the system to be delivered to the ship (see [4.2.7]).

The Society may accept Alternative Survey Scheme (BV Mode I) as per NR320, Sec 3 provided that the requirements are met, and that the system is provided with a ship-specific certificate.

Note 1: NR320 Certification Scheme of Materials and Equipment for the Classification of Marine Units.

2.2 Type approval of computer-based systems

2.2.1 Computer-based systems that are routinely manufactured and include standardized software functions may be type approved in accordance with specified rules of the Society. Hardware is to be documented according to the requirement in [4.2.4].

2.2.2 The type approval consist of two main verification activities:

- assessment of type-specific documentation
- survey and testing of the standardised functions.

2.2.3 Type approval will normally not yield exemption from ship-specific system certification since ship-specific functions, parameter configurations and installation elements demand ship-specific verification.

3 System categories

3.1 System category definitions

3.1.1 The categorisation of a system in the context of this Section is based on the potential severity of the consequences if the system serving the function fails. Tab 6 provides the definitions of the categories.

Table 6 : System categories

Category	Failure effects	Typical System functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the ship and/or threat to the environment	• Monitoring, informational and administrative functions
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the ship and/or threat to the environment	• Ship alarm, monitoring and control functions which are necessary to maintain the ship in its normal operational and habitable conditions
III	Those systems, failure of which could immediately lead to dangerous or catastrophic situations for human safety, safety of the ship and/or threat to the environment	• Control functions for maintaining the ship's propulsion and steering • Ship safety functions

3.2 Scope of verification by the Society

3.2.1 Information pertinent to category I systems is required upon request to determine the correct category or ensure that they do not influence the operation of systems in category II and category III.

Note 1: Cat I systems are normally not subject to verification by the Society, as failure of these systems is not to lead to dangerous situations.

3.3 System category examples

3.3.1 The category of a system is to be evaluated in the context of the specific ship in question; thus, the categorisation of a system may vary from one ship to the next. For determining the categorisation of systems for a specific ship, see [4.3.3].

Note 1:

- Examples of category I systems: Fuel monitoring system, maintenance support system, diagnostics and troubleshooting system, closed circuit television, cabin security, entertainment system, fish detection system.
- Examples of category II systems: Fuel oil treatment system, alarm monitoring and safety systems for propulsion and auxiliary machinery, Inert gas system, control, monitoring and safety system for cargo containment system.
- Examples of category III systems: Propulsion control system, steering gear control system, electric power system (including power management system), dynamic positioning system (IMO classes 2 and 3).

The list of example systems is not exhaustive.

4 Requirements on development and certification of computer-based system

4.1 General requirement

4.1.1 Life cycle approach with appropriate standards

A global top-down approach is to be undertaken in the design and development of both hardware and software and the integration in sub-systems, systems, and system of systems, spanning the complete system lifecycle. This approach is to be based on the standards as listed in this Section or other standards recognised by the Society.

Verification: This is verified by the Society as a part of the quality management system verification described in [4.1.2].

4.1.2 Quality management system

Systems Integrators and System Suppliers are to, in the development of computer-based systems for category II and category III, comply to a recognised quality standard such as ISO 9001:2015; also incorporating principles of IEEE/ISO/IEC 90003:2018.

The quality management system are to include the topics as per Tab 7, applicable for both category II and category III systems.

Verification: The quality management system may be verified by the Society by two alternative means:

a) The Society confirming that the quality management system is certified as compliant to a recognised standard by an organisation with accreditation under a national accreditation scheme.

b) The Society confirming compliance to a standard through a specific assessment of the quality management system. The documentation requirements is to be defined on a case-by-case basis.

Table 7 : Quality management system

Area		Role	
No.	Topic	System Supplier	Systems Integrator
1	Responsibilities and competency of the staff	X	X
2	The complete lifecycle of delivered software and of associated hardware	X	X
3	Specific procedure for unique identification of a computer-based system, its components and versions	X	
4	Creation and update of the ship's system architecture		X
5	Organisation set in place for acquisition of software and related hardware from suppliers	X	X
6	Organisation set in place for software code writing and verification	X	
7	Organisation set in place for system validation before integration in the ship	X	
8	Specific procedure for conducting and approving of systems at FAT and SAT	X	X
9	Creation and update of system documentation	X	
10	Specific procedure for software modification and installation on board the ship, including interactions with Shipyard and Owner	X	X
11	Specific procedures for verification of software code	X	
12	Procedures for integrating systems with other systems and testing of the system of systems for the ship	X	X
13	Procedures for managing changes to software and configurations before FAT	X	
14	Procedures for managing and documenting changes to software and configurations after FAT	X	X
15	Checkpoints for the organisation's own follow-up of adherence to the quality management system	X	X

4.2 Requirements on the System Supplier

4.2.1 Define and follow a quality plan

The System Supplier is to document that the quality management system is applied for the design, construction, delivery, and maintenance of the specific system to be delivered.

All applicable items described in [4.1.2] (for the System Supplier role) are to be demonstrated to exist and being followed, as relevant.

Verification:

- The quality plan for category I systems is not required.
- The quality plan for category II and III systems is to be available during survey (FAT) or submitted for information upon request.

4.2.2 Unique identification of systems and software

A method for unique identification of a system, its different software components and different revisions of the same software component are to be applied. The method is to be applied throughout the lifecycle of the system and the software.

See also [7.1] for related technical requirements on the system in question.

The documentation of the method is typically a part of the quality management system, see [4.1.2].

Verification:

- The unique identification of the category I systems is not required.
- The application of the identification system for category II and III is verified as a part of the FAT (see [4.2.7]) and SAT (see [4.3.6]).

4.2.3 System description

The system's specification and design is to be determined and documented in a system description. In addition to serve as a specification for the detailed design and implementation, the purpose of the system description is to document that the entire system-delivery is according to the specifications and in compliance with applicable rules and regulations.

The system description is to contain information of the following:

- Purpose and main functions, including any safety aspects
- System category as defined
- Key performance characteristics
- Compliance with the technical requirements and Society rules
- User interfaces/mimics
- Communication and Interface aspects
  - Identification and description of interfaces to other ship systems
- Hardware-arrangement related aspects:
  - Network-architecture/topology, including all network components like switches, routers, gateways, firewalls, etc.
  - Internal structure with regards to all interfaces and hardware nodes in the system (e.g. operator stations, displays, computers, programmable devices, sensors, actuators, I/O modules, etc).
  - I/O allocation (mapping of field devices to channel, communication link, hardware unit, logic function)
  - Power supply arrangement
  - Failure mode description.

Note 1: The system description may be divided into a number of different documents and models.

Verification:

- For category I systems, the system description documentation is to be submitted for information upon request.
- For category II and III, the system description documentation is to be submitted for approval.

4.2.4 Environmental compliance of hardware components

Evidence of environmental type testing according to Ch 3, Sec 6, [2] regarding hardware elements included in the system and sub-systems is to be submitted to the Society.

Verification:

- For category I systems, submitting evidence of environmental type testing is not mandatory. Reference to Type approval certificate or other evidence of type testing is to be submitted for information upon request, see [3.2].
- For category II and III, the reference to Type approval certificate or other evidence of type testing is to be submitted to the Society for information.

4.2.5 Software code creation, parameterisation, and testing

The software created, changed, or configured for the delivery project is to be developed and have the quality assurance activities assessed according to the selected standard(s) as described in the quality plan.

The quality assurance activities may be performed on several levels of the software-structure and are to include both custom-made software and configured components (e.g. software libraries) as appropriate.

The verification of the software is to verify the following aspects based on black-box methods:

- Correctness, completeness and consistency of any parametrisation and configuration of software components
- Intended functionality
- Intended robustness.

For components in systems of category II and III, the scope, purpose, and results of all performed reviews, analyses, tests, and other verification activities are to be documented in test reports.

Note 1: Some of the methods utilised in this activity are sometimes referred to as “software unit test” or “developer test” and may also include verification methods like code reviews and static or dynamic code analysis.

Verification:

- For category I systems, no documentation is required.
- For category II and III, software test reports are to be upon request submitted to the Society for information.

4.2.6 Internal system testing before FAT

The system is to be as far as practicable tested before the FAT. The main purpose of the system test is for the System Supplier to verify that the entire system delivery is according to the specifications, approved documentation and in compliance with applicable rules and regulations; and further, that the system is complete and ready for the FAT.

The testing is to verify the following aspects of the system:

- functionality
- effect of faults and failures (including diagnostic functions, detection, alerts response)
- performance
- integration between software and hardware components
- human-machine interfaces
- interfaces to other systems.

Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response.

Some of the testing may be performed by utilising simulators and replica hardware.

The test-environment is to be documented, including a description of any simulators, emulators, test-stubs, test-management tools, or other tools affecting the test environment and its limitations.

Test cases and test results are to be documented in test programs and test reports respectively.

Verification:

- For category I systems, no documentation is required.
- For category II and III systems, internal system test report are to be made available during FAT or submitted upon request for information.

4.2.7 Factory acceptance testing (FAT) before installation on board

A Factory Acceptance Test (FAT) is to be arranged for the system in question. The main purpose of the FAT is to demonstrate to the Society that the system is completed and compliant with applicable classification rules, thus enabling issuance of a Society Certificate for the system.

The FAT test program is to cover a representative selection of the test items from the internal system test (described in [4.2.6]), including normal system functionality and response to failures.

For category II and III systems, network testing to verify the network resilience requirements in [7.2.1] is to be performed. If agreed by all parties, the network testing may be performed as a part of the system test on board the ship.

As a rule, the FAT is to be performed with the project specific software operating on the actual hardware components to be installed on board, with necessary means for simulation of functions and failure responses. Other solutions such as replica hardware or simulated hardware (emulators) may be agreed with the Society.

For each test-case it is to be noted if the test is passed or failed, and the test-results are to be documented in a test report. The test report is to also contain a list of the software (including software versions) that were installed in the system when the test was executed.

Note 1: For complex systems there may be a large difference in scope between the “Internal system testing before FAT” activity and the FAT, while for some systems the scope may be identical.

Verification:

- For category I systems, FAT not required.
- For category II and III systems, the FAT program is to be approved before the test is executed. The FAT execution is to be witnessed by the Society. The FAT report is to be submitted to the Society for information.

Additional FAT documentation including, e.g. user manuals and internal system test report, is to be made available during FAT or submitted upon request for information.

4.2.8 Secure and controlled software installation on the ship

The initial installation and subsequent updates of the software components of the system are to be done according to a management of change procedure which has been agreed between the System Supplier and the Systems Integrator.

The management of change procedure is to comply with the requirements in [6].

Cyber security requirements are to be applied as defined in NR659, Ch 5, Sec 2, [6.3.5].

Verification:

- For category I systems, no management of change documentation is required.
- For category II and III systems, the management of change procedure is to be submitted for information upon request.

4.3 Requirements on the Systems Integrator

4.3.1 Responsibilities

For the purposes of this Section, the Shipyard is considered as the Systems Integrator in the development and delivery phase unless another organisation or person is explicitly appointed by the Shipyard.

4.3.2 Define and follow a quality plan

The Systems Integrator is to document that the quality management system is applied for the installation, integration, completion, and maintenance of the systems to be installed on board. All applicable items described in [4.1.2] (for the Systems Integrator role) are to be demonstrated to exist and being followed, as relevant.

Verification:

- For category I systems, no documentation is required.
- For category II and III systems, the quality plan is to be made available during survey (at SAT/SOST) or upon request submitted for information.

4.3.3 Determining the category of the system in question

For each system delivery to a particular ship, it is to be decided which category the system falls under based on the failure effects of the system (as defined in [3]). The category for a specific system is to be conveyed to the relevant System Supplier. The Society may decide that a risk-assessment is needed to verify the proper system category.

Verification:

- For category I, II and III systems, the category for the different systems is to be upon request documented and submitted for approval.

4.3.4 Risk assessment of the system

If requested by the Society, a risk assessment of a specific system in context of the specific ship in question is to be performed and documented in order to determine the applicable category for the system.

Note 1: IEC/ISO31010 “Risk management - Risk assessment techniques” may be used as guidance in order to determine method of risk assessment.

Verification:

- For category I, II and III systems, the risk assessment report is to be upon request submitted for approval.

4.3.5 Define the ship’s system-architecture

The System of Systems (SoS) is to be specified and documented. This architecture specification provides the basis for category determination and development of the different integrated systems by allocating functionality to individual systems and by identifying the main interfaces between the systems. It is also to serve as a basis for the testing of the integrated systems on the ship level (see [4.3.7]).

The ship’s system architecture is to at least contain description of:

- Overview of the total systems architecture (the system of systems)
- Each system’s purpose and main functionality
- Communication and interface aspects between different systems.

Note 1: See also NR659, Ch 3, Sec 2 for diagram of security zones and conduits.

Verification:

- For category I, II, and III systems, the ship’s system architecture is to be upon request submitted to the Society for information.

4.3.6 System acceptance test (SAT) on board the ship

A system acceptance test (SAT) is to be arranged on board the ship. The main purpose of the system acceptance test (SAT) is to verify the system functionality, after installation and integration with the applicable machinery/electrical/process systems on board including possible interfaces with other control and monitoring systems.

For each test-case it is to be noted if the test is passed or failed, and the test-results are to be documented in a test report. The test report is to also contain a list of the software (including software versions) that were installed in the system when the test was executed.

Verification:

- For category I systems, the SAT is not required.
- For category II and III systems, the SAT program is to be submitted for approval before the test is executed.

The SAT execution is to be witnessed by the Society. The SAT report is to be submitted to the Society for information.

4.3.7 Testing of integrated systems on ship-level (SOST)

Integration tests are to be conducted after installation and integration of the different systems in its final environment on board. The purpose of the tests is to verify the functionality of the complete installation (system of systems) including all interfaces and inter-dependencies in compliance with requirements and specifications.

The testing is to verify the following aspects of the system of systems:

- overall functionality of the interacting systems as a whole
- failure response between systems
- performance
- human-machine interfaces
- interfaces between the different systems.

Note 1: For complex systems there may be a large difference in scope between the “System acceptance test (SAT) on board the ship” activity and the SOST, while for some systems the scope may be overlapping or identical. It is possible to combine the two activities into one when the test scope is similar.

Verification:

- For category I systems, the testing of integrated systems on ship-level (SOST) is not required.
- For category II and III systems, the SOST program is to be submitted to the Society for approval before the test is executed.

The SOST execution is to be witnessed by the Society. The SOST report is to be submitted to the Society for information.

4.3.8 Change management

The Systems Integrator is to follow procedures for management of change to the system as described in [6].

Verification:

- For category I systems, the management of change procedure is not required.
- For category II and III systems, the management of change procedure is to be upon request submitted to the Society for information.

5 Requirements on maintenance of computer-based systems

5.1 Requirements on the Owner

5.1.1 Responsibilities

For the purposes of this Section, the Owner is considered to be the Systems Integrator in the operations phase unless another organisation or person is explicitly appointed by the Owner.

Accordingly, the Society is to be informed in a timely manner by the Owner about the appointed Systems Integrator who is responsible for implementing any changes to the systems in conjunction with System Supplier(s).

5.2 Requirements on the Systems Integrator

5.2.1 Change management

The Systems Integrator is to ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure(s). For details about change management, see [6].

Changes to computer-based systems in the operational phase is to be recorded.

The records are to contain information about the relevant software versions and other relevant information as described in [6.1.1].

Verification:

- For category I systems, the documentation about the change management is not required.
- For category II and III systems, see [6.12].

5.3 Requirements on the System Supplier

5.3.1 Change management

The System Supplier is to follow procedures for maintenance of the system including procedures for management of change as described in [6].

Verification:

- For category I systems, the documentation about the change management is not required.
- For category II and III systems, see [6.12].

5.3.2 Testing of changes before installation on board

The System Supplier is to make sure that the planned changes to a system have passed relevant in-house tests before the change is made to systems on board.

Verification:

- For category I systems, no documentation about testing of changes before installation on board is required.
- For category II and III, see [6.12].

6 Management of change

6.1 General

6.1.1 This Article provides requirements for the management of change throughout the lifecycle of a computer-based system. Different procedures for the management of change may be defined for specific phases in a system's lifecycle as the different phases typically involve different stakeholders. The Society's verification is described in [6.12].

6.2 Documented change management procedures

6.2.1 The organisation in question is to define and document change management procedures applicable for the computer-based system in question covering both hardware and software. After FAT, the System Supplier is to manage all changes to the system in accordance with the procedure. Examples could be qualification of new versions of acquired software, new hardware, modified control logic, changes to configurable parameters.

The procedure(s) are to describe the activities listed in [6.3] through [6.11]. The outcome of the impact analysis in [6.8] determines to what extent the activities in [6.3] to [6.12] are to be performed. Change records (described in [6.11]) are to be always produced.

6.3 Agreement between relevant stakeholders

6.3.1 The management of change process is to be coordinated and agreed between the relevant stakeholders along the different stages of the lifecycle of the computer-based system.

Note 1: Typically, the management of change address at least three different stages:

- Development and internal verification before FAT involving the System Supplier and sub-suppliers.
- From FAT to handover of the ship to the Owner involving the System Supplier, the Systems Integrator, the Society, and the Owner.
- In operation involving the System Supplier, Service Suppliers, the Owner, and the Society.

6.4 Approved software to be under change management

6.4.1 If changes are required to a system after it has been approved by applicable stakeholders (typically the Systems Integrator and the Society at FAT) the modifications are to follow defined change management procedures.

6.5 Unique identification of system and software versions

6.5.1 The System Supplier is to make sure that each system and software version is uniquely identifiable, see [4.2.2].

6.6 Handling of software master files

6.6.1 There are to be defined mechanisms for handling of the files that constitute the master-files for a software component. Personnel authorities are to be clearly defined along with the tools and mechanisms used to ensure the integrity of the master files.

6.7 Backup and restoration of onboard software

6.7.1 It is to be clearly defined how to perform backup and restoration of the software components of a computer-based system on board the ship.

6.8 Impact analysis before change is made

6.8.1 Before a change to the system is made, an impact analysis is to be performed in order to determine:

- Criticality of the change
- Impact on existing documentation
- Needed verification and test activities
- Need to inform other stakeholders about the change
- Need to obtain approval from other stakeholders (e.g. Society and/or Owner) before the change is made.

6.9 Roll-back in case of failed software changes

6.9.1 When maintenance includes installation of new versions of the software in the system, it is to be possible to perform a rollback of the software to the previous installed version with the purpose of returning the system to a known, stable state.

Roll-backs are to be documented and analysed to find and eliminate the root cause.

6.10 Verification and validation of system changes

6.10.1 To the largest degree practically possible, modifications are to be verified before being installed on board.

After installation, the modification(s) are to be verified on board according to a documented verification program containing:

- Verification that the new functionalities and/or improvements have had the intended effect
- Regression test to verify that the modification has not had any negative effects on functionality or capabilities that was not expected to be affected.

6.11 Change records

6.11.1 Changes to systems and software are to be documented in change records to allow for visibility and traceability of the changes. The change records are to contain at least the following items:

- The purpose for a change
- A description of the changes and modifications
- The main conclusions from the impact analysis (see [6.8])
- The identity and version of any new system or software version(s) (see [6.5])
- Test reports or tests summaries (see [6.10]).

Documentation of the changes to software may be recorded in the planned maintenance system (PMS), in a software registry or equivalent.

6.12 Verification of change management by the Society

6.12.1 During newbuilding

The verification of management of change in the newbuilding phase is divided into two parts:

- Procedures are verified as a part of the verification of the quality management system as per [4.1.2]
- Project specific implementation of the procedures are verified during FAT (see [4.2.7]), SAT (see [4.3.6]) and SOST (see [4.3.7]) activities.

7 Technical requirements on computer-based systems

7.1 Reporting of system and software identification and version

7.1.1 System identification

The system is to provide means to identify its name, version, identifier, and manufacturer.

Note 1: It is recommended that the system can automatically report the status of its software to a ship software logging system (SSLS) as specified in the international standard ISO 24060.

7.2 Data links

7.2.1 General requirements for category II and III systems

Loss of a data link is to be specifically addressed in risk assessment analysis/FMEA, refer to [4.2.3].

a) A single failure in data link is not to cause loss of ship-functions of category III. Any effect of such failures is to meet the principle of fail safe for the ship-function(s) being served.

b) For ship-functions of category II and III, any loss of functionality in the remote control system is to be compensated for by local/manual means.

c) The data link is to have means to prevent or cope with excessive communication rates.

d) Data links are to be self-checking, detecting failures or performance issues on the link itself and data communication failures on nodes connected to the link

e) Detected failures are to initiate an alarm.

7.2.2 Specific requirements for wireless data links

Category III systems are not to use wireless data links unless specifically considered by the Society on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to the Society.

Other categories of systems may use wireless data links with the following requirements:

- Recognised international wireless communication system protocols are to be employed, incorporating:
  - Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
  - Configuration and device authentication. Are only to permit connection of devices that are included in the system design.
  - Message encryption. Protection of the confidentiality and or criticality of the data content.
  - Security management. Protection of network assets, prevention of unauthorized access to network assets.
- The internal wireless system within the ship are to comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.
- Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.
- For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not self-fail as a result of electromagnetic interference during expected operating conditions.

7.2.3 Essential services

Loss of a data communication link is not to affect the ability to operate essential services by alternative means.

7.2.4 Automatic start

The data communication links for category II and III systems are to be automatically started when power is turned on, or restarted after loss of power.

7.2.5 Transmission cables for category II and III systems

The choice of transmission cable is to be made according to the environmental conditions. Particular attention is to be given to the level characteristics required for electromagnetic interferences.

The installation of transmission cables is to comply with the requirements stated in Ch 2, Sec 11. In addition, the routing of transmission cables is to be chosen so as to be in less exposed zones regarding mechanical, chemical or EMI damage. As far as possible, the routing of each cable is to be independent of any other cable. These cables are not normally allowed to be routed in bunches with other cables on the cable tray.

7.2.6 Coupling devices for category II and III systems

The coupling devices are to be designed, as far as practicable, so that in the event of a single fault, they do not alter the network function. When a failure of a coupling device occurs, an alarm is to be activated.

Addition of coupling devices is not to alter the network function.

Hardware connecting devices are to be chosen, when possible, in accordance with international standards.

When a computer based system is used with a non-essential system and connected to a network used for essential systems, the coupling device is to be of an approved type.

7.3 Verification of technical requirements by the Society

7.3.1 The implementation of the technical requirements provided in [7] is verified by the Society as part of the system description, FAT and SAT, described respectively in [4.2.3], [4.2.7], and [4.3.6].

7.4 Requirements for hardware regarding construction

7.4.1 General

The construction of systems is to comply with the requirements of Ch 3, Sec 4.

7.4.2 Housing

a) The housing of the system is to be designed to protect the printed circuit board and associated components from the environmental conditions, as defined in Ch 2, Sec 2, [1], in which it will be installed. When required, the cooling system is to be monitored, and an alarm is to be activated when the normal temperature is exceeded.

b) The mechanical construction is to be designed to withstand the vibration levels defined in Ch 2, Sec 2 depending on the applicable environmental condition.

7.5 Response time

7.5.1 The response time between the detection of an event and the related action or signalization is to be compatible with the application. As a general requirement without other specification, this time is to be less than 5 seconds.

7.6 Human-Machine Interface (HMI)

7.6.1 Ergonomic design

The design of the operator interface is to follow ergonomic principles. The standard IEC 60447:2004 Man-machine interface or equivalent recognized standard may be used.

7.6.2 Alarms

Means are to be provided to verify the activity of the system, or subsystem, and its proper function.

A visual and audible alarm is to be activated in the event of malfunction of the system, or subsystem. This alarm is to be such that identification of the failure is simplified.

7.6.3 Input devices - General requirements

Input devices are to be positioned such that the operator has a clear view of the related display. The operation of input devices, when installed, is to be logical and correspond to the direction of action of the controlled equipment.

7.6.4 Input devices - Conflicting control inputs

Control of essential functions is only to be available at one control station at any time. Failing this, conflicting control commands are to be prevented by means of interlocks and/or warnings.

7.6.5 Input devices - Confirmation and validity of input

The user is to be provided with positive confirmation of action. When keys are used for common/important controls, and several functions are assigned to such keys, the active function is to be recognisable. Means are to be provided to check validity of the manual input data into the system (e.g. checking the number of characters, range value, etc.).

7.6.6 Input devices - Protection against inadvertent activation

If use of a push button may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of two push buttons, repeated use of push buttons, etc.). Alternatively, this push button is to be protected against accidental activation by a suitable cover, or use of a pull button, if applicable.

7.6.7 Output devices

Video display units (VDU's) and other output devices are to be suitably lighted and dimmable when installed in the wheelhouse. The adjustment of brightness and colour of VDU's is to be limited to a minimum discernible level.

When VDU's are used for alarm purposes, the alarm signal, required by the Rules, is to be displayed whatever the other information on the screen. The alarms are to be displayed either

- according to the sequence of occurrence, or
- in order of priority as per IEC 62923-1:2018, or
- in order of priority as per other recognised standards at the discretion of the Society.

Note 1: IEC 62923-1:2018 "Maritime navigation and radiocommunication equipment and systems - Bridge alert management - Part 1: Operational and performance requirements, methods of testing and required test results"

Note 2: When displaying alarms as per IEC 62923-1:2018, the alarms are grouped by the display priorities. Within the groups the alarms are ordered by the time of the last state change and the most recent alarms are placed on top."

When alarms are displayed on a colour VDU, it is to be possible to distinguish alarm in the event of failure of a primary colour.

The position of the VDU is to be such as to be easily readable from the normal position of the personnel on watch. The size of the screen and characters is to be chosen accordingly.

When several control stations are provided in different spaces, an indication of the station in control is to be displayed at each control station. Transfer of control is to be effected smoothly and without interruption to the service.

7.6.8 Workstations

The number of workstations at control stations is to be sufficient to ensure that all functions may be provided with any one unit out of operation, taking into account any functions which are required to be continuously available.

Multifunction workstations for control and display are to be redundant and interchangeable.

The choice of colour, graphic symbols, etc. is to be consistent in all systems on board.

7.6.9 Computer dialogue

The computer dialogue is to be as simple and self-explanatory as possible. The screen content is to be logically structured and show only what is relevant to the user. Menus are to be organised so as to have rapid access to the most frequently used functions.

Means to go back to a safe state are to be always accessible.

A clear warning is to be displayed when using functions such as alteration of control condition, or change of data or programs in the memory of the system.

A "wait" indication is to warn the operator when the system is executing an operation.

7.7 Integrated systems

7.7.1 Integrated system is a system consisting of two or more subsystems having independent functions connected by a data transmission network and operated from one or more workstations. Operation with an integrated system is to be at least as effective as it would be with individual, stand alone equipment.

7.7.2 Failure of one part (individual module, equipment or subsystem) of the integrated system is not to affect the functionality of other parts, except for those functions directly dependent on information from the defective part.

7.7.3 A failure in connection between parts, cards connections or cable connections is not to affect the independent functionality of each connected part.

7.7.4 Alarm messages for essential functions are to have priority over any other information presented on the display.

8 Additional service feature SW-Registry

8.1 Software registry

8.1.1 Software registry is a detailed manual about the software and related hardware elements deployed on a specific ship. The additional service feature **SW-Registry** is assigned in accordance to Pt A, Ch 1, Sec 2, [4.16.15] to ships provided with a software registry meeting the requirements of the present Article.

8.1.2 The software registry is composed of the four following parts:

- software inventory as explained in [8.2]
- logical map of networks as explained in [8.3]
- inventory of integrated systems components as explained in [8.4]
- cyber security events as explained in [8.5].

8.1.3 Initial release of software registry is to be submitted for information to the Society after ship sea trials.

8.2 Software inventory

8.2.1 The software inventory is a part of the software registry.

8.2.2 The responsibilities of each parties are detailed hereafter:

a) Systems Supplier is to deliver a software inventory for their equipment.

b) Systems Integrator is to verify equipment compliance with delivered software inventory from the Systems Supplier. Verification may be done in a passive way or in an active way by using discovery tools to identify software on a single equipment or to identify network connected devices within systems. If software inventory is missing, the Systems Integrator is to write it. Systems Integrator ensures software inventory revision by adding any supplied equipment during integration.

c) Owner is to maintain software inventory delivered by the Systems Integrator. If missing, this document is to be established by the Owner.

8.2.3 The software inventory may be in a digital format, e.g. spreadsheet file. The software inventory is to contain the elements described in [8.2.4] to [8.2.7].

8.2.4 Global information

The software inventory is to be structured per equipment and is to contain:

- equipment name, brand, model or reference, supplier name, function and global version
- history of changes with dates, actors and motivations.

8.2.5 Operating system related information

If an equipment has multi, dual-boot system, each operating system is to be considered.

About operating system, the following information is to be delivered:

- operating system distribution name, editor's name, global version
- operating system detailed version (applied CVE should be listed)
- operating system installed desktop applications, relevant versions are to be applied)
- operating system installed system services, relevant versions are to be applied)
- license number.

8.2.6 Desktop applications related information

A desktop application is a software deployed in the onboard hardware to run without the use of any incoming connections through listening interface.

The following information are to be delivered regarding desktop applications:

- software name and publisher
- installation date, version number and motivations
- local and remote roles
- generic accounts
- dedicated accounts
- access control list with read, write and execution rights
- when existing, outgoing connections are to be considered (IP/Ports destination). If unknown, information is to be identified as "missing"
- license number.

8.2.7 Network services related information

Network service is software deployed in the onboard hardware to run with the use of incoming connections through listening interface (e.g. called ports for TCP/IP) over the network or any serial connection.

In addition to the information listed in [8.2.6] the following information is to be delivered.

For IP based Services:

- protocol name and version
- listening ports
- motivation for ports listening

For Non/IP based Services:

- listening interface
- motivation for interface listening.

8.3 Logical map of networks

8.3.1 The logical map of networks is part of the software registry.

8.3.2 The logical map represents the logical topology of networks, e.g. IP and non-IP addressing scheme, subnet names, logical links, principal devices in operation. The logical map can be organised in the form of inventories and a corresponding diagram.

8.3.3 Logical inventories

a) List of IP address ranges with the following information defined for each entry:
   - the list of switches concerned
   - the functional description of the IP range
   - the list of Dynamic Host Configuration Protocol (DHCP) servers, relevant IP address management plan and IP history recording policy
   - the list of equipment MAC address
   - interconnections with other ranges
   - flow matrix with source, destination, IP, ports, service, motivation, roles, volume estimation and time windows if any

b) List of non-IP networks with the following information defined for each network:
   - the list of MAC (Media Access Control) addresses or addresses specific to the industrial protocols on the network
   - the list of switches concerned
   - functional description of the network
   - devices connected to other networks (connectors)

c) List of non-Ethernet access points with the following information defined for each entry:
- the list of access ports
- addressing, if there is a special protocol
- the list of connected devices

d) List of logical servers and desktops with the following information defined for each entry, if applicable:
- IP addressing (network, mask, gateway)
- operating system version
- underlying physical server
- applications and their versions
- services and versions

e) List of connectors and communicating field devices (remote I/O, smart sensors, smart actuators, etc.) with, for each one:
- IP addressing (network, mask, gateway), the associated MAC addressing and network or the specific addressing, if appropriate
- applications.

8.3.4 Diagram

The diagram is to present the IP ranges (networks and sub-networks), their interconnections and is to demonstrate:
- functional description of the IP range
- interconnections with other ranges
- routers, switches and firewalls
- security devices (e.g. intrusion detection systems).

Note 1: In particular, this map should show connections to external networks, e.g. shore hosts of service providers, and all connections to the Internet.

8.4 Inventory of integrated systems components

8.4.1 The inventory of integrated systems components is a part of the software registry.

8.4.2 Physical inventories

The list of communicating devices is to be included. For each element the following information is to be specified:
- name, brand, model or reference (some devices (e.g. modular PLCs) contain several references
- the version of the embedded firmware (software version) and the product version if appropriate
- physical characteristics, if appropriate
- physical location (building, room, cabinet, bay)
- list of switches connected.

Note 1: For example, the list may include PLCs, remote I/O, sensors, actuators, variable speed drives, meters, circuit breakers, switches, physical servers, desktops and storage units.

The list of network communication devices is to be included, e.g. for switches, routers and protocol gateways. For each device the following information is to be specified:
- brand, model and reference
- embedded firmware version
- physical location (building, room, cabinet, bay).

For Ethernet switches the Virtual Local Area Network (VLAN) numbers for each port are to be specified.

8.4.3 Diagram

This is a representation of the various locations, showing:
- switches, associated VLAN numbers
- links between devices
- firewall and relevant rules
- passive and active network based cyber security equipment
- for remote connections, interconnection identifiers if any (MultiProtocol Label Switching (MPLS) or Virtual Private LAN Service (VPLS))
- any other relevant devices.

8.5 Cyber security events

8.5.1 Cyber security events as defined in NR659 are to be recorded in the software registry including, but not limited to:

- Results of the scans: Prior to installation, all artefacts, software code, executables and the physical medium used for installation on the ship are to be scanned for viruses and malicious software. Results of the scan are to be documented and kept with the software registry.

Section 4 Constructional Requirements

1 General

1.1 General

1.1.1 Automation systems are to be so constructed as:

- to withstand the environmental conditions, as defined in Ch 2, Sec 2, [1], in which they operate
- to have necessary facilities for maintenance work.

1.2 Materials

1.2.1 Materials are generally to be of the flame-retardant type.

1.2.2 Connectors are to be able to withstand standard vibrations, mechanical constraints and corrosion conditions as given in Ch 3, Sec 6.

1.3 Component design

1.3.1 Automation components are to be designed to simplify maintenance operations. They are to be so constructed as to have:

- easy identification of failures
- easy access to replaceable parts
- easy installation and safe handling in the event of replacement of parts (plug and play principle) without impairing the operational capability of the system, as far as practicable
- facility for adjustment of set points or calibration
- test point facilities, to verify the proper operation of components.

1.4 Environmental and supply conditions

1.4.1 The environmental and supply conditions are specified in Ch 3, Sec 1. Specific environmental conditions are to be considered for air temperature and humidity, vibrations, corrosion from chemicals and mechanical or biological attacks.

2 Electrical and/or electronic systems

2.1 General

2.1.1 Electrical and electronic equipment is to comply with the requirements of Part C, Chapter 2 and Part C, Chapter 3.

2.1.2 A separation is to be done between any electrical components and liquids, if they are in a same enclosure. Necessary drainage will be provided where liquids are likely to leak.

2.1.3 When plug-in connectors or plug-in elements are used, their contacts are not to be exposed to excessive mechanical loads. They are to be provided with a locking device.

2.1.4 All replaceable parts are to be so arranged that it is not possible to connect them incorrectly or to use incorrect replacements. Where this not practicable, the replacement parts as well as the associated connecting devices are to be clearly identified. In particular, all connection terminals are to be properly tagged. When replacement cannot be carried out with the system on, a warning sign is to be provided.

2.1.5 Forced cooling systems are to be avoided. Where forced cooling is installed, an alarm is to be provided in the event of failure of the cooling system.

2.1.6 The interface connection is to be so designed to receive the cables required. The cables are to be chosen according to Ch 2, Sec 3.

2.2 Electronic system

2.2.1 Printed circuit boards are to be so designed that they are properly protected against the normal aggression expected in their environment.

2.2.2 Electronic systems are to be constructed taking account of electromagnetic interferences.

Special precautions are to be taken for:

- measuring elements such as the analogue amplifier or analog/digital converter; and
- connecting different systems having different ground references.

2.2.3 The components of electronic systems (printed circuit board, electronic components) are to be clearly identifiable with reference to the relevant documentation.

2.2.4 Where adjustable set points are available, they are to be readily identifiable and suitable means are to be provided to protect them against changes due to vibrations and uncontrolled access.

2.2.5 The choice of electronic components is to be made according to the normal environmental conditions, in particular the temperature rating.

2.2.6 All stages of fabrication of printed circuit boards are to be subjected to quality control. Evidence of this control is to be documented.

2.2.7 Burn-in tests or equivalent tests are to be performed.

2.2.8 The programmable components are to be clearly tagged with the program date and reference.

Components are to be protected against outside alteration when loaded.

2.3 Electrical system

2.3.1 Cables and insulated conductors used for internal wiring are to be at least of the flame-retardant type, and are to comply with the requirements in Part C, Chapter 2.

2.3.2 If specific products (e.g. oil) are likely to come into contact with wire insulation, the latter is to be resistant to such products or properly shielded from them, and to comply with the requirements in Part C, Chapter 2.

3 Pneumatic systems

3.1

3.1.1 Pneumatic automation systems are to comply with Ch 1, Sec 10, [17].

3.1.2 Pneumatic circuits of automation systems are to be independent of any other pneumatic circuit on board.

4 Hydraulic systems

4.1

4.1.1 Hydraulic automation systems are to comply with Ch 1, Sec 10, [14].

4.1.2 Suitable filtering devices are to be incorporated into the hydraulic circuits.

4.1.3 Hydraulic circuits of automation systems are to be independent of any other hydraulic circuit on board.

5 Automation consoles

5.1 General

5.1.1 Automation consoles are to be designed on ergonomic principles. Handrails are to be fitted for safe operation of the console.

5.2 Indicating instruments

5.2.1 The operator is to receive feed back information on the effects of his orders.

5.2.2 Indicating instruments and controls are to be arranged according to the logic of the system in control. In addition, the operating movement and the resulting movement of the indicating instrument are to be consistent with each other.

5.2.3 The instruments are to be clearly labelled. When installed in the wheelhouse, all lighted instruments of consoles are to be dimmable, where necessary.

5.3 VDU's and keyboards

5.3.1 VDU's in consoles are to be located so as to be easily readable from the normal position of the operator. The environmental lighting is not to create any reflection which makes reading difficult.

5.3.2 The keyboard is to be located to give easy access from the normal position of the operator. Special precautions are to be taken to avoid inadvertent operation of the keyboard.

Section 5 Installation Requirements

1 General

1.1

1.1.1 Automation systems are to be installed taking into account:

- the maintenance requirements (test and replacement of systems or components)
- the influence of EMI. The IEC 60533 standard is to be taken as guidance
- the environmental conditions corresponding to the location in accordance with Ch 2, Sec 1and Ch 2, Sec 3, [6].

1.1.2 Control stations are to be arranged for the convenience of the operator.

1.1.3 Automation components are to be properly fitted. Screws and nuts are to be locked, where necessary.

2 Sensors and components

2.1 General

2.1.1 Sensors are to be selected and located such that their output is a realistic measure of the parameter. Sensors are to be installed in places where there is a minimum risk for damage during normal overhaul and maintenance.

2.1.2 The enclosure of the sensor and the cable entry are to be appropriate to the space in which they are located.

2.1.3 Means are to be provided for testing, calibration and replacement of automation components. Such means are to be designed, as far as practicable, so as to avoid perturbation of the normal operation of the system.

2.1.4 A tag number is to identify automation components and is to be clearly marked and attached to the component. These tag numbers are to be collected on the instrument list mentioned in Ch 3, Sec 1, Tab 1.

2.1.5 Electrical connections are to be arranged for easy replacement and testing of sensors and components. They are to be clearly marked.

2.1.6 Low level signal sensors are to be avoided. When installed they are to be located as close as possible to amplifiers, so as to avoid external influences. Failing this, the wiring is to be provided with suitable EMI protection and temperature correction.

2.2 Temperature elements

2.2.1 Temperature sensors, thermostats or thermometers are to be installed in a thermowell of suitable material, to permit easy replacement and functional testing. The thermowell is not to significantly modify the response time of the whole element.

2.3 Pressure elements

2.3.1 Three-way valves or other suitable arrangements are to be installed to permit functional testing of pressure elements, such as pressure sensors, pressure switches, without stopping the installation.

2.3.2 In specific applications, where high pulsations of pressure are likely to occur, a damping element, such as a capillary tube or equivalent, is to be installed.

2.4 Level switches

2.4.1 Level switches fitted to flammable oil tanks, or similar installations, are to be installed so as to reduce the risk of fire.

3 Cables

3.1 Installation

3.1.1 Cables are to be installed according to the requirements in Ch 2, Sec 12, [7].

3.1.2 Suitable installation features such as screening and/or twisted pairs and/or separation between signal and other cables are to be provided in order to avoid possible interference on control and instrumentation cables.

3.1.3 Specific transmission cables (coaxial cables, twisted pairs, etc.) are to be routed in specific cable-ways and mechanically protected to avoid loss of any important transmitted data. Where there is a high risk of mechanical damage, the cables are to be protected with pipes or equivalent.

3.1.4 The cable bend radius is to be in accordance with the requirements of Ch 2, Sec 12, [7.2].

For mineral insulated cables, coaxial cables or fibre optic cables, whose characteristics may be modified, special precautions are to be taken according to the manufacturer's instructions.

3.2 Cable terminations

3.2.1 Cable terminations are to be arranged according to the requirements in Part C, Chapter 2. Particular attention is to be paid to the connections of cable shields. Shields are to be connected only at the sensor end when the sensor is earthed, and only at the processor end when the sensor is floating.

3.2.2 Cable terminations are to be able to withstand the identified environmental conditions (shocks, vibrations, salt mist, humidity, etc.).

3.2.3 Terminations of all special cables such as mineral insulated cables, coaxial cables or fibre optic cables are to be arranged according to the manufacturer's instructions.

4 Pipes

4.1

4.1.1 For installation of piping circuits used for automation purposes, see the requirements in Ch 1, Sec 10.

4.1.2 As far as practicable, piping containing liquids is not to be installed in or adjacent to electrical enclosures (see Ch 3, Sec 4, [2.1.2]).

4.1.3 Hydraulic and pneumatic piping for automation systems is to be marked to indicate its function.

5 Automation consoles

5.1 General

5.1.1 Consoles or control panels are to be located so as to enable a good view of the process under control, as far as practicable. Instruments are to be clearly readable in the ambient lighting.

5.1.2 The location is to be such as to allow easy access for maintenance operations.

Section 6 Testing

1 General

1.1 General

1.1.1 Automation systems are to be tested for type approval, at works and on board, when required. Tests are to be carried out under the supervision of a Surveyor of the Society.

1.1.2 The type testing conditions for electrical, control and instrumentation equipment, computers and peripherals are described in Article [2].

1.1.3 Automation systems are to be inspected at works, according to the requirements of Article [3], in order to check that the construction complies with the Rules.

1.1.4 Automation systems are to be tested when installed on board and prior to sea trials, to verify their performance and adaptation on site, according to Article [4].

2 Type approval

2.1 General

2.1.1 The following requirements are applicable, but not confined, to electrical and electronic equipment which are intended to be type approved for control, monitoring, alarm and protection systems for use in ships.

2.1.2 The necessary documents to be submitted, prior to type testing, are listed in Ch 3, Sec 1, [2.2.1] and Ch 3, Sec 3, [3.1.1]. The type approval of automation systems refers to hardware type approval or software type approval, as applicable.

2.2 Hardware type approval

2.2.1 Hardware type approval of automation systems is obtained subject to the successful outcome of the tests described in Tab 1. These tests are to demonstrate the ability of the equipment to function as intended under the specified test conditions.

2.2.2 The extent of testing (i.e. selection and sequence of carrying out tests and number of pieces to be tested) is to be determined upon examination and evaluation of the equipment or component subject to testing, giving due regards to its intended usage.

Equipment is to be tested in its normal position if otherwise not specified in the test specification.

Vibration and salt mist testing may be performed on different specimens, where applicable.

Reset of the automation system is accepted between each test, where necessary.

Note 1: As used in this Section, and in contrast to a complete performance test, a functional test is a simplified test sufficient to verify that the equipment under test (EUT) has not suffered any deterioration caused by the individual environmental tests.

2.2.3 The following additional tests may be required, depending on particular manufacturing or operational conditions:

- mechanical endurance test
- temperature shock test (e.g. 12 shocks on exhaust gas temperature sensors from 20°C ± 5°C to maximum temperature of the range)
- immersion test
- oil resistance test
- shock test.

The test procedure is to be defined with the Society in each case.

2.3 Software type approval

2.3.1 Software of computer based systems are to be approved in accordance with Ch 3, Sec 3.

2.4 Loading instruments

2.4.1 Loading instrument approval consists of:

- approval of hardware according to [2.2], unless two computers are available on board for loading calculations only
- approval of basic software according to [2.3]

- approval of application software, consisting in data verification which results in the Endorsed Test Condition according to Part B
- installation testing according to [4].

2.5 Oil mist detection system

2.5.1 Type test of oil mist detection system are to be carried out according to Ch 3, App 1.

Table 1 : Type tests

No.	Test	Procedure **(6)**	Test parameters	Other information
1	Visual inspection	–	–	• drawings, design data
2	Performance test	Manufacturer performance test programme based upon specification and relevant rule requirements When the EUT is required to comply with an international performance standard, e.g. protection relays, verification of requirements in the standard are to be part of the performance testing required in this initial test and subsequent performance tests after environmental testing where required as per [2.2].	• standard atmosphere conditions • temperature: 25°C ± 10°C • relative humidity: 60% ± 30% • air pressure: 96 KPa ± 10 KPa	• confirmation that operation is in accordance with the requirements specified for particular automatic systems or equipment • checking of self-monitoring features • checking of specified protection against an access to the memory • checking against effect of unerroneous use of control elements in the case of computer systems
3	Power supply failure	–	• 3 interruptions during 5 minutes • switching- off time 30 s each case	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design • verification of possible corruption of programme or data held in programmable electronic systems, where applicable • the time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • for equipment which requires booting, one additional power supply interruption during booting to be performed
4a	Electric A.C. power supply variations	–	COMBINATION Voltage variation permanent / Frequency variation permanent + 6% / + 5% + 6% / – 5% – 10% / – 5% – 10% / + 5% Voltage transient (1,5s) / Frequency transient (5s) + 20% / + 10% – 20% / – 10%	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design • verification of possible corruption of programme or data held in programmable electronic systems, where applicable • the time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • for equipment which requires booting, one additional power supply interruption during booting to be performed

No.	Test	Procedure **(6)**	Test parameters	Other information
4b	Electric D.C. power supply variations	–	Voltage tolerance continuous: ± 10% Voltage cyclic variation: 5% Voltage ripple: 10% Electric battery supply: • +30% to –25% for equipment connected to charging battery or as determined by the charging/discharging characteristics, including ripple voltage from the charging device • +20% to –25% for equipment not connected to the battery during charging	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design • verification of possible corruption of programme or data held in programmable electronic systems, where applicable • the time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • for equipment which requires booting, one additional power supply interruption during booting to be performed
4c	Pneumatic and hydraulic power supply variations	–	Pressure: ± 20% Duration: 15 minutes	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design • verification of possible corruption of programme or data held in programmable electronic systems, where applicable • the time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • for equipment which requires booting, one additional power supply interruption during booting to be performed
5	Dry heat **(1)**	IEC 60068-2-2:2007 Test "Bb" for non-heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing • functional test **(9)** during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.
		IEC 60068-2-2:2007 Test "Be" for heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing with cooling system on if provided • functional test **(9)** during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.

No.	Test	Procedure **(6)**	Test parameters	Other information
6	Damp heat	IEC 60068-2-30:2005 Test Db	Temperature: 55°C Humidity: 95% Duration: 2 cycles (12 + 12 hours)	• measurement of insulation resistance before test • the test shall start with 25°C ± 3°C and at least 95% humidity • equipment operating during the complete first cycle and switched off during second cycle except for functional test • functional test during the first 2 hours of the first cycle at the test temperature and during the last 2 hours of the second cycle at the test temperature; Duration of the second cycle can be extended due to more convenient handling of the functional test • recovery at standard atmosphere conditions • insulation resistance measurements and performance test
7	Vibration	IEC 60068-2-6:2007 Test Fc	• 2 Hz ± 3/0 Hz to 13,2 Hz amplitude: ± 1mm • 13,2 Hz to 100 Hz acceleration: ± 0,7 g For severe vibration conditions such as, e. g., on diesel engines, air compressors, etc.: • 2,0 Hz to 25 Hz amplitude: ± 1,6 mm • 25 Hz to 100 Hz acceleration: ± 4,0 g Note: More severe conditions may exist for example on exhaust manifolds or fuel oil injection systems of diesel engines. For equipment specified for increased vibration levels the vibration test is to be conducted at the agreed vibration level, frequency range and duration. Values may be required to be in these cases: • 40 Hz to 2000 Hz • acceleration: ± 10,0 g at 600°C	• duration 90 minutes at 30 Hz in case of no resonance condition • duration 90 minutes at each resonance frequency at which $Q \geq 2$ is recorded • during the vibration test, functional tests are to be carried out • tests to be carried out in three mutually perpendicular planes • it is recommended as a guidance that Q does not exceed 5 • duration 120 minutes where sweep test is to be carried out instead of discrete frequency test and a number of resonant frequencies is detected close to each other. Sweep over a restricted frequency range between 0.8 and 1.2 times the critical frequencies can be used where appropriate. Note: Critical frequency is a frequency at which the equipment being tested may exhibit: • malfunction and/or performance deterioration • mechanical resonances and/or other response effects occur, e.g. chatter

No.	Test	Procedure **(6)**	Test parameters	Other information
8	Inclination	IEC 60092-504:2016	Static 22,5° Dynamic 22,5°	a) inclined to the vertical at an angle of at least 22,5° b) inclined to at least 22,5° on the other side of the vertical and in the same plane as in a) c) inclined to the vertical at an angle of at least 22,5° in plane at right angles to that used in a) d) inclined to at least 22,5° on the other side of the vertical and in the same plane as in c) Note: The period of testing in each position should be sufficient to fully evaluate the behaviour of the equipment Using the directions defined in a) to d) above, the equipment is to be rolled to an angle of 22,5° each side of the vertical with a period of 10 seconds The test in each direction is to be carried out for not less than 15 minutes Note: These inclination tests are normally not required for equipment with no moving parts.
9	Insulation resistance	Rated supply voltage / Test voltage (D.C. voltage) (V) Un ≤ 65 V — 2 x Un min. 24 V Un > 65V — 500 V	Minimum insulation resistance before / after 10 Mohms — 1,0 Mohms 100 Mohms — 10 Mohms	• insulation resistance test is to be carried out before and after: damp heat test, cold test, salt mist test and high-voltage test • between all phases and earth, and where appropriate between the phases Note: Certain components, e. g. for EMC protection, may be required to be disconnected for this test
10	High-voltage	Rated voltage Un Up to 65 V 66 V to 250 V 251 V to 500 V 501 V to 690 V	Test voltage (A.C. voltage 50 or 60Hz) 2 x Un + 500 V 1500 V 2000 V 2500 V	• separate circuits are to be tested against each other and all circuits connected with each other tested against earth • printed circuits with electronic components may be removed during the test • period of application of the test voltage: 1 minute Note: Certain components, e. g. printed circuits with electronic components, may be required to be disconnected for this test.
11	Cold	IEC 60068-2-1:2007	• Temperature: +5°C ± 3°C Duration: 2 hours, or • Temperature: –25°C ± 3°C Duration: 2 hours (see **(2)**)	• initial measurement of insulation resistance • equipment not operating during conditioning and testing except for functional test • functional test during the last hour at the test temperature • insulation resistance measurement and the functional test after recovery

No.	Test	Procedure **(6)**	Test parameters	Other information
12	Salt mist	IEC 60068-2-52:2017 Test Kb	Four spraying periods with a storage of seven days after each	• initial measurement of insulation resistance and initial functional test • equipment not operating during conditioning • functional test on the 7th day of each storage period • insulation resistance measurement and performance test 4 to 6h after recovery (see **(3)**) • on completion of exposure, the equipment shall be examined to verify that deterioration or corrosion (if any) is superficial in nature
13	Electrostatic discharge	IEC 61000-4-2:2008	Contact discharge: 6 kV Air discharge: 2 kV, 4 kV, 8 kV Interval between single discharges: 1 sec. No. of pulses: 10 per polarity According to test level 3	• to simulate electrostatic discharge as may occur when persons touch the appliance • the test is to be confined to the points and surfaces that can normally be reached by the operator • performance criterion B (see **(4)**)
14	Electromagnetic field	IEC 61000-4-3:2020 or IEC 61000-4-3:2006 + AMD1:2007 + AMD2:2010	Frequency range: 80 MHz to 6 GHz Modulation**: 80% AM at 1000Hz Field strength: 10V/m Frequency sweep rate: $\leq 1{,}5.10^{-3}$ decades/s (or 1% / 3 sec) According to test level 3	• to simulate electromagnetic fields radiated by different transmitters • the test is to be confined to the appliances exposed to direct radiation by transmitters at their place of installation • performance criterion A (see **(5)**) ** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen • If an equipment is intended to receive radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller), then the immunity limits at its communication frequency do not apply, subject to the provisions in Ch 3, Sec 3, [6.2].
15	Conducted low Frequency		A.C.: • Frequency range: rated frequency to 200th harmonic • Test voltage (rms): 10% of supply to 15th harmonic reducing to 1% at 100th harmonic and maintain this level to the 200th harmonic, min 3 V r.m.s, max. 2 W D.C.: • Frequency range: 50 Hz - 10 kHz • Test voltage (rms): 10% of supply, max. 2 W	• to simulate distortions in the power supply system generated, for instance, by electronic consumers and coupled in as harmonics • performance criterion A (see **(5)**) • see figure "Test set-up" (see **(8)**) • for keeping max. 2W, the voltage of the test signal may be lower

No.	Test	Procedure **(6)**	Test parameters	Other information
16	Conducted Radio Frequency	IEC 61000-4-6:2013	AC, DC, I/O ports and signal/ control lines Frequency range: 150 kHz - 80 MHz Amplitude: 3 V rms (see **(7)**) Modulation***: 80% AM at 1000 Hz Frequency sweep range: $\leq 1{,}5.10^{-3}$ decades/s (or 1% / 3sec.) According to test level 2	• to simulate electromagnetic fields coupled as high frequency into the test specimen via the connecting lines • performance criterion A (see **(5)**) *** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen
17	Electrical Fast Transients / Burst	IEC 61000-4-4:2012	Single pulse time: 5ns (between 10% and 90% value) Single pulse width: 50 ns (50% value) Amplitude (peak): 2 kV line on power supply port/earth; 1 kV on I/O data control and communication ports (coupling clamp) Pulse period: 300 ms Burst duration: 15 ms Duration/polarity: 5 min According to test level 3	• arcs generated when actuating electrical contacts • interface effect occurring on the power supply, as well as at the external wiring of the test specimen • performance criterion B (see **(4)**)
18	Surge	IEC 61000-4-5:2017	Test applicable to AC and DC power ports. Open-circuit voltage: • Pulse rise time: 1,2 µs (front time) • Pulse width: 50 µs (time of half value) • Amplitude (peak): 1 kV line/earth; 0,5kV line/line Short circuit current: • Pulse rise time: 8 µs (front time) • Pulse width: 20 µs (time of half value) Repetition rate: ≥ 1 pulse/min No of pulses: 5 per polarity Application: continuous According to test level 2	• to simulate interference generated, for instance, by switching “ON” or “OFF” high power inductive consumers • test procedure in accordance with figure 10 of the standard for equipment where power and signal lines are identical • performance criterion B (see **(4)**)

No.	Test	Procedure **(6)**	Test parameters	Other information
19	Radiated Emission	CISPR 16-2-3:2016 IEC 60945:2002 for 156-165 MHz	Limits below 1000MHz: • For equipment installed in the bridge and deck zone: Frequency range: (MHz) — Quasi peak limits: (dBµV/m) 0,15 - 0,30: 80- 52 0,30 - 30: 52- 34 30 - 1000: 54 except for: 156 - 165: 24 • For equipment installed in the general power distribution zone: Frequency range: (MHz) — Quasi peak limits: (dBµV/m) 0,15 - 30: 80 - 50 30 - 100: 60 - 54 100 - 1000: 54 except for: 156 - 165: 24 Limits above 1000MHz: Frequency range: (MHz) — Average limit: (dBµV/m) 1000-6000: 54	• procedure in accordance with the standard but distance 3 m between equipment and antenna • for the frequency band 156 MHz to 165 MHz the measurement is to be repeated with a receiver bandwidth of 9 kHz (as per IEC 60945:2002) • alternatively the radiation limit at a distance of 3 m from the enclosure port over the frequency 156 MHz to 165 MHz shall be 30 dB micro-V/m peak (as per IEC 60945:2002) • procedure in accordance with the standard (distance 3 m between equipment and antenna) Equipment intended to transmit radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller) may be exempted from limit, within its communication frequency range, subject to the provisions in Ch 3, Sec 3, [6.2]
20	Conducted Emission	CISPR 16-2-1:2017	Test applicable to AC and DC power ports • For equipment installed in the bridge and deck zone: Frequency range: — Limits: (dBµV) 10 - 150 kHz: 96 - 50 150 - 350 kHz: 60 - 50 0,35 - 30 MHz: 50 • For equipment installed in the general power distribution zone: Frequency range: — Limits: (dBµV) 10 - 150 kHz: 120 - 69 150 - 500 kHz: 79 0,50 - 30 MHz: 73	

No.	Test	Procedure **(6)**	Test parameters	Other information
21	Flame retardant	IEC 60092-101:2018 or IEC 60695-11-5:2016	Flame application: 5 times 15 s each Interval between each application: 15 s or 1 time 30 s	• the burnt out or damaged part of the specimen by not more than 60mm long • no flame, no incandescence or in the event of a flame or incandescence being present, it shall extinguish itself within 30 s of the removal of the needle flame without full combustion of the test specimen • any dripping material shall extinguish itself in such a way as not to ignite a wrapping tissue. The drip height is 200 mm ± 5 mm

(1) Dry heat at 70 °C is to be carried out to automation, control and instrumentation equipment subject to high degree of heat, for example mounted in consoles, housings, etc. together with other heat dissipating power equipment.

(2) For equipment installed in non-weather protected locations or cold locations, test is to be carried out at –25°C.

(3) Salt mist test is to be carried out for equipment installed in weather exposed areas.

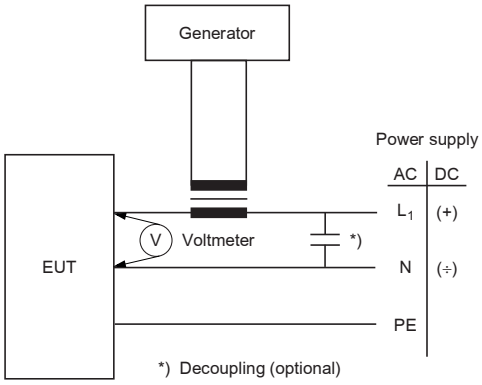
(4) Performance criterion B: (for transient phenomena): The Equipment Under Test shall continue to operate as intended after the tests. No degradation of performance or loss of function is allowed as defined in the technical specification published by the Manufacturer. During the test, degradation or loss of function or performance which is self recoverable is however allowed but no change of actual operating state or stored data is allowed.

(5) Performance criterion A (for continuous phenomena): The EUT shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed as defined in relevant equipment standard and the technical specification published by the Manufacturer.

(6) Column 3 indicates the testing procedure which is normally to be applied. However, equivalent testing procedure may be accepted by the Society provided that what is required in the other columns is fulfilled. Later versions (including revisions) of the international standards specified in this table are acceptable for use, provided the Society determines them to be equivalent to the technical specifications.

(7) For equipment installed on the bridge and deck zone, the test levels shall be increased to 10V rms for spot frequencies in accordance with IEC 60945:2002 at 2,3,4,6.2, 8.2, 12.6, 16.5, 18.8, 22, 25 MHz.

(8) Figure - Test set-up for Conducted Low Frequency.



(9) See [2.2.2], Note 1.

3 Acceptance testing

3.1 General

3.1.1 Acceptance tests are generally to be carried out at the manufacturer's facilities before the shipment of the equipment, when requested.

Acceptance tests refer to hardware and software tests as applicable.

3.2 Hardware testing

3.2.1 Final acceptance will be granted subject to:

- the results of the tests listed in [3.2.2]
- the type test report or type approval certificate.

3.2.2 Hardware acceptance tests include, where applicable:

- visual inspection
- operational tests and, in particular:
  - tests of all alarm and safety functions
  - verification of the required performance (range, calibration, repeatability, etc.) for analogue sensors
  - verification of the required performance (range, set points, etc.) for on/off sensors
  - verification of the required performance (range, response time, etc.) for actuators
  - verification of the required performance (full scale, etc.) for indicating instruments
- endurance test (burn-in test or equivalent)
- high-voltage test
- hydrostatic tests.

Additional tests may be required by the Society.

3.3 Software testing

3.3.1 Software acceptance tests of computer based systems are to be carried out according to Ch 3, Sec 3.

4 Onboard tests

4.1 General

4.1.1 The onboard tests are to be performed as per Ch 3, Sec 3, [4.3.6] and Ch 3, Sec 3, [4.3.7].

4.1.2 On board tests are to be carried out on automation systems associated with essential services to verify their compliance with the Rules, by means of visual inspection and the performance and functionality according to Tab 2.

On board testing is to verify that correct functionality has been achieved with all systems integrated.

When completed, automation systems are to be such that a single failure, for example loss of power supply, is not to result in a major degradation of the propulsion or steering of the ship. In addition, a blackout test is to be carried out to show that automation systems are continuously supplied.

Upon completion of on board tests, test reports are to be made available to the Surveyor.

4.1.3 For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not itself fail as a result of electromagnetic interference during expected operating conditions.

Note 1: Where electromagnetic interference caused by wireless data communication equipment is found to be causing failure of equipment required for Category II or III systems, the layout and/or equipment are/is to be changed to prevent further failures occurring.

Table 2 : On board tests

Equipment	Nature of tests
Electronic equipment	Main hardware and software functionalities with all systems integrated
Analogue sensors	Signal calibration, trip set point adjustment
On/off sensors	Simulation of parameter to verify and record the set points
Actuators	Checking of operation in whole range and performance (response time, pumping)
Reading instruments	Checking of calibration, full scale and standard reference value

Appendix 1 Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment

1 General

1.1 Scope

1.1.1 This Appendix is to specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines.

Note 1: This test procedure is also applicable to oil mist detection and alarm equipment intended for gear cases.

1.2 Reference

1.2.1 See Ch 3, Sec 6, [2] for test specification for type approval.

1.3 Purpose

1.3.1 The purpose of type testing crankcase oil mist detection and alarm equipment is to verify:

- the functionality of the system
- the effectiveness of the oil mist detectors
- the accuracy of oil mist detectors
- the alarm set points
- time delays between oil mist leaving the source and alarm activation
- functional failure detection
- the influence of optical obscuration on detection.

1.4 Test facilities

1.4.1 Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

- A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to the Society
- The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ± 10% in accordance with this procedure.
- When verifying the functionality, test houses are to consider the possible hazards associated with the generation of the oil mist required and take adequate precautions. The Society will accept the use of low toxicity, low hazard oils as used in other applications, provided it is demonstrated to have similar properties to SAE 40 monograde mineral oil specified.

2 Testing

2.1 Equipment testing

2.1.1 The range of tests for the alarm/monitoring panel is to include the following:

a) functional tests described in [2.2]

b) electrical power supply failure test

c) power supply variation test

d) dry heat test

e) damp heat test

f) vibration test

g) EMC test

h) insulation resistance test

i) high-voltage test

j) static and dynamic inclinations, if moving parts are contained.

2.1.2 The range of tests for the detectors is to include the following:

a) functional tests described in [2.2]

b) electrical power supply failure test

c) power supply variation test

d) dry heat test

e) damp heat test

f) vibration test

g) EMC test where susceptible

h) insulation resistance test

i) high-voltage test

j) static and dynamic inclinations.

2.2 Functional tests

2.2.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with [2.2.2] to [2.2.7] with an oil mist concentration in air, known in terms of mg/l to an accuracy of ± 10%.

2.2.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10%. See also [2.4.1], item a).

2.2.3 The oil mist detector monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10% of the lower explosive limit (LEL) or between 0 and a percentage of weight of oil in air determined by the Manufacturer based on the sensor measurement method (e.g. obscuration or light scattering) that is acceptable to the Society taking into account the alarm level specified in [2.2.4].

Note 1: The LEL corresponds to an oil mist concentration of approximately 50 mg/l (~4,1% weight of oil in air mixture).

2.2.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL or approximately 2,5 mg/l.

2.2.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

2.2.6 The performance of the oil mist detector in mg/l is to be demonstrated. This is to include the following:

- range (oil mist detector)
- resolution (oil mist detector)
- sensitivity (oil mist detector)

Note 1: Sensitivity of a measuring system: quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.

Note 2: Resolution: smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

2.2.7 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations. Piping is to be arranged to prevent pooling of oil condensate which may cause a blockage of the sampling pipe over time.

2.2.8 It is to be demonstrated that the openings of detector equipment does not become occluded or blocked under continuous splash and spray of engine lubricating oil, as may occur in the crankcase atmosphere. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by the classification society. The temperature, quantity and angle of impact of the oil to be used is to be declared and their selection justified by the manufacturer.

2.2.9 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment and it is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by the Society.

Note 1: This testing is in addition to that required by [2.1.2], item e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

2.2.10 It is to be demonstrated that an indication is given where lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication as required by Ch 1, Sec 2, [2.3.5].

2.3 Detectors and alarm equipment to be tested

2.3.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the Surveyor witnessing the tests.

2.3.2 Two detectors are to be tested. One is to be tested in clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

2.4 Method

2.4.1 The following requirements for oil mist generation are to be satisfied at type testing:

a) The ambient temperature in and around the test chamber is to be at the standard atmospheric conditions defined in Ch 3, Sec 6, [2] before any test run is started.

b) Oil mist is to be generated with suitable equipment using an SAE 40 monograde mineral oil or equivalent and supplied to a test chamber. The selection of the oil to be used is to take into consideration risks to health and safety, and the appropriate controls implemented. A low toxicity, low flammability oil of similar viscosity may be used as an alternative. The oil mist produced is to have an average (or arithmetic mean) droplet size not exceeding 5 µm. The oil droplet size is to be checked using the sedimentation method or an equivalent method to a relevant international or national standard. If the sedimentation method is chosen, the test chamber is to have a minimum height of 1m and a volume of not less than $1m^3$.

Note 1: The calculated oil droplet size using the sedimentation method represents the average droplet size.

c) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. Where an alternative technique is used its equivalence is to be demonstrated.

Note 2: For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 µm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

d) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

e) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10% below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

f) The filters require to be weighed to a precision of 0,1mg and the volume of air/oil mist sampled to 10 ml.

2.4.2 For type testing approval by the Society the testing is to be witnessed by authorised personnel from the Society.

2.4.3 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

2.4.4 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

2.5 Assessment

2.5.1 Assessment of oil mist detection equipment after testing is to address the following:

- The equipment to be tested is to have evidence of design appraisal/approval.
- Details of the detection equipment to be tested are to be recorded such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings, the maximum percentage level of lens obscuration used in [2.3.2].
- After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

2.6 Design series qualification

2.6.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

2.7 Test report

2.7.1 The test house is to provide a full report which includes the following information and documents:

- test specification
- details of equipment tested

- results of tests are to include a declaration by the manufacturer of the oil mist detector of its:
  - performance, in mg/L
  - accuracy, of oil mist concentration in air
  - precision, of oil mist concentration in air
  - range, of oil mist detector
  - resolution, of oil mist detector
  - response time, of oil mist detector
  - sensitivity, of oil mist detector
  - obscuration of sensor detection, declared as percentage of obscuration. 0% totally clean, 100% totally obscure
  - detector failure alarm.

2.8 Acceptance

2.8.1 Acceptance of crankcase oil mist detection equipment is at the discretion of the Society based on the appraisal plans and particulars and the test house report of the results of type testing.

2.8.2 The following information is to be submitted to the Society for acceptance of oil mist detection equipment and alarm arrangements:

- Description of oil mist detection equipment and system including alarms
- Copy of the test house report identified in [2.7]
- Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions
- Maintenance and test manual which is to include the following information:
  - intended use of equipment and its operation
  - functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified
  - maintenance routines and spare parts recommendations
  - limit setting and instructions for safe limit levels
  - where necessary, details of configurations in which the equipment is and is not to be used.

CHAPTER 4
FIRE PROTECTION, DETECTION AND EXTINCTION

Section 1 General
Section 2 Prevention of Fire
Section 3 Suppression of Fire: Detection and Alarm
Section 4 Suppression of Fire: Control of Smoke Spread
Section 5 Suppression of Fire: Containment of Fire
Section 6 Suppression of Fire: Fire Fighting
Section 7 Suppression of Fire: Structural Integrity
Section 8 Escape
Section 9 Fire Control Plans
Section 10 Helicopter Facilities
Section 11 Fuel for Auxiliary Vehicles
Section 12 Carriage of Dangerous Goods
Section 13 Protection of Vehicle, Special Category and Ro-ro Spaces
Section 14 Safety Centre on Passenger Ships
Section 15 Fire Safety Systems

Section 1 General

1 Application

1.1 General

1.1.1 This Chapter applies to passenger ships and cargo ships (including tankers) of 500 gross tonnage and upwards, engaged in international voyages. Ships other than those specified above are to comply with the specific Rules of the Society.

Note 1: This Chapter includes requirements of:

- Chapter II-2 of SOLAS 1974 as amended
- International Code of Fire Safety System (FSS Code), as adopted by IMO Maritime Safety Committee by Resolution MSC.98(73), as amended by the following IMO Resolutions: MSC.206(81), MSC.217(82), MSC.292(87), MSC.311(88), MSC.327(90), MSC.339(91), MSC.367(93), MSC.403(96), MSC.410(97), MSC.457(101), MSC.484(103)

1.1.2 Alternative design and arrangements

The Society may consider the acceptance of alternatives to the requirements set out in the present Chapter. If deemed necessary, the Society may require engineering analysis, evaluation and approval of the alternative design and arrangement to be carried out in accordance with IMO Circular MSC/Circ.1002, as amended.

1.2 National regulations

1.2.1 When the Administration of the State whose flag the ship is entitled to fly has issued specific rules covering fire protection, the Society may accept such rules for classification purposes in lieu of those given in this Chapter.

In such cases a special notation regarding the above is entered on the Certificate of Class of the ship concerned.

This may apply to cargo ships of less than 500 gross tonnage or to ships not engaged in international voyages.

1.3 Applicable requirements depending on ship type

1.3.1 Unless expressly provided otherwise:

a) requirements not referring to a specific ship type are applied to ships of all types

b) requirements referring to “passenger ships” are applied to passenger ships as defined in [2.37]

c) requirements referring to “cargo ships” are applied to cargo ships as defined in [2.9] and tankers as defined in [2.50].

1.3.2 Ships assigned the additional service feature **SPxxx**, **SPxxx-capable**, **IPxxx** or **IPxxx-capable** are to comply with the requirements of this chapter, considering the ship:

- as a cargo ship, when xxx is not more than 60
- as a passenger ship carrying not more than 36 passengers, when xxx is not more than 240 but greater than 60
- as a passenger ship carrying more than 36 passengers, when xxx is greater than 240.

1.4 Documentation to be submitted

1.4.1 The interested party is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted

No	I/A **(1)**	Document **(2)**
1	A	Structural fire protection, showing the method of construction, purpose and category of the various spaces of the ships, the fire rating of bulkheads and decks, means of closings of openings in A and B class divisions, draught stops
2	A	Natural and mechanical ventilation systems showing the penetrations on A class divisions, location of dampers, means of closing, arrangements of air conditioning rooms
3	A	Means of escape and, where required, the relevant dimensioning **(4)**. Escape route signage
4	A	Automatic fire detection systems and manually operated call points
5	A	Fire pumps and fire main including pumps head and capacity, hydrant and hose locations
6	A	Arrangement of fixed fire-extinguishing systems **(2)**
7	A	Arrangement of sprinkler or sprinkler equivalent systems including the capacity and head of the pumps **(2)**
8	A	Fire control plan
9	A	Fixed fire-extinguishing system in scavenge spaces of two-stroke crosshead type engines (see Ch 1, Sec 2, [2.4.1])

No	I/A **(1)**	Document **(2)**
10	A	Electrical diagram of the fixed gas fire-extinguishing systems
11	A	Electrical diagram of the sprinkler systems
12	A	Electrical diagram of power control and position indication circuits for fire doors
13	I	General arrangement plan
14	A	When fuel for auxiliary vehicles is intended to be carried onboard **(3)**: • Arrangement of the fuel storage and distribution system • Plan of hazardous areas • Diagram of the fuel storage and distribution system • Drawings showing the scantlings, material and arrangement of the fuel storage tank

(1) A : to be submitted for approval ; I : to be submitted for information

(2) Plans are to be schematic and functional and to contain all information necessary for their correct understanding and verification such as:

- service pressures
- capacity and head of pumps and compressors, if any
- materials and dimensions of piping and associated fittings
- volumes of protected spaces, for gas and foam fire-extinguishing systems
- surface areas of protected zones for automatic sprinkler and pressure water-spraying, low expansion foam and powder fire-extinguishing systems
- capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, automatic sprinkler, foam and powder fire-extinguishing systems
- type, number and location of nozzles of extinguishing media for gas, automatic sprinkler, pressure water-spraying, foam and powder fire-extinguishing systems.

All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.

(3) In the case of a retrofit, the drawings of the systems serving spaces related to fuel for auxiliary vehicles will also have to be submitted. Especially, attention is drawn on the following drawings:

- Diagrams of the bilge, scupper, discharge and drainage systems serving spaces related to the fuel for auxiliary vehicles
- Diagram of drip trays and gutterway draining system serving spaces related to the fuel for auxiliary vehicles
- Natural and mechanical ventilation systems
- Automatic fire detection systems and manually operated call points
- Arrangement of fixed fire-extinguishing systems
- Fire control plan
- Structural fire protection

(4) This includes the detailed arrangement of the means of escape from the lower part of machinery spaces of category A, including the internal clear opening of the protected enclosure, if any, and a side view showing the height of the access door to the protected enclosure / or door in the lower part of the space.

1.5 Type approved products

1.5.1 The following materials, equipment, systems or products in general used for fire protection are to be type approved by the Society, except for special cases for which the acceptance may be given for individual ships on the basis of suitable documentation or ad hoc tests:

a) A, B class fire divisions (bulkheads or decks) and associated openings

b) C-class divisions

c) Bulkhead or deck penetrations for pipes or ducts passing through A or B class divisions (where they are not of steel or other equivalent material)

d) Bulkhead or deck penetrations for electrical cables passing through A or B class divisions

e) Fire dampers

f) Prefabricated sanitary units

g) Prefabricated window casings

h) Fire door control systems

i) Flexible pipes and expansion bellows of non-conventional material for any type of fluid

j) Materials with low flame spread characteristic including paints, varnishes and similar, when they are required to have such characteristic

k) Non-combustible materials

l) Non-readily igniting materials for primary deck coverings

m) Fixed foam fire-extinguishing systems and associated foam-forming liquids

n) Fixed powder fire-extinguishing systems, including the powder

o) Equivalent water-mist fire-extinguishing systems

p) Equivalent fixed gas fire-extinguishing systems

q) Fixed water-based local application fire-extinguishing systems

r) Equivalent water-mist automatic sprinkler systems

s) Fixed fire-extinguishing systems for protection of galley cooking equipment

t) Portable fire-fighting device for stacked containers (according to Pt F, Ch 13, Sec 2, [5.1])

u) Portable fire-extinguishers

v) Non-portable and transportable extinguishers

w) Fire hoses

x) Portable foam applicators

y) Water and foam monitor

z) Foam proportioner/inductor

aa) Sprinkler heads for automatic sprinkler systems

ab) Nozzles for fixed pressure water-spraying fire-extinguishing systems for machinery spaces, boiler rooms, deep fat cooking equipment fire-extinguishing systems, and spaces intended for the carriage of vehicles and for hangars

ac) Sensing heads for automatic fire alarm and fire detection systems

ad) Fixed fire detection and fire alarm systems

ae) Flammable gas detection system

af) Explosive mixture detecting systems

ag) Portable explosive mixture detecting apparatus

ah) Fixed instruments for measuring the oxygen content for inert gas systems serving cargo tanks

ai) Portable instruments for measuring the oxygen content for inert gas systems serving cargo tanks

aj) Upholstered furniture, excluding the frame (for spaces defined in [2.39])

ak) Textile and non-textile materials suspended vertically, for example curtains (for spaces defined in [2.39])

al) Bedding components (for spaces defined in [2.39])

am) Low location lighting systems

an) Inert gas systems serving cargo tank.

ao) Fibre Reinforced Plastic (FRP) gratings used for safe access to bow (according to Pt D, Ch 7, Sec 2, [2.2.6], Pt D, Ch 8, Sec 3, [2.4] and Pt D, Ch 9, Sec 3, [1.2.14].

As regards the granting of type approval, the requirements of NR320 apply.

The Society may request type approval for other materials, equipment, systems or products required by the applicable provisions for ships or installations of special types.

2 Definitions

2.1 A class divisions

2.1.1 *"A" class divisions are those divisions formed by bulkheads and decks which comply with the following criteria:*

a) they are constructed of steel or other equivalent material

b) they are suitably stiffened

c) they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

- *class "A-60" : 60 minutes*
- *class "A-30" : 30 minutes*
- *class "A-15" : 15 minutes*
- *class "A-0" : 0 minutes*

d) they are so constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test; and

e) the Society required a test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code (see [2.22]) *to ensure that it meets the above requirements for integrity and temperature rise.*

2.1.2 The products indicated in Tab 2 may be installed without testing or approval.

Table 2 : Products installed without testing or approval

Classification	Product description
Class A-0 bulkhead	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 60 x 60 x 5 mm spaced at 600 mm or structural equivalent
Class A-0 deck	A steel deck with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 95 x 65 x 7 mm spaced at 600 mm or structural equivalent

2.2 Accommodation spaces

2.2.1 *Accommodation spaces are those spaces used for public spaces, corridors,* stairs, *lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces.*

2.2.2 Pantries or isolated pantries containing no cooking appliances may contain:

- toasters, microwave ovens, induction heaters and similar appliances each of them with a maximum power of 5 kW; and
- electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 2 kW and a surface temperature not above 150°C.

These pantries may also contain coffee machines, dish washers and water boilers with no exposed hot surfaces regardless of their power. A dining room containing such appliances should not be regarded as a pantry.

2.3 Atriums

2.3.1 Atriums are public spaces within a single main vertical zone spanning three or more open decks.

2.4 B class divisions

2.4.1 *"B" class divisions are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following criteria:*

a) they are constructed of approved non-combustible materials and all materials used in the construction and erection of "B" class divisions are non-combustible, with the exception that combustible veneers may be permitted provided they meet other appropriate requirements of this Chapter

b) they have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

- *class "B-15" : 15 minutes*
- *class "B-0" : 0 minutes*

c) they are so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test; and

d) the Society required a test of a prototype division in accordance with the Fire Test Procedures Code (see [2.22]) *to ensure that it meets the above requirements for integrity and temperature rise.*

2.4.2 In order to be defined as B class, a metal division is to have plating thickness not less than 2 mm when constructed of steel.

2.5 Bulkhead decks

2.5.1 *The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.*

2.6 C class divisions

2.6.1 *"C" class divisions are divisions constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet the requirements of this Chapter.*

2.7 Cabin balconies

2.7.1 *Cabin balcony is an open deck which is provided for the exclusive use of the occupants of a single cabin and has direct access from such a cabin.*

2.8 Calorific value

2.8.1 The gross calorific value is determined in accordance with test standard ISO 1716:2018.

2.8.2 Materials meeting the provisions of paragraphs 2.3 of Annex 2 of Fire Test Procedures Code are considered as satisfying the requirement of maximum gross calorific value (45 MJ/m2) without further testing.

2.9 Cargo ship

2.9.1 *Cargo ship is any ship which is not a passenger ship.*

2.10 Cargo spaces

2.10.1 *Cargo spaces are spaces used for cargo, cargo oil tanks, tanks for other liquid cargo and trunks to such spaces.*

2.11 Central control station

2.11.1 *The central control station is a control station in which the following control and indicator functions are centralized:*

a) fixed fire detection and fire alarm systems

b) automatic sprinkler, fire detection and fire alarm systems

c) fire door indicator panels

d) fire door closures

e) watertight door indicator panels

f) watertight door closures

g) ventilation fans

h) general/fire alarms

i) communication systems including telephones; and

Note 1: The communication systems referred to are only those required by this Chapter.

j) microphones to public address systems.

2.12 Chemical tankers

2.12.1 *A chemical tanker is a cargo ship constructed or adapted and used for the carriage in bulk of any liquid product of a flammable nature listed in Pt D, Ch 8, Sec 17.*

2.13 Closed ro-ro spaces

2.13.1 *Closed ro-ro spaces are ro-ro spaces which are neither open ro-ro spaces nor weather decks.*

2.14 Closed vehicle spaces

2.14.1 *Closed vehicle spaces are vehicle spaces which are neither open vehicle spaces nor weather decks.*

2.15 Combination carriers

2.15.1 *A combination carrier is a cargo ship designed to carry both oil and solid cargoes in bulk.*

2.16 Continuous B class ceilings or linings

2.16.1 *Continuous "B" class ceilings or linings are those "B" class ceilings or linings which terminate at an "A" or "B" class division.*

2.17 Continuously manned central control stations

2.17.1 *A continuously manned central control station is a central control station which is continuously manned by a responsible member of the crew.*

2.18 Control stations

2.18.1 *Control stations are those spaces in which the ship's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized.*

Any other spaces containing a centralized server used for the navigation and safety systems of the vessel (e.g. a data centre) are to be considered as control stations.

2.19 Dangerous goods

2.19.1 Dangerous goods are those goods belonging to the following classes:

- class 1 - Explosives
- class 2 - Gases: compressed, liquefied or dissolved under pressure
- class 3 - Flammable liquids
- class 4.1 - Flammable solids
- class 4.2 - Substances liable to spontaneous combustion
- class 4.3 - Substances which, in contact with water, emit flammable gases
- class 5.1 - Oxidising substances
- class 5.2 - Organic peroxides
- class 6.1 - Poisonous (toxic) substances
- class 6.2 - Infectious substances
- class 7 - Radioactive materials
- class 8 - Corrosives
- class 9 - Miscellaneous dangerous substances (that is any other substance which experience has shown, or may show, to be of such a dangerous character that the provisions of Part A, Chapter VII of SOLAS Convention are to be applied).

2.20 Deadweight

2.20.1 *The deadweight is the difference in tonnes between the displacement of a ship in water of a specific gravity of 1,025 at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship.*

2.21 Fire damper

2.21.1 *Fire damper is a device installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of fire. In using the above definition the following terms may be associated:*

a) automatic fire damper is a fire damper that closes independently in response to exposure to fire products

b) manual fire damper is a fire damper that is intended to be opened or closed by the crew by hand at the damper itself; and

c) remotely operated fire damper is a fire damper that is closed by the crew through a control located at a distance away from the controlled damper.

2.22 Fire Test Procedures Code

2.22.1 *Fire Test Procedures Code means the "International Code for Application of Fire Test Procedures, 2010" (2010 FTP Code), as adopted by the Maritime Safety Committee of the IMO by Resolution MSC.307 (88), as may be amended by the IMO.*

2.23 Gas carriers

2.23.1 *A gas carrier is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products of a flammable nature listed in Pt D, Ch 9, Sec 19.*

2.24 Helicopter facility

2.24.1 *Helicopter facility is a helideck including any refuelling and hangar facilities.*

2.25 Helicopter landing area

2.25.1 *Helicopter landing area is an area on a ship designated for occasional or emergency landing of helicopters but not designed for routine helicopter operations.*

2.26 Helideck

2.26.1 *Helideck is a purpose-built helicopter landing area located on a ship including all structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters.*

2.27 Lightweight

2.27.1 *The lightweight is the displacement of a ship, in tonnes, without cargo, fuel, lubricating oil, ballast water, fresh water and feed water in tanks, consumable stores and passengers and crew and their effects,* but including liquids in piping and mediums required for the fixed fire-fighting systems (e.g. fresh water, CO_2, dry chemical powder, foam concentrate, etc.).

2.28 Low flame-spread

2.28.1 *A low flame-spread means that the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the Fire Test Procedures Code.*

2.28.2 Non-combustible materials are considered as low flame spread. However, due consideration will be given by the Society to the method of application and fixing.

2.29 Machinery spaces

2.29.1 *Machinery spaces are machinery spaces of category A and other spaces containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.*

2.30 Machinery spaces of category A

2.30.1 *Machinery spaces of category A are those spaces and trunks to such spaces which contain either:*

a) internal combustion machinery used for main propulsion

b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

c) any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

2.31 Main vertical zones

2.31.1 *Main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by "A" class divisions, the mean length and width of which on any deck does not in general exceed 40 m.*

2.32 Non-combustible material

2.32.1 *Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the Fire Test Procedures Code. Any other material is a combustible material.*

2.32.2 In general, products made only of glass, concrete, ceramic products, natural stone, masonry units, common metals and metal alloys are considered as being non-combustible and may be installed without testing and approval.

2.33 Non-sparking fan

2.33.1 A fan is considered as non-sparking if in either normal or abnormal conditions it is unlikely to produce sparks. For this purpose, the following criteria are to be met:

a) Design criteria

1) The air gap between the impeller and the casing is to be not less than 1/10 of the shaft diameter in way of the impeller bearing and in any case not less than 2 mm, but need not exceed 13 mm.

2) Protective screens with square mesh of not more than 13 mm are to be fitted to the inlet and outlet of ventilation ducts to prevent objects entering the fan housing.

b) Materials

1) The impeller and the housing in way of the impeller are to be made of spark-proof materials which are recognised as such by means of an appropriate test to the satisfaction of the Society.

2) Electrostatic charges, both in the rotating body and the casing, are to be prevented by the use of antistatic materials. Furthermore, the installation on board of ventilation units is to be such as to ensure their safe bonding to the hull.

3) Tests may not be required for fans having the following material combinations:

- impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity
- impellers and housings of non-ferrous materials
- impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous material is fitted in way of the impeller
- any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm design tip clearance.

4) The following impeller and housing combinations are considered as sparking and therefore are not permitted:
   - impellers of an aluminium alloy or a magnesium alloy and a ferrous housing, regardless of tip clearance
   - housings made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance
   - any combination of ferrous impeller and housing with less than 13 mm design tip clearance.
5) Complete fans are to be type-tested in accordance with either the Society's requirements or national or international standards accepted by the Society.

2.34 Oil fuel unit

2.34.1 *The oil fuel unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 MPa.*

2.34.2 Oil fuel unit includes any equipment used for the preparation and delivery of oil fuel, heated or not, to boilers (including inert gas generators) and engines (including gas turbines) at a pressure of more than 0,18 N/mm^2. Oil fuel transfer pumps are not considered as oil fuel units.

2.35 Open ro-ro spaces

2.35.1 *Open ro-ro spaces are those ro-ro spaces which are either open at both ends or have an opening at one end, and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.*

2.36 Open vehicle spaces

2.36.1 *Open vehicle spaces are those vehicle spaces which are either open at both ends or have an opening at one end and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.*

2.37 Passenger ship

2.37.1 *Passenger ship is a ship which carries more than twelve passengers*

2.38 Public spaces

2.38.1 *Public spaces are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.*

2.39 Rooms containing furniture and furnishings of restricted fire risk

2.39.1 *Rooms containing furniture and furnishings of restricted fire risk, for the purpose of Ch 4, Sec 5, [1.3.3], are those rooms containing furniture and furnishings of restricted fire risk (whether cabins, public spaces, offices or other types of accommodation) in which:*

a) case furniture such as desks, wardrobes, dressing tables, bureaux, or dressers are constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2 mm may be used on the working surface of such articles

b) free-standing furniture such as chairs, sofas, or tables are constructed with frames of non-combustible materials

c) draperies, curtains and other suspended textile materials have qualities of resistance to the propagation of flame not inferior to those of wool having a mass of 0,8 kg/m^2, this being determined in accordance with the Fire Test Procedures Code (see [2.22])

d) floor coverings have low flame-spread characteristics;

e) exposed surfaces of bulkheads, linings and ceilings have low flame-spread characteristics

f) upholstered furniture has qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code (see [2.22]), *and*

g) bedding components have qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code (see [2.22]).

2.40 Ro-ro passenger ship

2.40.1 *Ro-ro passenger ship means a passenger ship with ro-ro spaces or special category spaces* as defined in [2.47].

2.41 Ro-ro spaces

2.41.1 *Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.*

2.42 Safety centre

2.42.1 *Safety centre is a control station dedicated to the management of emergency situations.*

Safety systems' operation, control and/or monitoring are an integral part of the safety centre.

2.43 Sauna

2.43.1 *Sauna is a hot room with temperatures normally varying between 80°C and 120°C where the heat is provided by a hot surface (e.g. by an electrically heated oven). The hot room may also include the space where the oven is located and adjacent bathrooms.*

2.44 Semi-enclosed space

2.44.1 A semi-enclosed space is a space limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation in the space are notably different from those obtained on open deck.

2.45 Service spaces

2.45.1 *Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store-rooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.*

2.45.2

a) Main pantries and pantries containing cooking appliances may contain:
   1) toasters, microwave ovens, induction heaters and similar appliances, each of them with a power of more than 5 kW; and
   2) electrically heated cooking plates and hot plates for keeping food warm, each of them with a maximum power of 5 kW.

   These pantries may also contain coffee machines, dish washers and water boilers, regardless of their power.

b) Spaces containing any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded, for the purpose of Ch 4, Sec 5, as galleys.

2.46 Smoke damper

2.46.1 *Smoke damper is a device installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of smoke and hot gases. A smoke damper is not expected to contribute to the integrity of a fire rated division penetrated by a ventilation duct. In using the above definition the following terms may be associated:*

a) automatic smoke damper is a smoke damper that closes independently in response to exposure to smoke or hot gases;

b) manual smoke damper is a smoke damper intended to be opened or closed by the crew by hand at the damper itself; and

c) remotely operated smoke damper is a smoke damper that is closed by the crew through a control located at a distance away from the controlled damper.

2.47 Special category spaces

2.47.1 *Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.*

2.48 Standard fire test

2.48.1 *A standard fire test is a test in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve in accordance with the test method specified in the Fire Test Procedures Code* (see [2.22]).

2.49 Steel or other equivalent material

2.49.1 *Steel or other equivalent material means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g., aluminium alloy with appropriate insulation).*

2.50 Tanker

2.50.1 *Tanker is a cargo ship constructed or adapted for the carriage in bulk of liquid cargoes of an inflammable nature.*

Note 1: For the purpose of this Chapter, the term tanker includes the following service notations (see Pt A, Ch 1, Sec 2, Tab 1): **chemical tanker**, **combination carrier/OBO**, **combination carrier/OOC**, **oil tanker**, **FLS tanker**, **oil recovery** or **liquefied gas carrier**.

2.51 Vehicle carrier

2.51.1 *Vehicle carrier means a cargo ship which only carries cargo in ro-ro spaces or vehicle spaces, and which is designed for the carriage of unoccupied motor vehicles without cargo, as cargo.*

2.52 Vehicle spaces

2.52.1 *Vehicle spaces are cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, including special category spaces.*

2.53 Weather decks

2.53.1 *Weather deck is a deck which is completely exposed to the weather from above and from at least two sides.*

2.54 Winching area

2.54.1 *Winching area is a pick-up area provided for the transfer by helicopter of personnel or stores to or from the ship, while the helicopter hovers above the deck.*

Section 2 Prevention of Fire

1 Probability of ignition

1.1 Arrangements for fuel oil, lubrication oil and other flammable oils

1.1.1 Limitation in the use of oils as fuel

See Ch 1, Sec 1, [2.12].

1.1.2 Arrangements for fuel oil

See Ch 1, Sec 10.

1.1.3 Arrangements for lubricating oil

See Ch 1, Sec 10.

1.1.4 Arrangements for other flammable oils

See Ch 1, Sec 10.

1.2 Arrangements for gaseous fuel for domestic purposes

1.2.1 *Where gaseous fuel is used for domestic purposes the arrangements for the storage, distribution and utilisation of the fuel shall be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the ship and the persons on board is preserved.*

See also Ch 1, Sec 10.

1.2.2 Gaseous fuel systems may only be considered for cargo ships.

1.2.3 *Storage of the gas bottles is to be located on the open deck or in a well ventilated space which opens only to the open deck.*

1.2.4 A portion of open deck, recessed into a deck structure, machinery casing, deck house, etc., utilized for the exclusive storage of gas bottles is considered acceptable provided that:

a) Such a recess has an unobstructed opening, except for small appurtenant structures, such as opening corner radii, small sills, pillars, etc. The opening may be provided with grating walls and door; and

b) The depth of such a recess is not greater than 1 m.

1.2.5 A portion of open deck meeting the above is to be considered as open deck in Ch 4, Sec 5, Tab 5 and Ch 4, Sec 5, Tab 6.

1.3 Miscellaneous items of ignition sources and ignitability

1.3.1 Electric radiators

Electric radiators, if used, shall be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiators shall be fitted with an element so exposed that clothing, curtains, or other similar materials can be scorched or set on fire by heat from the element.

1.3.2 Cellulose-nitrate based films

Cellulose-nitrate based films shall not be used for cinematograph installations.

1.3.3 Waste receptacles

In principle, *all waste receptacles shall be constructed of non-combustible materials with no openings in the sides or bottom.*

1.3.4 Insulation surfaces against oil penetration

In spaces where penetration of oil products is possible, the surface of insulation shall be impervious to oil or oil vapours.

1.3.5 Primary deck coverings

Primary deck coverings, if applied within accommodation and service spaces and control stations or if applied on cabin balconies of passenger ships, shall be of approved material which will not readily ignite, this being determined in accordance with the Fire Test Procedures Code (see Ch 4, Sec 1, [2.22]).

2 Fire growth potential

2.1 Control of air supply and flammable liquid to the space

2.1.1 Closing appliances and stopping devices of ventilation

a) *The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate whether the shut-off is open or closed.*

Ventilation inlets and outlets located at outside boundaries are to be fitted with closing appliances as required above and need not comply with Ch 4, Sec 5, [6.4.1].

b) *Power ventilation of accommodation spaces, service spaces, cargo spaces, control stations and machinery spaces shall be capable of being stopped from an easily accessible position outside the space being served. This position shall not be readily cut off in the event of a fire in the spaces served.*

These requirements do not apply to closed recirculating systems within a single space.

c) *In passenger ships carrying more than 36 passengers, all power ventilation, except machinery space and cargo space ventilation and any alternative system which may be required under Ch 4, Sec 4, [2.1.1], shall be fitted with controls so grouped that all fans may be stopped from either of two separate positions which shall be situated as far apart as practicable. Fans serving power ventilation systems to cargo spaces shall be capable of being stopped from a safe position outside such spaces.*

2.1.2 Means of control in machinery spaces

a) *Means of control shall be provided for opening and closure of skylights, closure of openings in funnels which normally allow exhaust ventilation and closure of ventilator dampers.*

The controls of ventilation fans and fire dampers serving engine rooms should also comply with Ch 4, Sec 15, [8.2.1], Note 1.

b) *Means of control shall be provided for stopping ventilating fans. Controls provided for the power ventilation serving machinery spaces shall be grouped so as to be operable from two positions, one of which shall be outside such spaces. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.*

c) *Means of control shall be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators (purifiers). However, items d) and e) hereafter need not apply to oily water separators.*

d) *The controls required in a) to c) above shall be located outside the space concerned so they will not be cut off in the event of fire in the space they serve.*

In machinery spaces of category A, controls to close off ventilation ducts and pipes are to be installed with due regard to the hot gases produced by a fire in the space concerned.

e) *In passenger ships, the controls required in items a) to d) above and in Ch 4, Sec 4, [3.2.1] and Ch 4, Sec 5, [4.2.2] and the controls for any required fire-extinguishing system shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Such positions shall have a safe access from the open deck.*

2.1.3 Closing appliances in emergency generator rooms

The following requirements apply to closable ventilation louvers and ventilator closing appliances serving emergency generator rooms, where fitted:

a) Ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic/pneumatic/electric) and are to be operable under a fire condition.

b) Hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where hand-operation is provided.

c) Power-operated ventilation louvers and closing appliances shall be of a fail-to-open type. Closed power-operated ventilation louvers and closing appliances are acceptable during normal operation of the vessel. Power-operated ventilation louvers and closing appliances shall open automatically whenever the emergency generator is starting/in operation.

d) It shall be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open/closed) shall be indicated at this position. Such closing shall not be possible from any other remote position.

Note 1: See also the requirements of Pt B, Ch 11, Sec 12, [9.1] regarding closing appliances for ventilation systems.

2.2 Fire protection materials

2.2.1 Use of non-combustible materials

a) *Insulating materials*

Insulating materials shall be non-combustible, except in cargo spaces, mail rooms, baggage rooms and refrigerated compartments of service spaces. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems, need not be of non-combustible materials, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame-spread characteristics.

Cold service means refrigeration systems and chilled water piping for air conditioning systems.

b) *Ceilings and linings*

1) Item 2 below applies to passenger ships and item 3 applies to cargo ships.

2) *Except in cargo spaces, all linings, grounds, draught stops and ceilings shall be of non-combustible materials except in mail rooms, baggage rooms, saunas or refrigerated compartments of service spaces.*

3) *All linings, ceilings, draught stops and their associated grounds shall be of non-combustible materials:*

- *in accommodation and service spaces and control stations for ships where method IC is specified as referred to in Ch 4, Sec 5, [1.4.1]; and*
- *in corridors and stairway enclosures serving accommodation and service spaces and control stations for ships where methods IIC or IIIC are specified as referred to in Ch 4, Sec 5, [1.4.1].*

c) *Partial bulkheads and decks on passenger ships*

1) *Partial bulkheads or decks used to subdivide a space for utility or artistic treatment shall be of non-combustible materials.*

2) *Linings, ceilings and partial bulkheads or decks used to screen or to separate adjacent cabin balconies shall be of non-combustible materials.*

2.2.2 Use of combustible materials

a) *General*

1) Item 2) below applies to passenger ships and item 3) applies to cargo ships.

2) *"A", "B" or "C" class divisions in accommodation and service spaces and cabin balconies which are faced with combustible materials, facings, mouldings, decorations and veneers shall comply with the provisions of b) to d) below and Article [3]. However, the provisions of c) need not apply to cabin balconies.*

3) *Non-combustible bulkheads, ceilings and linings fitted in accommodation and service spaces may be faced with combustible materials, facings, mouldings, decorations and veneers provided such spaces are bounded by non-combustible bulkheads, ceilings and linings in accordance with the provisions of b) to d) below and article [3].*

b) *Maximum calorific value of combustible materials*

Combustible materials used on the surfaces and linings specified in item a) shall have a calorific value not exceeding 45 MJ/m^2 of the area for the thickness used. The requirements of this paragraph are not applicable to the surfaces of furniture fixed to linings or bulkheads.

c) *Total volume of combustible materials*

Where combustible materials are used in accordance with the previous item a), the total volume of combustible facings, mouldings, decorations and veneers in accommodation and service spaces shall not exceed a volume equivalent to 2,5 mm veneer on the combined area of the walls and ceiling linings. Furniture fixed to linings, bulkheads or decks need not be included in the calculation of the total volume of combustible materials.

d) *Low flame-spread characteristics of exposed surface in passenger ships*

The following surfaces shall have low flame-spread characteristics in accordance with the Fire Test Procedures Code:

1) *exposed surfaces in corridors and stairway enclosures and of bulkhead and ceiling linings in accommodation and service spaces (except saunas) and control station*

2) *surfaces and grounds in concealed or inaccessible spaces in accommodation and services spaces and control stations*

3) *exposed surfaces of cabin balconies, except for natural wood decking systems.*

e) *Low flame spread characteristics of exposed surface in cargo ships*

The following surfaces shall have low flame spread characteristics in accordance with the Fire Test Procedures Code:

1) *exposed surfaces in corridors and stairway enclosures and of ceilings in accommodation and service spaces (except saunas) and control stations; and*

2) *surfaces and grounds in concealed or inaccessible spaces in accommodation and service spaces and control stations.*

2.2.3 Furniture in stairway enclosures

a) [2.2.3] applies to passenger ships.

b) Furniture in stairway enclosures shall be limited to seating. It shall be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk determined in accordance with the Fire Test Procedures Code, and shall not restrict the passenger escape route. The Society may permit additional seating in the main reception area within a stairway enclosure if it is fixed, non-combustible and does not restrict the passenger escape route. Furniture shall not be permitted in passenger and crew corridors forming escape routes in cabin areas. In addition to the above, lockers of non-combustible material, providing storage for non-hazardous safety equipment required by these regulations, may be permitted.

Drinking water dispensers and ice cube machines may be permitted in corridors provided they are fixed and do not restrict the width of the escape routes. This applies as well to decorative flower or plant arrangements, statues or other objects of art such as paintings and tapestries in corridors and stairways

2.2.4 Furniture and furnishings on cabin balconies of passenger ships

On passenger ships, furniture and furnishings shall comply with Ch 4, Sec 1, [2.39.1], items a), b), c), f) and g) unless such balconies are protected by a fixed pressure water-spraying and fixed fire detection and alarm systems complying with Ch 4, Sec 3, [4.6] and Ch 4, Sec 6, [5.1.3].

3 Smoke generation potential and toxicity

3.1 Paints, varnishes and other finishes

3.1.1 *Paints, varnishes and other finishes used on exposed interior surfaces shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code.*

3.1.2 This requirement only applies to accommodation spaces, service spaces and control stations as well as stairway enclosures.

3.1.3 *On passenger ships, paints, varnishes and other finishes used on exposed surfaces of cabin balconies shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code.*

3.2 Primary deck coverings

3.2.1 *Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not give rise to smoke or toxic or explosive hazards at elevated temperatures, this being determined in accordance to the Fire Test Procedures Code.*

3.2.2 *On passenger ships, primary deck coverings on cabin balconies shall be of approved material which will not give rise to smoke or toxic or explosive hazards at elevated temperatures, this being determined in accordance to the Fire Test Procedures Code.*

Section 3 Suppression of Fire: Detection and Alarm

1 General

1.1 Passenger ships

1.1.1 *A fixed fire detection and fire alarm system for passenger ships shall be capable of remotely and individually identifying each detector and manually operated call point.*

1.2 Minimum number of detectors

1.2.1 *Where a fixed fire detection and fire alarm system is required for the protection of spaces other than those specified in [4.2.1], at least one detector complying with the requirements given in Ch 4, Sec 15 shall be installed in each such space.*

2 Initial and periodical tests

2.1 General

2.1.1 *The function of fixed fire detection and fire alarm systems required by the relevant Sections of this Chapter shall be tested under varying conditions of ventilation after installation.*

3 Protection of machinery spaces

3.1 Installation

3.1.1 *A fixed fire detection and fire alarm system* complying with the relevant provisions given in Ch 4, Sec 15 *shall be installed in:*

a) periodically unattended machinery spaces of category A*,*

b) machinery spaces of category A *where:*

1) the installation of automatic and remote control systems and equipment has been approved in lieu of continuous manning of the space, and

2) the main propulsion and associated machinery, including the main sources of electrical power, are provided with various degrees of automatic or remote control and are under continuous manned supervision from a control room,

c) enclosed spaces containing incinerators,

d) spaces containing an inert gas generator or an ozone generator*,*

e) spaces intended for the storage or handling of solvent (as defined in Ch 1, Sec 12, [1.3.6]) on board ships fitted with an onboard carbon capture and storage system (OCC).

For fixed fire detection and fire alarm system in unattended machinery spaces, see also Part F, Chapter 3.

3.2 Design

3.2.1 *The fixed fire detection and fire alarm system required in [3.1.1] a) shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detectors shall not be permitted.*

The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in sufficient places to ensure that the alarms are heard and observed on the navigation bridge and by a responsible engineer officer. When the navigation bridge is unmanned, the alarm shall sound in a place where a responsible member of the crew is on duty.

4 Protection of accommodation and service spaces and control stations

4.1 Application

4.1.1 The provisions of [4.2] apply to ships of all types, those of [4.3] to [4.5] apply to passenger ships and those of [4.7] apply to cargo ships.

4.2 Smoke detectors in accommodation spaces

4.2.1 *Smoke detectors shall be installed in all stairways, corridors and escape routes within accommodation spaces. Consideration shall be given to the installation of special purpose smoke detectors within ventilation ducting.*

4.3 Requirements for passenger ships carrying more than 36 passengers

4.3.1 *A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors, stairways and escape routes within accommodation spaces. Smoke detectors need not be fitted in private bathrooms and galleys. Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with a fixed fire detection and alarm system.*

Heat detectors in lieu of smoke detectors may be installed in galleys. CO_2 rooms need not be protected by a fire detection system or a sprinkler system.

Detectors fitted in cabins, when activated, shall also be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located.

4.4 Requirements for passenger ships carrying not more than 36 passengers

4.4.1 *There shall be installed throughout each separate zone, whether vertical or horizontal, in all accommodation and service spaces and, where it is considered necessary by the Society, in control stations, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc., either:*

a) a fixed fire detection and fire alarm system so installed and arranged as to detect the presence of fire in such spaces and providing smoke detection in corridors, stairways and escape routes within accommodation spaces. Detectors fitted in cabins, when activated, shall also be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located; or

b) an automatic sprinkler, fire detection and fire alarm system of an approved type complying with the relevant requirements of Ch 4, Sec 15 and so installed and arranged as to protect such spaces and, in addition, a fixed fire detection and fire alarm system so installed and arranged as to provide smoke detection in corridors, stairways and escape routes within accommodation spaces.

CO_2 rooms need not be protected by a fire detection system or a sprinkler system.

4.5 Protection of atriums

4.5.1 *The entire main vertical zone containing the atrium shall be protected throughout with a smoke detection system.*

4.6 Protection of cabin balconies on passenger ships

4.6.1 A fixed fire detection and fire alarm system complying with the requirements of Ch 4, Sec 15 is to be installed on cabin balconies to which Ch 4, Sec 2, [2.2.4] applies, when furniture and furnishings on such balconies are not defined in Ch 4, Sec 1, [2.39.1], items a), b), c), f) and g).

4.7 Cargo ships

4.7.1 *Accommodation and service spaces and control stations of cargo ships shall be protected by a fixed fire detection and fire alarm system and/or an automatic sprinkler, fire detection and fire alarm system as follows, depending on a protection method adopted in accordance with Ch 4, Sec 5, [1.4.1].*

a) Method IC

A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

b) Method IIC

An automatic sprinkler, fire detection and fire alarm system of an approved type complying with the relevant requirements of Ch 4, Sec 15 shall be so installed and arranged as to protect accommodation spaces, galleys and other service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

c) Method IIIC

A fixed fire detection and fire alarm system shall be so installed and arranged as to detect the presence of fire in all accommodation spaces and service spaces, providing smoke detection in corridors, stairways and escape routes within accommodation spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

CO_2 rooms need not be protected by a fire detection system or a sprinkler system.

5 Protection of cargo spaces

5.1 Application and general requirements

5.1.1 The present Article applies to passenger ships.

5.1.2 *A fixed fire detection and fire alarm system* complying with the requirements of Ch 4, Sec 15 *or a sample extraction smoke detection system* complying with the requirements of Ch 4, Sec 15 *shall be provided in any cargo space which, in the opinion of the Society, is not accessible, except where it is shown to the satisfaction of the Society that the ship is engaged on voyages of such short duration that it would be unreasonable to apply this requirement.*

6 Manually operated call points

6.1 General requirements

6.1.1 *Manually operated call points complying with the requirements of Ch 4, Sec 15 shall be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point shall be located at each exit. Manually operated call points shall be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.*

7 Inspection hatches

7.1 Application

7.1.1 The present Article applies to passenger ships.

7.2 Inspection hatches

7.2.1 *The construction of ceilings and bulkheads shall be such that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible places, except where in the opinion of the Society there is no risk of fire originating in such places.*

8 Fire alarm signalling systems

8.1 Application

8.1.1 The present Article applies to passenger ships.

8.2 Control panel

8.2.1 *The control panel of fixed fire detection and fire alarm systems shall be designed on the fail-safe principle, e.g. an open detector circuit shall cause an alarm condition.*

8.3 Passenger ships carrying more than 36 passengers

8.3.1 *Passenger ships carrying more than 36 passengers shall have the fire detection alarms for the systems required by [4.3] centralized in a continuously manned central control station. In addition, controls for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location. The ventilation fans shall be capable of reactivation by the crew at the continuously manned control station. The control panels in the central control station shall be capable of indicating open or closed positions of fire doors and closed or off status of the detectors, alarms and fans. The control panel shall be continuously powered and shall have an automatic change-over to standby power supply in case of loss of normal power supply. The control panel shall be powered from the main source of electrical power and the emergency source of electrical power defined in Pt D, Ch 11, Sec 5, [2] unless other arrangements are permitted by the Rules, as applicable.*

8.4 Special alarm

8.4.1 *A special alarm, operated from the navigation bridge or fire control station, shall be fitted to summon the crew. This alarm may be part of the ship's general alarm system and shall be capable of being sounded independently of the alarm to the passenger spaces.*

9 Protection of battery rooms

9.1 Li-ion batteries above 20kWh

9.1.1 In battery rooms, a combined heat and smoke detection and alarm system, complying with the requirements of Ch 4, Sec 15, [8],is to be installed.

Section 4 Suppression of Fire: Control of Smoke Spread

1 General

1.1 Application

1.1.1 The provisions of [2.1] to [4.1] except [3.2.2] apply to ships of all types. Those of [3.2.2] and [5.1] apply to passenger ships.

2 Protection of control stations outside machinery spaces

2.1 General

2.1.1 *Practicable measures shall be taken for control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained so that, in the event of fire, the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided and air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimized. At the discretion of the Society, such requirements need not apply to control stations situated on, and opening onto, an open deck or where local closing arrangements would be equally effective.*

The ventilation system serving safety centres may be derived from the ventilation system serving the navigation bridge, unless located in an adjacent main vertical zone.

2.1.2 For ships other than passenger ships carrying more than 36 passengers, equally effective local closing arrangements means that in the case of ventilators these are to be fitted with fire dampers or smoke dampers which are to be easily closed within the control station in order to maintain the absence of smoke in the event of fire.

3 Release of smoke from machinery spaces

3.1 Release of smoke

3.1.1 *Suitable arrangements shall be made to permit the release of smoke, in the event of fire, from the space to be protected. The normal ventilation systems may be acceptable for this purpose.*

3.2 Controls

3.2.1 *Means of control shall be provided for permitting the release of smoke and such controls shall be located outside the space concerned so that they will not be cut off in the event of fire in the space they serve.*

3.2.2 *The controls required by [3.2.1] shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Such positions shall have a safe access from the open deck.*

4 Draught stops

4.1

4.1.1 *Air spaces enclosed behind ceilings, panelling or linings,* including raised floors*, shall be divided by close-fitting draught stops spaced not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.*

5 Smoke extraction systems

5.1 Atriums

5.1.1 *Atriums shall be equipped with a smoke extraction system. The smoke extraction system shall be activated by the required smoke detection system and be capable of manual control. The fans shall be sized such that the entire volume within the space can be exhausted in 10 min or less.*

Section 5 Suppression of Fire: Containment of Fire

1 Thermal and structural boundaries

1.1 Application

1.1.1 The provisions of [1.2] apply to ships of all types, those of [1.3] apply to passenger ships, those of [1.4] apply to cargo ships and those of [1.5] apply to tankers.

1.2 Thermal and structural subdivision

1.2.1 *Ships of all types shall be subdivided into spaces by thermal and structural divisions having regard to the fire risk of the space.*

1.3 Passenger ships

1.3.1 Main vertical zones and horizontal zones

a) *In ships carrying more than 36 passengers, the hull, superstructure and deckhouses shall be subdivided into main vertical zones by A-60 class divisions. Steps and recesses shall be kept to a minimum, but where they are necessary they shall also be A-60 class divisions. Where a category (5), (9) or (10) space defined in item b) of [1.3.3] is on one side or where fuel oil tanks are on both sides of the division the standard may be reduced to A-0.*

b) *In ships carrying not more than 36 passengers, the hull, superstructure and deckhouses in way of accommodation and service spaces shall be subdivided into main vertical zones by A class divisions. These divisions shall have insulation values in accordance with Tab 3 and Tab 4.*

c) *As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck. The length and width of main vertical zones may be extended to a maximum of 48 m in order to bring the ends of main vertical zones to coincide with watertight subdivision bulkheads or in order to accommodate a large public space extending for the whole length of the main vertical zone provided that the total area of the main vertical zone is not greater than 1600 m^2 on any deck. The length or width of a main vertical zone is the maximum distance between the furthermost points of the bulkheads bounding it.*

   If a stairway serves two main vertical zones, the maximum length of any one main vertical zone need not be measured from the far side of the stairway enclosure. In this case all boundaries of the stairway enclosure are to be insulated as main vertical zone bulkheads and access doors leading into the stairway are to be provided from the two outside zones. The number of main vertical zones of 48 m length is not limited as long as they comply with all the requirements.

d) *Such bulkheads shall extend from deck to deck and to the shell or other boundaries.*

e) *On ships designed for special purposes, such as automobile or railroad car ferries, where the provision of main vertical zone bulkheads would defeat the purpose for which the ship is intended, equivalent means for controlling and limiting a fire shall be substituted and specifically approved by the Society.*

   However, in a ship with special category spaces, such spaces shall comply with the applicable provisions of Ch 4, Sec 13 and, where such compliance would be inconsistent with other requirements for passenger ships specified in this Chapter, the requirements of Ch 4, Sec 13 shall prevail.

1.3.2 Bulkheads within a main vertical zone

a) *For ships carrying more than 36 passengers, bulkheads which are not required to be A class divisions shall be at least B class or C class divisions as prescribed in Tab 1 and Tab 2.*

b) *For ships carrying not more than 36 passengers, bulkheads within accommodation and service spaces which are not required to be A class divisions shall be at least B class or C class divisions as prescribed in Tab 3 and Tab 4. In addition, corridor bulkheads, where not required to be A class, shall be B class divisions which shall extend from deck to deck except:*

   1) *when continuous B class ceilings or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining shall be of material which, in thickness and composition, is acceptable in the construction of B class divisions, but which shall be required to meet B class integrity standards only in so far as is reasonable and practicable in the opinion of the Society; and*

   2) *in the case of a ship protected by an automatic sprinkler system complying with the provisions of* Ch 4, Sec 15, *the corridor bulkheads may terminate at a ceiling in the corridor provided such bulkheads and ceilings are of B class standard in compliance with* [1.3.4]. *All doors and frames in such bulkheads shall be of non-combustible materials and shall have the same fire integrity as the bulkhead in which they are fitted.*

c) Bulkheads required to be B class divisions, except corridor bulkheads as prescribed in item b) above, shall extend from deck to deck and to the shell or other boundaries. However, where a continuous B class ceiling or lining is fitted on both sides of a bulkhead which is at least of the same fire resistance as the adjoining bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

Table 1 : Bulkheads not bounding either main vertical zones or horizontal zones in passenger ships carrying more than 36 passengers

SPACES		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Control stations	(1)	B-0 [a]	A-0	A-0	A-0	A-0	A-60	A-60	A-60	A-0	A-0	A-60	A-60	A-60	A-60
Stairways	(2)		A-0 [a]	A-0	A-0	A-0	A-0	A-15	A-15	A-0 [c]	A-0	A-15	A-30	A-15	A-30
Corridors	(3)			B-15	A-60	A-0	B-15	B-15	B-15	B-15	A-0	A-15	A-30	A-0	A-30
Evacuation stations and external escape routes	(4)				–	A-0	A-60 [b][d]	A-60 [b][d]	A-60 [b][d]	A-0 [d]	A-0	A-60 [b]	A-60 [b]	A-60 [b]	A-60 [b]
Open deck spaces	(5)					–	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of minor fire risk	(6)						B-0	B-0	B-0	C	A-0	A-0	A-30	A-0	A-30
Accommodation spaces of moderate fire risk	(7)							B-0	B-0	C	A-0	A-15	A-60	A-15	A-60
Accommodation spaces of greater fire risk	(8)								B-0	C	A-0	A-30	A-60	A-15	A-60
Sanitary and similar spaces	(9)									C	A-0	A-0	A-0	A-0	A-0
Tanks, voids and auxiliary machinery spaces having little or no fire risk	(10)										A-0 [a]	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk	(11)											A-0 [a]	A-0	A-0	A-15
Machinery spaces and main galleys	(12)												A-0 [a]	A-0	A-60
store-rooms, workshops, pantries etc.	(13)													A-0 [a]	A-0
Other spaces in which flammable liquids are stowed	(14)														A-30

Note 1: (to be applied to Tab 1 and Tab 2, as appropriate)

[a] : Where adjacent spaces are in the same numerical category and letter "a" appears, a bulkhead or deck between such spaces need not be fitted if deemed unnecessary by the Society. For example, in category (12) a bulkhead need not be required between a galley and its annexed pantries provided the pantry bulkheads and decks maintain the integrity of the galley boundaries. A bulkhead is, however, required between a galley and machinery space even though both spaces are in category (12).

[b] : The ship's side, to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to liferafts and evacuation slides may be reduced to A-30.

[c] : Where public toilets are installed completely within the stairway enclosure, the public toilet bulkhead within the stairway enclosure can be of B class integrity.

[d] : Where spaces of category (6), (7), (8) and (9) are located completely within the outer perimeter of the assembly station, the bulkheads of these spaces are allowed to be of B-0 class integrity. Control positions for audio, video and light installations may be considered as part of the assembly station.

Table 2 : Decks not forming steps in main vertical zones nor bounding horizontal zones in passenger ships carrying more than 36 passengers

SPACE below		SPACE above													
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Control stations	(1)	A-30	A-30	A-15	A-0	A-0	A-0	A-15	A-30	A-0	A-0	A-0	A-60	A-0	A-60
Stairways	(2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-30
Corridors	(3)	A-15	A-0	A-0 [a]	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-30	A-0	A-30
Evacuation stations and external escape routes	(4)	A-0	A-0	A-0	A-0	–	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Open deck spaces	(5)	A-0	A-0	A-0	A-0	–	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of minor fire risk	(6)	A-60	A-15	A-0	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of moderate fire risk	(7)	A-60	A-15	A-15	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of greater fire risk	(8)	A-60	A-15	A-15	A-60	A-0	A-15	A-15	A-30	A-0	A-0	A-0	A-0	A-0	A-0
Sanitary and similar spaces	(9)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Tanks, voids and auxiliary machinery spaces having little or no fire risk	(10)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [a]	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk	(11)	A-60	A-60	A-60	A-60	A-0	A-0	A-15	A-30	A-0	A-0	A-0 [a]	A-0	A-0	A-30
Machinery spaces and main galleys	(12)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30	A-30 [a]	A-0	A-60
store-rooms, workshops, pantries, etc.	(13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0	A-0
Other spaces in which flammable liquids are stowed	(14)	A-60	A-60	A-60	A-60	A-0	A-30	A-60	A-60	A-0	A-0	A-0	A-0	A-0	A-0
Note 1: The notes of Tab 1 apply to Tab 2, as appropriate.															

1.3.3 Fire integrity of bulkheads and decks in ships carrying more than 36 passengers

a) In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned in [1.3.1] and [1.3.2], the minimum fire integrity of all bulkheads and decks shall be as prescribed in Tab 1 and Tab 2. Where, due to any particular structural arrangements in the ship, difficulty is experienced in determining from the tables the minimum fire integrity value of any divisions, such values shall be determined to the satisfaction of the Society.

b) The following requirements shall govern application of Tab 1 and Tab 2:

1) Tab 1 shall apply to bulkheads not bounding either main vertical zones or horizontal zones.

Tab 2 shall apply to decks not forming steps in main vertical zones nor bounding horizontal zones.

2) For determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (14) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of the present Section, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in Tab 1 and Tab 2. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- *(1) Control stations*

  Spaces containing emergency sources of power and lighting

  Wheelhouse and chartroom

  Spaces containing the ship's radio equipment

  Fire control stations

  Control room for propulsion machinery when located outside the propulsion machinery space

  Spaces containing centralized fire alarm equipment

  Spaces containing centralized emergency public address system stations and equipment.

- *(2) Stairways*

  Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) for passengers and crew and enclosures thereto

  In this connection a stairway which is enclosed at only one level shall be regarded as part of the space from which it is not separated by a fire door.

- *(3) Corridors*

  Passenger and crew corridors and lobbies.

- *(4) Evacuation stations and external escape routes*

  Survival craft stowage area

  Open deck spaces and enclosed promenades forming lifeboat and liferaft embarkation and lowering stations

  Assembly stations, internal and external

  External stairs and open decks used for escape routes

  The ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferaft and evacuation slide embarkation areas.

- *(5) Open deck spaces*

  Open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and lowering stations. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces are to be naturally ventilated through permanent openings, having a combined area of at least 30% of the total area of the space boundaries adjacent to the outside.

  Air spaces (the space outside superstructures and deckhouses).

- *(6) Accommodation spaces of minor fire risk*

  Cabins containing furniture and furnishings of restricted fire risk

  Offices and dispensaries containing furniture and furnishings of restricted fire risk

  Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of less than 50 m^2.

- *(7) Accommodation spaces of moderate fire risk*

  Spaces as in category (6) above but containing furniture and furnishings of other than restricted fire risk

  Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of 50 m^2 or more

  Isolated lockers and small store-rooms in accommodation spaces having areas less than 4 m^2 (in which flammable liquids are not stowed)

  Motion picture projection and film stowage rooms

  Diet kitchens (containing no open flame)

  Cleaning gear lockers (in which flammable liquids are not stowed)

  Laboratories (in which flammable liquids are not stowed)

  Pharmacies

  Small drying rooms (having a deck area of 4 m^2 or less)

  Specie rooms

  Operating rooms.

- *(8) Accommodation spaces of greater fire risk*

  Public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m^2 or more

  Barber shops and beauty parlours

  Sale shops

  Saunas.

- *(9) Sanitary and similar spaces*

  Communal sanitary facilities, showers, baths, water closets, etc.

  Small laundry rooms

  Indoor swimming pool area

  Isolated pantries containing no cooking appliances in accommodation spaces

  Private sanitary facilities shall be considered a portion of the space in which they are located.

- *(10) Tanks, voids and auxiliary machinery spaces having little or no fire risk*

  Water tanks forming part of the ship's structure

  Voids and cofferdams

  Auxiliary machinery spaces which do not contain machinery having a pressure lubrication system and where storage of combustibles is prohibited, such as:

  - *ventilation and air-conditioning rooms*
  - *windlass room*
  - *steering gear room*
  - *stabiliser equipment room*
  - *electric propulsion motor room*
  - *rooms containing section switchboards and purely electrical equipment other than oil-filled electrical transformers (above 10 kVA)*
  - *shaft alleys and pipe tunnels, and*
  - *spaces for pumps and refrigeration machinery (not handling or using flammable liquids)*

  Closed trunks serving the spaces listed above

  Other closed trunks such as pipe and cable trunks

  Spaces dedicated to urea or sodium hydroxide solution tanks for selective catalytic reduction (SCR) systems, exhaust gas recirculation (EGR) systems or exhaust gas cleaning systems (EGCS), when separated from the engine room.

  Ballast Water Management Rooms (BWMR) not containing oil-fired inert gas generators (i.e. for ballast water management systems other than category 3b and 3c according to Ch 1, Sec 13, Tab 1).

- *(11) Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk*

  Cargo oil tanks

  Cargo holds, trunkways and hatchways

  Refrigerated chambers

  Oil fuel tanks (where installed in a separate space with no machinery)

  Shaft alleys and pipe tunnels allowing storage of combustibles

  Auxiliary machinery spaces as in category (10) which contain machinery having a pressure lubrication system or where storage of combustibles is permitted

  Oil fuel filling stations

  Spaces containing oil-filled electrical transformers (above 10 kVA)

  Spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines of power output up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.

  Closed trunks serving the spaces listed above

  Spaces intended for the storage or handling of solvent (as defined in Ch 1, Sec 12, [1.3.6]) on board ships fitted with an onboard carbon capture and storage system (OCC).

- *(12) Machinery spaces and main galleys*

  Main propulsion machinery rooms (other than electric propulsion motor rooms) and boiler rooms

  Auxiliary machinery spaces other than those in categories (10) and (11) which contain internal combustion machinery or other oil-burning, heating or pumping units

  Main galleys and annexes

  Trunks and casings to the spaces listed above

  Ballast Water Management Rooms (BWMR) containing oil-fired inert gas generators (i.e. for ballast water management systems category 3b and 3c according to Ch 1, Sec 13, Tab 1).

- *(13) Store-rooms, workshops, pantries, etc.*

  Main pantries not annexed to galleys

  Main laundry

  Large drying rooms (having a deck area of more than 4 m^2)

  Miscellaneous stores

  Mail and baggage rooms

  Garbage rooms

  Workshops (not part of machinery spaces, galleys, etc.)

  Lockers and store-rooms having areas greater than 4 m^2, other than those spaces that have provisions for the storage of flammable liquids

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if no flammable products are stored

Note 1: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

- *(14) Other spaces in which flammable liquids are stowed*

  Paint lockers

  Store-rooms containing flammable liquids (including dyes, medicines, etc.)

  Laboratories (in which flammable liquids are stowed)

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if flammable products are stored

Note 2: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

Spaces where oxygen is stored or produced.

3) *Notwithstanding the provisions of [1.3.2], there are no special requirements for material or integrity of boundaries where only a dash appears in the tables.*

4) *The Society shall determine in respect of category (5) spaces whether the insulation values in Tab 1 shall apply to ends of deckhouses and superstructures, and whether the insulation values in Tab 2 shall apply to weather decks. In no case shall the requirements of category (5) of Tab 1 or Tab 2 necessitate enclosure of spaces which in the opinion of the Society need not be enclosed.*

c) *Continuous B class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.*

d) *In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.*

e) *Construction and arrangement of saunas*

- *The perimeter of the sauna shall be of "A" class boundaries and may include changing rooms, showers and toilets. The sauna shall be insulated to "A-60" standard against other spaces except those inside the perimeter and spaces of categories (5), (9) and (10).*
- *Bathrooms with direct access to saunas may be considered as part of them. In such cases, the door between sauna and the bathroom need not comply with fire safety requirements.*
- *The traditional wooden lining on the bulkheads and ceiling are permitted in the sauna. The ceiling above the oven shall be lined with a non-combustible plate with an air gap of at least 30 mm. The distance from the hot surfaces to combustible materials shall be at least 500 mm or the combustible materials shall be protected (e.g. non-combustible plate with an air gap of at least 30 mm).*
- *The traditional wooden benches are permitted to be used in the sauna.*
- *The sauna door shall open outwards by pushing.*
- *Electrically heated ovens shall be provided with a timer.*

Note 3: For the purpose of this Chapter, hammams are treated as saunas.

f) Battery rooms containing Li Ion-type batteries are to be considered as a machinery space of category A for structural fire protection purpose. The boundaries between battery rooms containing Li Ion-type batteries and machinery spaces of category A are to have A-60 fire integrity.

1.3.4 Fire integrity of bulkheads and decks in ships carrying not more than 36 passengers

a) In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned in [1.3.1] and [1.3.2], the minimum fire integrity of bulkheads and decks shall be as prescribed in Tab 3 and Tab 4.

b) The following requirements govern application of the tables:

1) Tab 3 and Tab 4 shall apply, respectively, to the bulkheads and decks separating adjacent spaces.

2) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (11) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of the present Section, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30% communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in Tab 3 and Tab 4. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- *(1) Control stations*

  Spaces containing emergency sources of power and lighting

  Wheelhouse and chartroom

  Spaces containing the ship's radio equipment

  Fire control stations

  Control room for propulsion machinery when located outside the machinery space

  Spaces containing centralized fire alarm equipment.

- *(2) Corridors*

  Passenger and crew corridors and lobbies.

- *(3) Accommodation spaces*

  Spaces as defined in Ch 4, Sec 1, [2.2] excluding corridors.

- *(4) Stairways*

  Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto

  In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

- *(5) Service spaces (low risk)*

  Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if no flammable products are stored and if the area of the space is less than 4m^2

Note 1: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

- *(6) Machinery spaces of category A*

  Spaces as defined in Ch 4, Sec 1, [2.30]

  Ballast Water Management Rooms (BWMR) containing oil-fired inert gas generators (i.e. for ballast water management systems category 3b and 3c according to Ch 1, Sec 13, Tab 1).

- *(7) Other machinery spaces*

  Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces)

  Spaces as defined in Ch 4, Sec 1, [2.29], excluding machinery spaces of category A.

  Spaces dedicated to urea or sodium hydroxide solution tanks for selective catalytic reduction (SCR) systems, exhaust gas recirculation (EGR) systems or exhaust gas cleaning systems (EGCS), when separated from the engine room

  Ballast Water Management Rooms (BWMR) not containing oil-fired inert gas generators (i.e. for ballast water management systems other than category 3b and 3c according to Ch 1, Sec 13, Tab 1)

  Spaces intended for the storage or handling of solvent (as defined in Ch 1, Sec 12, [1.3.6]) on board ships fitted with an onboard carbon capture and storage system (OCC).

- *(8) Cargo spaces*

  All spaces used for cargo (including cargo oil tanks) and trunkways and hatchways to such spaces, other than special category spaces.

- *(9) Service spaces (high risk)*

  Galleys, pantries containing cooking appliances, paint lockers, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, saunas and workshops other than those forming part of the machinery spaces.

Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if flammable products are stored or if the area of the space is above 4m^2.

Note 2: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

Spaces where oxygen is stored or produced.

- *(10) Open decks*

  Open deck spaces and enclosed promenades having little or no fire risk. Enclosed promenades shall have no significant fire risk, meaning that furnishing shall be restricted to deck furniture. In addition, such spaces are to be naturally ventilated through permanent openings, having a combined area of at least 30% of the total area of the space boundaries adjacent to the outside.

  Air spaces (the space outside superstructures and deckhouses).

- *(11) Special category and ro-ro spaces*

  Spaces as defined in Ch 4, Sec 1, [2.41] and Ch 4, Sec 1, [2.47].

3) *In determining the applicable fire integrity standard of a boundary between two spaces within a main vertical zone or horizontal zone which is not protected by an automatic sprinkler system complying with the provisions of Ch 4, Sec 15 or between such zones neither of which is so protected, the higher of the two values given in the tables shall apply.*

4) *In determining the applicable fire integrity standard of a boundary between two spaces within a main vertical zone or horizontal zone which is protected by an automatic sprinkler system complying with the provisions of Ch 4, Sec 15 or between such zones both of which are so protected, the lesser of the two values given in the tables shall apply. Where a zone with sprinklers and a zone without sprinklers meet within accommodation and service spaces, the higher of the two values given in the tables shall apply to the division between the zones.*

c) *Continuous B class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.*

d) *External boundaries which are required in Ch 4, Sec 7, [2.1.1] to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of passenger ships to have A class integrity. Similarly, in such boundaries which are not required to have A class integrity, doors may be constructed of materials which are to the satisfaction of the Society.*

e) *In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.*

f) *Saunas shall comply with [1.3.3], item e).*

g) A navigation locker that can only be accessed from the wheelhouse should be considered as a control station with respect to the provisions of Tab 3 and the bulkhead separating the wheelhouse and such a locker should have fire integrity of at least "B-0" class.

h) Battery rooms containing Li Ion-type batteries are to be considered as a machinery space of category A for structural fire protection purpose. The boundaries between battery rooms containing Li Ion-type batteries and machinery spaces of category A are to have A-60 fire integrity.

1.3.5 Protection of stairways and lifts in accommodation area

a) *Stairways shall be within enclosures formed of A class divisions, with positive means of closure at all openings, except that:*

1) *a stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or self-closing doors in one 'tweendeck space. When a stairway is closed in one 'tweendeck space, the stairway enclosure shall be protected in accordance with the tables for decks in [1.3.3] or [1.3.4].*

   The door provided at this stairway enclosure is to be of the self-closing type.

2) *stairways may be fitted in the open in a public space, provided they lie wholly within the public space.*

b) *Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one 'tweendeck to another and shall be provided with means of closing so as to permit the control of draught and smoke. Machinery for lifts located within stairway enclosures shall be arranged in a separate room, surrounded by steel boundaries, except that small passages for lift cables are permitted. Lifts which open into spaces other than corridors, public spaces, special category spaces, stairways and external areas shall not open into stairways included in the means of escape.*

1.3.6 Arrangement of cabin balconies

Non-load bearing partial bulkheads which separate adjacent cabin balconies shall be capable of being opened by the crew from each side for the purpose of fighting fires.

1.3.7 Protection of atriums

a) *Atriums shall be within enclosures formed of "A" class divisions having a fire rating determined in accordance with Tab 2 and Tab 4, as applicable.*

b) *Decks separating spaces within atriums shall have a fire rating determined in accordance with Tab 2 and Tab 4, as applicable.*

Table 3 : Fire integrity of bulkheads separating adjacent spaces in passenger ships carrying not more than 36 passengers

SPACES		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Control stations	(1)	A-0 [c]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60
Corridors	(2)		C [e]	B-0 [e]	A-0 [a] B-0 [e]	B-0 [e]	A-60	A-0	A-0	A-15 A-0 [d]	*	A-30
Accommodation spaces	(3)			C [e]	A-0 [a] B-0 [e]	B-0 [e]	A-60	A-0	A-0	A-15 A-0 [d]	*	A-30 A-0 [d]
Stairways	(4)				A-0 [a] B-0 [e]	A-0 [a] B-0 [e]	A-60	A-0	A-0	A-15 A-0 [d]	*	A-30
Service spaces (low risk)	(5)					C [e]	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	(6)						*	A-0	A-0	A-60	*	A-60
Other machinery spaces	(7)							A-0 [b]	A-0	A-0	*	A-0
Cargo spaces	(8)								*	A-0	*	A-0
Service spaces (high risk)	(9)									A-0 [b]	*	A-30
Open decks	(10)										–	A-0
Special category and ro-ro spaces	(11)											A-30

Note 1: (to be applied to Tab 3 and Tab 4, as appropriate)

[a] : For clarification as to which applies, see [1.3.2] and [1.3.5].

[b] : Where spaces are of the same numerical category and letter "b" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an A-0 bulkhead.

[c] : Bulkheads separating the wheelhouse and chartroom from each other may have a B-0 rating. No fire rating is required for those partitions separating the navigation bridge and the safety centre when the latter is within the navigation bridge.

[d] : See items b) 3) and b) 4) of [1.3.4].

[e] : For the application of item b) of [1.3.1], B-0 and C, where appearing in Tab 3, are to be read as A-0.

[f] : Fire insulation need not be fitted if the machinery space in category (7), in the opinion of the Society, has little or no fire risk

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material, but is not required to be of A class standard. However, where a deck, except in a category (10) space, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-extinguishing system is fitted.

For the application of item b) of [1.3.1], an asterisk, where appearing in Tab 4, except for categories (8) and (10), is to be read as A-0.

Table 4 : Fire integrity of decks separating adjacent spaces in passenger ships carrying not more than 36 passengers

SPACE below		SPACE above										
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Control stations	(1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-60
Corridors	(2)	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	(3)	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30 A-0 [d]
Stairways	(4)	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	(5)	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	(6)	A-60	A-60	A-60	A-60	A-60	*	A-60 [f]	A-30	A-60	*	A-60
Other machinery spaces	(7)	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	(8)	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0
Service spaces (high risk)	(9)	A-60	A-30 A-0 [d]	A-30 A-0 [d]	A-30 A-0 [d]	A-0	A-60	A-0	A-0	A-0	*	A-30
Open decks	(10)	*	*	*	*	*	*	*	*	*	–	A-0
Special category and ro-ro spaces	(11)	A-60	A-30	A-30 A-0 [d]	A-30	A-0	A-60	A-0	A-0	A-30	A-0	A-30

Note 1: The notes to Tab 3 apply to this table as appropriate.

1.4 Cargo ships except tankers

1.4.1 Methods of protection in accommodation area

a) *One of the following methods of protection shall be adopted in accommodation and service spaces and control stations:*

1) *Method IC*

The construction of internal divisional bulkheads of non-combustible B or C class divisions generally without the installation of an automatic sprinkler, fire detection and fire alarm system in the accommodation and service spaces, except as required by item a) of Ch 4, Sec 3, [4.7.1], or

2) *Method IIC*

The fitting of an automatic sprinkler, fire detection and fire alarm system as required by item b) of Ch 4, Sec 3, [4.7.1] for the detection and extinction of fire in all spaces in which fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheads, or

3) *Method IIIC*

The fitting of a fixed fire detection and fire alarm system, as required by item c) of Ch 4, Sec 3, [4.7.1], in spaces in which a fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheads, except that in no case shall the area of any accommodation space or spaces bounded by an A or B class division exceed 50 m^2. However, consideration may be given by the Society to increasing this area for public spaces.

b) *The requirements for the use of non-combustible materials in the construction and insulation of boundary bulkheads of machinery spaces, control stations, service spaces, etc., and the protection of the above stairway enclosures and corridors will be common to all three methods outlined in a).*

c) *In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.*

1.4.2 Bulkheads within accommodation area

a) *Bulkheads required to be B class divisions shall extend from deck to deck and to the shell or other boundaries. However, where a continuous B class ceiling or lining is fitted on both sides of the bulkhead, the bulkhead may terminate at the continuous ceiling or lining.*

b) *Method IC*

Bulkheads not required by this or other Sections for cargo ships to be A or B class divisions shall be of at least C class construction.

c) *Method IIC*

There shall be no restriction on the construction of bulkheads not required by this or other Sections for cargo ships to be A or B class divisions except in individual cases where C class bulkheads are required in accordance with Tab 5.

d) *Method IIIC*

There shall be no restriction on the construction of bulkheads not required for cargo ships to be A or B class divisions except that the area of any accommodation space or spaces bounded by a continuous A or B class division shall in no case exceed 50 m^2, except in individual cases where C class bulkheads are required in accordance with Tab 5. However, consideration may be given by the Society to increasing this area for public space.

1.4.3 Fire integrity of bulkheads and decks

a) *In addition to complying with the specific provisions for fire integrity of bulkheads and decks of cargo ships, the minimum fire integrity of bulkheads and decks shall be as prescribed in Tab 5 and Tab 6.*

b) *The following requirements shall govern application of Tab 5 and Tab 6:*

1) *Tab 5 and Tab 6 shall apply respectively to the bulkheads and decks separating adjacent spaces.*

2) *For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (11) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of the present Section, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in Tab 5 and Tab 6. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.*

- *(1) Control stations*

  Spaces containing emergency sources of power and lighting

  Wheelhouse and chartroom

  Spaces containing the ship's radio equipment

  Fire control stations

  Control room for propulsion machinery when located outside the machinery space

  Spaces containing centralised fire alarm equipment.

- *(2) Corridors*

  Corridors and lobbies.

- *(3) Accommodation spaces*

  Spaces as defined in Ch 4, Sec 1, [2.2], excluding corridors.

- *(4) Stairways*

  Interior stairways, lifts, totally enclosed emergency space trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto

  In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

- *(5) Service spaces (low risk)*

  Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if no flammable products are stored and if the area of the space is less than 4m^2

Note 1: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

- *(6) Machinery spaces of category A*

  Spaces as defined in Ch 4, Sec 1, [2.30]

  Ballast Water Management Rooms (BWMR) containing oil-fired inert gas generators (i.e. for ballast water management systems category 3b and 3c according to Ch 1, Sec 13, Tab 1).

- *(7) Other machinery spaces*

  Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces)

  Spaces as defined in Ch 4, Sec 1, [2.29], excluding machinery spaces of category A.

  Spaces dedicated to urea or sodium hydroxide solution tanks for selective catalytic reduction (SCR) systems, exhaust gas recirculation (EGR) systems or exhaust gas cleaning systems (EGCS), when separated from the engine room.

  Ballast Water Management Rooms (BWMR) not containing oil-fired inert gas generators (i.e. for ballast water management systems other than category 3b and 3c according to Ch 1, Sec 13, Tab 1)

  Spaces intended for the storage or handling of solvent (as defined in Ch 1, Sec 12, [1.3.6]) on board ships fitted with an onboard carbon capture system (OCC).

- *(8) Cargo spaces*

  All spaces used for cargo (including cargo oil tanks) and trunkways and hatchways to such spaces.

- *(9) Service spaces (high risk)*

  Galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, and workshops other than those forming part of the machinery spaces.

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if flammable products are stored or if the area of the space is above 4 m^2.

Note 2: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

  Spaces where oxygen is stored or produced.

- *(10) Open decks*

  Open deck spaces and enclosed promenades having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces are to be naturally ventilated through permanent openings, having a combined area of at least 30% of the total area of the space boundaries adjacent to the outside.

  Air spaces (the space outside superstructures and deckhouses).

- *(11) Ro-ro and vehicle spaces*

  Ro-ro spaces as defined in Ch 4, Sec 1, [2.41]

  Vehicle spaces as defined in Ch 4, Sec 1, [2.52].

3) *Continuous B class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.*

4) *External boundaries which are required in Ch 4, Sec 7, [2.1.1] to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of cargo ships to have A class integrity. Similarly, in such boundaries which are not required to have A class integrity, doors may be constructed of materials which are to the satisfaction of the Society.*

c) Saunas shall comply with [1.3.3], item e).

d) A navigation locker that can only be accessed from the wheelhouse should be considered as a control station with respect to the provisions of Tab 5 and the bulkhead separating the wheelhouse and such a locker should have fire integrity of at least "B-0" class.

e) Battery rooms containing Li Ion-type batteries are to be considered as a machinery space of category A for structural fire protection purpose. The boundaries between battery rooms containing Li Ion-type batteries and machinery spaces of category A are to have A-60 fire integrity.

Table 5 : Fire integrity of bulkheads separating adjacent spaces in cargo ships

SPACES		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Control stations	(1)	A-0 [e]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60
Corridors	(2)		C	B-0	A-0 [c] B-0	B-0	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	(3)			C [a,b]	A-0 [c] B-0	B-0	A-60	A-0	A-0	A-0	*	A-30
Stairways	(4)				A-0 [c] B-0	A-0 [c] B-0	A-60	A-0	A-0	A-0	* *	A-30
Service spaces (low risk)	(5)					C	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	(6)						*	A-0	A-0 [g]	A-60	*	A-60 [f]
Other machinery spaces	(7)							A-0 [d]	A-0	A-0	*	A-0
Cargo spaces	(8)								*	A-0	*	A-0
Service spaces (high risk)	(9)									A-0 [d]	*	A-30
Open decks	(10)										–	A-0
Ro-ro and vehicle spaces	(11)											A-30

Note 1: (to be applied to Tab 5 and Tab 6, as appropriate)

[a] : No special requirements are imposed upon bulkheads in methods IIC and IIIC fire protection.

[b] : In case of method IIIC, B class bulkheads of B-0 rating are to be provided between spaces or groups of spaces of 50m^2 and over in area.

[c] : For clarification as to which applies, see [1.4.2] and [1.4.4].

[d] : Where spaces are of the same numerical category and letter "d" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an A-0 bulkhead.

[e] : Bulkheads separating the wheelhouse, chartroom and radio room from each other may have a B-0 rating.

[f] : An A-0 rating may be used if no dangerous goods are intended to be carried or if such goods are stowed not less than 3 m horizontally from such a bulkhead.

[g] : For cargo spaces in which dangerous goods are intended to be carried, Ch 4, Sec 12, [2.9] applies.

[h] : Fire insulation need not be fitted in the machinery space in category (7) if, in the opinion of the Society, it has little or no fire risk.

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of A class standard. However where a deck, except an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-extinguishing system is fitted.

Table 6 : Fire integrity of decks separating adjacent spaces in cargo ships

SPACE below		SPACE above										
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Control stations	(1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-60
Corridors	(2)	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	(3)	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Stairways	(4)	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	(5)	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	(6)	A-60	A-60	A-60	A-60	A-60	*	A-60 [h]	A-30	A-60	*	A-60
Other machinery spaces	(7)	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	(8)	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0
Service spaces (high risk)	(9)	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0 [d]	*	A-30
Open decks	(10)	*	*	*	*	*	*	*	*	*	–	A-0
Ro-ro and vehicle spaces	(11)	A-60	A-30	A-30	A-30	A-0	A-60	A-0	A-0	A-30	A-0	A-30
Note 1: The notes to Tab 5 apply to this Table as appropriate.												

1.4.4 Protection of stairways and lift trunks in accommodation spaces, service spaces and control stations

a) Stairways which penetrate only a single deck shall be protected, at a minimum, at one level by at least B-0 class divisions and self-closing doors. Lifts which penetrate only a single deck shall be surrounded by A-0 class divisions with steel doors at both levels. Stairways and lift trunks which penetrate more than a single deck shall be surrounded by at least A-0 class divisions and be protected by self-closing doors at all levels.

Dumb-waiters are to be regarded as lifts.

b) On ships having accommodation for 12 persons or less, where stairways penetrate more than a single deck and where there are at least two escape routes direct to the open deck at every accommodation level, the A-0 requirements of item a) above may be reduced to B-0.

1.5 Tankers

1.5.1 Application

For tankers, only method IC as defined in item a) of [1.4.1] shall be used.

1.5.2 Fire integrity of bulkheads and decks

a) In lieu of the requirements of [1.4] and in addition to complying with the specific provisions for fire integrity of bulkheads and decks of tankers, the minimum fire integrity of bulkheads and decks shall be as prescribed in Tab 7 and Tab 8.

b) The following requirements shall govern application of Tab 7 and Tab 8:

1) Tab 7 and Tab 8 shall apply respectively to the bulkheads and decks separating adjacent spaces.

2) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (10) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of the present Section, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed areas within a space that have less than 30 % communicating openings to that space are considered separate areas. The fire integrity of the boundary bulkheads and decks of such smaller spaces shall be as prescribed in Tab 7 and Tab 8. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- *(1) Control stations*

  Spaces containing emergency sources of power and lighting

  Wheelhouse and chartroom

  Spaces containing the ship's radio equipment

  Fire control stations

  Control room for propulsion machinery when located outside the machinery space

  Spaces containing centralized fire alarm equipment.
- *(2) Corridors*

  Corridors and lobbies.
- *(3) Accommodation spaces*

  Spaces as defined in Ch 4, Sec 1, [2.2], excluding corridors.

- *(4) Stairways*

  Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto

  In this connection a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

- *(5) Service spaces (low risk)*

  Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if no flammable products are stored and if the area of the space is less than 4m^2

Note 1: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

- *(6) Machinery spaces of category A*

  Spaces as defined in Ch 4, Sec 1, [2.30]

  Ballast Water Management Rooms (BWMR) containing oil-fired inert gas generators (i.e. for ballast water management systems category 3b and 3c according to Ch 1, Sec 13, Tab 1).

- *(7) Other machinery spaces*

  Electrical equipment rooms (auto-telephone exchange and air-conditioning duct spaces)

  Spaces as defined in Ch 4, Sec 1, [2.29], excluding machinery spaces of category A.

  Spaces dedicated to urea or sodium hydroxide solution tanks for selective catalytic reduction (SCR) systems, exhaust gas recirculation (EGR) systems or exhaust gas cleaning systems (EGCS), when separated from the engine room.

  Ballast Water Management Rooms (BWMR) not containing oil-fired inert gas generators (i.e. for ballast water management systems other than category 3b and 3c according to Ch 1, Sec 13, Tab 1)

  Spaces intended for the storage or handling of solvent (as defined in Ch 1, Sec 12, [1.3.6]) on board ships fitted with an onboard carbon capture and storage system (OCC).

- *(8) Cargo pump-rooms*

  Spaces containing cargo pumps and entrances and trunks to such spaces

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended, if located in the cargo area in accordance with Ch 1, Sec 13

Note 2: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1 require chemical or additive storage.

Ballast Water Management Rooms (BWMR), if located in the cargo area in accordance with Ch 1, Sec 13

- *(9) Service spaces (high risk)*

  Galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, and workshops other than those forming part of the machinery spaces.

  Spaces where the storage of liquid or solid chemicals for ballast water management systems is intended if flammable products are stored or if the area of the space is above 4 m^2.

Note 3: Note 3: Only chemical injection (cat.6 as per Ch 1, Sec 13, Tab 1), in-line flocculation (cat.2 as per Ch 1, Sec 13, Tab 1 and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Ch 1, Sec 13, Tab 1) require chemical or additive storage.

Spaces where oxygen is stored or produced.

- *(10) Open decks*

  Open deck spaces and enclosed promenades having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces are to be naturally ventilated through permanent openings, having a combined area of at least 30% of the total area of the space boundaries adjacent to the outside.

  Air spaces (the space outside superstructures and deckhouses).

c) *Continuous B class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.*

d) *External boundaries which are required in Ch 4, Sec 7, [2.1.1] to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of tankers to have A class integrity. Similarly, in such boundaries which are not required to have A class integrity, doors may be constructed of materials which are to the satisfaction of the Society.*

e) *Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation shall be constructed of steel and insulated to A-60 standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. The distance of 3 m shall be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation shall be carried up to the underside of the deck of the navigation bridge.*

Windows and side scuttles within these limits are to be of the fixed type and constructed to the A-60 standard.

f) Skylights to cargo pump-rooms shall be of steel, shall not contain any glass and shall be capable of being closed from outside the pump-room.

g) In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.

h) Saunas shall comply with [1.3.3], item e).

i) A navigation locker that can only be accessed from the wheelhouse should be considered as a control station with respect to the requirements in Tab 7 and the bulkhead separating the wheelhouse and such a locker should have fire integrity of at least "B-0" class.

j) Battery rooms containing Li Ion-type batteries are to be considered as a machinery space of category A for structural fire protection purpose. The boundaries between battery rooms containing Li Ion-type batteries and machinery spaces of category A are to have A-60 fire integrity.

Table 7 : Fire integrity of bulkheads separating adjacent spaces in tankers

SPACES		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Control stations	(1)	A-0 [c]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*
Corridors	(2)		C	B-0	A-0 [a] B-0	B-0	A-60	A-0	A-60	A-0	*
Accommodation spaces	(3)			C	A-0 [a] B-0	B-0	A-60	A-0	A-60	A-0	*
Stairways	(4)				A-0 [a] B-0	A-0 [a] B-0	A-60	A-0	A-60	A-0	*
Service spaces (low risk)	(5)					C	A-60	A-0	A-60	A-0	*
Machinery spaces of category A	(6)						*	A-0	A-0 [d]	A-60	*
Other machinery spaces	(7)							A-0 [b]	A-0	A-0	*
Cargo pump-rooms	(8)								*	A-60	*
Service spaces (high risk)	(9)									A-0 [b]	*
Open decks	(10)										–

Note 1: (to be applied to Tab 7 and Tab 8, as appropriate)

[a] : For clarification as to which applies, see [1.4.2] and [1.4.4].

[b] : Where spaces are of the same numerical category and letter "b" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an A-0 bulkhead.

[c] : Bulkheads separating the wheelhouse, chartroom and radio room from each other may have a B-0 rating.

[d] : Bulkheads and decks between cargo pump-rooms and machinery spaces of category A may be penetrated by cargo pump shaft glands and similar gland penetrations, provided that gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal are fitted in way of the bulkheads or decks.

[e] : Fire insulation need not be fitted in the machinery space in category (7) if, in the opinion of the Society, it has little or no fire risk

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material, but is not required to be of A class standard. However, where a deck, except an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-extinguishing system is fitted.

Table 8 : Fire integrity of decks separating adjacent spaces in tankers

SPACE below		SPACE above									
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Control stations	(1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	–	A-0	*
Corridors	(2)	A-0	*	*	A-0	*	A-60	A-0	–	A-0	*
Accommodation spaces	(3)	A-60	A-0	*	A-0	*	A-60	A-0	–	A-0	*
Stairways	(4)	A-0	A-0	A-0	*	A-0	A-60	A-0	–	A-0	*
Service spaces (low risk)	(5)	A-15	A-0	A-0	A-0	*	A-60	A-0	–	A-0	*
Machinery spaces of category A	(6)	A-60	A-60	A-60	A-60	A-60	*	A-60 [e]	A-0	A-60	*
Other machinery spaces	(7)	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*
Cargo pump-rooms	(8)	–	–	–	–	–	A-0 [d]	A-0	*	–	*
Service spaces (high risk)	(9)	A-60	A-0	A-0	A-0	A-0	A-60	A-0	–	A-0 [b]	*
Open decks	(10)	*	*	*	*	*	*	*	*	*	–

Note 1: The notes to Tab 7 apply to this Table as appropriate.

2 Penetrations in fire-resisting divisions and prevention of heat transmission

2.1 Penetrations in A class divisions

2.1.1 *Where A class divisions are penetrated, such penetration shall be tested in accordance with the Fire Test Procedures Code. In the case of ventilation ducts, requirements [6.2.3] and [6.4.1] apply. However, where a pipe penetration is made of steel or equivalent material having a thickness of 3 mm or greater and a length of not less than 900 mm (preferably 450 mm on each side of the division), and there are no openings, testing is not required. Such penetrations shall be suitably insulated by extension of the insulation at the same level of the division.*

2.2 Penetrations in B class divisions

2.2.1 *Where B class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., of for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired, subject to the provisions of paragraph [6.4.2]. Pipes other that steel or copper that penetrate B class divisions shall be protected by either:*

- *a fire-tested penetration device suitable for the fire resistance of the division pierced and the type of pipe used, or*
- *a steel sleeve, having a thickness of not less than 1,8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or more and not less than 600 mm for pipe diameters of less than 150 mm (preferably equally divided to each side of the division). The pipe shall be connected to the ends of the sleeve by flanges or couplings; or the clearance between the sleeve and the pipe shall not exceed 2,5 mm; or any clearance between pipe and sleeve shall be made tight by means of non-combustible or other suitable material.*

2.3 Pipes penetrating A or B class divisions

2.3.1 *Uninsulated metallic pipes penetrating A or B class divisions shall be of materials having a melting temperature which exceeds 950°C for A-0 and 850°C for B-0 class divisions.*

2.3.2 *Where the Society may permit the conveying of oil and combustible liquids through accommodation and service spaces, the pipes conveying oil or combustible liquids shall be of a material approved by the Society having regard to the fire risk.*

2.4 Prevention of heat transmission

2.4.1 *In approving structural fire protection details, the Administration shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers. The insulation of a deck or bulkhead shall be carried past the penetration, intersection or terminal point for a distance of at least 450 mm in the case of steel and aluminium structures. If a space is divided with a deck or a bulkhead of A class standard having insulation of different values, the insulation with the higher value shall continue on the deck or bulkhead with the insulation of the lesser value for a distance of at least 450 mm.*

3 Protection of openings in fire-resisting divisions

3.1 Application

3.1.1 The provisions of [3.2] apply to passenger ships and those of [3.3] apply to cargo ships.

3.2 Openings in bulkheads and decks

3.2.1 Openings in A class divisions

a) *Except for hatches between cargo, special category, store and baggage spaces, and between such spaces and the weather decks, openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.*

b) *The construction of doors and door frames in A class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkheads in which the doors are situated, this being determined in accordance with the Fire Test Procedures Code. Such doors and door frames shall be constructed of steel or other equivalent material.*

   Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm.

   A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

c) *Watertight doors need not be insulated.*

d) *It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.*

e) *Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than power-operated watertight doors and those which are normally locked shall satisfy the following requirements:*

1) *the doors shall be self-closing and be capable of closing with an angle of inclination of up to 3,5° opposing closure*

2) *the approximate time of closure for hinged fire doors shall be no more than 40 s and no less than 10 s from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding doors shall be of no more than 0,2 m/s and no less than 0,1 m/s with the ship in upright position*

3) *the doors, except those for emergency escape trunks, shall be capable of remote release from the continuously manned central control station, either simultaneously or in groups, and shall be capable of release also individually from a position at both sides of the door. Release switches shall have an on-off function to prevent automatic resetting of the system*

4) *hold-back hooks not subject to central control station release are prohibited*

5) *a door closed remotely from the central control station shall be capable of being re-opened from both sides of the door by local control. After such local opening, the door shall automatically close again*

6) *indication shall be provided at the fire door indicator panel in the continuously manned central control station whether each door is closed*

7) *the release mechanism shall be so designed that the door will automatically close in the event of disruption of the control system or central power supply*

8) *local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated at least ten times (fully opened and closed) after disruption of the control system or central power supply using the local controls*

9) *disruption of the control system or central power supply at one door shall not impair the safe functioning of the other doors*

10) *remote-released sliding or power-operated doors shall be equipped with an alarm that sounds at least 5 s but no more than 10 s, after the door is released from the central control station and before the door begins to move and continues sounding until the door is completely closed*

11) *a door designed to re-open upon contacting an object in its path shall re-open not more than 1 m from the point of contact*

12) *double-leaf doors equipped with a latch necessary for their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the system*

13) *doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in items 3) and 10)*

14) *the components of the local control system shall be accessible for maintenance and adjusting*

15) *power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire and be in accordance with the Fire Test Procedures Code. This system shall satisfy the following requirements:*

- *the control system shall be able to operate the door at the temperature of at least 200°C for at least 60 min, served by the power supply*
- *the power supply for all other doors not subject to fire shall not be impaired, and*
- *at temperatures exceeding 200°C, the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945°C.*

f) *The requirements for A class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles, provided that there is no requirement for such boundaries to have A class integrity in item c) of [3.2.3]. The requirements for A class integrity of the outer boundaries of the ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing life-saving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.*

g) *Except for watertight doors, weathertight doors (semi-watertight doors), doors leading to the open deck and doors which need to be reasonably gas-tight, all A class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port. The material, construction and fire resistance of the hose port shall be equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges or, in the case of sliding doors, nearest the opening.*

3.2.2 Openings in B class divisions

a) *Doors and door frames in B class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions, this being determined in accordance with the Fire Test Procedures Code, except that ventilation openings may be permitted in the lower portion of such doors. Where such opening is in or under a door, the total net area of any such opening or openings shall not exceed 0,05 m^2. Alternatively, a non-combustible air*

balance duct routed between the cabin and the corridor, and located below the sanitary unit, is permitted where the cross-sectional area of the duct does not exceed 0,05 m². All ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible.

Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm.

b) Cabin doors in B class divisions shall be of a self-closing type. Hold-back hooks are not permitted.

c) The requirements for B class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles. Similarly, the requirements for B class integrity shall not apply to exterior doors in superstructures and deckhouses. For ships carrying not more than 36 passengers, the Society may permit the use of combustible materials in doors separating cabins from the individual interior sanitary spaces such as showers.

d) B15 doors for shops leading to corridors shall be self-closing and equipped with hold-back capable of remote release from the continuous manned central control station. Such remote release may be grouped with the release of the nearest remote controlled A class fire door. Individual release shall also be possible locally from a position in the corridor close to the door.

3.2.3 Windows and sidescuttles

a) Windows and sidescuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of item f) of [3.2.1] and item c) of [3.2.2] apply shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted, this being determined in accordance with the Fire Test Procedures Code.

b) Notwithstanding the requirements of Tab 1 to Tab 4, windows and sidescuttles in bulkheads separating accommodation and service spaces and control stations from weather shall be constructed with frames of steel or other suitable material. The glass shall be retained by a metal glazing bead or angle.

c) For ships carrying more than 36 passengers, windows facing survival craft, embarkation and assembly stations, external stairs and open decks used for escape routes, and windows situated below liferaft and escape slide embarkation areas shall have fire integrity as required in Tab 1. Where automatic dedicated sprinkler heads are provided for windows, A-0 windows may be accepted as equivalent. To be considered under this paragraph, the sprinkler heads must either be:

1) dedicated heads located above the windows, and installed in addition to the conventional ceiling sprinklers; or

2) conventional ceiling sprinkler heads arranged such that the window is protected by an average application rate of at least 5 l/min per square metre and the additional window area is included in the calculation of the area of coverage; or

3) approved water-mist nozzles; and

Windows located in the ship's side below the lifeboat embarkation area shall have fire integrity at least equal to A-0 class.

d) For ships carrying not more than 36 passengers, windows facing survival craft and escape slide, embarkation areas and windows situated below such areas shall have fire integrity at least equal to A-0 class.

3.3 Doors in fire-resisting divisions

3.3.1 *The fire resistance of doors shall be equivalent to that of the division in which they are fitted, this being determined in accordance with the Fire Test Procedures Code.*

Doors approved as A class without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm and a non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door. Doors approved as B class without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm.

Doors and door frames in A class divisions shall be constructed of steel. Doors in B class divisions shall be non-combustible. Doors fitted in boundary bulkheads of machinery spaces of category A shall be reasonably gas-tight and self-closing. In ships constructed according to method IC, the Society may permit the use of combustible materials in doors separating cabins from individual interior sanitary accommodation such as showers.

3.3.2 *Doors required to be self-closing shall not be fitted with hold-back hooks. However, hold-back arrangements fitted with remote release devices of the fail-safe type may be utilized.*

3.3.3 *In corridor bulkheads, ventilation openings may be permitted in and under the doors of cabins and public spaces. Ventilation openings are also permitted in B class doors leading to lavatories, offices, pantries, lockers and store-rooms. Except as permitted below, the openings shall be provided only in the lower half of a door. Where such an opening is in or under a door, the total net area of any such opening or openings shall not exceed 0,05 m². Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit, is permitted where the cross-sectional area of the duct does not exceed 0,05 m². Ventilation openings, except those under the door, shall be fitted with a grill made of non-combustible material.*

3.3.4 *Watertight doors need not be insulated.*

4 Protection of openings in machinery space boundaries

4.1 Application

4.1.1 *The provisions of Article [4] shall apply to machinery spaces of category A and, where the Society considers it desirable, to other machinery spaces.*

The provisions of [4.2] apply to ships of all types, except those of [4.2.3] and [4.2.5] which apply to passenger ships.

4.2 Protection of openings in machinery space boundaries

4.2.1

a) The number of skylights, doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

b) Skylights shall be of steel and shall not contain glass panels.

4.2.2 *Means of control shall be provided for closing power-operated doors or actuating release mechanisms on doors other than power-operated watertight doors. The controls shall be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve.*

4.2.3 *The means of control required in [4.2.2] shall be situated at one control position or grouped in as few positions as possible, to the satisfaction of the Society. Such positions shall have safe access from the open deck.*

4.2.4 *When access to any machinery space of category A is provided at a low level from an adjacent shaft tunnel, there shall be provided in the shaft tunnel, near the watertight door, a light steel fire-screen door operable from each side.*

4.2.5 *Doors, other than power-operated watertight doors, shall be so arranged that positive closure is assured in case of fire in the space by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3,5° opposing closure, and having a fail-safe hold-back arrangement, provided with a remotely operated release device. Doors for emergency escape trunks need not be fitted with a fail-safe hold-back facility and a remotely operated release device.*

4.2.6 *Windows shall not be fitted in machinery space boundaries. However, this does not preclude the use of glass in control rooms within the machinery spaces.*

5 Protection of cargo space boundaries

5.1 Application

5.1.1 The provisions of [5.2] to [5.3] apply to passenger ships.

5.2 Passenger ships carrying more than 36 passengers

5.2.1 *The boundary bulkheads and decks of special category and ro-ro spaces shall be insulated to A-60 class standard. However, where a category (5), (9) or (10) space, as defined in [1.3.3], is on one side of the division, the standard may be reduced to A-0. Where fuel oil tanks are below a special category space, the integrity of the deck between such spaces may be reduced to A-0 standard.*

5.3 Indicators

5.3.1 *Indicators shall be provided on the navigation bridge which shall indicate when any fire door leading to or from the special category spaces is closed.*

6 Ventilation systems

6.1 Application

6.1.1 The provisions of [6.2]] to [6.4], [6.6], and [6.7] apply to ships of all types.

The provisions of [6.5] and [6.8] apply to passenger ships carrying more than 36 passengers.

6.2 General

6.2.1 *Ventilation ducts, including single and double wall ducts, shall be of steel or equivalent material except flexible bellows of short length not exceeding 600 mm used for connecting fans to the ducting in air-conditioning rooms. Unless expressly provided otherwise in [6.2.7], any other material used in the construction of ducts, including insulation, shall also be non-combustible.*

A ventilation duct made of material other than steel may be considered equivalent to a ventilation duct made of steel, provided the material is non-combustible and has passed a standard fire test in accordance with Annex 1: Part 3 of the Fire Test Procedures Code as non-load bearing structure for 30 minutes following the requirements for testing "B" class divisions.

6.2.2 *However, short ducts, not generally exceeding 2 m in length and with a free cross-sectional area not exceeding 0,02 m^2, need not be of steel or equivalent material, subject to the following conditions:*

a) The ducts shall be made of non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value not exceeding 45 MJ/m2 of their surface area for the thickness used;

b) The ducts are only used at the end of the ventilation device; and

c) The ducts are not situated less than 600 mm, measured along the duct, from an opening in an "A" or "B" class division, including continuous "B" class ceiling.

Note 1: The term free cross-sectional area means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner dimensions of the duct itself and not the insulation.

6.2.3 *The following arrangements shall be tested in accordance with the Fire Test Procedures Code:*

a) Fire dampers, including their relevant means of operation. However, the testing is not required for dampers located at the lower end of the duct in exhaust ducts for galley ranges, which must be of steel and capable of stopping the draught in the duct; and

b) Duct penetrations through "A" class divisions. However, the test is not required where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed connections or by welding.

6.2.4 *Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection hatch on which the identification number of the fire damper is marked. The fire damper identification number shall also be marked on any remote controls provided.*

6.2.5 *Ventilation ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.*

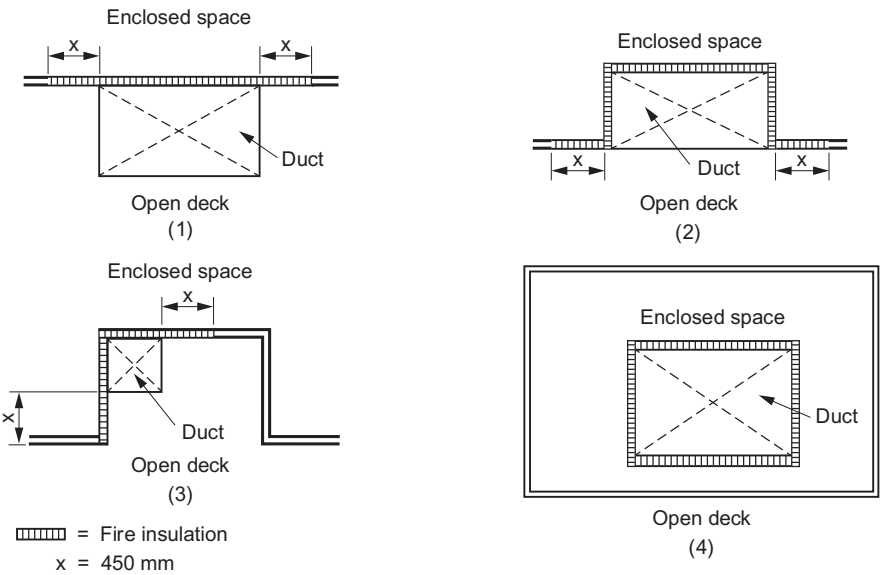
6.2.6 *The main inlets and outlets of ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate the operating position of the closing device.*

6.2.7 *Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of openings in "A" or "B" class divisions and in ducts required to be of "A" class construction.*

6.2.8 *Ventilation openings or air balance ducts between two enclosed spaces shall not be provided except as permitted by [3.2.2] and [3.3.3].*

6.2.9 With respect to the application of [6.3] and [6.6] for determining fire insulation for trunks and ducts which pass through an enclosed space, the term "pass through" pertains to the part of the trunk/duct contiguous to the enclosed space. The following sketches (Fig 1) are given as examples:

Figure 1 : Examples of ducts contiguous to enclosed space



6.3 Arrangement of ducts

6.3.1 *The ventilation systems for machinery spaces of category A, vehicle spaces, ro-ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation systems serving other spaces. However, the galley ventilation systems on cargo ships of less than 4,000 gross tonnage and in passenger ships carrying not more than 36 passengers need not be completely separated from other ventilation systems, but may be served by separate ducts from a ventilation unit serving other spaces. In such a case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit.*

6.3.2 *Ducts provided for the ventilation of machinery spaces of category A, galleys, vehicle spaces, ro-ro spaces or special category spaces shall not pass through accommodation spaces, service spaces, or control stations unless they comply with [6.3.4].*

6.3.3 *Ducts provided for the ventilation of accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, galleys, vehicle spaces, ro-ro spaces or special category spaces unless they comply with [6.3.4].*

6.3.4 *As permitted by [6.3.2] and [6.3.3] ducts shall be either:*

a)

1) *constructed of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0.075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0.075 m^2 and 0.45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0.45 m^2;*
2) *suitably supported and stiffened;*
3) *fitted with automatic fire dampers close to the boundaries penetrated; and*
4) *insulated to "A-60" class standard from the boundaries of the spaces they serve to a point at least 5 m beyond each fire damper; or*

b)

1) *constructed of steel in accordance with item a) 1) and item a) 2); and*
2) *insulated to "A-60" class standard throughout the spaces they pass through, except for ducts that pass through spaces of category (9) or (10) as defined in [1.3.3], item b).*

6.3.5 *For the purposes of [6.3.4], item a) 4) and [6.3.4], item b) 2), ducts shall be insulated over their entire cross-sectional external surface. Ducts that are outside but adjacent to the specified space, and share one or more surfaces with it, shall be considered to pass through the specified space, and shall be insulated over the surface they share with the space for a distance of 450 mm past the duct.*

6.3.6 *Where it is necessary that a ventilation duct passes through a main vertical zone division, an automatic fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The control location shall be readily accessible and be clearly and prominently marked. The duct between the division and the damper shall be constructed of steel in accordance with [6.3.4], item a) 1) and [6.3.4], item a) 2) and insulated to at least the same fire integrity as the division penetrated. The damper shall be fitted on at least one side of the division with a visible indicator showing the operating position of the damper.*

6.4 Details of fire dampers and duct penetrations

6.4.1 *Ducts passing through "A" class divisions shall meet the following requirements:*

a) *Where a thin plated duct with a free cross sectional area equal to, or less than, 0,02 m^2 passes through "A" class divisions, the opening shall be fitted with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated.*

b) *Where ventilation ducts with a free cross-sectional area exceeding 0,02 m^2, but not more than 0,075 m^2, pass through "A" class divisions, the openings shall be lined with steel sheet sleeves. The ducts and sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the division through which the duct passes.*

   The fire insulation required by the above paragraph is to be provided only to the part of the duct and/or sleeve that is on the same side of the division being fire insulated, and be extended for a minimum of 450 mm along the duct and/or sleeve.

   Equivalent penetration protection may be provided to the satisfaction of the Society, and

c) *Automatic fire dampers shall be fitted in all ducts with a free cross-sectional area exceeding 0,075 m^2 that pass through "A" class divisions. Each damper shall be fitted close to the division penetrated and the duct between the damper and the division penetrated shall be constructed of steel in accordance with* [6.3.4] *item a) 1) and* [6.3.4] *item a) 2). The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the division. The damper shall be fitted with a visible indicator which shows the operating position of the damper. Fire dampers are not required, however,*

where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they penetrate. A duct of cross-sectional area exceeding 0,075 m² shall not be divided into smaller ducts at the penetration of an "A" class division and then recombined into the original duct once through the division to avoid installing the damper required by this provision.

d) Ducts or pipes with free sectional area of 0.075 m² or less need to be fitted with fire damper at their passage through Class "A" divisions in those cases indicated in [6.3.2] and [6.3.3]. The fire damper can be omitted if the duct is arranged in compliance with the requirements of [6.3.4], item b) 1) and item b) 2).

6.4.2 *Ventilation ducts with a free cross-sectional area exceeding 0,02 m² passing through "B" class bulkheads shall be lined with steel sheet sleeves of 900 mm in length, divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length.*

When a duct passing through a division is to be in accordance with [2.2.1] and the above paragraph, no clearance should be allowed between the duct and the division.

6.4.3 *All fire dampers shall be capable of manual operation. The dampers shall have a direct mechanical means of release or, alternatively, be closed by electrical, hydraulic, or pneumatic operation. All dampers shall be manually operable from both sides of the division. Automatic fire dampers, including those capable of remote operation, shall have a failsafe mechanism that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss. Remotely operated fire dampers shall be capable of being reopened manually at the damper.*

6.5 Ventilation systems for passenger ships carrying more than 36 passengers

6.5.1 *In addition to the requirements in [6.2], [6.3] and [6.4], the ventilation system of a passenger ship carrying more than 36 passengers shall also meet the following requirements.*

6.5.2 *In general, the ventilation fans shall be so arranged that the ducts reaching the various spaces remain within a main vertical zone.*

6.5.3 *Stairway enclosures shall be served by an independent ventilation fan and duct system (exhaust and supply) which shall not serve any other spaces in the ventilation systems.*

6.5.4 *A duct, irrespective of its cross-section, serving more than one 'tween-deck accommodation space, service space or control station, shall be fitted, near the penetration of each deck of such spaces, with an automatic smoke damper that shall also be capable of being closed manually from the protected deck above the damper. Where a fan serves more than one 'tween-deck space through separate ducts within a main vertical zone, each dedicated to a single 'tween-deck space, each duct shall be provided with a manually operated smoke damper fitted close to the fan.*

6.5.5 *Vertical ducts shall, if necessary, be insulated as required by Tab 1 and Tab 2. Ducts shall be insulated as required for decks between the space they serve and the space being considered, as applicable.*

6.6 Exhaust ducts from galley ranges

6.6.1 Requirements for passenger ships carrying more than 36 passengers

a) In addition to the requirements in [6.2], [6.3] and [6.4], exhaust ducts from galley ranges shall be constructed in accordance with [6.3.4], item b) 1) and [6.3.4], item b) 2). They shall also be fitted with:

1) a grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;

2) a fire damper located in the lower end of the duct at the junction between the duct and the galley range hood which is automatically and remotely operated and, in addition, a remotely operated fire damper located in the upper end of the duct close to the outlet of the duct;

3) a fixed means for extinguishing a fire within the duct;

4) remote-control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in item a) 2) and for operating the fire-extinguishing system, which shall be placed in a position outside the galley close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

5) suitably located hatches for inspection and cleaning, including one provided close to the exhaust fan and one fitted in the lower end where grease accumulates.

The requirements given in item a) 1) to item a) 5) apply to all exhaust ducts from galley ranges in which grease or fat is likely to accumulate from galley ranges.

b) Exhaust ducts from ranges for cooking equipment installed on open decks shall conform to item a), as applicable, when passing through accommodation spaces or spaces containing combustible materials.

6.6.2 Requirements for cargo ships and passenger ships carrying not more than 36 passengers

When passing through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed in accordance with [6.3.4], item a) 1) and [6.3.4], item a) 2). Each exhaust duct shall be fitted with:

a) a grease trap readily removable for cleaning;

b) an automatically and remotely operated fire damper located in the lower end of the duct at the junction between the duct and the galley range hood and, in addition, a remotely operated fire damper in the upper end of the duct close to the outlet of the duct;

c) arrangements, operable from within the galley, for shutting off the exhaust and supply fans; and

d) fixed means for extinguishing a fire within the duct.

6.7 Ventilation rooms serving machinery spaces of category A containing internal combustion machinery

6.7.1 *Where a ventilation room serves only such an adjacent machinery space and there is no fire division between the ventilation room and the machinery space, the means for closing the ventilation duct or ducts serving the machinery space shall be located outside of the ventilation room and machinery space.*

6.7.2 *Where a ventilation room serves such a machinery space as well as other spaces and is separated from the machinery space by a "A-0" class division, including penetrations, the means for closing the ventilation duct or ducts for the machinery space can be located in the ventilation room.*

6.8 Ventilation systems for laundries in passenger ships carrying more than 36 passengers

6.8.1 *Exhaust ducts from laundries and drying rooms of category (13) spaces as defined in [1.3.3], item b) shall be fitted with:*

a) filters readily removable for cleaning purposes;

b) a fire damper located in the lower end of the duct which is automatically and remotely operated;

c) remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating the fire damper mentioned in item b); and

d) suitably located hatches for inspection and cleaning.

Section 6 Suppression of Fire: Fire Fighting

1 Water supply systems

1.1 General

1.1.1 *Ships shall be provided with fire pumps, fire mains, hydrants and hoses complying with the applicable requirements of this Section.*

1.2 Fire mains and hydrants

1.2.1 General

Materials readily rendered ineffective by heat shall not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them. The arrangement of pipes and hydrants shall be such as to avoid the possibility of freezing. Suitable drainage provisions shall be provided for fire main piping. Isolation valves shall be installed for all open deck fire main branches used for purposes other than fire fighting. In ships where deck cargo may be carried, the positions of the hydrants shall be such that they are always readily accessible and the pipes shall be arranged as far as practicable to avoid risk of damage by such cargo.

1.2.2 Ready availability of water supply

The arrangements for the ready availability of water supply shall be:

a) in passenger ships:

1) of 1000 gross tonnage and upwards such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of one required fire pump,

2) of less than 1000 gross tonnage by automatic start of at least one fire pump or by remote starting from the navigation bridge of at least one fire pump. If the pump starts automatically or if the bottom valve cannot be opened from where the pump is remotely started, the bottom valve shall always be kept open, and

3) if fitted with periodically unattended machinery spaces, the Society shall determine provisions for fixed water fire-extinguishing arrangements for such spaces equivalent to those required for normally attended machinery spaces;

b) in cargo ships:

with a periodically unattended machinery space or when only one person is required on watch, there shall be immediate water delivery from the fire main system at a suitable pressure, either by remote starting of one of the main fire pumps with remote starting from the navigation bridge and fire control station, if any, or permanent pressurization of the fire main system by one of the main fire pumps, except that the Society may waive this requirement for cargo ships of less than 1600 gross tonnage if the fire pump starting arrangement in the machinery space is in an easily accessible position.

1.2.3 Diameter of fire mains

The diameter of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously, except that in the case of cargo ships other than those included in [6.3], the diameter need only be sufficient for the discharge of 140 m^3/hour.

1.2.4 Isolating valves and relief valves

a) Isolating valves to separate the section of the fire main within the machinery space containing the main fire pump or pumps from the rest of the fire main shall be fitted in an easily accessible and tenable position outside the machinery spaces. The fire main shall be so arranged that when the isolating valves are shut all the hydrants on the ship, except those in the machinery space referred to above, can be supplied with water by another fire pump or an emergency fire pump. The emergency fire pump, its seawater inlet, and suction and delivery pipes and isolating valves shall be located outside the machinery space. If this arrangement cannot be made, the sea-chest may be fitted in the machinery space if the sea inlet *valve is remotely controlled from a position in the same compartment as the emergency fire pump and the suction pipe is as short as practicable. Short lengths of suction or discharge piping may penetrate the machinery space, provided they are enclosed in a substantial steel casing or are insulated to A-60 class standards. The pipes shall have substantial wall thickness, but in no case less than 11 mm, and shall be welded except for the flanged connection to the sea inlet valve.*

b) Any part of the fire main routed through a category A machinery space, except for short lengths of suction or discharge piping complying with item a), is to be fitted with isolating valves outside of the space. The arrangements of the fire mains are to allow for fire water from the fire pumps or emergency fire pump to reach all hydrants outside of the isolated space. Isolation requirements of item a) are not applicable to the piping from fire pumps located in spaces other than category A machinery spaces.

c) In cases where suction or discharge piping of emergency fire pumps penetrating machinery spaces are enclosed in a substantial steel casing, or are insulated to "A-60" class standards, it is not necessary to enclose or insulate "distance pieces", "sea inlet valves" and "sea-chests". The method for insulating pipes to "A-60" class standards is that they are to be covered/protected in a practical manner by insulation material which is approved as a part of "A-60" class divisions in accordance with the IMO FTP Code. Where the sea inlet valve is in the machinery space, the valve is not to be a fail-close type. Where the sea inlet valve is in the machinery space and is not a fail-open type, measures are to be taken so that the valve can be opened in the event of fire, e.g. control piping, actuating devices and/or electric cables with fire resistant protection equivalent to "A- 60" class standards.

d) In cases where main fire pumps are provided in compartments outside machinery spaces and where the emergency fire pump suction or discharge piping penetrates such compartments, the above interpretation of item c) is to be applied to the piping.

e) *A valve shall be fitted to serve each fire hydrant so that any fire hose may be removed while the fire pumps are in operation.*

f) *Relief valves shall be provided in conjunction with fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves shall be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.*

g) *In tankers, isolation valves shall be fitted in the fire main at the poop front in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in case of fire or explosion.*

1.2.5 Number and position of hydrants

a) *The number and position of hydrants shall be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated and any part of any cargo space when empty, any ro-ro space or any vehicle space, in which latter case the two jets shall reach any part of the space, each from a single length of hose. Furthermore, such hydrants shall be positioned near the accesses to the protected spaces.*

At least two hydrants are to be provided in machinery spaces of category A.

b) *In addition to the requirements in item a) above, passenger ships shall comply with the following:*

1) *in the accommodation, service and machinery spaces, the number and position of hydrants shall be such that the requirements of item a) above may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed, and*

2) *where access is provided to a machinery space of category A at a low level from an adjacent shaft tunnel, two hydrants shall be provided external to, but near the entrance to, that machinery space. Where such access is provided from other spaces, in one of those spaces two hydrants shall be provided near the entrance to the machinery space of category A. Such provision need not be made where the tunnel or adjacent spaces are not part of the escape route.*

1.2.6 Pressure at hydrants

With the two pumps simultaneously delivering water through the nozzles specified in [1.4.3], with the quantity of water as specified in [1.2.3], through any adjacent hydrants, the following minimum pressures shall be maintained at all hydrants:

a) *for passenger ships:*

- *4000 gross tonnage and upwards : 0,40 N/mm^2*
- *less than 4000 gross tonnage : 0,30 N/mm^2*

b) *for cargo ships:*

- *6000 gross tonnage and upwards : 0,27 N/mm^2*
- *less than 6000 gross tonnage : 0,25 N/mm^2*

and

c) *the maximum pressure at any hydrant shall not exceed that at which the effective control of a fire hose can be demonstrated.*

1.2.7 International shore connection

Ships of 500 gross tonnage and upwards shall be provided with at least one international shore connection complying with Ch 4, Sec 15. Facilities shall be available enabling such a connection to be used on either side of the ship.

1.3 Fire pumps

1.3.1 Pumps accepted as fire pumps

Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil and that, if they are subject to occasional duty for the transfer or pumping of oil fuel, suitable change-over arrangements are fitted.

The emergency fire pump mentioned in [1.3.3] may also be used for other suitable purposes subject to approval by the Society in each case.

1.3.2 Number of fire pumps

Ships shall be provided with independently driven fire pumps as follows:

a) in passenger ships of:

- *4000 gross tonnage and upwards : at least 3*
- *less than 4000 gross tonnage : at least 2*

b) in cargo ships of:

- *1000 gross tonnage and upwards : at least 2*
- *less than 1000 gross tonnage : at least 2 power-driven pumps, one of which shall be independently driven.*

1.3.3 Arrangement of fire pumps and fire mains

a) Fire pumps

The arrangement of sea connections, fire pumps and their sources of power shall be as to ensure that:

1) in passenger ships of

- *1000 gross tonnage and upwards, in the event of a fire in any one compartment, all the fire pumps will not be put out of action*
- *less than 1000 gross tonnage, if a fire in any one compartment could put all the pumps out of action, there shall be an alternative means consisting of an emergency fire pump complying with Ch 4, Sec 15, [11.1.1] with its source of power and sea connection located outside the space where the main fire pumps or their sources of power are located.*

2) in cargo ships of 500 gross tonnage and upwards,

- unless the two main fire pumps and the fuel supply or source of power for each pump are situated within compartments separated at least by an A-0 class division, so that a fire in any one compartment will not render both fire pumps inoperable, a fixed independent power operated emergency fire pump complying with the following requirements and those of Ch 4, Sec 15, [11] is to be fitted (for cargo ships of less than 2000 gross tonnage only, Ch 4, Sec 15, [11.1.1] applies). An arrangement in which one main fire pump is located in a steel compartment having more than one bulkhead and/or deck adjacent to the compartment containing the other main fire pump will also require an emergency fire pump
- Where a power operated emergency fire pump is fitted, its fuel or power supply is to be so arranged that it will not readily be affected by a fire in the compartment containing the main fire pumps.

b) Requirements for the space containing the emergency fire pump in cargo ships

1) Location of the space

The space containing the fire pump shall not be contiguous to the boundaries of machinery spaces of category A or those spaces containing main fire pumps. Where this is not practicable, the common bulkhead between the two spaces shall be insulated to a standard of structural fire protection equivalent to that required for a control station in Ch 4, Sec 5, [1.4.3].

2) Access to the emergency fire pump

No direct access shall be permitted between the machinery space and the space containing the emergency fire pump and its source of power. When this is impracticable, the Society may accept an arrangement where the access is by means of an airlock with the door of the machinery space being of A-60 class standard and the other door being at least steel, both reasonably gastight, self-closing and without any hold-back arrangements. Alternatively, the access may be through a watertight door capable of being operated from a space remote from the machinery space and the space containing the emergency fire pump and unlikely to be cut off in the event of fire in those spaces. In such cases, a second means of access to the space containing the emergency fire pump and its source of power shall be provided.

When a single access to the emergency fire pump room is through another space adjoining a machinery space of category A or the spaces containing the main fire pumps, an A-60 class boundary is required between such other space and the machinery space of category A or the spaces containing the main fire pumps.

3) Ventilation of the emergency fire pump space

Ventilation arrangements to the space containing the independent source of power for the emergency fire pump shall be such as to preclude, as far as practicable, the possibility of smoke from a machinery space fire entering or being drawn into that space.

If the space is mechanically ventilated the power is to be supplied by the emergency source.

4) Illumination of the space

The room where the emergency fire pump prime mover is located is to be illuminated from the emergency source of supply and is to be well ventilated.

c) Additional pumps for cargo ships

In addition, in cargo ships where other pumps, such as general service, bilge and ballast, etc., are fitted in a machinery space, arrangements shall be made to ensure that at least one of these pumps, having the capacity and pressure required by [1.3.4] item b) and by [1.2.6] item b), is capable of providing water to the fire main.

1.3.4 Capacity of fire pumps

a) Total capacity of required fire pumps

The required fire pumps shall be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in [1.2.6], as follows:

1) pumps in passenger ships: the quantity of water is not less than two thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping, and

2) pumps in cargo ships, other than any emergency pump: the quantity of water is not less than four thirds of the quantity required in Ch 1, Sec 10 to be dealt with by each of the independent bilge pumps in a passenger ship of the same dimension when employed in bilge pumping, provided that in no cargo ship other than those included in [6.3], need the total required capacity of the fire pumps exceed 180 m^3/hour.

b) When the main water supply for other fixed fire-extinguishing systems is from the fire pumps, the total capacity of the fire pumps is to be sufficient for the simultaneous use of:

- the minimum required number of jets of water at the required pressure from the fire main, and
- other fixed fire-extinguishing systems primarily fed by the fire main at their required output, or likely combination thereof.

c) Capacity of each fire pump

Each of the required fire pumps (other than any emergency pump required in [1.3.3] a) for cargo ships) shall have a capacity not less than 80% of the total required capacity divided by the minimum number of required fire pumps, but in any case not less than 25 m^3/hour, and each such pump shall in any event be capable of delivering at least the two required jets of water. These fire pumps shall be capable of supplying the fire main system under the required conditions. Where more pumps than the minimum of required pumps are installed, such additional pumps shall have a capacity of at least 25 m^3/h and shall be capable of delivering at least the two jets of water required in [1.2.5] a).

d) Specific requirements for ships designed to carry five or more tiers of containers on or above the weather deck

- in cases where the mobile water monitors are supplied by separate pumps and piping system, the total capacity of the main fire pumps need not exceed 180 m^3/h and the diameter of the fire main and water service pipes (hereinafter referred to "the pipework diameter") need only be sufficient for the discharge of 140 m^3/h.
- in cases where the mobile water monitors are supplied by the main fire pumps; the total capacity of required main fire pumps and the pipework diameter shall be sufficient for simultaneously supplying both the required number of fire hoses and mobile water monitors. However, the total capacity shall not be less than the following, whichever is smaller:
  - four thirds of the capacity required under Ch 1, Sec 10, [6.7.4] for each bilge pump or group of bilge pump; or
  - 180m^3/h
- in cases where the mobile water monitors and the "water-spray system" (fixed arrangement of spraying nozzles or flooding the cargo space with water) required by Ch 4, Sec 12, [2.2.3] are supplied by the main fire pumps, the total capacity of the main fire pumps and the pipework diameter need only be sufficient to supply whichever of the following is the greater:
  - the mobile water monitors and the four nozzles required by Ch 4, Sec 12, [2.2.2]; or
  - the four nozzles required by Ch 4, Sec 12, [2.2.2] and the water-spray system required by Ch 4, Sec 12, [2.2.3]

  The total capacity, however, is not to be less than specified in the above bullet point.

1.4 Fire hoses and nozzles

1.4.1 General specifications

a) Fire hoses shall be of non-perishable material approved by the Society and shall be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Each hose shall be provided with a nozzle and the necessary couplings. Hoses specified in this Chapter as "fire hoses" shall, together with any necessary fittings and tools, be kept ready for use in conspicuous positions near the water service hydrants or connections. Additionally, in interior locations in passenger ships carrying more than 36 passengers, fire hoses shall be connected to the hydrants at all times. Fire hoses shall have a length of at least 10 m, but not more than:

- *15 m in machinery spaces*
- *20 m in other spaces and open decks, and*
- *25 m for open decks on ships with a maximum breadth in excess of 30 m.*

b) Unless one hose and nozzle is provided for each hydrant in the ship, there shall be complete interchangeability of hose couplings and nozzles.

1.4.2 Number and diameter of fire hoses

a) Ships shall be provided with fire hoses, the number and diameter of which shall be to the satisfaction of the Society.

b) In passenger ships, there shall be at least one fire hose for each of the hydrants required by [1.2.5] and these hoses shall be used only for the purposes of extinguishing fires or testing the fire-extinguishing apparatus at fire drills and surveys.

c) In cargo ships:

1) of 1000 gross tonnage and upwards, the number of fire hoses to be provided shall be one for each 30 m length of the ship and one spare, but in no case less than five in all. This number does not include any hoses required in any engine-room or boiler room. The Society may increase the number of hoses required so as to ensure that hoses in sufficient number are available and accessible at all times, having regard to the type of ship and the nature of trade in which the ship is employed. Ships carrying dangerous goods in accordance with Ch 4, Sec 12 shall be provided with three hoses and nozzles, in addition to those required above.

Hydrants in machinery spaces of category A shall be provided with fire hoses*, and*

2) of less than 1000 gross tonnage, the number of fire hoses to be provided shall be calculated in accordance with the provisions of item 1) above. However the number of hoses shall in no case be less than three.

1.4.3 Size and type of nozzles

a) For the purposes of this Chapter, standard nozzle sizes shall be 12 mm, 16 mm and 19 mm or as near thereto as possible. Larger diameter nozzles may be permitted at the discretion of the Society.

b) For accommodation and service spaces, a nozzle size greater than 12 mm need not be used.

c) For machinery spaces and exterior locations, the nozzle size shall be such as to obtain the maximum discharge possible from two jets at the pressure mentioned in [1.2.6] from the smallest pump, provided that a nozzle size greater than 19 mm need not be used.

d) Nozzles shall be of an approved dual-purpose type (i.e. spray/jet type) incorporating a shut-off.

2 Portable fire extinguishers

2.1 Type and design

2.1.1 *Portable fire extinguishers shall comply with the requirements of Ch 4, Sec 15.*

2.2 Arrangement of fire extinguishers

2.2.1 *Accommodation spaces, service spaces and control stations shall be provided with portable fire extinguishers of appropriate types and in sufficient number to the satisfaction of the Society. Ships of 1000 gross tonnage and upwards shall carry at least five portable fire extinguishers.*

The number and the type of portable fire extinguishers required for the above-mentioned spaces are to be as follows:

- in accommodation and service spaces of passenger ships: one foam extinguisher or equivalent, for each group of adjacent spaces with easy access between them having total deck area not exceeding 200 m^2
- in accommodation spaces of cargo ships of 1000 gross tonnage and upwards: at least five foam extinguishers or equivalent, but not less than one for each 'tweendeck
- in accommodation spaces of cargo ships of less than 1000 gross tonnage: at least two foam extinguishers or equivalent, but not less than one for each 'tweendeck
- in the proximity of any electric switchboard or section board having a power of 20 kW and upwards: at least one CO_2 or powder extinguisher
- in any service space where deep fat cooking equipment is installed: at least one foam extinguisher or equivalent
- in the proximity of any paint or flammable product locker: at least one foam extinguisher or equivalent
- on the navigation bridge: one CO_2 extinguisher or equivalent.

2.2.2 *One of the portable fire extinguishers intended for use in any space shall be stowed near the entrance to that space.*

3 Fixed fire-extinguishing systems

3.1 Types of fixed fire-extinguishing systems

3.1.1 *A fixed fire extinguishing system required by article [4] may be any of the following systems:*

a) a fixed gas fire-extinguishing system complying with the provisions of Ch 4, Sec 15

b) a fixed high-expansion foam fire-extinguishing system complying with the provisions of Ch 4, Sec 15, and

c) a fixed pressure water spraying fire-extinguishing system complying with the provisions of Ch 4, Sec 15.

3.1.2 *Where a fixed fire-extinguishing system not required by this Chapter is installed, it shall meet* the relevant requirements of this Chapter.

3.1.3 *Fire-extinguishing systems using Halon 1211, 1301, and 2402 and perfluorocarbons shall be prohibited.*

3.1.4 *In general, the Society shall not permit the use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems.*

3.2 Closing appliances for fixed gas fire-extinguishing systems

3.2.1 *Where a fixed gas fire-extinguishing system is used, openings which may admit air to, or allow gas to escape from, a protected space shall be capable of being closed from outside the protected space.*

3.3 Storage rooms of fire-extinguishing medium

3.3.1 *When the fire-extinguishing medium is stored outside a protected space, it shall be stored in a room which is located behind the forward collision bulkhead, and is used for no other purposes. Any entrance to such a storage room shall preferably be from the open deck and shall be independent of the protected space. If the storage space is located below deck, it shall be located no more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck. Spaces which are located below deck or spaces where access from the open deck is not provided shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour. Access doors shall open outwards, and bulkheads and decks, including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces, shall be gastight. For the purpose of the application of Ch 4, Sec 5, Tab 1 to Ch 4, Sec 5, Tab 8, such storage rooms shall be treated as fire control stations.*

3.4 Water pumps for other fire-extinguishing systems

3.4.1 *Pumps, other than those serving the fire main, required for the provision of water for fire-extinguishing systems required by the present Chapter, their sources of power and their controls shall be installed outside the space or spaces protected by such systems and shall be so arranged that a fire in the space or spaces protected will not put any such system out of action.*

4 Fire-extinguishing arrangements in machinery spaces

4.1 Machinery spaces arrangement

4.1.1 General

a) The arrangement of machinery spaces is to be such that safe storage and handling of flammable liquids is ensured.

b) All spaces where oil-consuming installations, settling tanks or daily service fuel tanks are located are to be easily accessible and well ventilated.

c) Where leakage of flammable liquids may occur during normal service or routine maintenance work, special arrangement is to be made to prevent these fluids from reaching other parts of the machinery where danger of ignition may arise.

d) Materials used in machinery spaces are not normally to have properties increasing the fire potential of these rooms. Neither combustible nor oil-absorbing materials are to be used as flooring, bulkhead lining, ceiling or deck in the control room, machinery spaces, shaft tunnel or rooms where oil tanks are located. Where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours.

4.1.2 Fuel oil purifiers and other systems for preparing flammable liquids

a) The provisions of the present requirement apply to the following systems:
- systems (such as purifiers) for preparing flammable liquids for use in boilers and machinery
- separate oil systems with working pressure above 1,5 MPa and which are not part of the main engines, auxiliary engines or boilers, etc.

b) In general, the main components of the systems are to be placed in a separate room, enclosed by steel bulkheads extending from deck to deck, provided with self-closing steel doors, and complying with the provisions of item c). Alternative arrangements complying with the provisions of item d) may be accepted.

Transfer pumps may be placed outside this room.

Lubricating oil systems part of the main machinery may be located in the main engine room in a location ventilated by extraction.

c) Where provided, rooms in which flammable liquids are handled are to be provided with:
- independent mechanical ventilation or ventilation arrangements which can be isolated from the machinery space ventilation
- a fire detecting system
- a fixed fire-extinguishing installation. The fire-extinguishing installation is to be capable of being activated from outside the room. The fire-extinguishing system is to be separated for the room, but may be a part of the main fire-extinguishing system for the machinery space. Closing of ventilation openings is to be effected from a position close to where the extinguishing system is activated.

d) As an alternative to placing the main components of the systems in a separate room, specific measures with regard to the location, containment of possible leakages and shielding of the components and to ventilation may be submitted to the Society, such as:

- fitting of drip trays and shielding for leakage containment
- exhaust ventilation ducts inlets located close to the system so as to avoid flammable gas accumulation in the vicinity
- exhaust ducts covering the system separate from the rest of the machinery space, and which may be served by common ventilation exhaust fans.

Other alternative arrangements ensuring leakage containment, minimizing flammable gas accumulation and limiting the risk of recirculating flammable gases in the engine room may also be considered on a case-by-case basis by the Society.

A local fixed fire-extinguishing system as required by [4.7] is to be provided, capable of being activated automatically or activated manually from the machinery control position or from another suitable location. If automatic release is provided, additional manual release is to be arranged.

4.2 Machinery spaces containing oil-fired boilers or oil fuel units

4.2.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing oil fired boilers or oil fuel units shall be provided with any one of the fixed fire-extinguishing systems in [3.1].

In each case, if the engine-room and boiler room are not entirely separate, or if fuel oil can drain from the boiler room into the engine-room, the combined engine and boiler rooms shall be considered as one compartment.

4.2.2 Additional fire-extinguishing arrangements

a) There shall be in each boiler room or at an entrance outside of the boiler room at least one portable foam applicator unit complying with the provisions of Ch 4, Sec 15.

b) There shall be at least two portable foam extinguishers or equivalent in each firing space in each boiler room and in each space in which a part of the oil fuel installation is situated. There shall be not less than one approved foam-type extinguisher of at least 135 l capacity or equivalent in each boiler room. These extinguishers shall be provided with hoses on reels suitable for reaching any part of the boiler room. In the case of domestic boilers of less than 175 kW, or boilers protected by fixed water-based local application fire-extinguishing systems as required by [4.7], an approved foam-type extinguisher of at least 135 l capacity is not required.

In the proximity of any electric switchboard or section board having a power of 20 kW and upwards at least one CO_2 or powder extinguisher is to be fitted.

c) In each firing space there shall be a receptacle containing at least 0,1 m^3 sand, sawdust impregnated with soda, or other approved dry material, along with a suitable shovel for spreading the material. An approved portable extinguisher may be substituted as an alternative.

4.3 Machinery spaces of category A containing internal combustion machinery

4.3.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing internal combustion machinery shall be provided with one of the fixed fire-extinguishing systems required in [3.1].

4.3.2 Additional fire-extinguishing arrangements

a) There shall be at least one portable foam applicator unit complying with the provisions of Ch 4, Sec 15.

b) There shall be in each such space approved foam-type fire extinguishers, each of at least 45 l capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed onto any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards. In addition, there shall be provided a sufficient number of portable foam extinguishers or equivalent which shall be so located that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space. For smaller spaces of cargo ships, the Society may consider relaxing this requirement.

c) In the case of machinery spaces containing both boilers and internal combustion engines, [4.2] and [4.3] apply, with the exception that one of the foam fire extinguishers of at least 45 l capacity or equivalent may be omitted provided that the 136 l extinguisher can efficiently and readily protect the area covered by the 45 l extinguishers.

d) There shall be at least one CO_2 or powder extinguisher in the proximity of any electric switchboard or section board having a power of 20 kW and upwards.

4.4 Machinery spaces containing steam turbines or enclosed steam engines

4.4.1 Fixed fire-extinguishing systems

In spaces containing steam turbines or enclosed steam engines used for main propulsion or other purposes having in the aggregate a total output of not less than 375 kW, one of the fire-extinguishing systems specified in [3.1] shall be provided if such spaces are periodically unattended.

4.4.2 Additional fire-extinguishing arrangements

a) There shall be approved foam fire extinguishers, each of at least 45 l capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the pressure lubrication system, on to any part of the casings enclosing pressure-lubricated parts of the turbines, engines or associated gearing, and any other fire hazards. However, such extinguishers shall not be required if protection, at least equivalent to that required by this item, is provided in such spaces by a fixed fire-extinguishing system fitted in compliance with [3.1].

b) There shall be a sufficient number of portable foam extinguishers or equivalent which shall be so located that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space, except that such extinguishers shall not be required in addition to any provided in compliance with item b) of [4.2.2].

c) There shall be at least one CO_2 or powder extinguisher in the proximity of any electric switchboard or section board having a power of 20 kW and upwards.

4.5 Other machinery spaces

4.5.1 *Where, in the opinion of the Society, a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in [4.2], [4.3] and [4.4], there shall be provided in, or adjacent to, that space such a number of approved portable fire extinguishers or other means of fire extinction as the Society may deem sufficient.*

4.5.2 Spaces intended for the storage or handling of solvent onboard ships fitted with an onboard carbon capture and storage system (OCC)

Spaces intended for the storage or handling of solvent (as defined in Ch 1, Sec 12, [1.3.6]) on board ships fitted with an OCC are to be provided with one of the following fixed fire-extinguishing system:

- a fixed high-expansion foam fire-extinguishing system complying with the provisions of Ch 4, Sec 15 and using a foam concentrate suitable for extinguishing amine-based solvent fires, or
- a fixed pressure water spraying fire-extinguishing system complying with the provisions of Ch 4, Sec 15.

4.6 Additional requirements for passenger ships

4.6.1 *In passenger ships carrying more than 36 passengers, each machinery space of category A shall be provided with at least two suitable water fog applicators*, complying with Ch 4, Sec 15.

4.7 Fixed local application fire-extinguishing systems

4.7.1 *The present sub-article shall apply to passenger ships of 500 gross tonnage and above and cargo ships of 2000 gross tonnage and above.*

4.7.2 *Machinery spaces of category A above 500 m^3 in volume shall, in addition to the fixed fire-extinguishing system required in [4.2.1], be protected by* a fixed water-based or equivalent local application fire-extinguishing system complying with the provisions of Ch 4, Sec 15. *In the case of periodically unattended machinery spaces, the fire-extinguishing system shall have both automatic and manual release capabilities. In the case of continuously manned machinery spaces, the fire-extinguishing system is only required to have a manual release capability.*

4.7.3 *Fixed local application fire-extinguishing systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:*

a) the fire hazard portions of internal combustion machinery. In multi-engine installations, at least two sections are to be arranged.

b) boiler fronts

c) the fire hazard portions of incinerators, and

d) purifiers for heated fuel oil.

4.7.4 *Activation of any local application system shall give a visual and distinct audible alarm in the protected space and at continuously manned stations. The alarm shall indicate the specific system activated. The system alarm requirements described within this requirement are in addition to, and not a substitute for, the detection and fire alarm system required elsewhere in this Chapter.*

5 Fire-extinguishing arrangements in control stations, accommodation and service spaces

5.1 Sprinkler and water-spray systems in passenger ships

5.1.1 *Passenger ships carrying more than 36 passengers shall be equipped with an automatic sprinkler, fire detection and fire alarm system of an approved type complying with the requirements of Ch 4, Sec 15 in all control stations, accommodation and service spaces, including corridors and stairways. Alternatively, control stations, where water may cause damage to essential equipment, may be fitted with an approved fixed fire-extinguishing system of another type. Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with an automatic sprinkler system.*

5.1.2 *In passenger ships carrying not more than 36 passengers, when a fixed smoke detection and fire alarm system complying with the provisions of Ch 4, Sec 15 is provided only in corridors, stairways and escape routes within accommodation spaces, an automatic sprinkler system shall be installed in accordance with Ch 4, Sec 3, [4.4.1], item b).*

5.1.3 *A fixed pressure water spraying fire-extinguishing system complying with the provisions of Ch 4, Sec 15, [6.1.3] shall be installed on cabin balconies to which Ch 4, Sec 2, [2.2.4] applies, when furniture and furnishings on such balconies are not as defined in Ch 4, Sec 1, [2.39.1], items a), b), c), f) and g).*

5.2 Sprinkler systems for cargo ships

5.2.1 *In cargo ships in which method IIC specified in a)2) of Ch 4, Sec 5, [1.4.1] is adopted, an automatic sprinkler, fire detection and fire alarm system shall be fitted in accordance with the requirements of Ch 4, Sec 3, [4.7.1], item b).*

5.3 Spaces containing flammable liquid

5.3.1 *Paint lockers shall be protected by:*

a) a carbon dioxide system, designed to give a minimum volume of free gas equal to 40% of the gross volume of the protected space

b) a dry powder system, designed for at least 0,5 kg powder/m^3

c) a water spraying or sprinkler system, designed for 5 l/m^2 min. water spraying systems may be connected to the fire main of the ship, or

d) a system providing equivalent protection, as determined by the Society.

In all cases, the system shall be operable from outside the protected space.

5.3.2 *Flammable liquid lockers shall be protected by an appropriate fire-extinguishing arrangement approved by the Society.*

5.3.3 *For lockers of a deck area of less than 4 m^2, which do not give access to accommodation spaces, a portable carbon dioxide fire extinguisher sized to provide a minimum volume of free gas equal to 40% of the gross volume of the space may be accepted in lieu of a fixed system. A discharge port shall be arranged in the locker to allow the discharge of the extinguisher without having to enter into the protected space. The required portable fire extinguisher shall be stowed adjacent to the port. Alternatively, a port or hose connection may be provided to facilitate the use of fire main water.*

5.4 Deep-fat cooking equipment

5.4.1 *Deep-fat cooking equipment installed in enclosed spaces or on open decks shall be fitted with the following:*

a) an automatic or manual fire-extinguishing system tested to an international standard

b) a primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat

c) arrangements for automatically shutting off the electrical power upon activation of the fire-extinguishing system

d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed, and

e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

6 Fire-extinguishing arrangements in cargo spaces

6.1 Fixed gas fire-extinguishing systems for general cargo

6.1.1 *Except as provided for in [6.2], the cargo spaces of passenger ships of 1000 gross tonnage and upwards shall be protected by a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of Ch 4, Sec 15 or by a fixed high-expansion foam fire-extinguishing system which gives equivalent protection.*

6.1.2 *Where it is shown to the satisfaction of the Society that a passenger ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirements of [6.1.1] and also in ships of less than 1000 gross tonnage, the arrangements in cargo spaces shall be to the satisfaction of the Society, provided that the ship is fitted with steel hatch covers and effective means of closing all ventilators and other openings leading to the cargo spaces.*

6.1.3 *Except for ro-ro and vehicle spaces* (see Ch 4, Sec 13)*, cargo spaces on cargo ships of 2000 gross tonnage and upwards shall be protected by a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of Ch 4, Sec 15, or by a fire-extinguishing system which gives equivalent protection.*

6.1.4 *The Society may exempt from the requirements of [6.1.3] and [6.2] cargo spaces of any cargo ship if constructed, and solely intended, for the carriage of ore, coal, grain, unseasoned timber, non-combustible cargoes or cargoes which, in the opinion of the Society, constitute a low fire risk. Such exemptions may be granted only if the ship is fitted with steel hatch covers and effective means of closing all ventilators and other openings leading to the cargo spaces. When such exemptions are granted*, this will be reported on the Certificate of Classification.

Note 1: The list of solid bulk cargoes for which a fixed gas fire-extinguishing system may be exempted is given in the IMO Circular MSC.Circ.1395, as amended.

6.2 Fixed gas fire-extinguishing systems for dangerous goods

6.2.1 *A ship engaged in the carriage of dangerous goods* on deck or *in any cargo spaces shall be provided with a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of Ch 4, Sec 15 or with a fire-extinguishing system which, in the opinion of the Society, gives equivalent protection for the cargoes carried.*

6.3 Firefighting for ships designed to carry containers on or above the weather deck

6.3.1 *Ships shall carry, in addition to the equipment and arrangements required by article [1], at least one water mist lance.*

The water mist lance shall consist of a tube with a piercing nozzle which is capable of penetrating a container wall and producing water mist inside a confined space (container, etc.) when connected to the fire main.

6.3.2 *Ships designed to carry five or more tiers of containers on or above the weather deck shall carry, in addition to the requirements of [6.3.1], mobile water monitors as follows, and comply with item a) to e):*

- *ships with breadth less than 30 m: at least two mobile water monitors; or*
- *ships with breadth of 30 m or more: at least four mobile water monitors.*

a) The mobile water monitors, all necessary hoses, fittings and required fixing hardware shall be kept ready for use in a location outside the cargo space area not likely to be cut-off in the event of a fire in the cargo spaces.

b) A sufficient number of fire hydrants shall be provided such that:

1) all provided mobile water monitors can be operated simultaneously for creating effective water barriers forward and aft of each container bay;

2) the two jets of water required by item a) of [1.2.5] can be supplied at the pressure required by [1.2.6]; and

3) each of the required mobile water monitors can be supplied by separate hydrants at the pressure necessary to reach the top tier of containers on deck.

c) The mobile water monitors may be supplied by the fire main, provided the capacity of fire pumps and fire main diameter are adequate to simultaneously operate the mobile water monitors and two jets of water from fire hoses at the required pressure values. If carrying dangerous goods, the capacity of fire pumps and fire main diameter shall also comply with Ch 4, Sec 12, [2.2.5], as far as applicable to on-deck cargo areas.

d) The operational performance of each mobile water monitor shall be tested during initial survey on board the ship to the satisfaction of the Society. The test shall verify that:

1) the mobile water monitor can be securely fixed to the ship structure ensuring safe and effective operation; and

2) the mobile water monitor jet reaches the top tier of containers with all required monitors and water jets from fire hoses operated simultaneously.

e) The mobile water monitors are to be of a type approved by the Society according to IMO Circular MSC.1/Circ.1472.

7 Fire-extinguishing arrangements for ballast water management rooms

7.1 Fixed fire-extinguishing system

7.1.1 Where fitted, fixed fire-extinguishing systems are to comply with the relevant provisions of Ch 4, Sec 15.

7.1.2 Ozone-based ballast water management systems

Ballast water management rooms containing equipment related to ozone-based ballast water management systems are to be provided with a fixed fire-extinguishing system suitable for category A machinery spaces and capable of manual release.

7.1.3 Where a fixed fire-extinguishing system is provided in the ballast water management room, it is to be compatible with the ballast water management system and the chemical products that are used, produced or stored in the ballast water management room. Specific attention is to be paid to potential chemical reactions between the fire-extinguishing medium and chemical products used for water treatment.

Especially, water-based fire-extinguishing systems are to be avoided in case of sulfuric acid storage.

7.1.4 Foam fixed fire-extinguishing system

For all kinds of ballast water management systems, in case a foam fire-extinguishing system is installed in the ballast water management room, its efficiency is not to be impaired by chemicals used by the ballast water management system where relevant.

7.1.5 Where a fixed fire-extinguishing system is installed in the ballast water management room, automatic shutdown of the ballast water management system upon release of the fixed fire-extinguishing system is to be arranged. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence.

7.1.6 Where a ballast water management system that includes air or O_2 storage is located in a room covered by a fixed gas fire-extinguishing system, air or O_2 storage is to be taken into account for the gas capacity calculation, unless the discharge pipe from safety valves for air or O_2 storage are led directly to outside the room.

7.2 Portable fire-fighting equipment

7.2.1 At least one portable fire extinguisher complying with the provisions of Ch 4, Sec 15, [3] and suitable for electrical fires is to be provided in the ballast water management room containing UV-type ballast water management system.

8 Fire-extinguishing arrangements for battery rooms

8.1 Li Ion-type batteries above 20kWh

8.1.1 A fixed fire-extinguishing system is to be installed according to [3.1]. This system is to be compatible with the technology of the battery employed, according to the battery manufacturer specification.

Section 7 Suppression of Fire: Structural Integrity

1 Application

1.1 General

1.1.1 The provisions of Articles [2] to [5] apply to ships of all types and those of Article [6] apply to tankers.

2 Material of hull, superstructures, structural bulkheads, decks and deckhouses

2.1 General

2.1.1 *The hull, superstructures, structural bulkheads, decks and deckhouses shall be constructed of steel or other equivalent material. For the purpose of applying the definition of steel or other equivalent material as given in Ch 4, Sec 1, [2.49.1], the "applicable fire exposure" shall be according to the integrity and insulation standards given in Ch 4, Sec 5, Tab 1 to Ch 4, Sec 5, Tab 4. For example, where divisions such as decks or sides and ends of deckhouses are permitted to have B-0 fire integrity, the "applicable fire exposure" shall be half an hour.*

3 Structure of aluminium alloy

3.1 General

3.1.1 *Unless otherwise specified in [2.1.1], in cases where any part of the structure is of aluminium alloy, the following shall apply:*

a) The insulation of aluminium alloy components of A or B class divisions, except structure which, in the opinion of the Society, is non-load-bearing, shall be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure to the standard fire test, and

b) Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and A and B class divisions to ensure:

1) that for such members supporting lifeboat and liferaft areas and A class divisions, the temperature rise limitation specified in the preceding item a) shall apply at the end of one hour, and

2) that for such members required to support B class divisions, the temperature rise limitation specified in the preceding item a) shall apply at the end of half an hour.

4 Machinery spaces of category A

4.1 Crowns and casings

4.1.1 *Crowns and casings of machinery spaces of category A shall be of steel construction and shall be insulated as required by Ch 4, Sec 5, Tab 5 and Ch 4, Sec 5, Tab 7, as appropriate.*

The crown of a machinery space of category A should be understood to mean the underside of the deck and the uppermost horizontal part of the main space of the machinery space. If the upper side bulkheads are sloping, the sloping parts of the bulkheads should be included in the crown.

4.2 Floor plating

4.2.1 *The floor plating of normal passageways in machinery spaces of category A shall be made of steel.*

5 Materials of overboard fittings

5.1 General

5.1.1 *Materials readily rendered ineffective by heat shall not be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.*

6 Protection of cargo tank structure against pressure or vacuum

6.1 Reference to Part D

6.1.1 The requirements relevant to the protection of cargo tank structure against pressure or vacuum are given in Pt D, Ch 7, Sec 4, [4.2] and Pt D, Ch 7, Sec 4, [4.5].

Section 8 Escape

1 Notification of crew and passengers

1.1 Application

1.1.1 The provisions of [1.2] apply to ships of all types and those of [1.3] and [1.4] apply to passenger ships.

1.2 General emergency alarm system

1.2.1 *A general emergency alarm system required in Ch 2, Sec 3, [3.14] shall be used for notifying crew and passengers of a fire.*

1.3 Special alarm to summon the crew

1.3.1 *A special alarm, operated from the navigation bridge or fire control station, shall be fitted to summon the crew. This alarm may be part of the ship's general alarm system but it shall be capable of being sounded independently of the alarm to the passenger spaces.*

1.4 Public address systems

1.4.1 *A public address system or other effective means of communication complying with the requirements of Ch 2, Sec 3, [3.15] shall be available throughout the accommodation and service spaces and control stations and open decks.*

2 Means of escape

2.1 General requirements

2.1.1 *Unless expressly provided otherwise in this Article, at least two widely separated and ready means of escape shall be provided from all spaces or groups of spaces.*

2.1.2 *Lifts shall not be considered as forming one of the means of escape as required by this Article.*

2.2 Means of escape from control stations, accommodation spaces and service spaces

2.2.1 Application

The provisions of [2.2.2] apply to ships of all types, those of [2.2.3] apply to passenger ships and those of [2.2.4] apply to cargo ships.

2.2.2 General requirements

a) Stairways and ladders shall be so arranged as to provide ready means of escape to the lifeboat and liferaft embarkation deck from passenger and crew accommodation spaces and from spaces in which the crew is normally employed, other than machinery spaces.

b) Unless expressly provided otherwise in this Article, a corridor, lobby, or part of a corridor from which there is only one route of escape shall be prohibited. Dead-end corridors used in service areas which are necessary for the practical utility of the ship, such as fuel oil stations and athwartship supply corridors, shall be permitted, provided such dead-end corridors are separated from crew accommodation areas and are inaccessible from passenger accommodation areas. Also, a part of a corridor that has a depth not exceeding its width is considered a recess or local extension and is permitted.

c) All stairways in accommodation and service spaces and control stations shall be of steel frame construction except where the Society sanctions the use of other equivalent material.

d) If a radiotelegraph station has no direct access to the open deck, two means of escape from, or access to, the station shall be provided, one of which may be a porthole or window of sufficient size or other means to the satisfaction of the Society.

e) Doors in escape routes shall, in general, open in way of the direction of escape, except that:

1) individual cabin doors may open into the cabins in order to avoid injury to persons in the corridor when the door is opened, and

2) doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and for access.

2.2.3 Means of escape in passenger ships

a) Escape from spaces below the bulkhead deck

1) Below the bulkhead deck, two means of escape, at least one of which shall be independent of watertight doors, shall be provided from each watertight compartment or similarly restricted space or group of spaces. Exceptionally, the Society may dispense with one of the means of escape for crew spaces that are entered only occasionally, if the required escape route is independent of watertight doors.

2) Where the Society has granted dispensation under the provisions of a) 1) above, this sole means of escape shall provide safe escape. However, stairways shall not be less than 800 mm in clear width with handrails on both sides.

b) Escape from spaces above the bulkhead deck

Above the bulkhead deck there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which shall give access to a stairway forming a vertical escape.

c) Direct access to stairway enclosures

Stairway enclosures in accommodation and service spaces shall have direct access from the corridors and be of a sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for non-hazardous safety equipment and open information counters are permitted. Only corridors, lifts, public toilets, special category spaces and open ro-ro spaces to which any passengers carried can have access, other escape stairways required by the following item d) and external areas are permitted to have direct access to these stairway enclosures. Public spaces may also have direct access to stairway enclosures except for the backstage of a theatre. Small corridors or lobbies used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of 4,5 m^2, a width of no less than 900 mm and contain a fire hose station.

d) Details of means of escape

1) At least one of the means of escape required by the preceding items a) 1) and b) shall consist of a readily accessible enclosed stairway, which shall provide continuous fire shelter from the level of its origin to the appropriate lifeboat and liferaft embarkation decks, or to the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting in accordance with Ch 2, Sec 3 and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck shall have fire integrity, including insulation values, in accordance with Ch 4, Sec 5, Tab 1 to Ch 4, Sec 5, Tab 4, as appropriate.

2) Protection of access from the stairway enclosures to the lifeboat and liferaft embarkation areas shall be provided either directly or through protected internal routes which have fire integrity and insulation values for stairway enclosures as determined by Ch 4, Sec 5, Tab 1 to Ch 4, Sec 5, Tab 4, as appropriate.

3) Stairways serving only a space and a balcony in that space shall not be considered as forming one of the required means of escape.

4) Each level within an atrium shall have two means of escape, one of which shall give direct access to an enclosed vertical means of escape meeting the requirements of d) 1) above.

The same requirement applies in general to public spaces spanning two decks.

5) The widths, number and continuity of escapes shall be in accordance with the requirements in Ch 4, Sec 15.

e) Marking of escape routes

1) In addition to the emergency lighting required by Pt D, Ch 11, Sec 5 and Ch 2, Sec 3, the means of escape, including stairways and exits, shall be marked by lighting or photoluminescent strip indicators placed not more than 300 mm above the deck at all points of the escape route, including angles and intersections. The marking must enable passengers to identify the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip will not result in the marking being ineffective. Additionally, escape route signs and fire equipment location markings shall be of photoluminescent material or marked by lighting. The Society shall ensure that such lighting or photoluminescent equipment has been evaluated, tested and applied in accordance with Ch 4, Sec 15.

2) In passenger ships carrying more than 36 passengers, the requirements of item e) 1) above shall also apply to the crew accommodation areas.

3) In lieu of the escape route lighting system required by item e) 1) above, alternative evacuation guidance systems may be accepted if approved.

f) Normally locked doors that form part of an escape route

Cabin and stateroom doors shall not require keys to unlock them from inside the room. Neither shall there be any doors along any designated escape route which require keys to unlock them when moving in the direction of escape.

Escape doors from public spaces that are normally latched shall be fitted with a means of quick release. Such means shall consist of a door-latching mechanism incorporating a device that releases the latch upon the application of a force in the direction of escape flow. Quick release mechanisms shall be designed and installed to the satisfaction of the Society and, in particular:

1) consist of bars or panels, the actuating portion of which extends across at least one half of the width of the door leaf, at least 760 mm and not more than 1120 mm above the deck

2) cause the latch to release when a force not exceeding 67 N is applied, and

3) not be equipped with any locking device, set screw or other arrangement that prevents the release of the latch when pressure is applied to the releasing device.

g) Evacuation analysis for passenger ships

For passenger ships carrying more than 36 passengers and ro-ro passenger ships, escape routes shall be evaluated by an evacuation analysis early in the design process, in line with IMO Circular MSC.1/Circ.1533 "Revised Guidelines on evacuation analyses for new and existing passenger ships".

The analysis shall be used to identify and eliminate, as far as practicable, congestion which may develop during an abandonment, due to normal movement of passengers and crew along escape routes, including the possibility that crew may need to move along these routes in a direction opposite to the movement of passengers. In addition, the analysis shall be used to demonstrate that escape arrangements are sufficiently flexible to provide for the possibility that certain escape routes, assembly stations, embarkation stations or survival craft may not be available as a result of a casualty.

2.2.4 Means of escape in cargo ships

a) General

At all levels of accommodation there shall be provided at least two widely separated means of escape from each restricted space or group of spaces.

b) Escape from spaces below the lowest open deck

Below the lowest open deck the main means of escape shall be a stairway and the second escape may be a trunk or a stairway.

c) Escape from spaces above the lowest open deck

Above the lowest open deck the means of escape shall be stairways or doors to an open deck or a combination thereof.

d) Dead-end corridors

No dead-end corridors having a length of more than 7 m shall be accepted.

e) Width and continuity of escape routes

The width, number and continuity of escape routes shall be in accordance with the requirements in Ch 4, Sec 15.

f) Dispensation from two means of escape

Exceptionally the Society may dispense with one of the means of escape, for crew spaces that are entered only occasionally, if the required escape route is independent of watertight doors.

2.3 Means of escape from machinery spaces

2.3.1 Application

The provisions of [2.3.3] apply to passenger ships, those of [2.3.4] apply to cargo ships.

2.3.2 Safe position

For the application of the subsequent requirements, a safe position can be any space, such as steering gear spaces where hydraulic oils for the steering gear equipment are stowed, and vehicle and ro-ro spaces, from which access is provided and maintained clear of obstacles to the open deck. This excludes cargo spaces, lockers and storerooms, cargo pump-rooms and spaces where flammable liquids are stowed.

2.3.3 Means of escape on passenger ships

Means of escape from each machinery space in passenger ships shall comply with the following provisions:

a) Escape from spaces below the bulkhead deck

Where the space is below the bulkhead deck, the two means of escape shall consist of either:

1) two sets of steel ladders as widely separated as possible, leading to doors in the upper part of the space, similarly separated and from which access is provided to the appropriate lifeboat and liferaft embarkation decks. One of these ladders shall be located within a protected enclosure that satisfies Ch 4, Sec 5, [1.3.3], category (2), or Ch 4, Sec 5, [1.3.4], category (4), as appropriate, from the lower part of the space it serves to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800 mm × 800 mm, and shall have emergency lighting provisions, or

2) one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

b) Escape from spaces above the bulkhead deck

Where the space is above the bulkhead deck, the two means of escape shall be as widely separated as possible and the doors leading from such means of escape shall be in a position from which access is provided to the appropriate lifeboat and liferaft embarkation decks. Where such means of escape require the use of ladders, these shall be of steel.

c) Dispensation from two means of escape

In a ship of less than 1000 gross tonnage, the Society may dispense with one of the means of escape, due regard being paid to the width and disposition of the upper part of the space. In a ship of 1000 gross tonnage and above, the Society may dispense with one means of escape from any such space, including a normally unattended auxiliary machinery space, so long as either a door or a steel ladder provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space. In the steering gear space, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

d) Escape from machinery control rooms

Two means of escape shall be provided from a machinery control room located within a machinery space, at least one of which will provide continuous fire shelter to a safe position outside the machinery space.

e) Escape from main workshops within machinery spaces

Two means of escape shall be provided from the main workshop within a machinery space. At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

f) Inclined ladders and stairways

All inclined ladders/stairways fitted to comply with a) with open treads in machinery spaces being part of or providing access to escape routes but not located within a protected enclosure shall be made of steel. Such ladders/stairways shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

Inclined ladders/stairways in machinery spaces being part of, or providing access to, escape routes but not located within a protected enclosure shall not have an inclination greater than 60° and shall not be less than 600 mm in clear width. Such requirement need not be applied to ladders/stairways not forming part of an escape route, only provided for access to equipment or components, or similar areas, from one of the main platforms or deck levels within such spaces.

g) Protected enclosure

A protected enclosure providing escape from machinery spaces of category A to an open deck fitted to comply with a) may be fitted with a hatch as means of egress from the enclosure to the open deck. The hatch is to have minimum internal dimensions of 800 mm x 800 mm.

Internal dimensions are to be interpreted as clear width, so that a passage having diameter of 800 mm is available throughout the vertical enclosure, as shown in Fig 1, clear of ship's structure, with insulation and equipment, if any. The ladder within the enclosure can be included in the internal dimensions of the enclosure. When protected enclosures include horizontal portions their clear width is not to be less than 600 mm.

2.3.4 Means of escape on cargo ships

Means of escape from each machinery space in cargo ships shall comply with the following provisions:

a) Escape from machinery spaces of category A

Except as provided in the following item b), two means of escape shall be provided from each machinery space of category A. In particular, one of the following provisions shall be complied with:

1) two sets of steel ladders, as widely separated as possible, leading to doors in the upper part of the space, similarly separated and from which access is provided to the open deck. One of these ladders shall be located within a protected enclosure that satisfies Ch 4, Sec 5, [1.4.3], category (4), from the lower part of the space it serves to a safe position outside

the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The enclosure shall have minimum internal dimensions of at least 800 mm × 800 mm, and shall have emergency lighting provisions, or

2) one steel ladder leading to a door in the upper part of the space from which access is provided to the open deck and, additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

b) Dispensation from two means of escape

In a ship of less than 1000 gross tonnage, the Society may dispense with one of the means of escape required under item a), due regard being paid to the dimension and disposition of the upper part of the space.

In addition, the means of escape from machinery spaces of category A need not comply with the requirement for an enclosed fire shelter listed in item a) 1) above. In the steering gear space, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

c) Escape from machinery spaces other than those of category A

From machinery spaces other than those of category A, two escape routes shall be provided except that a single escape route may be accepted for spaces that are entered only occasionally and for spaces where the maximum travel distance to the door is 5 m or less.

Note 1: In machinery spaces other than those of category A, which are not entered only occasionally, the travel distance shall be measured from any point normally accessible to the crew, taking into account machinery and equipment within the space.

d) With regard to application of items b) and c), the following applies:

- Steering gear spaces which do not contain the emergency steering position need only have one means of escape.
- Steering gear spaces containing the emergency steering position can have one means of escape provided it leads directly onto the open deck. Otherwise, two means of escape are to be provided but they do not need to lead directly onto the open deck.
- Escape routes that pass only through stairways and/or corridors are considered as providing a "direct access to the open deck", provided that the escape routes from the steering gear spaces have fire integrity protection equivalent to steering gear spaces or stairways/corridors, whichever is more stringent.

e) Escape from machinery control rooms in machinery spaces of category "A"

Two means of escape shall be provided from the machinery control room located within a machinery space. At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

f) Escape from main workshops in machinery spaces of category "A"

Two means of escape shall be provided from the main workshop within a machinery space. At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

g) Inclined ladders and stairways

All inclined ladders/stairways fitted to comply with a) with open treads in machinery spaces being part of or providing access to escape routes but not located within a protected enclosure shall be made of steel. Such ladders/stairways shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

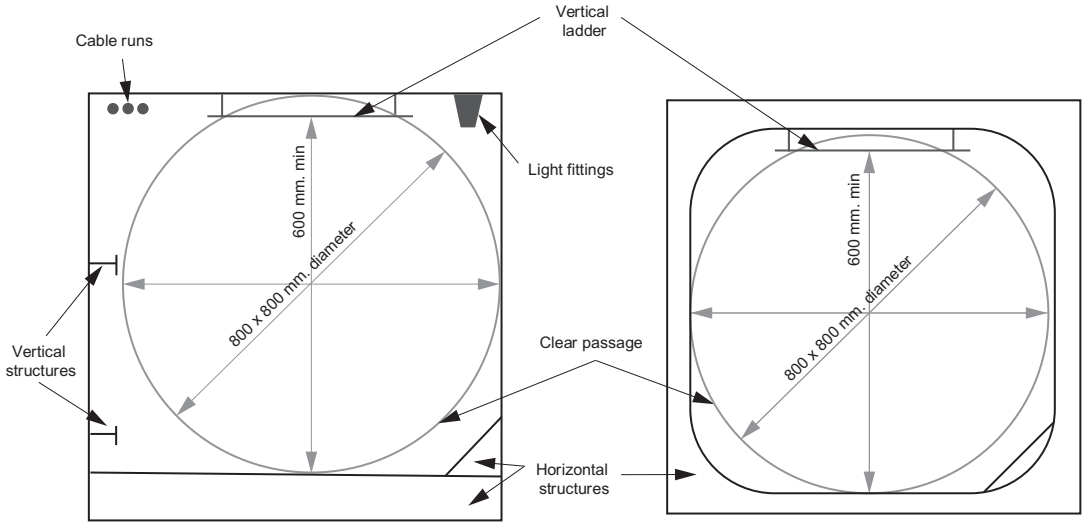
Inclined ladders/stairways in machinery spaces being part of, or providing access to, escape routes but not located within a protected enclosure shall not have an inclination greater than 60° and shall not be less than 600 mm in clear width. Such requirement need not be applied to ladders/stairways not forming part of an escape route, only provided for access to equipment or components, or similar areas, from one of the main platforms or deck levels within such spaces.

h) Protected enclosure

A protected enclosure providing escape from machinery spaces of category A to an open deck fitted to comply with a) may be fitted with a hatch as means of egress from the enclosure to the open deck. The hatch is to have minimum internal dimensions of 800 mm x 800 mm.

Internal dimensions are to be interpreted as clear width, so that a passage having diameter of 800 mm is available throughout the vertical enclosure, as shown in Fig 1, clear of ship's structure, with insulation and equipment, if any. The ladder within the enclosure can be included in the internal dimensions of the enclosure. When protected enclosures include horizontal portions their clear width is not to be less than 600 mm.

Figure 1 : Example of possible arrangements of the protected enclosure



2.4 Means of escape on passenger ships from special category and open ro-ro spaces to which any passengers carried can have access

2.4.1 *In special category and open ro-ro spaces to which any passengers carried can have access, the number and locations of the means of escape both below and above the bulkhead deck shall be to the satisfaction of the Society and, in general, the safety of access to the embarkation deck shall be at least equivalent to that provided for in items a) 1), b), d) 1) and d) 2) of [2.2.3].*

Such spaces shall be provided with designated walkways to the means of escape with a breadth of at least 600 mm. The parking arrangements for the vehicles shall maintain the walkways clear at all times.

2.4.2 Direct access to special category spaces

One of the escape routes from the machinery spaces where the crew is normally employed shall avoid direct access to any special category space.

2.5 Means of escape from ro-ro spaces

2.5.1 *At least two means of escape shall be provided in ro-ro spaces where the crew are normally employed. The escape routes shall provide a safe escape to the lifeboat and liferaft embarkation decks and shall be located at the fore and aft ends of the space.*

One of the means of escape should be a stairway, the second escape may be a trunk or a stairway.

The fore and aft ends of the ro-ro space are considered as the areas being within the distance equal to the breadth of the ro-ro space, measured at its widest point, from its forward most and aftmost point.

2.6 Additional requirements for ro-ro passenger ships

2.6.1 General

a) Escape routes shall be provided from every normally occupied space on the ship to an assembly station. These escape routes shall be arranged so as to provide the most direct route possible to the assembly station, and shall be marked with symbols in accordance with the recommendations of IMO Resolution A.1116 (30).

b) The escape route from cabins to stairway enclosures shall be as direct as possible, with a minimum number of changes in direction. It shall not be necessary to cross from one side of the ship to the other to reach an escape route. It shall not be necessary to climb more than two decks up or down in order to reach an assembly station or open deck from any passenger space.

c) External routes shall be provided from open decks, as referred to in item b), to the survival craft embarkation stations.

d) Where enclosed spaces adjoin an open deck, openings from the enclosed space to the open deck shall, where practicable, be capable of being used as an emergency exit.

e) Escape routes shall not be obstructed by furniture and other obstructions. With the exception of tables and chairs which may be cleared to provide open space, cabinets and other heavy furnishings in public spaces and along escape routes shall be secured in place to prevent shifting if the ship rolls or lists. Floor coverings shall also be secured in place. When the ship is under way, escape routes shall be kept clear of obstructions such as cleaning carts, bedding, luggage and boxes of goods.

2.6.2 Instruction for safe escape

a) Decks shall be sequentially numbered, starting with "1" at the tank top or lowest deck. The numbers shall be prominently displayed at stair landings and lift lobbies. Decks may also be named, but the deck number shall always be displayed with the name.

b) Simple "mimic" plans showing the "you are here" position and escape routes marked by arrows shall be prominently displayed on the inside of each cabin door and in public spaces. The plan shall show the directions of escape and shall be properly oriented in relation to its position on the ship.

2.6.3 Strength of handrails and corridors

a) Handrails or other handholds shall be provided in corridors along the entire escape route so that a firm handhold is available at every step of the way, where possible, to the assembly stations and embarkation stations. Such handrails shall be provided on both sides of longitudinal corridors more than 1,8 m in width and transverse corridors more than 1 m in width. Particular attention shall be paid to the need to be able to cross lobbies, atriums and other large open spaces along escape routes. Handrails and other handholds shall be of such strength as to withstand a distributed horizontal load of 750 N/m applied in the direction of the centre of the corridor or space, and a distributed vertical load of 750 N/m applied in the downward direction. The two loads need not be applied simultaneously.

b) The lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes shall be able to sustain a load of 750 N/m to allow them to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.

Section 9 Fire Control Plans

1 Application

1.1 General

1.1.1 This Section applies to passenger ships and cargo ships.

2 Fire control plans

2.1 Compilation of the fire control plans

2.1.1 *General arrangement plans shall be permanently exhibited for the guidance of the ship's officers, showing clearly for each deck the control stations, the various fire sections enclosed by A class divisions, the sections enclosed by B class divisions together with particulars of the fire detection and fire alarm systems, the sprinkler installation, the fire-extinguishing appliances, means of access to different compartments, decks, etc. and the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section, and the position of fuel oil quick-closing valve remote control and fuel oil pump stops,* or, for ships assigned with the additional service feature **CNGfuel**, **LNGfuel**, **LPGfuel**, **methanolfuel**, **ammoniafuel**, **hydrogenfuel** or **LFPfuel**, position of the fuel supply closing valve and fuel supply pumps or compressor stops.

Alternatively, at the discretion of the Society, the aforementioned details may be set out in a booklet, a copy of which shall be supplied to each officer, and one copy shall at all times be available on board in an accessible position.

Plans and booklets shall be kept up to date; any alterations thereto shall be recorded as soon as practicable. Description in such plans and booklets shall be in the language or languages required by the Society. If the language is neither English nor French, a translation into one of those languages shall be included.

In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire shall be kept under one cover, readily available in an accessible position.

The graphical symbols for the fire control plan are to be in accordance with IMO Resolution A.1116(30) table 1 and table 3, with symbols updated as per ISO 17131:2022. For symbols not already covered by the aforementioned resolution and for A-class and B-class divisions, IMO Resolution A.952(23) is to be used.

2.1.2 The number of portable equipment available at each location is to be specified.

2.1.3 *In ships carrying more than 36 passengers, plans and booklets required by [2.1.1] shall provide information regarding fire protection, fire detection and fire extinction* including*:*

- ship's keel laying date and application of the SOLAS Convention and amendments
- which additional fire safety measures, if any, were applied
- dates and description of any modifications to the ship which in any way alter its fire safety.

2.1.4 Special equipment provided for the carriage of dangerous goods, if fitted, is to be shown.

2.1.5 Where fitted in compliance with the requirements of Ch 4, Sec 11, [2], the controls for jettisoning fuel for auxiliary vehicles are to be shown.

2.1.6 For ships equipped with an exhaust gas pollution prevention system, in line with the requirements of Ch 1, Sec 11, [3.6] or Ch 1, Sec 11, [4.8] or in line with the requirements of risk analysis performed in line with Ch 1, Sec 11, [5.2], the following elements are to be shown:

- storage location of personal protective equipment (PPE)
- location of eyewash station.

2.1.7 For ships equipped with a Ballast Water Management System, in line with the requirements of Ch 1, Sec 13, [2.10], the following elements are to be shown:

- storage location of personal protective equipment (PPE)
- location of decontamination showers and eyewash
- location of emergency breathing apparatus (EEBD), if any
- storage location of the personal ozone detectors pursuant to Ch 1, Sec 13, [2.10.5]
- storage location of the two-way portable radiotelephone pursuant to Ch 1, Sec 13, [2.10.6].

2.1.8 In compliance with the requirements of NR547, Section 8, for ships assigned the additional service feature **fuelcell**, the emergency shutdown push buttons are to be shown.

2.1.9 In compliance with the requirements of NR529, for ships assigned the additional service feature **LNGfuel** or **CNGfuel** and provided with ESD-protected machinery space, the emergency shutdown push buttons are to be shown.

2.1.10 In compliance with the requirements of NR678, for ships assigned the additional service feature **hydrogenfuel**, storage location of personal protective equipment (PPE) is to be shown.

2.1.11 In compliance with the requirements of NR671, for ships assigned the additional service feature ammoniafuel, the following elements are to be shown:

- storage location of personal protective equipment (PPE)
- location of the emergency showers and eye rinsing equipment.

2.1.12 In compliance with the requirements of Pt F, Ch 10, Sec 3, for ships assigned the additional class notation **CBRN** or **CBRN-WASHDOWN**, the following elements are to be shown:

- citadel and/or shelter
- storage location of personal protective equipment (PPE)
- CBRN detection system
- pre-wetting and wash down system and associated control valves.

2.1.13 in compliance with the requirements of Pt F, Ch 13, Sec 2, for ships assigned the additional class notation **ECFP-1**, **ECFP-2** or **ECFP-3**, the following elements are to be shown, as applicable:

- storage location of portable equipment (water mist lances, portable fire-fighting devices for stacked containers, fire fighter's outfits, portable thermal imaging camera)
- compressed air system for breathing apparatus
- fixed water monitors covering the on-deck cargo stowage area and associated controls
- water-spray system below hatch cover and associated control valves
- flooding system for the cargo hold and associated control valves
- water-spray system for the protection of the superstructure block or equivalent system and associated control valves.

2.2 Location of the fire control plans

2.2.1 *A duplicate set of fire control plans or a booklet containing such plans shall be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shore-side fire-fighting personnel.*

Section 10 Helicopter Facilities

1 General

1.1 Application

1.1.1 In addition to complying with the requirements of the other Sections of this Chapter, as appropriate, ships equipped with helicopter or airborne vehicle facilities are to comply with those of this Section. For the purpose of applying the requirements of this Section, airborne vehicles are to be considered as helicopters.

Items d) and e) of [3.1.1] and Articles [5] and [6] do not contain requirements applicable for the purpose of classification; they have been reproduced for reference purposes only.

2 Structure

2.1 Construction of steel or other equivalent materials

2.1.1 *In general, the construction of the helidecks shall be of steel or other equivalent materials. If the helideck forms the deckhead of a deckhouse or superstructure, it shall be insulated to A-60 class standard.*

2.2 Construction of aluminium or other low melting point metals

2.2.1 *If the Society permits aluminium or other low melting point metal construction that is not made equivalent to steel and if the platform is located above the ship's deckhouse or similar structure, the following conditions shall be satisfied:*

a) the deckhouse top and bulkheads under the platform shall have no opening

b) windows under the platform shall be provided with steel shutters.

2.3 Means of escape

2.3.1 *A helideck shall be provided with both a main and an emergency means of escape and access for fire-fighting and rescue personnel. These shall be located as far apart from each other as is practicable and preferably on opposite sides of the helideck.*

3 Fire-fighting appliances

3.1 General

3.1.1 *In close proximity to the helideck, the following fire-fighting appliances shall be provided and stored near the means of access to that helideck:*

a) at least two dry powder extinguishers having a total capacity of not less than 45 kg

b) carbon dioxide extinguishers of a total capacity of not less than 18 kg or equivalent

c) foam firefighting appliances complying with the provisions of Ch 4, Sec 15, [14]

d) two sets of fire-fighter's outfits, and

e) at least the following equipment, stored in a manner that provides for immediate use and protection from the elements:

- *adjustable wrench*
- *blanket, fire-resistant*
- *cutters, bolt 60 cm*
- *hook, grab or salving*
- *hacksaw, heavy duty complete with 6 spare blades*
- *ladder*
- *lift line 5 mm diameter and 15 m in length*
- *pliers, side-cutting*
- *set of assorted screwdrivers, and*
- *harness knife complete with sheath.*

3.2 Drainage facilities

3.2.1 *Drainage facilities in way of helidecks shall be constructed of steel and shall lead directly overboard independent of any other system and shall be designed so that drainage does not fall onto any part of the ship.*

4 Helicopter refuelling and hangar facilities (if fitted)

4.1 Helicopter fuel system and refuelling facilities

4.1.1 Fuels having a flashpoint below or equal to 43°C

Helicopter fuel systems and refuelling facilities for fuels having a flashpoint below or equal to 43°C are to comply with the requirements of Ch 4, Sec 11.

4.1.2 Fuels having a flashpoint above 43°C

Helicopter fuel systems and refuelling facilities for fuels having a flashpoint above 43°C are to comply with the following requirements:

- Ch 4, Sec 11, [1.4.1], Ch 4, Sec 11, [1.4.3]
- Ch 4, Sec 11, [2.2.1]
- Ch 4, Sec 11, [3.6.1], Ch 4, Sec 11, [3.6.2], Ch 4, Sec 11, [3.6.3] and Ch 4, Sec 11, [3.6.4]
- Ch 4, Sec 11, [4.1.1]

Tanks and associated equipment shall be protected against physical damage and from a fire in an adjacent space or area.

4.2 Arrangement of hangar facilities and spaces containing the refuelling installations

4.2.1 Application

Helicopter refuelling and hangar facilities are to comply with the requirements of [4.2.2] to [4.2.4] whatever the flashpoint of the helicopter fuel.

4.2.2 Suppression of fire

Hangar, refuelling and maintenance facilities and spaces where fuel handling is intended are to be treated as a category A machinery space with regards to fire protection, fixed fire extinguishing and detection system requirements.

Hangar facilities and spaces containing the refuelling installations are also to comply with the requirements of Ch 4, Sec 11, [4.4.2].

4.2.3 Helicopter refuelling and hangar facilities are to comply with the requirements of Ch 4, Sec 11, [4.2.2].

4.2.4 Electric equipment and wiring

Electric equipment and wiring in enclosed hangars or enclosed spaces containing refuelling installations shall comply with the requirements of Ch 4, Sec 13, [2.2], Ch 4, Sec 13, [2.3], and Ch 4, Sec 13, [2.4] or, for fuels having a flashpoint below or equal to 43°C, see Ch 4, Sec 11, [4.3.1]. These requirements are summarized below.

In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zone 0, 1 and 2 according to Ch 2, Sec 1, [3.13.3]. The different spaces and areas are to be classified according to:

- Tab 1 for fuels having a flashpoint above 43°C
- Ch 4, Sec 11, Tab 1 for fuels having a flashpoint below or equal to 43°C.

Table 1 : Space descriptions and hazardous area zones for fuels having a flashpoint above 43°C

N°	Description of spaces or areas	Hazardous area
1	Enclosed hangar or enclosed spaces containing refuelling installations if the ventilation rate is less than 10 air changes per hour	Zone 1
2	Areas below a height of 450 mm from the deck in enclosed hangar or enclosed spaces containing refuelling installations, if the ventilation system is so designed and operated as to provide continuous ventilation of the space at the rate of at least 10 air changes per hour	Zone 1
3	Exhaust ventilation ducts serving enclosed hangar or enclosed spaces containing refuelling installations	Zone 1
4	Areas above a height of 450 mm from the deck in enclosed hangar or enclosed spaces containing refuelling installations, if the ventilation system is so designed and operated as to provide continuous ventilation of the space at the rate of at least 10 air changes per hour	Zone 2

5 Occasional and emergency helicopter operations

5.1 General

5.1.1 *Where helicopters land or conduct winching operations on an occasional or emergency basis on ships without helidecks, fire-fighting equipment fitted in accordance with the requirements of Ch 4, Sec 1 may be used. This equipment shall be made readily available in close proximity to the landing or winching areas during helicopter operations.*

5.1.2 Helicopter landing areas are to be provided with foam firefighting appliances in accordance with the requirements of Ch 4, Sec 15, [14.3.4].

6 Operations manual

6.1 General

6.1.1 *Each helicopter facility shall have an operations manual, including a description and a checklist of safety precautions, procedures and equipment requirements. This manual may be part of the ship's emergency response procedures.*

Section 11 Fuel for Auxiliary Vehicles

1 General

1.1 Application

1.1.1 This Section applies to filling, storage and refuelling arrangements for oil fuels dedicated to auxiliary vehicles used during normal ship operation such as zodiac, jet ski or helicopter.

1.1.2 This Section applies neither to the transportation of petroleum products as cargo nor to the ship fuel oil system.

1.1.3 Fuels covered by this section are typically jet A-1 aviation fuel, diesel or gasoline and may have a flashpoint below 60°C.

1.1.4 This Section does not cover installations for toxic fuels. In case an installation for toxic fuel is foreseen, a dedicated risk assessment covering this specific risk is to be performed and the installation is to be considered on a case-by-case basis by the Society.

1.1.5 The requirements of this Section may be disregarded for fuels having a flashpoint above 43°C provided:

- the fuel tanks are located outside of machinery spaces of category A
- provisions for the measurement of oil temperature are provided on the suction pipe of the fuel pumps
- stop valves and/or cocks are provided on the inlet side and outlet side of the fuel strainers
- pipe joints of welded construction or of circular cone type or spherical type union joint are applied as much as possible
- fuel pipes are routed out of high fire risk spaces such as machinery spaces of category A, galleys, stores, ro-ro spaces, cargo spaces
- the relevant provisions of Ch 1, Sec 10 are complied with.

Whatever their flashpoint, helicopter and airborne vehicle fuel systems are to comply with the requirements of Ch 4, Sec 10, [4].

1.1.6 Two types of installations are foreseen:

- jettisonable fuel tanks, with manual refuelling of the auxiliary vehicles. In addition to the requirements of Article [1] and [4], the arrangement of jettisonable fuel tanks is to comply with the requirements of Article [2]
- fixed installations including fuel tanks, filling station and refuelling station. In addition to the requirements of Article [1] and [4], fixed fuel installation are to comply with the requirements of Article [3].

Both kinds of installations may be installed on a ship, if dedicated to different fuels.

As a general principle, the aggregate quantity of fuel for auxiliary vehicles carried on board is to be kept to a minimum, considering fuel(s) carried in portable and fixed fuel tanks. It is to be demonstrated that the total quantity of fuel for auxiliary vehicles carried on board corresponds to, and does not exceed, the ship's operational needs, taking into account the intended use of the auxiliary vehicles, possible refilling frequency etc.

1.2 Definitions

1.2.1 Fuel

In this Section, “fuel” refers to fuel for auxiliary vehicles.

1.2.2 Jettisonable tank

A jettisonable tank is a tank capable of being jettisoned, i.e. thrown overboard, in case of an emergency.

1.2.3 Flame screen

A flame screen is a device utilizing wire mesh to prevent the passage of unconfined flames. Flame screens required in this section are to be approved in accordance with Pt D, Ch 7, App 1.

1.2.4 Fuel handling

Fuel handling includes fuel pumping as well as any operation on the fuel that could be needed between storage onboard and refuelling the auxiliary vehicle.

1.2.5 Filling station

The filling station refers to the area or space containing the connection between the shipboard fuel piping system and the shore piping system, for the purpose of filling the fuel tanks. The filling station is sometimes referred to as the “bunkering station”.

1.2.6 Refuelling station

In this Section, the refuelling station refers to the area or space where the auxiliary vehicles or portable tanks are refuelled.

1.2.7 Storage hold

In this Section, the storage hold refers the space where an independent tank containing fuel for auxiliary vehicles is located.

1.3 Segregation

1.3.1 Facilities for fuel for auxiliary vehicles are to be segregated from any other fuel system.

1.4 Storage arrangement

1.4.1 *A designated area is to be provided for the storage of fuel tanks, which is to be:*

- *as remote as practicable from accommodation spaces, escape routes and embarkation stations, and*
- *isolated from areas containing a source of vapour ignition.*

1.4.2 The fuel tank storage area is to be located outside of machinery spaces not dedicated to the storage or handling of this fuel, accommodation spaces, service spaces and control stations, and is to comply with the requirements of [2.1] or [3.2] as applicable.

1.4.3 *The fuel storage area is to be provided with arrangements whereby fuel spillage may be collected and drained to a safe location.*

1.5 Vapour detection

1.5.1 The ship is to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air and at least two portable oxygen analysers.

Note 1: The number of portable detection instruments required above is considered equivalent to one portable instrument for measuring flammable vapour concentration, one portable instrument for measuring oxygen and sufficient spares.

Note 2: Gas detectors are to be of a type approved by the Society.

1.6 Marking and instructions

1.6.1 All facilities for the storage and handling of fuel for auxiliary vehicles on board are to be grade identified.

1.6.2 The fuel storage and handling areas are to be permanently marked. Instructions for filling fuel and, if appropriate, emptying fuel, are to be posted in the vicinity of the filling area.

1.6.3 Installations for fuel for auxiliary vehicles are to be taken into consideration in the emergency procedures related to safety and pollution prevention.

2 Jettisonable fuel tanks

2.1 Storage arrangement

2.1.1 Jettisonable fuel tanks are in principle to be stored on the open deck at a location complying with the requirements of [2.1.2], [2.1.3] and [2.1.4].

As an alternative, jettisonable tanks may be installed in an enclosed space provided compliance with [2.1.2], [2.1.3] and with the requirements dedicated to independent tanks storage holds in [3.1.3] and [3.2], except [3.2.2], are complied with.

2.1.2 In case of an emergency, it is to be possible to:

- Either dispose quickly of the tanks through an overboard chute or equivalent arrangement; or
- Quickly drain the full content of the tank to the sea through a quick-draining mechanism.

The control for the disposal or quick-drainage of the tanks is to be available from a location:

- as remote as possible from the storage area but from which the proper activation of the system can be visually ascertained, and
- as remote as possible from any pre-designed evacuation route

This control position is to be reported on the fire control and safety plan and is to be provided with adequate signage.

2.1.3 The proper functioning of overboard chutes is to be demonstrated through a functioning test. The test is to be carried out under load after installation of the chute on board.

2.1.4 For jettisonable fuel tanks stored on the open deck:

a) The tanks are to be suitably secured and protected from physical damage due to e.g. dropped objects or severe weather conditions

b) The tanks are to be stored in a well-ventilated area

c) Suitable drip trays are to be provided in way of the fuel tanks, fitted with means to drain any fuel leakage to a dedicated tank complying with the requirements of [3.5.2]. Alternatively, drip trays without draining means may be accepted provided their capacity is sufficient to contain all the fuel stored in any one of the tanks, considering a 10% margin. The arrangement of the drip tray is to prevent splashing due to ship motion. Drip trays are also to comply with the relevant requirements of Ch 1, Sec 10, [5.10.4].

2.2 Tank design

2.2.1 *Where portable fuel tanks are used, special attention shall be given to:*

- *design of the tank for its intended purpose*
- *mounting and securing arrangements*
- *electric bonding; and*
- *inspection procedures.*

2.2.2 Portable tanks are to be constructed and approved according to IMO IMDG Code for the transported fuel.

2.2.3 Each portable tank is to be clearly marked to indicate its content.

2.2.4 Non portable fuel tanks are to comply with the requirements of [3.1].

3 Fixed fuel installations

3.1 Tank design

3.1.1 Fuel tanks are to comply with the requirements of Ch 1, Sec 10 for fuel oil tanks and flammable liquid tanks. The scantlings of fuel tanks are to be in compliance with the provisions of Pt B, Ch 5, Sec 6 and Part B, Chapter 7.

3.1.2 High and low level alarm arrangements are to be provided. High level alarm is to indicate when fuel tanks are close to being filled in excess of maximum operating levels.

3.1.3 Fuel tanks are to be part of the ship's structure.

Independent fuel tanks of limited capacity may however be permitted provided:

a) The scantlings of independent tanks are in compliance with the provisions of Pt B, Ch 5, Sec 6 and Part B, Chapter 7, except that the net thickness is not to be less than 5 mm.

b) The requirements of [3.2] are complied with.

c) Suitable drip trays are provided in way of the tanks, in line with [3.4.7].

3.1.4 Fuel *tanks are to be fitted with a cock or valve directly on the tank capable of being closed from a safe position outside the space concerned in the event of a fire occurring in the space in which the tanks are situated.*

3.1.5 The venting outlet of the fuel tank is to be led to the atmosphere in a safe and well ventilated position and is to be provided with a flame screen.

3.1.6 Overflow pipes are to be fitted to tanks which can be filled by pumping and are designed for a hydrostatic pressure lower than that corresponding to the height of the air pipe. Where fitted, overflow systems are to be dedicated to this specific fuel and are to comply with the applicable requirements of Ch 1, Sec 10.

3.2 Tank location and protection

3.2.1 Application

Structural tanks are to comply with the requirements of [3.2.2] to [3.2.4].

Independent tanks are to comply with [3.2.2] to [3.2.4] and with:

- the requirements of [3.2.5] and [3.2.6]when located in an enclosed space
- the requirements of [3.2.7] and [3.2.8] when located on the open deck.

3.2.2 Protection against collision and grounding

Fuel tanks are to be located as follows, with respect to the rule length L defined in Pt B, Ch 1, Sec 3, [2.1.1] and ship's moulded breadth B defined in Pt B, Ch 1, Sec 3, [2.1.4]:

a) Inboard from the ship's side:

B/5 or 11,5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught. Alternatively, the calculation methodology given in Rule Note NR529, [5.3.4], as amended, may be used to determine the acceptable location of the fuel tanks.

b) Inboard from the shell plating or from aft terminal of the ship:

- for passenger ships: B/10 but in no case less than 0,8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11,5 m, whichever is less, as required above.
- for cargo ships:
  - for $V_c = 1000$ m^3:

    0,8 m
  - for 1000 m^3 < V_c < 5000 m^3:

    0,75 + $V_c \cdot 0,2 / 4000$ m
  - for 5000 m^3 ≤ V_c < 30000 m^3:

    0,8 + $V_c / 25000$ m
  - for V_c ≥ 30000 m^3:

    2,0 m

  where:

  V_c : Corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

c) Above the bottom shell plating:

B/15 or 2,0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline.

d) Abaft a transverse plane at 0,08L measured from the forward perpendicular for passenger ships and abaft the collision bulkhead for cargo ships.

Note 1: NR529 Gas fuelled ships

Note 2: These distances are to be measured considering the most restrictive between the outermost and the lowermost boundary of the fuel tank.

3.2.3 *Fuel tanks are to be located outside of category A machinery spaces*. Fuel tanks may however be located in the storage hold or fuel handling room dedicated to this fuel.

3.2.4 Segregation from other spaces

Fuel tanks are to be segregated from machinery spaces, propeller shaft tunnels, dry cargo spaces, accommodation, service spaces and control stations and from drinking water and stores for human consumption, by means of a cofferdam, void space, pump-room, empty tank, ship oil fuel tank, or other similar space complying with the requirements of [3.3]. In the case of independent tanks, a cofferdam need not be required provided:

- the hold space complies with the requirements of [3.3]; or
- the fuel tank is located on the open deck and the distance between the tank boundaries and the boundaries of the spaces from which the tank is to be segregated complies with the requirements of [3.3.3].

3.2.5 Storage holds are to be treated as a category A machinery spaces for structural fire protection, fire extinction and detection purposes.

The boundaries between storage holds and other category A machinery spaces are to have A-60 fire integrity and the boundaries between storage holds for different fuels are to have A-30 fire integrity.

3.2.6 Storage holds are to be dedicated to the storage of one specific fuel. Fuel pumps and other equipment intended for handling this fuel may however be located in the storage hold.

3.2.7 Fuel tanks located on the open deck are to be protected by a manually activated water-spray system with a capacity of at least 5L/min/m^2 of protected area. The water-spray system is to provide coverage for exposed parts of the fuel tank and for the boundaries of normally manned superstructures facing the fuel tanks and located within 10 m of their boundaries.

Note 1: Both horizontal and vertical surfaces to be protected are to be considered when determining the capacity of the water-spray system.

3.2.8 Decks and superstructure boundaries located within 10 m of the boundaries of the fuel tanks are to be provided with fire integrity equivalent to the fire integrity required with respect to a category A machinery space. Navigation bridge windows however are not required to have such fire integrity.

In addition, fuel tanks are to be segregated from cargo in accordance with the requirements of the International Maritime Dangerous Goods (IMDG) Code where the fuel tanks are regarded as a class 2.1 bulk package.

3.3 Cofferdams

3.3.1 Cofferdams surrounding structural fuel tanks and required by [3.2.4] are to comply with the requirement of this sub-article.

3.3.2 Direct access from the open deck

Access to the cofferdams is to be direct from the open deck. Alternatively, access to the cofferdams may be provided through void spaces or spaces dedicated to fuel handling or storage or machinery spaces, subject to consideration of ventilation aspects.

3.3.3 Access to the cofferdams is to be provided through gas-tight openings, with the following minimum clear width:

- 600 x 600 mm for horizontal openings
- 600 x 800 mm for vertical openings.

3.3.4 Drainage from the cofferdams surrounding fuel tanks is to comply with the requirements of [3.5.1].

3.4 Piping

3.4.1 Fuel piping is to comply with the requirements of Ch 1, Sec 10 for fuel oil piping and flammable liquid piping.

3.4.2 The connections between the various pipe sections are to be carried out by means of butt welding. Other types of connections including threaded connections and flange connections are not permitted.

3.4.3 Fuel piping is to be located at a distance from the ship's side of at least 800 mm measured inboard from the ship's side at right angles to the centerline at the level of the summer load line draught.

3.4.4 Fuel piping is not to be led directly through accommodation spaces, service spaces, electrical equipment rooms, control stations or category A machinery spaces not related to the handling of this specific fuel.

3.4.5 Fuel piping led through ro-ro spaces, special category spaces and on open decks is to be protected against mechanical damage.

3.4.6 Fuel piping in non-hazardous enclosed spaces is to be completely enclosed by a steel gastight double pipe or duct which is to be:

- at an inclination such that the fuel naturally returns towards a safe draining location in the case of leakage or failure in delivery pressure
- fitted with inspection openings with gastight doors in way of connections of pipes within it, with an automatic closing drain-trap leading to a safe location, set in such a way as to discharge leakage of fuel into a safe location
- fitted with a vent pipe at the highest part of the duct. This vent pipe is to be led to the atmosphere in a safe position. The outlet is to be fitted with a flame screen
- of a thickness not less than the minimum thickness given in Ch 1, Sec 10, Tab 6 for pipes in general.

3.4.7 Containment and detection of a leakage

Suitable drip trays are to be provided at locations where fuel leakage could occur, i.e. in way of independent tanks, pumps, tank connections, piping connections, filling manifold etc. The drip trays are to be fitted with means to drain any fuel leakage to a dedicated drainage tank complying with [3.5.2].

An alarm is to be provided in case of fuel leakage in the drip tray.

Note 1: Double walled independent tanks need not be provided with an additional drip tray. It should however be possible to detect, and dispose of, any fuel leakage in the interbarrier space.

3.4.8 Means are to be provided to drain fuel piping after filling and refuelling operations. Means of drainage may however be omitted for fuel piping located in the storage hold.

3.5 Drainage

3.5.1 Drainage and/or bilge pumping of cofferdams and of spaces intended for fuel storage or fuel handling is to be separated from the ship bilge system, and is not to be led to machinery spaces or to other spaces where ignition sources may be present. Drainage directly to the sea is to be avoided as far as possible.

3.5.2 Drainage tank

The tank intended to gather drainage from for spaces intended for fuel storage or fuel handling is to be:

- closed
- dedicated to these spaces
- located outside of the machinery spaces
- provided with a vent pipe to a safe location on the open deck
- fitted with level position indicators with relevant alarms, in order to detect leakages.
- provided with a capacity sufficient to manage the whole content of any one fuel tank.

3.5.3 The space containing the bilge pumps is to be provided with mechanical ventilation complying with [4.4]. If the space has access from another enclosed space, the door is to be self-closing.

3.6 Fuel handling

3.6.1 *Storage tank fuel pumps are to be provided with means which permit shutdown from a safe remote location in the event of a fire. Where a gravity fuelling system is installed, equivalent closing arrangements are to be provided to isolate the fuel source.*

3.6.2 *The fuel pumping unit is to be connected to one tank at a time. The piping between the tank and the pumping unit are to be of steel or equivalent material, as short as possible, and protected against damage.*

3.6.3 *Electrical fuel pumping units and associated control equipment are to be of a type suitable for the location and potential hazards.*

3.6.4 *Fuel pumping units are to incorporate a device which will prevent over-pressurization of the delivery or filling hose.*

3.6.5 Spaces containing fuel handling equipment are to be treated as category A machinery spaces for structural fire protection, fire extinction and detection purposes.

3.7 Filling station

3.7.1 For structural fire protection purposes, enclosed or semi-enclosed filling stations are to be handled as:

- auxiliary machinery spaces of moderate fire risk i.e. cat(11) on passenger ships carrying more than 36 passengers
- other machinery spaces i.e. cat(7) on other ships

In addition, the safety measures detailed in [3.7.2] to [3.7.4] are to be applied.

3.7.2 The boundaries between enclosed or semi-enclosed filling stations and other enclosed spaces are to be A-60 class divisions and reasonably gastight.

3.7.3 Fixed fire-extinguishing system

Enclosed filling stations are to be provided with a fixed fire-extinguishing system suitable for category A machinery spaces. Depending on the quantity of fuel, duration of the filling operation and filling procedure, alternative arrangements based on portable fire extinguishing equipment may be accepted on a case-by-case basis.

Open or semi enclosed filling stations are to be covered by a manually activated water-spray system with a capacity of at least 5L/min/m^2 of protected area (horizontally projected surfaces).

3.7.4 Fixed fire detection and fire alarm system

Enclosed and semi-enclosed filling stations are to be covered by a fixed fire detection and fire alarm system complying with the requirements of Ch 4, Sec 15, [8]. The fixed fire detection system is to combine smoke detection and another way of detecting fire which may be by means of fusible elements designed to melt at temperatures between 98°C and 104°C, or by area fire detection methods.

In the case of an open filling station, a fixed fire detection and alarm system is to cover the filling manifold.

3.8 Refuelling station

3.8.1 Refuelling stations are to be treated as a category A machinery space with regards to fire protection, fixed fire extinguishing and detection system requirements.

3.8.2 Semi-enclosed refuelling stations

Semi-enclosed refuelling stations are to be covered by a manually activated water-spray system with a minimum water discharge density in line with MSC.1/Circ.1430 of:

- at least 5L/min/m2 of protected area (horizontally projected surfaces) for decks having a height equal or less than 2,5 m
- at least 10 L/min/m2 f protected area (horizontally projected surfaces) for decks having a height in excess of 2,5 m but equal or less than 6,5 m
- at least 15 L/min/m2 f protected area (horizontally projected surfaces) for decks having a height in excess of 6,5 m but equal or less than 10 m.

3.8.3 Open refuelling stations

One 25 kg powder extinguisher and one foam applicator are to be arranged for protection of refuelling stations located on the open deck.

3.8.4 Refuelling equipment

Refuelling hoses are to be designed and constructed according to a recognized standard, made of one continuous length, smooth bore, synthetic rubber construction, and semi-conducting.

Recognized standards for refuelling hoses include, but are not limited to, ISO 1825:2017 type C and EI 1529:2015.

3.8.5 It is to be possible to shut down the refuelling pump from the refuelling station. This control is to be located at an easily accessible position close to the escape from this space or area.

4 Prevention of explosion

4.1 Electrical bonding

4.1.1 Fuel tanks, piping and *equipment used in refuelling or filling operations are to be electrically bonded.*

4.2 Source of ignition

4.2.1 Access to areas intended for or affected by filling, storage, and refuelling of fuel for auxiliary vehicles is to be limited to crew members on duty.

4.2.2 *"NO SMOKING" signs are to be displayed at appropriate locations* in areas intended for the filling, storage, and refuelling of fuel for auxiliary vehicles, as well as in helicopter hangar facilities.

4.2.3 Any equipment which may constitute a source of ignition of flammable vapours is not to be installed in hazardous spaces or areas.

4.2.4 As a general rule, electrical equipment and wiring is not to be fitted in hazardous spaces or areas, unless it is essential for operational purposes or enhancing safety. If electrical equipment is fitted in such spaces, it is to be suitable for use in dangerous environment as per Ch 2, Sec 3, [10].

Portable equipment that need to be used in hazardous spaces or areas is to be of a suitable certified safe type.

Note 1: On a case-by-case basis, the Society might however allow electrical equipment not suitable for use in dangerous environment to be installed in hazardous spaces or areas related to refilling or refuelling operations, provided:

- suitable interlocks and operational procedures are provided to ensure that non-certified safe equipment will be disconnected in all scenarios that may lead to the presence of an explosive atmosphere
- such equipment need not be used during refuelling or refilling operations
- suitable justification of the above is provided

4.2.5 Exhausts of internal combustion machinery are to be led outside of hazardous areas.

4.3 Hazardous areas

4.3.1 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zone 0, 1 and 2 according to Ch 2, Sec 1, [3.13.3]. The different spaces and areas are to be classified according to Tab 1.

Note 1: As an alternative to Table 1, more refined hazardous spaces and areas may be defined in line with the requirements of IEC 60079-10 and based on relevant analysis to the satisfaction of the Society.

4.3.2 Protection by overpressure

Where a space has an opening into an adjacent hazardous space or area, it may be made into a non-hazardous space in accordance with the following requirements:

a) A minimum overpressure of 25 Pa (0,25 mbar) with respect to the adjacent, hazardous space or area is to be maintained at all points inside the space and its associated ducts at which leaks are liable to occur, all doors and windows being closed.

b) During initial start-up or after shut-down, it is necessary, before energizing any electrical apparatus within the space which is not suitably protected for the classification of the space in the absence of pressurization, to either ensure that the internal atmosphere is non-hazardous, or proceed with prior purging of sufficient duration that the internal atmosphere may be considered as non-hazardous, and pressurize the space.

   The atmosphere is considered non-hazardous when, at all points in the space, the equipment enclosures and any associated ducts, the concentration of explosive gases or vapours is below 30% of the lower explosive limit. The place of measurement should be judiciously chosen to determine the highest concentration of gas.

c) Monitoring is to be provided to ensure the satisfactory functioning of pressurization of spaces having an opening into a more hazardous zone.

d) Where a flow monitoring device is used to indicate failure of pressurization, it should be verified that either the pressurization level required by item a) is maintained with any door or other opening open, or an alarm is given if any door or opening is not closed.

e) In the event of the loss of overpressure, the following protective measures are to apply to electrical equipment not protected for use in hazardous areas:
   - suitable alarm (visible and audible)
   - immediate action to restore pressurization
   - programmed disconnection of power supply if the pressurization cannot be restored for an extended period or if the concentration of flammable gas is rising to a dangerous level.

4.3.3 Airlock

Access between a hazardous area Zone 1 and a non-hazardous area may be provided through an airlock, consisting of two self-closing, substantially gastight, steel doors without holding back arrangements and capable of maintaining the overpressure. The airlock space is to be mechanically ventilated from a non-hazardous area and maintained at the minimum overpressure with respect to the hazardous area Zone 1 defined in [4.3.2], item a). If the airlock is complying with all requirements of [4.3.2], the airlock is considered as a non-hazardous space

Table 1 : Space descriptions and hazardous area zones

No.	Description of spaces	Hazardous area
1	The interior of fuel tanks, any pipework or pressure-relief or other venting system for fuel, pipes and equipment containing the fuel or developing flammable gases and vapours. • Drainage tanks as defined in [3.5.2] are covered by this item. • Scuppers and discharges as defined in [3.5.1] are covered by this item • Overflow tanks are covered by this item	Zone 0
2	Enclosed or semi-enclosed filling stations, refuelling stations and installations, enclosed helicopter hangars (for fuels having a flashpoint below or equal to 43°C), storage holds and fuel handling spaces	Zone 1
3	Ventilation ducts serving the spaces identified in item 2 and item 8	Zone 1
4	Areas on open deck, or semi-enclosed spaces on open deck: • within 1,5 m of any exhaust ventilation outlet of a hazardous area zone 1 • within 1,5 m of entrances to, or openings in, filling station or fuel pump room entrances • Within 0.5 m of ventilation inlets of filling stations or fuel pump rooms • Within 0.5 m of any opening into zone 1 spaces	Zone 1
5	Areas on open deck, or semi-enclosed spaces on open deck, within 3m of any venting outlet from the spaces defined in item 1	Zone 1
6	Areas on open deck within filling manifold drip trays and 1,5 m around these	Zone 1
7	Enclosed or semi-enclosed spaces having a direct opening into any of the spaces as identified in item 2 or item 3, unless appropriate measures are taken to prevent flammable gas from entering such spaces (protection by overpressure as per [4.3.2], airlock as per [4.3.3] or gastight door as detailed in item 11). This item does not cover areas adjacent to ventilation inlets and outlets which are covered by item 4.	Zone 1
8	Air space between the fuel piping and the wall of the outer pipe or duct of double walled fuel piping as per [3.4.6]	Zone 1
9	Spaces adjacent to fuel tanks including cofferdams required in [3.2.4]	Zone 1
10	Areas on open deck within 1,5 m of fuel tank surfaces exposed to the weather **(2)**	Zone 1
11	Enclosed or semi-enclosed spaces having a direct opening into any of the spaces as identified in item 2 or item 3, which are separated from such space by a self-closing, substantially gastight, steel door without holding back arrangement. This item does not cover areas adjacent to ventilation inlets and outlets which are covered by item 4.	Zone 2
12	Spaces forming an airlock as defined in [4.3.3] **(3)**	Zone 2
13	Areas of 1,5 m surrounding open or semi-enclosed spaces of zone 1	Zone 2

(1) Drainage tanks as defined in [3.5.2], scuppers and discharges as defined in [3.5.1] and overflow tanks are covered by this item.

(2) In the case of double wall tanks, this hazardous area may be omitted provided the secondary barrier of the tank is able to contain any leakage from the tank and remain gastight.

(3) If the airlock is complying to requirements listed in [4.3.2], then the airlock is considered as non-hazardous.

4.4 Ventilation of hazardous spaces

4.4.1 Hazardous spaces are to be fitted with extraction-type mechanical ventilation capable of providing at least 6 air changes per hour.

4.4.2 Ventilation

Enclosed hangar facilities or enclosed spaces containing refuelling installations are to be provided with mechanical ventilation as required by Ch 4, Sec 13, [2] for closed ro-ro spaces of cargo ships. Ventilation fans are to be of a non-sparking type (see Ch 4, Sec 1, [2.33]).

4.4.3 Filling stations, refuelling stations, fuel pump rooms and storage holds are to be fitted with mechanical ventilation of the extraction type, capable of providing at least 15 air changes per hour. A reduced rate of mechanical ventilation capacity may be considered for such spaces when they are of a semi-enclosed type.

4.4.4 Any loss of the ventilating capacity required in [4.4.1] or [4.4.3] is to trigger a visual alarm at the entrance door of the considered space, an audible alarm inside the space and at the navigation bridge.

4.4.5 Arrangements are to be provided to permit rapid shutdown and effective closure of the ventilation system from outside of the space in case of fire, taking into account the weather and sea conditions. It is to be possible to shut-off the ventilation of each compartment separately.

4.4.6 The fans are to be non-sparking.

4.4.7 Electrical equipment and wiring, if installed in an exhaust ventilation duct, are to be of a type approved for use in explosive petrol and air mixtures.

4.4.8 *Electric motors driving fans of the ventilation systems of hazardous spaces are to be located outside of the ventilation ducting unless they are of a certified safe type.*

4.4.9 Ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces

4.4.10 Air inlets for hazardous enclosed spaces are to be taken from areas which, in the absence of the considered inlet, would be non-hazardous.

4.4.11 Air outlets for hazardous enclosed spaces are to be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

4.5 Ventilation and door openings of non-hazardous spaces

4.5.1 Air inlets and door openings for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1.5m from the limits of any hazardous area. Where the inlet duct passes through a hazardous area, the inlet duct is to have over-pressure in relation to this area unless the mechanical integrity and gas-tightness of the duct is considered by the Society to be such that no pressure differential is required to ensure that gases will not leak into the duct.

4.5.2 Air outlets from non-hazardous enclosed spaces are to be located in a non-hazardous open area.

4.5.3 Air outlets from high fire risk spaces are to be located at least 3 m away from fuel tanks, filling stations or refuelling stations located on the open deck or in semi-enclosed spaces.

Note 1: "High fire risk spaces" means machinery spaces of category A, ro-ro spaces, cargo holds where fixed fire-fighting systems are required (See Ch 4, Sec 6, [6.1]),galleys, pantries containing cooking appliances, laundry with drying equipment, spaces where oxygen is stored or produced, spaces in which flammable liquids or gases are stored, battery rooms and workshops.

Section 12 Carriage of Dangerous Goods

1 General requirements

1.1 Application

1.1.1 *In addition to complying with the requirements of the other Sections of this Chapter, as appropriate, ship types and cargo spaces, referred to in [1.1.2], intended for the carriage of dangerous goods shall comply with the requirements of this Section, as appropriate, except when carrying dangerous goods in limited quantities and excepted quantities unless such requirements have already been met by compliance with the requirements elsewhere in this Chapter. The types of ships and modes of carriage of dangerous goods are referred to in [1.1.2] and in Tab 1, where the items of the list in [1.1.2] are referred to in the head of table.*

Note 1: "limited quantities" as per the IMO "International Maritime Dangerous Goods Code" (IMDG Code).

1.1.2 *The following ship types and cargo spaces shall govern the application of Tab 1 and Tab 2:*

a) Ships and cargo spaces not specifically designed for the carriage of freight containers, but intended for the carriage of dangerous goods in packaged form, including goods in freight containers and portable tanks

b) Purpose-built container ships and cargo spaces intended for the carriage of dangerous goods in freight containers and portable tanks (see Note 1)

c) Ro-ro ships and ro-ro spaces intended for the carriage of dangerous goods (see Note 2)

d) Ships and cargo spaces intended for the carriage of solid dangerous goods in bulk, and

e) Ships and cargo spaces intended for carriage of dangerous goods other than liquids and gases in bulk in shipborne barges.

Note 1: A purpose-built container space is a cargo space fitted with cell guides for stowage and securing of containers.

Note 2: Ro-ro spaces include special category spaces and vehicle spaces.

2 Special requirements

2.1 General

2.1.1 *Unless otherwise specified, the following requirements shall govern the application of Tab 1, Tab 2 and Tab 3 to both "on-deck" and "under-deck" stowage of dangerous goods where the numbers of following subarticles [2.2] to [2.11] are indicated in the first column of the tables.*

2.2 Water supplies

2.2.1 *Arrangements shall be made to ensure immediate availability of a supply of water from the fire main at the required pressure either by permanent pressurisation or by suitably placed remote arrangements for the fire pumps.*

2.2.2 *The quantity of water delivered shall be capable of supplying four nozzles of a size and at pressures as specified in Ch 4, Sec 6, [1.2.6], capable of being trained on any part of the cargo space when empty. This amount of water may be applied by equivalent means to the satisfaction of the Society.*

Note 1: The number and position of hydrants should be such that at least two of the required four jets of water, when supplied by single lengths of hose, may reach any part of the cargo space when empty; and all four jets of water, each supplied by single lengths of hose may reach any part of ro-ro cargo spaces.

2.2.3 *Means shall be provided for effectively cooling the designated under-deck cargo space by at least 5 l/min per square metre of the horizontal area of cargo spaces, either by a fixed arrangement of spraying nozzles or by flooding the cargo space with water. Hoses may be used for this purpose in small cargo spaces and in small areas of larger cargo spaces at the discretion of the Society. However, the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces. The drainage system shall be sized to remove no less than 125% of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible, the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Society in its approval of the stability information.*

Table 1 : Application of the requirements to different modes of carriage of dangerous goods in ships and cargo spaces

Requirements of Article [2]	Requirement [1.1.2]						
	Weather decks a) to e) inclusive	a)	b)	c)		d)	e)
		Not specifically designed	Container cargo spaces	Closed ro-ro spaces **(5)**	Open ro-ro spaces	Solid dangerous goods in bulk	Shipborne barges
[2.2.1]	x	x	x	x	x	For application of requirements of Ch 4, Sec 12 to different classes of dangerous goods, see Tab 2	x
[2.2.2]	x	x	x	x	x		–
[2.2.3]	–	x	x	x	x		x
[2.2.4]	–	x	x	x	x		x
[2.3]	–	x	x	x	x		x **(4)**
[2.4]	–	x	x	x	–		x **(4)**
[2.5.1]	–	x	x **(1)**	x	–		x **(4)**
[2.5.2]	–	x	x **(1)**	x	–		x **(4)**
[2.6]	–	x	x **(1)**	x	–		–
[2.7.1]	x	x	x	x	x		–
[2.7.3]	x	x	x	x	x		–
[2.8]	x	x	–	–	x		–
[2.9]	x	x	x **(2)**	x	x		–
[2.10]	–	–	–	x **(3)**	x		–
[2.11.1]	–	–	–	x	–		–
[2.11.2]	–	–	–	x	–		–

x : Where "x" appears in the Table, it means that this requirement is applicable to all classes of dangerous goods as given in the appropriate line of Tab 3, except as indicated by the following notes.

(1) For classes 4 and 5.1 solids, not applicable to closed freight containers. For classes 2, 3, 6.1 and 8 when carried in closed freight containers, the ventilation rate may be reduced to not less than two air changes per hour. For classes 4 and 5.1 liquids when carried in closed freight containers, the ventilation rate may be reduced to not less than two air changes per hour.

For the purpose of this requirement, a portable tank is a closed freight container.

(2) Applicable to decks only.

(3) Applies only to closed ro-ro spaces, not capable of being sealed.

(4) In the special case where the barges are capable of containing flammable vapours or, alternatively, if they are capable of discharging flammable vapours to a safe space outside the barge carrier compartment by means of ventilation ducts connected to the barges, these requirements may be reduced or waived to the satisfaction of the Society.

(5) Special category spaces shall be treated as closed ro-ro spaces when dangerous goods are carried.

Table 2 : Application of the requirements to different classes of dangerous goods for ships and cargo spaces carrying solid dangerous goods in bulk

Requirements of Article [2]	Class						
	4.1	4.2	4.3 **(1)**	5.1	6.1	8	9
[2.2.1]	x	x	–	x	–	–	x
[2.2.2]	x	x	–	x	–	–	x
[2.3]	x	x **(2)**	x	x **(3)**	–	–	x **(3)**
[2.5.1]	–	x **(2)**	x	–	–	–	–
[2.5.2]	x **(4)**	x **(2)**	x	x **(2) (4)**	–	–	x **(2) (4)**
[2.5.3]	x	x	x	x	x	x	x
[2.7]	x	x	x	x	x	x	x
[2.9]	x	x	x	x **(2)**	–	–	x **(5)**

(1) The hazards of substances in this class which may be carried in bulk are such that special consideration shall be given by the Society to the construction and equipment of the ship involved in addition to meeting the requirements enumerated in this Table.

(2) Only applicable to Seedcake containing solvent extractions, to Ammonium nitrate and to Ammonium nitrate fertilizers.

(3) Only applicable to Ammonium nitrate and to Ammonium nitrate fertilizers. However, a degree of protection in accordance with standards contained in the "International Electrotechnical Commission, publication 60079 - Electrical Apparatus for Explosive Gas Atmospheres" is sufficient.

(4) Only suitable wire mesh guards are required.

(5) The requirements of the "International Maritime Solid Bulk Cargoes (IMSBC) Code", as amended, are sufficient.

Table 3 : Application of the requirements to different classes of dangerous goods except solid dangerous goods in bulk

Requirements of Article [2]	Class																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	1.1 to 1.6	1.4S	2.1	2.2	2.3 flammable **(10)**	2.3 non-flammable	3 FP **(5)** < 23°C	3 23°C ≤ FP **(5)** ≤ 60°C	4.1	4.2	4.3 liquids **(11)**	4.3 solids	5.1	5.2 **(6)**	6.1 liquids	6.1 liquids FP **(5)** < 23°C	6.1 liquids 23°C ≤ FP **(5)** ≤ 60°C	6.1 solids	8 liquids	8 liquids FP **(5)** < 23°C	8 liquids 23°C ≤ FP **(5)** ≤ 60°C	8 solids	9
[2.2.1]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
[2.2.2]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	–
[2.2.3]	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
[2.2.4]	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
[2.3]	x	–	x	–	x	–	x	–	–	–	x **(8)**	–	–	–	–	x	–	–	–	x	–	–	x **(7)**
[2.4]	x	x	x	x	–	x	x	x	x	x	x	x	x	–	x	x	x	x	x	x	x	x	–
[2.5.1]	–	–	x	–	–	x	x	–	x **(1)**	x **(1)**	x	x	x **(1)**	–	–	x	x	x **(1)**	–	x	x	–	x **(1)**
[2.5.2]	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	x **(7)**
[2.6]	–	–	–	–	–	–	x	–	–	–	–	–	–	–	x	x	x	–	x **(9)**	x	x **(9)**	–	–
[2.7]	–	–	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x **(4)**
[2.8]	–	–	–	–	–	–	x	x	x	x	x	x	x	–	–	x	x	–	–	x	x	–	–
[2.9]	x **(2)**	–	x	x	x	x	x	x	x	x	x	x	x **(3)**	x	–	x	x	–	–	x	x	–	–
[2.10]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
[2.11.1]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
[2.11.2]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

(1) When “mechanically-ventilated spaces” are required by the IMDG Code.
(2) Stow 3 m horizontally away from the machinery space boundaries in all cases.
(3) Refer to the IMDG Code.
(4) As appropriate for the goods to be carried.
(5) FP means flashpoint.
(6) Under the provisions of the IMDG Code, stowage of class 5.2 dangerous goods under deck or in enclosed ro-ro spaces is prohibited.
(7) Only applicable to dangerous goods evolving flammable vapour listed in the IMDG Code.
(8) Only applicable to dangerous goods having a flashpoint < 23ºC listed in the IMDG Code.
(9) Only applicable to dangerous goods having a subsidiary risk class 6.1.
(10) Under the provisions of the IMDG Code, stowage of class 2.3 having subsidiary risk class 2.1 under deck or in enclosed ro-ro spaces is prohibited.
(11) Under the provisions of the IMDG Code, stowage of class 4.3 liquids having a flashpoint < 23ºC under deck or in enclosed ro-ro spaces is prohibited.

2.2.4 *Provision to flood a designated under-deck cargo space with suitable specified media may be substituted for the requirements in [2.2.3].*

A high expansion foam system complying with Ch 4, Sec 15 is acceptable unless cargoes react dangerously with water (see the IMO "International Maritime Dangerous Goods Code").

2.2.5 *The total required capacity of the water supply shall satisfy the requirements of [2.2.2] and [2.2.3], if applicable, simultaneously calculated for the largest designed cargo space. The capacity requirements of [2.2.2] shall be met by the total capacity of the main fire pump(s), not including the capacity of the emergency fire pump, if fitted. If a drencher system is used to satisfy the requirements of [2.2.3], the drencher pump shall also be taken into account in this total capacity calculation.*

2.3 Sources of ignition

2.3.1 *Electrical equipment and wiring shall not be fitted in enclosed cargo spaces or vehicle spaces unless it is essential for operational purposes in the opinion of the Society. However, if electrical equipment is fitted in such spaces, it shall be of a certified safe type for use in the dangerous environments to which it may be exposed unless it is possible to completely isolate the electrical system (e.g. by removal of links in the system, other than fuses). Cable penetrations of the decks and bulkheads shall be sealed against the passage of gas or vapour. Through runs of cables and cables within the cargo spaces shall be protected against damage from impact. Any other equipment which may constitute a source of ignition of flammable vapour shall not be permitted.*

2.3.2 The hazardous areas are to be defined in accordance with IEC 60092-506 standard, Special features - Ships carrying specific dangerous goods and materials hazardous only in bulk.

2.3.3 In addition, when carrying flammable liquids having flashpoints less than 23°C as Class 3, 6.1 or 8 in cargo spaces, the bilge pipes with flanges, valves, pumps, etc. constitute a source of release and the enclosing spaces (e.g. pipe tunnels, bilge pump rooms, etc.) are to be classified as an extended hazardous area (comparable with Zone 2) unless these spaces are continuously mechanically ventilated with a capacity for at least six air changes per hour.

Except where the space is protected with redundant mechanical ventilation capable of starting automatically, equipment not certified for Zone 2 are to be automatically disconnected following loss of ventilation while essential systems such as bilge and ballast systems are to be certified for Zone 2.

Where redundant mechanical ventilation is employed, equipment and essential systems not certified for Zone 2 shall be interlocked so as to prevent inadvertent operation if the ventilation is not operational. Audible and visible alarms shall be provided at a manned station if failure occurs.

2.3.4 For pipes having open ends (e.g. ventilation and bilge pipes, etc.) in a hazardous area, the pipe itself is to be classified as hazardous area.

2.4 Detection system

2.4.1 *Ro-ro spaces shall be fitted with a fixed fire detection and fire alarm system complying with the requirements of Ch 4, Sec 15. All other types of cargo spaces shall be fitted with either a fixed fire detection and fire alarm system or a sample extraction smoke detection system complying with the requirements of Ch 4, Sec 15. If a sample extraction smoke detection system is fitted, particular attention shall be given to item c) of Ch 4, Sec 15, [9.1.1] in order to prevent the leakage of toxic fumes into occupied areas.*

2.5 Ventilation arrangement

2.5.1 *Adequate power ventilation shall be provided in enclosed cargo spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space, based on an empty cargo space, and for removal of vapours from the upper or lower parts of the cargo space, as appropriate.*

2.5.2 *The fans shall be such as to avoid the possibility of ignition of flammable gas/air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.*

Exhaust fans are to be of non-sparking type.

Note 1: The purpose of "suitable wire mesh guards" is to prevent foreign objects from entering into the fan casing. The standard wire mesh guards should have a size of 13 mm x 13 mm.

2.5.3 *Natural ventilation shall be provided in enclosed cargo spaces intended for the carriage of solid dangerous goods in bulk, where there is no provision for mechanical ventilation.*

2.5.4 If adjacent spaces are not separated from cargo spaces by gastight bulkheads or decks, then they should be considered as part of the enclosed cargo space and the ventilation requirements should apply to the adjacent space as for the enclosed cargo space itself.

For open-top container ships, power ventilation should be required only for the lower part of the cargo hold for which purpose ducting is required. The ventilation capacity should be at least two air changes per hour, based on the empty hold volume below weather deck.

Note 1: Additional requirements are given in the IMO Circular MSC.1/Circ.1120, for cargoes liable to give off vapours or gases which can form an explosive mixture with air and for cargoes liable to spontaneous combustion.

2.6 Bilge pumping

2.6.1 *Where it is intended to carry flammable or toxic liquids in enclosed cargo spaces, the bilge pumping system shall be designed to protect against inadvertent pumping of such liquids through machinery space piping or pumps. Where large quantities of such liquids are carried, consideration shall be given to the provision of additional means of draining those cargo spaces.* These means shall be to the satisfaction of the Society.

2.6.2 Cargo spaces intended for carriage of flammable liquids with flashpoint less than 23°C or toxic liquids are to be fitted with a fixed bilge drainage system independent of or separated from the bilge system in the machinery space and located outside such space.

If a single bilge drainage system completely independent of the machinery space is provided, the system is to comply with the requirements of Ch 1, Sec 10.

For open top container holds, bilge systems for cargo holds should be independent of the machinery space bilge system and be located outside of the machinery space.

2.6.3 *If the bilge drainage system is additional to the system served by pumps in the machinery space, the capacity of the system shall be not less than 10 m^3/h per cargo space served. If the additional system is common, the capacity need not exceed 25 m^3/h. The additional bilge system need not be arranged with redundancy.*

2.6.4 *Whenever flammable* liquids with flashpoint less than 23°C *or toxic liquids are carried, the bilge line into the machinery space shall be isolated either by fitting a blank flange or by a closed lockable valve.*

2.6.5 *Enclosed spaces outside machinery spaces containing bilge pumps serving cargo spaces intended for carriage of flammable or toxic liquids shall be fitted with separate mechanical ventilation giving at least 6 air changes per hour.* Electrical equipment in the space is to be in accordance with Part C, Chapter 2. *If the space has access from another enclosed space, the door shall be self-closing.*

The reduced air changes per hour as per Note 1 of Tab 1 also apply when the bilge pump is located directly inside a container cargo space. In case several container cargo spaces are served by the same bilge pump, the bilge pump is to be installed in the container cargo hold with the highest ventilation rate, compared to the other container cargo spaces.

2.6.6 Bilge drainage pipes are not to pass through the engine room unless they are made of steel with reinforced thickness as per Ch 1, Sec 10, Tab 6 and are joined only by welding.

2.6.7 *If bilge drainage of cargo spaces is arranged by gravity drainage, the drainage shall be either led directly overboard or to a closed drain tank located outside the machinery spaces. The tank shall be provided with a vent pipe to a safe location on the open deck. Drainage from a cargo space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the cargo space above.*

2.7 Personnel protection

2.7.1 *Four sets of full protective clothing, resistant to chemical attack, shall be provided in addition to the fire-fighter's outfits required by* SOLAS, chapter II-2, *regulation 10.10 and shall be selected taking into account the hazards associated with the chemicals being transported and the standards developed by IMO according to the class and physical state. The protective clothing shall cover all skin, so that no part of the body is unprotected.*

2.7.2 The required protective clothing, required in [2.7.1], is for emergency purposes.

For solid bulk cargoes the protective clothing is to satisfy the equipment requirements specified in Appendix 1 of the IMSBC Code for the individual substances. For packaged goods the protective clothing is to satisfy the equipment requirements specified in emergency procedures (EmS) of the Supplement to IMDG Code for the individual substances.

2.7.3 *At least two self-contained breathing apparatuses additional to those required by* SOLAS, chapter II-2, *regulation 10 shall be provided. Two spare charges suitable for use with the breathing apparatus shall be provided for each required apparatus. Passenger ships carrying not more than 36 passengers and cargo ships that are equipped with suitably located means for fully recharging the air cylinders free from contamination need carry only one spare charge for each required apparatus.*

2.7.4 For each of the breathing apparatuses required in [2.7.3], two complete sets of air bottles are required. These spare bottles are to be in addition to the spare bottles required for fire-fighter's outfit.

2.8 Portable fire extinguishers

2.8.1 *Portable fire extinguishers with a total capacity of at least 12 kg of dry powder or equivalent shall be provided for the cargo spaces. These extinguishers shall be in addition to any portable fire extinguishers required elsewhere in this Chapter.*

2.9 Insulation of machinery space boundaries

2.9.1 *Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to A-60 class standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to A-60 class standard.*

2.9.2 In the case that a closed or semi-closed cargo space is located partly above a machinery space and the deck above the machinery space is not insulated, dangerous goods are prohibited in the whole of that cargo space. If the uninsulated deck above the machinery space is a weather deck, dangerous goods are prohibited only for the portion of the deck located above the machinery space.

2.10 Water-spray system

2.10.1 *Each open ro-ro space having a deck above it and each space deemed to be a closed ro-ro space not capable of being sealed shall be fitted with an approved fixed pressure water-spraying system for manual operation which shall protect all parts of any deck and vehicle platform in the space, except that the Society may permit the use of any other fixed fire-extinguishing system that has been shown by full-scale test to be no less effective. However, the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces. The drainage system shall be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible, the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Society in its approval of the stability information.*

2.11 Separation of ro-ro spaces

2.11.1 *In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and an adjacent open ro-ro space. The separation shall be such as to minimise the passage of dangerous vapours and liquids between such spaces. Alternatively, such separation need not be provided if the ro-ro space is considered to be a closed cargo space over its entire length and fully complies with the relevant special requirements of this Section.*

2.11.2 *In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and the adjacent weather deck. The separation shall be such as to minimise the passage of dangerous vapours and liquids between such spaces. Alternatively, a separation need not be provided if the arrangements of the closed ro-ro spaces are in accordance with those required for the dangerous goods carried on adjacent weather decks.*

Section 13 Protection of Vehicle, Special Category and Ro-ro Spaces

1 General requirements

1.1 Application

1.1.1 *In addition to complying with the requirements of the other Sections of this Chapter, as appropriate, vehicle, special category and ro-ro spaces shall comply with the requirements of the present Section.*

1.1.2 *On all ships, vehicles with fuel in their tanks for their own propulsion may be carried in cargo spaces other than vehicle, special category or ro-ro spaces, provided that all the following conditions are met:*

- *the vehicles do not use their own propulsion within the cargo spaces;*
- *the cargo spaces are in compliance with the appropriate requirements of Ch 4, Sec 12; and*
- *the vehicles are carried in accordance with the IMO IMDG Code.*

1.2 Basic principles for passenger ships

1.2.1 *The basic principle underlying the provisions of this Section is that the main vertical zoning required by Ch 4, Sec 5, [1] may not be practicable in vehicle spaces of passenger ships and, therefore, equivalent protection must be obtained in such spaces on the basis of a horizontal zone concept and by the provision of an efficient fixed fire-extinguishing system. Based on this concept, a horizontal zone for the purpose of this Section may include special category spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.*

1.2.2 *The basic principle underlying the provisions of [1.2.1] is also applicable to ro-ro spaces.*

1.2.3 *The requirements of ventilation systems, openings in A class divisions and penetrations in A class divisions for maintaining the integrity of vertical zones in this Chapter shall be applied equally to decks and bulkheads forming the boundaries separating horizontal zones from each other and from the remainder of the ship.*

2 Precaution against ignition of flammable vapours in closed vehicle spaces, closed ro-ro spaces and special category spaces

2.1 Ventilation systems

2.1.1 Capacity of ventilation systems

There shall be provided an effective power ventilation system sufficient to give at least the following air changes:

a) Passenger ships:

- *Special category spaces: 10 air changes per hour*
- *Closed ro-ro and vehicle spaces other than special category spaces for ships carrying more than 36 passengers: 10 air changes per hour*
- *Closed ro-ro and vehicle spaces other than special category spaces for ships carrying not more than 36 passengers: 6 air changes per hour*

b) Cargo ships: 6 air changes per hour.

The Society may require an increased number of air changes when vehicles are being loaded and unloaded.

2.1.2 Performance of ventilation systems

a) In passenger ships, the power ventilation system shall be separate from other ventilation systems. The power ventilation system shall be operated to give at least the number of air changes required in [2.1.1] at all times when vehicles are in such spaces, except where an air quality control system in accordance with d) is provided. Ventilation ducts serving such cargo spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.

b) In cargo ships, the ventilation fans shall normally be run continuously and give at least the number of air changes required in [2.1.1] whenever vehicles are on board, except where an air quality control system in accordance with item d) is provided. Where this is impracticable, they shall be operated for a limited period daily as weather permits and in any case for a reasonable period prior to discharge, after which period the ro-ro or vehicle space shall be proved gas-free. One or more

portable combustible gas detecting instruments shall be carried for this purpose. The system shall be entirely separate from other ventilation systems. Ventilation ducts serving ro-ro or vehicle spaces shall be capable of being effectively sealed for each cargo space. The system shall be capable of being controlled from a position outside such spaces.

c) In passenger and cargo ships, *the ventilation system shall be such as to prevent air stratification and the formation of air pockets.*

d) For all ships, where an air quality control system is provided based on the guidelines developed by IMO, the ventilation system may be operated at a decreased number of air changes and/or a decreased amount of ventilation. This relaxation does not apply to spaces to which at least ten air changes per hour is required by [2.2.2] and spaces subject to the requirements of [6] and Sec 11, [2.5.1].

Note 1: Refer to the Revised design guidelines and operational recommendations for ventilation systems in ro-ro cargo spaces (MSC/Circ.1515)

e) Fans are to be of non-sparking type.

2.1.3 Indication of ventilation systems

Means shall be provided on the navigation bridge to indicate any loss of the required ventilating capacity.

2.1.4 Closing appliances and ducts

a) Arrangements shall be provided to permit a rapid shut-down and effective closure of the ventilation system from outside of the space in case of fire, taking into account the weather and sea conditions.

For this purpose, the requirements of either 1) or 2) below are to be complied with:

1) The access routes to the controls for closure of the ventilation system are to be:

- clearly marked and at least 600 mm clear width, and
- provided with a single handrail or wire rope lifeline not less than 10 mm in diameter, supported by stanchions not more than 10 m apart in way of any route which involves traversing a deck exposed to weather, and
- fitted with appropriate means of access (such as ladders or steps) to the closing devices of ventilators located in high positions (i.e. 1,8 m and above).

2) Alternatively, remote closing and position indicator arrangements from the bridge or a fire control station for those ventilator closures is acceptable.

b) Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel. In passenger ships, ventilation ducts that pass through other horizontal zones or machinery spaces shall be A-60 class steel ducts constructed in accordance with Ch 4, Sec 5, [6.3.4], items a) and b).

2.1.5 Permanent openings

Permanent openings in the side plating, the ends or deckhead of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.

2.2 Electrical equipment and wiring

2.2.1 *Except as provided in [2.2.2], electrical equipment and wiring shall be of a type suitable for use in an explosive petrol and air mixture.*

Electrical installations in vehicle, special category and ro-ro spaces are to comply with the requirements of Pt D, Ch 1, Sec 4 or Pt D, Ch 12, Sec 4 as applicable.

2.2.2 *In case of other than special category spaces below the bulkhead deck, notwithstanding the provisions in [2.2.1], above a height of 450 mm from the deck and from each platform of vehicles, if fitted, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment of a type so enclosed and protected as to prevent the escape of sparks shall be permitted as an alternative, on condition that the ventilation system is so designed and operated as to provide continuous ventilation of the cargo spaces at the rate of at least ten air changes per hour whenever vehicles are on board.*

2.3 Electrical equipment and wiring in exhaust ventilation ducts

2.3.1 *Electrical equipment and wiring, if installed in an exhaust ventilation duct, shall be of a type approved for use in explosive petrol and air mixtures and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.*

2.4 Other ignition sources

2.4.1 *Other equipment which may constitute a source of ignition of flammable vapours shall not be permitted.*

2.5 Scuppers and discharges

2.5.1 *Scuppers shall not be led to machinery or other spaces where sources of ignition may be present.*

3 Detection and alarm

3.1 Fixed fire detection and fire alarm systems

3.1.1 *There shall be provided a fixed fire detection and fire alarm system complying with the requirements of Ch 4, Sec 15. The fixed fire detection system shall be capable of rapidly detecting the onset of fire. The type of detectors and their spacing and location shall be to the satisfaction of the Society, taking into account the effects of ventilation and other relevant factors. After being installed, the system shall be tested under normal ventilation conditions and shall give an overall response time to the satisfaction of the Society.*

Fire detectors are to be smoke detectors.

3.2 Sample extraction smoke detection systems

3.2.1 *Except open ro-ro spaces, open vehicle spaces and special category spaces, a sample extraction smoke detection system complying with the requirements of Ch 4, Sec 15 may be used as an alternative for the fixed fire detection and fire alarm system required in [3.1].*

3.3 Special category spaces

3.3.1 *Manually operated call points shall be spaced so that no part of the space is more than 20 m from a manually operated call point, and one shall be placed close to each exit from such spaces.*

4 Structural protection

4.1 General

4.1.1 *Notwithstanding the provisions of Ch 4, Sec 5, [1.3], in passenger ships carrying more than 36 passengers, the boundary bulkheads and decks of special category spaces and ro-ro spaces shall be insulated to A-60 class standard. However, where a category (5), (9) or (10) space, as defined in Ch 4, Sec 5, [1.3.3] is on one side of the division, the standard may be reduced to A-0. Where fuel oil tanks are below a special category space or a ro-ro space, the integrity of the deck between such spaces may be reduced to A-0 standard.*

5 Fire extinction

5.1 Fixed fire-extinguishing systems

5.1.1 *Vehicle spaces and ro-ro spaces, which are not special category spaces and are capable of being sealed from a location outside of the cargo spaces, shall be fitted with one of the following fixed fire-extinguishing systems:*

a) a fixed gas fire-extinguishing system complying with the provisions of Ch 4, Sec 15

b) a fixed high-expansion foam fire-extinguishing system complying with the provisions of Ch 4, Sec 15; or

c) a fixed water-based fire fighting system for ro-ro spaces and special category spaces complying with the provisions of Ch 4, Sec 15.

5.1.2 *Vehicle spaces and ro-ro spaces not capable of being sealed and special category spaces shall be fitted with a fixed water-based fire-fighting system for ro-ro spaces and special category spaces complying with the provisions of Ch 4, Sec 15, which shall protect all parts of any deck and vehicle platform in such spaces.*

Such a water-based fire-fighting system shall have:

- *a pressure gauge on the valve manifold*
- *clear marking on each manifold valve indicating the spaces served*
- *instructions for maintenance and operation located in the valve room; and*
- *a sufficient number of drainage valves to ensure complete drainage of the system.*

5.1.3 *The Society may permit the use of any other fixed fire-extinguishing system that has been shown, by a full-scale test in conditions simulating a flowing petrol fire in a vehicle space or a ro-ro space, to be not less effective in controlling fires likely to occur in such a space.*

5.2 Portable fire extinguishers

5.2.1 *Portable fire extinguishers shall be provided at each deck level in each hold or compartment where vehicles are carried, spaced not more than 20 m apart on both sides of the space. At least one portable fire extinguisher shall be located at each access to such a cargo space.*

5.2.2 *In addition to the provision of [5.2.1], the following fire-extinguishing appliances shall be provided in vehicle, ro-ro and special category spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion:*

a) at least three water-fog applicators, and

b) one portable foam applicator unit complying with the provisions of Ch 4, Sec 15, provided that at least two such units are available in the ship for use in such spaces.

6 Vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion

6.1 Spaces intended for carriage of motor vehicles with compressed natural gas in their tanks

6.1.1 Electrical equipment and wiring

All electrical equipment and wiring shall be of a certified safe type for use in an explosive methane and air mixture

Note 1: Refer to the recommendations of the International Electrotechnical Commission, in particular, publication IEC 60079.

6.1.2 Ventilation arrangement

a) Electrical equipment and wiring, if installed in any ventilation duct, shall be of a certified safe type for use in explosive methane and air mixtures.

b) The fans shall be such as to avoid the possibility of ignition of methane and air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

6.1.3 Other ignition sources

Other equipment which may constitute a source of ignition of methane and air mixtures shall not be permitted.

6.2 Spaces intended for carriage of motor vehicles with compressed hydrogen in their tanks

6.2.1 Electrical equipment and wiring

All electrical equipment and wiring shall be of a certified safe type for use in an explosive hydrogen and air mixture

Note 1: Refer to the recommendations of the International Electrotechnical Commission, in particular, publication IEC 60079.

6.2.2 Ventilation arrangement

a) Electrical equipment and wiring, if installed in any ventilation duct, shall be of a certified safe type for use in explosive hydrogen and air mixtures and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.

b) The fans shall be designed such as to avoid the possibility of ignition of hydrogen and air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

6.2.3 Other ignition sources

Other equipment which may constitute a source of ignition of hydrogen and air mixtures shall not be permitted.

6.3 Detection

6.3.1 *When a vehicle carrier carries as cargo one or more motor vehicles with either compressed hydrogen or compressed natural gas in their tanks for their own propulsion, at least two portable gas detectors shall be provided. Such detectors shall be suitable for the detection of the gas fuel and be of a certified safe type for use in the explosive gas and air mixture.*

Section 14 Safety Centre on Passenger Ships

1 General

1.1 Application

1.1.1 *Passenger ships shall have on board a safety centre complying with the requirements of this Section.*

1.2 Location and arrangement

1.2.1 *The safety centre shall either be a part of the navigation bridge or be located in a separate space adjacent to and having direct access to the navigation bridge, so that the management of emergencies can be performed without distracting watch officers from their navigational duties.*

2 Layout and ergonomic design

2.1

2.1.1 *The layout and ergonomic design of the safety centre shall take into account the guidelines* laid down in MSC.1/Circ.1368.

3 Communications

3.1

3.1.1 *Means of communication between the safety centre, the central control station, the navigation bridge, the engine control room, the storage room(s) for fire extinguishing system(s) and fire equipment lockers shall be provided.*

4 Control and monitoring of safety systems

4.1

4.1.1 *Notwithstanding the requirements set out elsewhere in the* Rules*, the full functionality (operation, control, monitoring or any combination thereof, as required) of the safety systems listed below shall be available from the safety centre:*

a) all powered ventilation systems

b) fire doors

c) general emergency alarm system

d) public address system

e) electrically powered evacuation guidance systems

f) watertight and semi-watertight doors

g) indicators for shell doors, loading doors and other closing appliances

h) water leakage of inner/outer bow doors, stern doors and any other shell door

i) television surveillance system

j) fire detection and alarm system

k) fixed fire-fighting local application system(s)

l) sprinkler and equivalent systems

m) water-based systems for machinery spaces

n) alarm to summon the crew

o) atrium smoke extraction system

p) flooding detection systems; and

q) fire pumps and emergency fire pumps.

Section 15 Fire Safety Systems

1 General

1.1 Application

1.1.1 This Section applies to fire safety systems as referred to in the Rules

1.1.2 Piping systems included in fire safety systems covered by this Section are to comply with the requirements of Ch 1, Sec 10, unless otherwise specified in the present Section.

1.1.3 Pressure vessels included in fire safety systems covered by this Section are to comply with the requirements of Ch 1, Sec 3, unless otherwise specified in the present Section.

1.2 Use of toxic extinguishing media

1.2.1 *The use of a fire-extinguishing medium which, in the opinion of the Society, either by itself or under expected conditions of use gives off toxic gases, liquids and other substances in such quantities as to endanger persons shall not be permitted.*

2 International shore connections

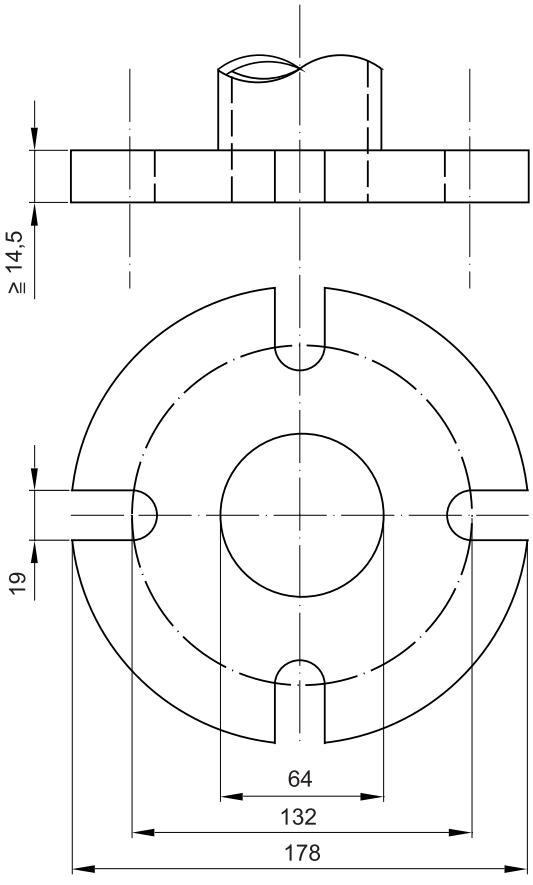
2.1 Engineering specifications

2.1.1 Standard dimensions

Standard dimensions of flanges for the international shore connection shall be in accordance with Tab 1.

Table 1 : Standard dimensions of flanges for the international shore connection

Description	Dimension
Outside diameter	178 mm
Inside diameter	64 mm
Bolt circle diameter	132 mm
Slots in flange	4 holes, 19 mm in diameter spaced equidistantly on a bolt circle of the above diameter, slotted to the flange periphery
Flange thickness	14,5 mm minimum
Bolts and nuts	4, each of 16 mm diameter, 50 mm in length



2.1.2 Materials and accessories

International shore connections shall be of steel or other equivalent material and shall be designed for 1,0 N/mm^2 services. The flange shall have a flat face on one side and, on the other side, it shall be permanently attached to a coupling that will fit the ship's hydrant and hose. The connection shall be kept aboard the ship together with a gasket of any material suitable for 1,0 N/mm^2 services, together with four bolts of 16 mm diameter and 50 mm in length, four 16 mm nuts and eight washers.

3 Fire extinguishers

3.1 Type approval

3.1.1 *All fire extinguishers shall be of approved types and designs.*

3.2 Engineering specifications

3.2.1 Fire extinguisher

a) Safety requirements

Fire extinguishers containing an extinguishing medium which, in the opinion of the Society, either by itself or under the expected conditions of use gives off toxic gases in such quantities as to endanger persons or which is an ozone depleting substance shall not be permitted.

b) Quantity of medium

1) Each powder or carbon dioxide extinguisher shall have a capacity of at least 5 kg and each foam extinguisher shall have a capacity of at least 9 l. The mass of all portable fire extinguishers shall not exceed 23 kg and they shall have a fire-extinguishing capability at least equivalent to that of a 9 l fluid extinguisher.

2) The Society shall determine the equivalents of fire extinguishers.

3.2.2 Portable foam applicators

a) A portable foam applicator unit shall consist of a foam nozzle/branch pipe, either of a self-inducing type or in combination with a separate inductor, capable of being connected to the fire main by a fire hose, together with a portable tank containing at least 20 l of foam concentrate and at least one spare tank of foam concentrate of the same capacity.

b) System performance

1) The nozzle/branch pipe and inductor shall be capable of producing effective foam suitable for extinguishing an oil fire, at a foam solution flow rate of at least 200 l/min at the nominal pressure in the fire main.

2) The foam concentrate shall be approved.

3) The values of the foam expansion and drainage time of the foam produced by the portable foam applicator unit shall not differ more than ± 10% of that determined in item 2).

4) The portable foam applicator unit shall be designed to withstand clogging, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered on ships.

3.2.3 Waterfog applicators

A waterfog applicator might consist of a metal L-shaped pipe, the long limb being about 2 m in length capable of being fitted to a fire hose and the short limb being about 250 mm in length fitted with a fixed water fog nozzle or capable of being fitted with a water-spray nozzle.

4 Fixed gas fire-extinguishing systems

4.1 Engineering specifications

4.1.1 General

a) Fire-extinguishing medium

1) Where the quantity of the fire-extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected. The system shall be fitted with normally closed control valves arranged to direct the agent into the appropriate space. Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions should be considered as the same space.

2) The volume of starting air receivers, converted to free air volume, shall be added to the gross volume of the machinery space when calculating the necessary quantity of the fire-extinguishing medium. Alternatively, a discharge pipe from the safety valves may be fitted and led directly to the open air.

3) Means shall be provided for the crew to safely check the quantity of the fire-extinguishing medium in the containers. It shall not be necessary to move the containers completely from their fixing position for this purpose. For carbon dioxide systems, hanging bars for a weighing device above each bottle row, or other means shall be provided. For other types of extinguishing media, suitable surface indicators may be used.

4) *Containers for the storage of fire-extinguishing medium, piping and associated pressure components shall be designed to pressure codes of practice to the satisfaction of the Society having regard to their locations and maximum ambient temperatures expected in service.*

b) *Installation requirements*

1) *The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of the medium is obtained. System flow calculations shall be performed using a calculation technique acceptable to the Society.*

In large cargo spaces, at least two distribution pipes are to be provided, one on the fore part, the second at the aft part.

In machinery spaces, the discharge nozzles are to be positioned in the upper and lower parts of these spaces.

2) *Except as otherwise permitted by the Society, pressure containers required for the storage of the fire-extinguishing medium, other than steam, shall be located outside the protected spaces in accordance with Ch 4, Sec 6, [3.3].*

3) The storage of the fire extinguishing medium is not permitted within spaces which may contain air/flammable gas mixtures.

4) *In piping sections where valve arrangements introduce sections of closed piping, such sections shall be fitted with a pressure relief valve and the outlet of the valve shall be led to open deck.*

5) *All discharge piping, fittings and nozzles in the protected spaces shall be constructed of materials having a melting temperature which exceeds 925°C. The piping and associated equipment shall be adequately supported.*

6) *A fitting shall be installed in the discharge piping to permit the air testing as required in [4.1.3], item g)4).*

c) *System control requirements*

1) *The necessary pipes for conveying fire-extinguishing medium into the protected spaces shall be provided with control valves so marked as to indicate clearly the space to which the pipes are led. Suitable provision shall be made to prevent inadvertent release of the medium into the space. Where a cargo space fitted with a gas fire-extinguishing system is used as a passenger space, the gas connection shall be blanked during such use. The pipes may pass through accommodation areas provided that they are of substantial thickness and that their tightness is verified with a pressure test, after their installation, at a pressure head not less than 5 N/mm^2. In addition, pipes passing through accommodation areas shall be joined only by welding and shall not be fitted with drains or other openings within such spaces. The pipes shall not pass through refrigerated spaces.*

Control valves are to be capable of local operation.

The open or closed position of control valves is to be indicated.

Means are to be provided in order to permit the blowing through each branch line of the piping system downstream of the master (control) valves.

2) *Means shall be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches, and other spaces in which personnel normally work or to which they have access. The audible alarms shall be located so as to be audible throughout the protected space with all machinery operating, and the alarms should be distinguished from other audible alarms by adjustment of sound pressure or sound patterns. The pre-discharge alarm shall be automatically activated (e.g. by opening of the release cabinet door). The alarm shall operate for the length of time needed to evacuate the space, but in no case less than 20 seconds before the medium is released.*

Conventional cargo spaces and small spaces (such as compressor rooms, paint lockers, etc.) with only a local release need not be provided with such an alarm. However, ro-ro cargo spaces, holds in container ships equipped for integrated reefer containers and other spaces where personnel can be expected to enter and where the access is therefore facilitated by doors or manway hatches are to be provided with such an alarm.

Where audible alarms are fitted to warn of the release of fire-extinguishing medium into pump rooms, they may be of the pneumatic or electrical type:

- pneumatically operated alarms

  Air operated alarms may be used provided the air supply is clean and dry.

- electrically operated alarms

  When electrically operated alarms are used, the arrangements are to be such that the electrical actuating mechanism is located outside the pump room except where the alarms are certified intrinsically safe.

Electrically operated alarms are to be supplied with power from the main and an emergency source of power. They are to differ from other signals transmitted to the protected space.

3) *The means of control of any fixed gas fire-extinguishing system shall be readily accessible, simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel.*

4) *Automatic release of fire-extinguishing medium shall not be permitted, except as permitted by the Society.*

4.1.2 Carbon dioxide systems - General

a) Quantity of fire-extinguishing medium

1) For cargo spaces the quantity of carbon dioxide available shall, unless otherwise provided, be sufficient to give a minimum volume of free gas equal to 30% of the gross volume of the largest cargo space to be protected in the ship.

2) For vehicle spaces and ro-ro spaces which are not special category spaces, the quantity of carbon dioxide available shall be at least sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the largest such cargo space which is capable of being sealed, and the arrangements shall be such as to ensure that at least two thirds of the gas required for the relevant space shall be introduced within 10 min. Carbon dioxide systems shall not be used for the protection of special category spaces.

3) For machinery spaces the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

- *40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing, or*
- *35% of the gross volume of the largest machinery space protected, including the casing.*

  In the calculation of 35% of the above-mentioned volume, the net volume of the funnel shall be considered up to a height equal to the whole casing height if the funnel space is in open connection with the machinery space without inter-position of closing means.

4) The percentages specified in item 3) above may be reduced to 35% and 30%, respectively, for cargo ships of less than 2000 gross tonnage.

In this case, where two or more machinery spaces are not entirely separate, they are to be considered as forming one space.

5) For the purpose of this item the volume of free carbon dioxide shall be calculated at 0,56 m^3/kg.

6) For machinery spaces, the fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 minutes.

7) For container and general cargo spaces (primarily intended to carry a variety of cargoes separately secured or packed) the fixed piping system shall be such that at least two thirds of the gas can be discharged into the space within 10 min. For solid bulk cargo spaces the fixed piping system shall be such that at least two thirds of the gas can be discharged into the space within 20 min. The system controls shall be arranged to allow one third, two thirds or the entire quantity of gas to be discharged based on the loading condition of the hold.

b) Controls

1) Carbon dioxide systems for the protection of ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches, and other spaces in which personnel normally work or to which they have access shall comply with the following requirements:

- *two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used for opening the valve of the piping which conveys the gas into the protected space and a second control shall be used to discharge the gas from its storage containers. Positive means (see Note 1) shall be provided so they can only be operated in that order; and*
- *the two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be in a break-glass-type enclosure conspicuously located adjacent to the box.*

2) The pre-discharge alarm may be activated before the two separate system release controls are operated (e.g. by a micro-switch that activates the pre-discharge alarm upon opening the release cabinet door as per [4.1.1], item c) 2). Therefore, the two separate controls for releasing carbon dioxide into the protected space (i.e. one control to open the valve of the piping which conveys the gas into the protected space and a second control used to discharge the gas from its storage containers) as per item b) 1) above can be independent of the control for activating the alarm.

A single control for activation of the alarm is sufficient.

Note 1: The "positive means", referred to for the correct sequential operation of the controls, is to be achieved by a mechanical and/or electrical interlock that does not depend on any operational procedure to achieve the correct sequence of operation.

Note 2: The controls requirements detailed in item b) apply to the spaces identified in [4.1.1], item c) 2) to be provided with a pre-discharge alarm.

4.1.3 High-pressure carbon dioxide systems

a) The system is to be designed for an ambient temperature range of 0°C/55°C, as a rule.

b) Containers for the storage of the fire-extinguishing medium are to be designed and tested in accordance with the relevant requirements of Part C, Chapter 1.

c) The filling ratio of carbon dioxide bottles is to be normally 0,67 kg/l, or less, of the total internal volume; however, for bottles to be fitted in ships which are to operate solely outside the tropical zone, the filling ratio may be 0,75 kg/l.

d) Piping and accessories are to generally satisfy the relevant requirements of Part C, Chapter 1.

e) For systems where carbon dioxide is stored at ambient temperature, the thickness of steel pipes is not to be less than the values given in Tab 2.

Slightly smaller thicknesses may be accepted provided they comply with national standards.

The thickness of threaded pipes is to be measured at the bottom of the thread.

f) Pipes are to be appropriately protected against corrosion. Steel pipes are to be, at least, zinc or paint coated, except those fitted in machinery spaces, with the reservation of the Society's acceptance.

g) After mounting onboard, and in complement to tests and inspections at the Manufacturer's workshop, as per requirements of Part C, Chapter 1, carbon dioxide pipes and their accessories are to undergo the following tests:

1) pipe lengths between bottles and master valves:

a hydraulic test, at the workshop or on board, at 128 bar. When the hydraulic test is carried out at the workshop, at least test with inert gas or air, at 7 bar, is to be carried out on board

2) pipe lengths between master valves and nozzles:

a test on board with inert gas or air, at 7 bar

3) master valves:

a hydraulic test at 128 bar

4) a test of the free air flow in all pipes and nozzles; and

5) a functional test of the alarm equipment.

Table 2 : Minimum wall thickness for steel pipes for CO_2 fire-extinguishing systems

External diameter (mm)	Minimum wall thickness (mm)	
	between bottles and master valves	between master valves and nozzles
21,3 - 26,9	3,2	2,6
30,0 - 48,3	4,0	3,2
51,0 - 60,3	4,5	3,6
63,5 - 76,1	5,0	3,6
82,5 - 88,9	5,6	4,0
101,6	6,3	4,0
108,0 - 114,3	7,1	4,5
127,0	8,0	4,5
133,0 - 139,7	8,0	5,0
152,4 - 168,3	8,8	5,6

4.1.4 Low-pressure carbon dioxide systems

When carbon dioxide, instead of being contained in non-refrigerated high pressure bottles, is contained in refrigerated low pressure vessels, in addition to the requirements in [4.1.2] the following are to be complied with.

a) General

Except where different requirements are given in this item, the requirements of [4.1.3] for systems with carbon dioxide contained in high pressure bottles are generally to be complied with.

b) Vessels and associated devices

1) The system control devices and the refrigerating plants are to be located within the same room where the pressure vessels are stored.

2) The rated amount of liquid carbon dioxide is to be stored in vessels under the working pressure in the range of 1,8 MPa to 2,2 MPa. The normal liquid charge in the container is to be limited to provide sufficient vapour space to allow for expansion of the liquid under the maximum storage temperatures that can be obtained corresponding to the setting of the pressure relief valves, but is not to exceed 95% of the volumetric capacity of the container.

3) The vessels are to be designed, constructed and tested in accordance with the requirements of Ch 1, Sec 3. For this purpose the design pressure is to be taken not less than the relief valve setting. In addition, for each vessel, *provision is to be made for:*

- *a pressure gauge*
- *a high pressure alarm: not more than the setting of the relief valve*
- *a low pressure alarm: not less than 1,8 MPa*
- *branch pipes with stop valves for filling the vessel*
- *discharge pipes*
- *a liquid CO_2 level indicator, fitted on the vessel*
- *two safety relief valves arranged so that either valve can be shut off while the other is connected to the vessel. The setting of the relief valves is to be not less than 1,1 times the working pressure. The capacity of each valve is to be such that the vapours generated due to fire can be discharged with a pressure rise not more than 20% above the setting pressure. The discharge from the safety valves is to be led to the open.*

4) *The vessels and outgoing pipes permanently filled with carbon dioxide are to have thermal insulation preventing the operation of the safety valve for 24 hours after de-energising the plant, at ambient temperature of 45°C and an initial pressure equal to the starting pressure of the refrigeration unit.* The insulating materials and their liners are to be to the satisfaction of the Society, bearing in mind, in particular, their fire resistance and mechanical properties, as well as protection against penetration of water vapours.

c) Refrigerating plant

1) *The vessels are to be serviced by two automated completely independent refrigerating units solely intended for this purpose, each comprising a compressor and the associated prime mover, evaporator and condenser.*

2) The refrigerating plant is to comply with the relevant requirements of Ch 1, Sec 16. *The refrigerating capacity and the automatic control of each unit are to be such as to maintain the required temperature under conditions of continuous operation for 24 hours at a sea temperature up to 32°C and ambient air temperature up to 45°C.*

3) In the event of failure of either one of the refrigerating units, the other is to be actuated automatically. Provision is to be made for local manual control of the refrigerating plant.

4) *Each electrical refrigerating unit is to be supplied from the main switchboard busbars by a separate feeder.*

5) *The cooling water supply to the refrigerating plant (where required) is to be provided from at least two circulating pumps, one of which being used as a standby. The standby pump may be a pump used for other services so long as its use for cooling would not interfere with any other essential service of the ship. Cooling water is to be taken from not less than two sea connections, preferably one port and one starboard.*

d) Pipes, valves and associated fittings

1) The pipes, valves and fittings are to be in accordance with the requirements of Ch 1, Sec 10 for a design pressure not less than the design pressure of the CO_2 vessels.

2) *Safety relief devices are to be provided in each section of pipe that may be isolated by block valves and in which there could be a build up of pressure in excess of the design pressure of any of the components.*

3) The piping system is to be designed in such a way that the CO_2 pressure at the nozzles should not be less than 1 Mpa.

e) Control of fire-extinguishing system operation

The machinery alarm system is to be equipped with audible and visual alarms activated when:

1) *the pressure in the vessels reaches the low and the high values according to item b) 2) above*

2) *any one of the refrigerating units fails to operate*

3) *the lowest permissible level of the liquid in the vessels is reached.*

f) Release control

1) The release of CO_2 is to be initiated manually.

2) *If a device is provided which automatically regulates the discharge of the rated quantity of carbon dioxide into the protected spaces, it is also to be possible to regulate the discharge manually.*

3) *If the system serves more than one space, means for control of discharge quantities of CO_2 are to be provided, e.g. automatic timer or accurate level indicators located at the control positions or positions.*

g) Testing

1) The pipes, valves and fittings and assembled system are to be tested to the satisfaction of the Society.

2) The pipes from the vessels to the release valves on the distribution manifold are to be subjected to a pressure test to not less than 1,5 times the set pressure of the safety relief valves.

3) The pipes from the release valves on the distribution manifold to the nozzles are to be tested for tightness and free flow of CO_2, after having been assembled on board.

4) After having been fitted on board, the refrigerating plant is to be checked for its proper operation.

5) If deemed necessary by the Society, a discharge test may be required to check the fulfilment of the requirements of item d) 3) above.

4.2 Equivalent fixed gas fire-extinguishing systems

4.2.1 Fixed gas fire-extinguishing systems equivalent to those specified in [4.1] are to be specially considered by the Society.

4.3 Requirements of steam systems

4.3.1 *The boiler or boilers available for supplying steam are to have an evaporation of at least 1 kg of steam per hour for each 0,75 m^3 of the gross volume of the largest space so protected. In addition to complying with the foregoing requirements, the systems in all respects are to be as determined by, and to the satisfaction of, the Society.*

5 Fixed foam fire-extinguishing systems

5.1 General

5.1.1 Application

The Article [5] details the specifications for fixed foam fire-extinguishing systems for:

- the protection of machinery spaces in accordance with Ch 4, Sec 6, [3.1.1], item b)
- cargo spaces in accordance with Ch 4, Sec 6, [6.1.1]
- cargo pump-rooms in accordance with Pt D, Ch 7, Sec 6, [4.2.2], item a) 2) and
- vehicle, special category and ro-ro spaces in accordance with Ch 4, Sec 13, [5.1.1].

This Article does not apply to cargo pump-rooms of chemical tankers carrying liquid cargoes, unless the Society specifically accepts the use of these systems based on additional tests with alcohol-based fuel and alcohol resistant foam.

5.1.2 Definitions

a) Design filling rate *is at least the minimum nominal filling rate used during the approval tests.*

b) Foam *is the extinguishing medium produced when foam solution passes through a foam generator and is mixed with air.*

c) Foam solution *is a solution of foam concentrate and water.*

d) Foam concentrate *is a liquid which, when mixed with water in the appropriate concentration forms a foam solution.*

e) Foam delivery ducts *are supply ducts for introducing high-expansion foam into the protected space from foam generators located outside the protected space.*

f) Foam mixing ratio *is the percentage of foam concentrate mixed with water forming the foam solution.*

g) Foam generators *are discharge devices or assemblies through which high-expansion foam solution is aerated to form foam that is discharged into the protected space. Foam generators using inside air typically consist of a nozzle or set of nozzles and a casing. The casing is typically made of perforated steel/stainless steel plates shaped into a box that enclose the nozzle(s). Foam generators using outside air typically consist of nozzles enclosed within a casing that spray onto a screen. An electric, hydraulic or pneumatically driven fan is provided to aerate the solution.*

h) High-expansion foam fire-extinguishing systems *are fixed total flooding extinguishing systems that use either inside air or outside air for aeration of the foam solution. A high-expansion foam system consists of both the foam generators and the dedicated foam concentrate approved during the fire testing specified in [5.2.1], item c).*

i) Inside air foam system *is a fixed high-expansion foam fire-extinguishing system with foam generators located inside the protected space and drawing air from that space.*

j) Nominal flow rate *is the foam solution flow rate expressed in l/min.*

k) Nominal application rate *is the nominal flow rate per area expressed in l/min/m^2.*

l) Nominal foam expansion ratio *is the ratio of the volume of foam to the volume of foam solution from which it was made, under non-fire conditions, and at an ambient temperature of e.g. around 20°C.*

m) Nominal foam production *is the volume of foam produced per time unit, i.e. nominal flow rate times nominal foam expansion ratio, expressed in m^3/min.*

n) Nominal filling rate *is the ratio of nominal foam production to the area, i.e. expressed in m/min.*

o) Nominal filling time *is the ratio of the height of the protected space to the nominal filling rate, i.e. expressed in minutes.*

p) Outside air foam system *is a fixed high-expansion foam system with foam generators installed outside the protected space that are directly supplied with fresh air.*

5.2 Fixed high-expansion foam fire-extinguishing systems

5.2.1 Principal performance

a) *The system shall be capable of manual release, and shall be designed to produce foam at the required application rate within 1 minute of release. Automatic release of the system shall not be permitted unless appropriate operational measures or interlocks are provided to prevent any local application systems required by Ch 4, Sec 6, [4.7], from interfering with the effectiveness of the system.*

b) *The foam concentrates shall be approved by the Society based on IMO Circular MSC/Circ.670. Different foam concentrate types shall not be mixed in a high-expansion foam system.*

c) *The system shall be capable of fire extinction and manufactured and tested to the satisfaction of the Society based on IMO Circular MSC.1/Circ.1384.*

d) *The system and its components shall be suitably designed to withstand ambient temperature changes, vibration, humidity, shock, clogging and corrosion normally encountered on ships. Piping, fittings and related components inside the protected spaces (except gaskets) shall be designed to withstand 925°C.*

e) *System piping, foam concentrate storage tanks, components and pipe fittings in contact with the foam concentrate shall be compatible with the foam concentrate and be constructed of corrosion resistant materials such as stainless steel, or equivalent. Other system piping and foam generators shall be full galvanized steel or equivalent. Distribution pipework shall have self-draining capability.*

f) *Means for testing the operation of the system and assuring the required pressure and flow shall be provided by pressure gauges at both inlets (water and foam concentrate supply) and at the outlet of the foam proportioner. A test valve shall be installed on the distribution piping downstream of the foam proportioner, along with orifices which reflect the calculated pressure drop of the system. All sections of piping shall be provided with connections for flushing, draining and purging with air. All nozzles shall be able to be removed for inspection in order to prove clear of debris.*

g) *Means shall be provided for the crew to safely check the quantity of foam concentrate and take periodic control samples for foam quality.*

h) *Operating instructions for the system shall be displayed at each operating position.*

i) *Spare parts shall be provided based on the manufacturer's instruction.*

j) *If an internal combustion engine is used as a prime mover for the seawater pump for the system, the fuel oil tank to the prime mover shall contain sufficient fuel to enable the pump to run on full load for at least 3 h and sufficient reserves of fuel shall be available outside the machinery space of category A to enable the pump to be run on full load for an additional 15 h. If the fuel tank serves other internal combustion engines simultaneously, the total fuel tank capacity shall be adequate for all connected engines.*

k) *The arrangement of foam generators and piping in the protected space shall not interfere with access to the installed machinery for routine maintenance activities.*

l) *The system source of power supply, foam concentrate supply and means of controlling the system shall be readily accessible and simple to operate, and shall be arranged at positions outside the protected space not likely to be cut off by a fire in the protected space. All electrical components directly connected to the foam generators shall have at least an IP 54 rating.*

m) *The piping system shall be sized in accordance with a hydraulic calculation technique to ensure availability of flows and pressures required for correct performance of the system.*

Note 1: Where the Hazen-Williams method is used, the values of the friction factor C given in Tab 3 for different pipe types which may be considered should apply:

n) *The arrangement of the protected spaces shall be such that they may be ventilated as the space is being filled with foam. Procedures shall be provided to ensure that upper level dampers, doors and other suitable openings are kept open in case of a fire. For inside air foam systems, spaces below 500 m^3 need not comply with this requirement.*

o) *Onboard procedures shall be established to require personnel re-entering the protected space after a system discharge to wear breathing apparatus to protect them from oxygen deficient air and products of combustion entrained in the foam blanket.*

p) *Installation plans and operating manuals shall be supplied to the ship and be readily available on board. A list or plan shall be displayed showing spaces covered and the location of the zone in respect of each section. Instructions for testing and maintenance shall be available on board.*

q) All installation, operation and maintenance instructions/plans for the system shall be in the working language of the ship. If the working language of the ship is not English, French, nor Spanish, a translation into one of these languages shall be included.

r) The foam generator room shall be ventilated to protect against overpressure, and shall be heated to avoid the possibility of freezing.

s) The quantity of foam concentrate available shall be sufficient to produce a volume of foam equal to at least five times the volume of the largest protected space enclosed by steel bulkheads, at the nominal expansion ratio, or enough for 30 min of full operation for the largest protected space, whichever is greater.

t) Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces shall be provided with audible and visual alarms within the protected space warning of the release of the system. The alarms shall operate for the length of time needed to evacuate the space, but in no case less than 20 s.

Table 3 : Friction factor C

Pipe type	C
Black or galvanized mild steel	100
Copper or copper alloys	150
Stainless steel	150

5.2.2 Inside air foam systems

a) Systems for the protection of machinery spaces and cargo pump-rooms

1) The system shall be supplied by both main and emergency sources of power. The emergency power supply shall be provided from outside the protected space.

2) Sufficient foam-generating capacity shall be provided to ensure the minimum design filling rate for the system is met and in addition shall be adequate to completely fill the largest protected space within 10 min.

Where such a machinery space includes a casing (e.g. an engine casing in a machinery space of category A containing internal combustion machinery, and/or a boiler), the volume of such casing, above the level up to which foam shall be filled to protect the highest position of the fire risk objects within the machinery space, need not be included in the volume of the protected space.

The level up to which foam shall be filled to protect the highest positioned fire risk objects within the machinery space shall not be less than whichever is higher between 1 m above the highest point of any such object; and the lowest part of the casing.

Where such a machinery space does not include a casing, the volume of the largest protected space shall be that of the space in its entirety, irrespective of the location of any fire risk object therein.

Fire risk objects include, but may not be limited to, those listed in Ch 4, Sec 1, [2.30.1], and those defined in Ch 4, Sec 1, [2.34.1], although not referred to in those requirements, they may also include items having a similar fire risk such as exhaust gas boilers or oil fuel tanks.

3) The arrangement of foam generators shall in general be designed based on the approval test results. A minimum of two generators shall be installed in every space containing combustion engines, boilers, purifiers, and similar equipment. Small workshops and similar spaces may be covered with only one foam generator.

4) Foam generators shall be uniformly distributed under the uppermost ceiling in the protected spaces including the engine casing. The number and location of foam generators shall be adequate to ensure all high risk areas are protected in all parts and at all levels of the spaces. Extra foam generators may be required in obstructed locations. The foam generators shall be arranged with at least 1 m free space in front of the foam outlets, unless tested with less clearance. The generators shall be located behind main structures, and above and away from engines and boilers in positions where damage from an explosion is unlikely.

b) Systems for the protection of vehicle, ro-ro, special category and cargo spaces

1) The system shall be supplied by the ship's main power source. An emergency power supply is not required.

2) Sufficient foam-generating capacity shall be provided to ensure the minimum design filling rate for the system is met and in addition shall be adequate to completely fill the largest protected space within 10 min. However, for systems protecting vehicle and ro-ro spaces and special category spaces, with decks that are reasonably gas-tight and that have a deck height of 3 m or less, the filling rate shall be not less than two thirds of the design filling rate and in addition sufficient to fill the largest protected space within 10 min.

3) The system may be divided into sections, however, the capacity and design of the system shall be based on the protected space demanding the greatest volume of foam. Adjacent protected spaces need not be served simultaneously if the boundaries between the spaces are "A" class divisions.

4) *The arrangement of foam generators shall in general be designed based on the approval test results. The number of generators may be different, but the minimum design filling rate determined during approval testing shall be provided by the system. A minimum of two generators shall be installed in every space. The foam generators shall be arranged to uniformly distribute foam in the protected spaces, and the layout shall take into consideration obstructions that can be expected when cargo is loaded on board. As a minimum, generators shall be located on every second deck, including movable decks. The horizontal spacing of the generators shall ensure rapid supply of foam to all parts of the protected space. This shall be established on the basis of full scale tests.*

5) *The foam generators shall be arranged with at least 1 m free space in front of the foam outlets, unless tested with less clearance.*

5.2.3 Outside air foam systems

a) *Systems for the protection of machinery spaces and cargo pump-rooms*

1) *The system shall be supplied by both main and emergency sources of power. The emergency power supply shall be provided from outside the protected machinery space.*

2) *Sufficient foam-generating capacity shall be provided to ensure the minimum design filling rate for the system is met and in addition shall be adequate to completely fill the largest protected space within 10 min.*

3) *The arrangement of foam delivery ducts shall in general be designed based on the approval test results. The number of ducts may be different, but the minimum design filling rate determined during approval testing shall be provided by the system. A minimum of two ducts shall be installed in every space containing combustion engines, boilers, purifiers, and similar equipment. Small workshops and similar spaces may be covered with only one duct.*

4) *Foam delivery ducts shall be uniformly distributed under the uppermost ceiling in the protected spaces including the engine casing. The number and location of ducts shall be adequate to ensure all high risk areas are protected in all parts and at all levels of the spaces. Extra ducts may be required in obstructed locations. The ducts shall be arranged with at least 1 m free space in front of the foam delivery ducts, unless tested with less clearance. The ducts shall be located behind main structures, and above and away from engines and boilers in positions where damage from an explosion is unlikely.*

5) *The arrangement of the foam delivery ducts shall be such that a fire in the protected space will not affect the foam-generating equipment. If the foam generators are located adjacent to the protected space, foam delivery ducts shall be installed to allow at least 450 mm of separation between the generators and the protected space, and the separating divisions shall be class "A-60" rated. Foam delivery ducts shall be constructed of steel having a thickness of not less than 5 mm. In addition, stainless steel dampers (single or multi-bladed) with a thickness of not less than 3 mm shall be installed at the openings in the boundary bulkheads or decks between the foam generators and the protected space. The dampers shall be automatically operated (electrically, pneumatically or hydraulically) by means of remote control of the foam generator related to them, and arranged to remain closed until the foam generators begin operating.*

6) *The foam generators shall be located where an adequate fresh air supply can be arranged.*

b) *Systems for the protection of vehicle and ro-ro spaces and special category and cargo spaces*

1) *The system shall be supplied by the ship's main power source. An emergency power supply is not required.*

2) *Sufficient foam-generating capacity shall be provided to ensure the minimum design filling rate for the system is met and in addition shall be adequate to completely fill the largest protected space within 10 min. However, for systems protecting vehicle and ro-ro spaces and special category spaces, with decks that are reasonably gas-tight and that have a deck height of 3 m or less, the filling rate shall be not less than two thirds of the design filling rate and in addition sufficient to fill the largest protected space within 10 min.*

3) *The system may be divided into sections, however, the capacity and design of the system shall be based on the protected space demanding the greatest volume of foam. Adjacent protected spaces need not be served simultaneously if the boundaries between the spaces are "A" class divisions.*

4) *The arrangement of foam delivery ducts shall in general be designed based on the approval test results. The number of ducts may be different, but the minimum design filling rate determined during approval testing shall be provided by the system. A minimum of two ducts shall be installed in every space. The foam generators shall be arranged to uniformly distribute foam in the protected spaces, and the layout shall take into consideration obstructions that can be expected when cargo is loaded on board. As a minimum, ducts shall be led to every second deck, including movable decks. The horizontal spacing of the ducts shall ensure rapid supply of foam to all parts of the protected space. This shall be established on the basis of full scale tests.*

5) *The system shall be arranged with at least 1 m free space in front of the foam outlets, unless tested with less clearance.*

6) *The arrangement of the foam delivery ducts shall be such that a fire in the protected space will not affect the foam-generating equipment. If the foam generators are located adjacent to the protected space, foam delivery ducts shall be installed to allow at least 450 mm of separation between the generators and the protected space, and the separating divisions shall be class "A-60" rated. Foam delivery ducts shall be constructed of steel having a thickness of not less than 5 mm. In addition, stainless steel dampers (single or multi-bladed) with a thickness of not less than 3 mm shall be installed at the openings in the boundary bulkheads or decks between the foam generators and the protected space. The dampers shall be automatically operated (electrically, pneumatically or hydraulically) by means of remote control of the foam generator related to them, and arranged to remain closed until the foam generators begin operating.*

7) *The foam generators shall be located where an adequate fresh air supply can be arranged.*

5.2.4 Installation testing requirements

a) *After installation, the pipes, valves, fittings and assembled systems shall be tested to the satisfaction of the Society, including functional testing of the power and control systems, water pumps, foam pumps, valves, remote and local release stations and alarms. Flow at the required pressure shall be verified for the system using orifices fitted to the test line. In addition, all distribution piping shall be flushed with freshwater and blown through with air to ensure that the piping is free of obstructions.*

b) *Functional tests of all foam proportioners or other foam mixing devices shall be carried out to confirm that the mixing ratio tolerance is within +30 to –0% of the nominal mixing ratio defined by the system approval. For foam proportioners using foam concentrates of Newtonian type with kinematic viscosity equal to or less than 100 cSt at 0°C and density equal to or less than 1,100 kg/m^3, this test can be performed with water instead of foam concentrate. Other arrangements shall be tested with the actual foam concentrate.*

5.2.5 Systems using outside air with generators installed inside the protected space

Systems using outside air but with generators located inside the protected space and supplied by fresh air ducts may be accepted by the Society provided that these systems have been shown to have performance and reliability equivalent to systems defined in [5.2.3]. For acceptance, the Society should consider the following minimum design features:

- *lower and upper acceptable air pressure and flow rate in supply ducts;*
- *function and reliability of damper arrangements;*
- *arrangements and distribution of air delivery ducts including foam outlets; and*
- *separation of air delivery ducts from the protected space.*

5.3 Fixed low-expansion foam fire-extinguishing systems

5.3.1 Quantity and foam concentrates

a) *The foam concentrates of low-expansion foam fire-extinguishing systems shall be approved by the Society based on IMO Circular MSC.1/Circ.1312. Different foam concentrate types shall not be mixed in a low-expansion foam system. Foam concentrates of the same type from different manufacturers shall not be mixed unless they are approved for compatibility.*

b) *The system shall be capable of discharging through fixed discharge outlets, in no more than 5 min, a quantity of foam sufficient to produce an effective foam blanket over the largest single area over which oil fuel is liable to spread.*

5.3.2 Installation requirements

a) *Means shall be provided for effective distribution of the foam through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the foam to be effectively directed by fixed sprayers onto other main fire hazards in the protected space. The means for effective distribution of the foam shall be proven acceptable to the Society through calculation or by testing.*

b) *The means of control of any such systems shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in the protected space.*

6 Fixed pressure water spraying and water-mist fire-extinguishing systems

6.1 Engineering specifications

6.1.1 Fixed pressure water spraying fire-extinguishing systems

Fixed-pressure water spraying fire-extinguishing systems for machinery spaces and cargo pump-rooms shall be approved by the Society based on IMO Circular MSC.1/Circ.1165, as amended.

6.1.2 Equivalent water-mist fire-extinguishing systems

Water-mist fire-extinguishing systems for machinery spaces and cargo pump rooms shall be approved by the Society based on IMO Circular MSC.1/Circ.1165, as amended.

6.1.3 Fixed pressure water spraying fire-extinguishing systems for cabin balconies

Fixed pressure water spraying fire-extinguishing systems for cabin balconies shall be approved by the Society based on IMO Circular MSC.1/Circ.1268.

6.1.4 Fixed water-based fire-fighting systems for ro-ro spaces, vehicle spaces and special category spaces

Fixed water-based fire-fighting systems for ro-ro spaces, vehicle spaces and special category spaces shall be approved by the Society based on IMO Circular MSC.1/Circ.1430, as amended.

6.1.5 Fixed water-based local application fire-fighting systems

Fixed water-based local application fire-fighting systems are to be approved by the Society based on IMO Circular MSC.1/Circ.1387 as corrected by MSC.1/Circ.1387/Corr.1 and installed according to IMO Circular MSC.1/Circ.1276/Rev.1.

7 Automatic sprinkler, fire detection and fire alarm systems

7.1 Engineering specifications

7.1.1 General

a) *Type of sprinkler systems*

The automatic sprinkler systems shall be of the wet pipe type, but small exposed sections may be of the dry pipe type where, in the opinion of the Society, this is a necessary precaution. Control stations, where water may cause damage to essential equipment, may be fitted with a dry pipe system or a pre-action system as permitted by regulation Pt C, Ch 4, Sec 6, [5.1.1]. Saunas shall be fitted with a dry pipe system, with sprinkler heads having an operating temperature up to 140°C.

b) *Automatic sprinkler systems equivalent to those specified in [7.1.2] to [7.1.4] shall be approved by the Society,* according to IMO Resolution A.800(19), as amended by MSC.265(84) and MSC.284(86).

7.1.2 Sources of power supply

a) *Passenger ships*

There shall be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where the sources of power for the pump are electrical, these shall be a main generator and an emergency source of power. One supply for the pump shall be taken from the main switchboard, and one from the emergency switchboard by separate feeders reserved solely for that purpose. The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards, and shall be run to an automatic change-over switch situated near the sprinkler pump. This switch shall permit the supply of power from the main switchboard so long as a supply is available therefrom, and be so designed that upon failure of that supply it will automatically change-over to the supply from the emergency switchboard. The switches on the main switchboard and the emergency switchboard shall be clearly labelled and normally kept closed. No other switch shall be permitted in the feeders concerned. One of the sources of power supply for the alarm and detection system shall be an emergency source. Where one of the sources of power for the pump is an internal combustion engine it shall, in addition to complying with the provisions of [7.1.4], item c), be so situated that a fire in any protected space will not affect the air supply to the machinery.

b) *Cargo ships*

There shall be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. If the pump is electrically driven, it shall be connected to the main source of electrical power, which shall be capable of being supplied by at least two generators. The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards. One of the sources of power supply for the alarm and detection system shall be an emergency source. Where one of the sources of power for the pump is an internal combustion engine, it shall, in addition to complying with the provisions of [7.1.4], item c), be so situated that a fire in any protected space will not affect the air supply to the machinery.

7.1.3 Component requirements

a) *Sprinklers*

The sprinklers shall be resistant to corrosion by the marine atmosphere. In accommodation and service spaces the sprinklers shall come into operation within the temperature range from 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30°C above the maximum deckhead temperature.

b) *Pressure tanks*

1) *A pressure tank having a volume equal to at least twice that of the charge of water specified in this item shall be provided. The tank shall contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in item c) 2) below, and the arrangements shall be provided for maintaining an air pressure in the tank such as to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank shall be provided. A glass gauge shall be provided to indicate the correct level of the water in the tank.*

   The tank is to be designed and built in compliance with the requirements for pressure vessels given in Ch 1, Sec 3.

2) *Means shall be provided to prevent the passage of sea water into the tank.*

c) *Sprinkler pumps*

1) *An independent power pump shall be provided solely for the purpose of continuing automatically the discharge of water from the sprinklers. The pump shall be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.*

2) *The pump and the piping system shall be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of 280 m^2 at the application rate specified in [7.1.5], item b) 3). The hydraulic capability of the system shall be confirmed by the review of hydraulic calculations, followed by a test of the system, if deemed necessary by the Society.*

3) *The pump shall have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe shall be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in item b) 1) above.*

7.1.4 Installation requirements

a) *General*

1) *Any parts of the system which may be subjected to freezing temperatures in service shall be suitably protected against freezing.*

2) *Special attention shall be paid to the specification of water quality provided by the system manufacturer to prevent internal corrosion of sprinklers and clogging or blockage arising from products of corrosion or scale-forming minerals.*

b) *Piping arrangements*

1) *Sprinklers shall be grouped into separate sections, each of which shall contain not more than 200 sprinklers. In passenger ships, any section of sprinklers shall not serve more than two decks and shall not be situated in more than one main vertical zone. However, the Society may permit such a section of sprinklers to serve more than two decks or be situated in more than one main vertical zone, if it is satisfied that the protection of the ship against fire will not thereby be reduced.*

Sprinkler heads installed to fulfil the provisions of Ch 4, Sec 5, [3.2.3] are not required to be solely dedicated to the windows and sidescuttles they are to protect, provided that the sprinkler heads protecting the room and having a spraying density of 5 l/(m^2 min) are arranged such that the window or sidescuttle is covered with the same spraying density and the relevant area is considered in the calculation as per [7.1.5].

2) *Each section of sprinklers shall be capable of being isolated by one stop-valve only. The stop-valve in each section shall be readily accessible in a location outside of the associated section or in cabinets within stairway enclosures. The valve's location shall be clearly and permanently indicated. Means shall be provided to prevent the operation of the stop-valves by any unauthorized person.*

3) *A test valve shall be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section shall be situated near the stop-valve for that section.*

4) *The sprinkler system shall have a connection from the ship's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.*

The automatic sprinkler fire detection and fire alarm system shall be an independent unit and therefore no other piping system shall be connected to it, except for the following:

- *connections for feeding the system from shoreside sources, fitted with adjacent stop valves and non-return valves*
- *connection from the fire main as required above.*

The valves on the shore filling connection and on the fire main connection shall be fitted with clear and permanent labels indicating their service. These valves shall be capable of being locked in the "closed" position.

5) *A gauge indicating the pressure in the system shall be provided at each section stop-valve and at a central station.*

6) *The sea inlet to the pump shall, wherever possible, be in the space containing the pump and shall be so arranged that when the ship is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.*

c) *Location of systems*

The sprinkler pump and tank shall be situated in a position reasonably remote from any machinery space of category A and shall not be situated in any space required to be protected by the sprinkler system.

7.1.5 System control requirements

a) *Ready availability*

1) *Any required automatic sprinkler, fire detection and fire alarm system shall be capable of immediate operation at all times and no action by the crew shall be necessary to set it in operation.*

2) *The automatic sprinkler system shall be kept charged at the necessary pressure and shall have provision for a continuous supply of water as required in this Section.*

b) *Alarm and indication*

1) *Each section of sprinklers shall include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems shall be such as to indicate if any fault occurs in the system. Such units shall indicate in which section served by the system a fire has occurred and shall be centralized on the navigation bridge or in the continuously-manned central control station and, in addition, visible and audible alarms from the unit shall also be placed in a position other than on the aforementioned spaces to ensure that the indication of fire is immediately received by the crew.*

2) *Switches shall be provided at one of the indicating positions referred to in the previous item 1) which will enable the alarm and the indicators for each section of sprinklers to be tested.*

3) *Sprinklers shall be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 l/m²/minute over the nominal area covered by the sprinklers. For this purpose, nominal area shall be taken as the gross horizontal projection of the area to be covered. However, the Society may permit the use of sprinklers providing such an alternative amount of water suitably distributed as has been shown, to the satisfaction of the Society, to be not less effective.*

4) *A list or plan shall be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance shall be available.*

c) *Testing*

Means shall be provided for testing the automatic operation of the pump on reduction of pressure in the system.

8 Fixed fire detection and fire alarm systems

8.1 Definitions

8.1.1 Section *means a group of fire detectors and manually operated call points as reported in the indicating unit(s).*

8.1.2 Section identification capability *means a system with the capability of identifying the section in which a detector or manually operated call point has activated.*

8.1.3 Individually identifiable *means a system with the capability to identify the exact location and type of detector or manually activated call point which has activated, and which can differentiate the signal of that device from all others.*

8.2 Engineering specifications

8.2.1 General requirements

a) *Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times (this does not require a backup control panel). Notwithstanding this, particular spaces may be disconnected, for example, workshops during hot work and ro-ro spaces during on and off-loading. The means for disconnecting the detectors shall be designed to automatically restore the system to normal surveillance after a predetermined time that is appropriate for the operation in question. The space shall be manned or provided with a fire patrol when detectors required by regulation are disconnected. Detectors in all other spaces shall remain operational.*

b) *The fire detection system shall be designed to:*

1) *control and monitor input signals from all connected fire and smoke detectors and manual call points;*

2) *provide output signals to the navigation bridge, continuously manned central control station or onboard safety centre to notify the crew of fire and fault conditions;*

3) *monitor power supplies and circuits necessary for the operation of the system for loss of power and fault conditions; and*

4) *the system may be arranged with output signals to other fire safety systems including:*

- *paging systems, fire alarm or public address systems*
- *fan stops* (See Note 1)
- *fire doors*
- *fire dampers* (See Note 1)
- *sprinkler systems*
- *smoke extraction systems*
- *low-location lighting systems*
- *fixed local application fire-extinguishing systems*
- *closed circuit television (CCTV) systems, and*
- *other fire safety systems.*

Note 1: The ventilation fans and the fire dampers serving a machinery room equipped with internal combustion engines taking their combustion air directly inside the room are not to be automatically stopped or closed in case of fire detection, in order to prevent depressurization of the room.

c) *The fire detection system may be connected to a decision management system provided that:*

1) *the decision management system is proven to be compatible with the fire detection system;*

2) *the decision management system can be disconnected without losing any of the functions required by this chapter for the fire detection system; and*

3) *any malfunction of the interfaced and connected equipment should not propagate under any circumstance to the fire detection system.*

d) *Detectors and manual call points shall be connected to dedicated sections of the fire detection system. Other fire safety functions, such as alarm signals from the sprinkler valves, may be permitted if in separate sections.*

e) *The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships. All electrical and electronic equipment on the bridge or in the vicinity of the bridge shall be tested for electromagnetic compatibility, taking into account IMO Resolution A.813(19).*

f) *Fixed fire detection and fire alarm systems with individually identifiable fire detectors shall be so arranged that:*

1) *means are provided to ensure that any fault (e.g. power break, short circuit, earth, etc.) occurring in the section will not prevent the continued individual identification of the remainder of the connected detectors in the section;*

2) *all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (e.g. electrical, electronic, informatics, etc.);*

3) *the first initiated fire alarm will not prevent any other detector from initiating further fire alarms; and*

4) *no section will pass through a space twice. When this is not practical (e.g. for large public spaces), the part of the section which by necessity passes through the space for a second time shall be installed at the maximum possible distance from the other parts of the section.*

g) *In passenger ships, the fixed fire detection and fire alarm system shall be capable of remotely and individually identifying each detector and manually operated call point. Fire detectors fitted in passenger ship cabins, when activated, shall also be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located. In cargo ships and on passenger ship cabin balconies the fixed fire detection and fire alarm system shall, as a minimum, have section identification capability.*

h) *In cargo ships and on passenger ship cabin balconies, where an individually identifiable system is fitted, notwithstanding the provisions in item f)1), isolator modules need not be provided at each fire detector if the system is arranged in such a way that the number and location of individually identifiable fire detectors rendered ineffective due to a fault would not be larger than an equivalent section in a section identifiable system, arranged in accordance with [8.2.4], item a).*

8.2.2 Sources of power supply

a) *There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fixed fire detection and fire alarm system, one of which shall be an emergency source of power. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in, or adjacent to, the control panel for the fire detection system. The change-over switch shall be arranged such that a fault will not result in the loss of both power supplies. The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.*

b) *The operation of the automatic changeover switch or a failure of one of the power supplies shall not result in loss of fire detection capability. Where a momentary loss of power would cause degradation of the system, a battery of adequate capacity shall be provided to ensure continuous operation during change-over.*

c) *There shall be sufficient power to permit the continued operation of the system with all detectors activated, but not more than 100 if the total exceeds this figure.*

d) *The emergency source of power specified in item a) above may be supplied by accumulator batteries or from the emergency switchboard. The power source shall be sufficient to maintain the operation of the fire detection and fire alarm system for the periods required under Ch 2, Sec 3 for cargo ships and Pt D, Ch 11, Sec 5 for passenger ships and, at the end of that period, shall be capable of operating all connected visual and audible fire alarm signals for a period of at least 30 min.*

e) *Where the system is supplied from accumulator batteries, they shall be located in or adjacent to the control panel for the fire detection system, or in another location suitable for use in an emergency. The rating of the battery charge unit shall be sufficient to maintain the normal output power supply to the fire detection system while recharging the batteries from a fully discharged condition.*

8.2.3 Component requirements

a) *Detectors*

1) *Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered by the Society provided that they are no less sensitive than such detectors.*

2) *Smoke detectors required in all stairways, corridors and escape routes within accommodation spaces shall be certified to operate before the smoke density exceeds 12,5% obscuration per metre, but not until the smoke density exceeds 2% obscuration per metre, when tested according to standards EN 54:2001 and IEC 60092-504. Alternative testing standards may be used as determined by the Society. Smoke detectors to be installed in other spaces shall operate within sensitivity limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.*

3) *Heat detectors shall be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute, when tested according to standards EN 54:2001 and IEC 60092-504. Alternative testing standards may be used as determined by the Society. At higher rates of temperature rise, the heat detector shall operate within temperature limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.*

4) *The operation temperature of heat detectors in drying rooms and similar spaces of a normal high ambient temperature may be up to 130°C, and up to 140°C in saunas.*

5) *Flame detectors shall be tested according to standards EN 54-10:2001 and IEC 60092-504. Alternative testing standards may be used as determined by the Society.*

6) *All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.*

7) *Fixed fire detection and fire alarm systems for cabin balconies shall be approved by the Society, based on IMO Circular MSC.1/Circ.1242.*

8) *Detectors fitted in hazardous areas shall be tested and approved for such service. Detectors required by Ch 4, Sec 13, [3] and installed in spaces that comply with Ch 4, Sec 13, [2.2.2] need not be suitable for hazardous areas. Detectors fitted in spaces carrying dangerous goods, required in Ch 4, Sec 12, Tab 3 to comply with Ch 4, Sec 12, [2.3], shall be suitable for hazardous areas.*

b) *Control panel*

The control panel for the fire detection system shall be tested according to standards EN 54-2:1997, EN 54-4:1997 and IEC 60092-504:2001. Alternative standards may be used as determined by the Society.

c) *Cables*

Cables used in the electrical circuits shall be flame retardant according to standard IEC 60332-1. On passenger ships, cables routed through other main vertical zones that they serve, and cables to control panels in an unattended fire control station shall be fire resisting according to standard IEC 60331, unless duplicated and well separated.

8.2.4 Installation requirements

a) *Sections*

1) *Detectors and manually operated call points shall be grouped into sections.*

2) *A section of fire detectors which covers a control station, a service space or an accommodation space shall not include a machinery space of category A,* a ballast water management room containing equipment related to ozone based ballast water management system *or a ro-ro space. A section of fire detectors which covers a ro-ro space shall not include a machinery space of category A. For fixed fire detection systems with remotely and individually identifiable fire detectors, a section covering fire detectors in accommodation, service spaces and control stations shall not include fire detectors in machinery spaces of category A or ro-ro spaces.*

3) *Where the fixed fire detection and fire alarm system does not include means of remotely identifying each detector individually, no section covering more than one deck within accommodation spaces, service spaces and control stations shall normally be permitted except a section which covers an enclosed stairway. In order to avoid delay in identifying the source of fire, the number of enclosed spaces included in each section shall be limited as determined by the Society. If the detection system is fitted with remotely and individually identifiable fire detectors, the sections may cover several decks and serve any number of enclosed spaces.*

4) *In passenger ships, a section of detectors and manually operated call points shall not be situated in more than one main vertical zone, except on cabin balconies.*

b) *Positioning of detectors*

1) *Detectors shall be located for optimum performance. Positions near beams and ventilation ducts, or other positions where patterns of air flow could adversely affect performance, and positions where impact or physical damage is likely, shall be avoided. Detectors shall be located on the overhead at a minimum distance of 0,5 m away from bulkheads, except in corridors, lockers and stairways.*

2) *The maximum spacing of detectors shall be in accordance with Tab 4. The Society may require or permit other spacing based upon test data which demonstrate the characteristics of the detectors. Detectors located below moveable ro-ro decks shall be in accordance with Tab 4.*

3) *Detectors in stairways shall be located at least at the top level of the stair and at every second level beneath.*

4) *When fire detectors are installed in freezers, drying rooms, saunas, parts of galleys used to heat food, laundries and other spaces where steam and fumes are produced, heat detectors may be used.*

5) *Where a fixed fire detection and fire alarm system is required by regulation Ch 4, Sec 3, [4], spaces having little or no fire risk need not be fitted with detectors. Such spaces include void spaces with no storage of combustibles, private bathrooms, public toilets, fire-extinguishing medium storage rooms, cleaning gear lockers (in which flammable liquids are not stowed), open deck spaces and enclosed promenades having little or no fire risk and that are naturally ventilated by permanent openings.*

c) *Arrangement of cables*

1) *Cables which form part of the system shall be so arranged as to avoid galleys, machinery spaces of category A and other enclosed spaces of high fire risk except where it is necessary to provide for fire detection or fire alarms in such spaces or to connect to the appropriate power supply.*

2) *A section with individually identifiable capability shall be arranged so that it cannot be damaged at more than one point by a fire.*

Table 4 : Spacing of detectors

Type of detector	Maximum floor area per detector	Maximum distance apart between centres	Maximum distance away from bulkheads
Heat	37 m^2	9 m	4,5 m
Smoke	74 m^2	11 m	5,5 m

8.2.5 Visual and audible fire signals

a) The activation of any detector or manually operated call point shall initiate a visual and audible fire detection alarm signal at the control panel and indicating units. If the signals have not been acknowledged within 2 minutes, an audible fire alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A. This alarm sounder system need not be an integral part of the detection system.

The alarm sounder system utilized by the fixed fire detection and fire alarm system should be powered from no less than two sources of power, one of which should be an emergency source of power.

For ships provided with a transitional source of emergency electrical power, as required by:

- Pt D, Ch 11, Sec 5, [2],
- Ch 2, Sec 3, [2], and
- Ch 2, Sec 3, [3],

the alarm sounder system should also be powered from this power source.

b) In passenger ships, the control panel shall be located in the onboard safety centre. In cargo ships, the control panel shall be located on the navigation bridge or in the fire control station.

c) In passenger ships, an indicating unit that is capable of individually identifying each detector that has been activated or manually operated call point that has operated shall be located on the navigation bridge. In cargo ships, an indicating unit shall be located on the navigation bridge if the control panel is located in the fire control station. In ships with a cargo control room, an additional indicating unit shall be located in the cargo control room. In cargo ships and on passenger cabin balconies, indicating units shall, as a minimum, denote the section in which a detector has activated or manually operated call point has been operated.

A space in which a cargo control console is installed, but does not serve as a dedicated cargo control room (e.g. ship's office, machinery control room), should be regarded as a cargo control room for the purposes of this requirement and therefore be provided with an additional indicating unit.

d) Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

e) Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power and fault conditions, as appropriate, including:

- *a single open or power break fault caused by a broken wire;*
- *a single ground fault caused by the contact of a wiring conductor to a metal component; and*
- *a single wire to wire fault caused by the contact of two or more wiring conductors.*

Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

f) Means to manually acknowledge all alarm and fault signals shall be provided at the control panel. The audible alarm sounders on the control panel and indicating units may be manually silenced. The control panel shall clearly distinguish between normal, alarm, acknowledged alarm, fault and silenced conditions.

g) The system shall be arranged to automatically reset to the normal operating condition after alarm and fault conditions are cleared.

h) When the system is required to sound a local audible alarm within the cabins where the detectors are located, a means to silence the local audible alarms from the control panel shall not be permitted.

i) In general, audible alarm sound pressure levels at the sleeping positions in the cabins and 1 m from the source shall be at least 75 dB(A) and at least 10 dB(A) above ambient noise levels existing during normal equipment operation with the ship under way in moderate weather. The sound pressure level should be in the 1/3 octave band about the fundamental frequency. Audible alarm signals shall not exceed 120 dB(A).

9 Sample extraction smoke detection systems

9.1 Engineering specifications

9.1.1 General requirements

a) *Wherever in the text of Article [9] the word "system" appears, it shall mean "sample extraction smoke detection system".*

A sample extraction smoke detection system consists of the following main components:

1) *smoke accumulators: air collection devices installed at the open ends of the sampling pipes in each cargo hold that perform the physical function of collecting air samples for transmission to the control panel through the sampling pipes, and may also act as discharge nozzles for the fixed-gas fire-extinguishing system, if installed;*

2) *sampling pipes: a piping network that connects the smoke accumulators to the control panel, arranged in sections to allow the location of the fire to be readily identified;*

3) *three-way valves: if the system is interconnected to a fixed-gas fire-extinguishing system, three-way valves are used to normally align the sampling pipes to the control panel and, if a fire is detected, the three-way valves are re-aligned to connect the sampling pipes to the fire-extinguishing system discharge manifold and isolate the control panel; and*

4) *control panel: the main element of the system which provides continuous monitoring of the protected spaces for indication of smoke. It typically may include a viewing chamber or smoke sensing units. Extracted air from the protected spaces is drawn through the smoke accumulators and sampling pipes to the viewing chamber, and then to the smoke sensing chamber where the airstream is monitored by electrical smoke detectors. If smoke is sensed, the repeater panel (normally on the bridge) automatically sounds an alarm (not localized). The crew can then determine at the smoke sensing unit which cargo hold is on fire and operate the pertinent three-way valve for discharge of the extinguishing agent.*

b) *Any required system shall be capable of continuous operation at all times except that systems operating on a sequential scanning principle may be accepted, provided that the interval between scanning the same position twice gives a maximum allowable interval determined as follows:*

The interval (I) should depend on the number of scanning points (N) and the response time of the fans (T), with a 20% allowance:

$I = 1,2\ T\ N$

However, the maximum allowable interval should not exceed 120 s (Imax = 120 s).

c) *The system shall be designed, constructed and installed so as to prevent the leakage of any toxic or flammable substances or fire-extinguishing media into any accommodation and service space, control station or machinery space.*

d) *The system and equipment shall be suitably designed to withstand supply voltage variations and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships and to avoid the possibility of ignition of a flammable gas-air mixture.*

e) *The system shall be of a type that can be tested for correct operation and restored to normal surveillance without the renewal of any component.*

f) *An alternative power supply for the electrical equipment used in the operation of the system shall be provided.*

9.1.2 Component requirements

a) *The sensing unit shall be certified to operate before the smoke density within the sensing chamber exceeds 6,65% obscuration per metre.*

b) *Duplicate sample extraction fans shall be provided. The fans shall be of sufficient capacity to operate with the normal conditions or ventilation in the protected area and the connected pipe size shall be determined with consideration of fan suction capacity and piping arrangement to satisfy the conditions of [9.1.4], item b) 2). Sampling pipes shall be a minimum of 12 mm internal diameter. The fan suction capacity should be adequate to ensure the response of the most remote area within the time criteria required in [9.1.4], item b) 2). Means to monitor airflow shall be provided in each sampling line.*

c) *The control panel shall permit observation of smoke in the individual sampling pipes.*

d) *The sampling pipes shall be so designed as to ensure that, as far as practicable, equal quantities of airflow are extracted from each interconnected accumulator.*

e) *Sampling pipes shall be provided with an arrangement for periodically purging with compressed air.*

f) *The control panel for the smoke detection system shall be tested according to standards EN 54-2 (1997), EN 54-4 (1997) and IEC 60092-504 (2001). Alternative standards may be used as determined by the Society.*

9.1.3 Installation requirements

a) *Smoke accumulators*

1) *At least one smoke accumulator shall be located in every enclosed space for which smoke detection is required. However, where a space is designed to carry oil or refrigerated cargo alternatively with cargoes for which a smoke sampling system is required, means may be provided to isolate the smoke accumulators in such compartments for the system. Such means shall be to the satisfaction of the Society.*

2) *Smoke accumulators shall be located on the overhead or as high as possible in the protected space and shall be spaced so that no part of the overhead deck area is more than 12 m measured horizontally from an accumulator. Where systems are used in spaces which may be mechanically ventilated, the position of the smoke accumulators shall be considered having regard to the effects of ventilation. At least one additional smoke accumulator is to be provided in the upper part of each exhaust ventilation duct. An adequate filtering system shall be fitted at the additional accumulator to avoid dust contamination.*

3) *Smoke accumulators shall be positioned where impact or physical damage is unlikely to occur.*

4) *Sampling pipe networks shall be balanced to ensure compliance with [9.1.2], item d). The number of accumulators connected to each sampling pipe shall ensure compliance with [9.1.4], item b) 2).*

5) *Smoke accumulators from more than one enclosed space shall not be connected to the same sampling pipe.*

6) *In cargo holds where non-gastight "'tween deck panels" (movable stowage platforms) are provided, smoke accumulators shall be located in both the upper and lower parts of the holds.*

b) *Sampling pipes*

1) *The sampling pipe arrangements shall be such that the location of the fire can be readily identified.*

2) *Sampling pipes shall be self-draining and suitably protected from impact or damage from cargo working.*

9.1.4 System control requirements

a) *Visual and audible fire signals*

1) *The detection of smoke or other products of combustion shall initiate a visual and audible signal at the control panel and indicating units.*

2) *The control panel shall be located on the navigation bridge or in the fire control station. An indicating unit shall be located on the navigation bridge if the control panel is located in the fire control station.*

the control panel can be located in the CO_2 room provided that an indicating unit is located on the navigation bridge. Indicating unit has the same meaning as repeater panel and observation of smoke should be made either by electrical means or by visual on repeater panel.

3) *Clear information shall be displayed on, or adjacent to, the control panel and indicating units designating the spaces covered.*

4) *Power supplies necessary for the operation of the system shall be monitored for loss of power. Any loss of power shall initiate a visual and audible signal at the control panel and the navigation bridge which shall be distinct from a signal indicating smoke detection.*

5) *Means to manually acknowledge all alarm and fault signals shall be provided at the control panel. The audible alarm sounders on the control panel and indicating units may be manually silenced. The control panel shall clearly distinguish between normal, alarm, acknowledged alarm, fault and silenced conditions.*

6) *The system shall be arranged to automatically reset to the normal operating condition after alarm and fault conditions are cleared.*

b) *Testing*

1) *Suitable instructions and component spares shall be provided for the testing and maintenance of the system.*

2) *After installation, the system shall be functionally tested using smoke generating machines or equivalent as a smoke source. An alarm shall be received at the control unit in not more than 180 s for vehicle decks, and not more than 300 s for container and general cargo holds, after smoke is introduced at the most remote accumulator.*

10 Low-location lighting systems

10.1 Application

10.1.1 *This Article details the specifications for low-location lighting systems as required by Ch 4, Sec 8.*

10.2 Engineering specification

10.2.1 General requirements

Any required low-location lighting systems shall be approved by the Society based on IMO resolution A.752(18) and on the Recommendations by the International Organization for Standardization, in particular, publication ISO 15370 on Low-location lighting on passenger ships.

11 Fixed emergency fire pumps

11.1 Engineering specifications

11.1.1 Type of emergency fire pumps

The emergency fire pump shall be a fixed independently driven power-operated pump.

11.1.2 Component requirements

a) Emergency fire pumps

1) Capacity of the pump

The capacity of the pump shall not be less than 40% of the total capacity of the fire pumps required by Ch 4, Sec 6, [1.3.4] and in any case not less than the following:

- *for passenger ships of less than 1000 gross tonnage and for cargo ships of 2000 gross tonnage and upwards: 25 m^3/h, and*
- *for cargo ships of less than 2000 gross tonnage: 15 m^3/h.*

The emergency pump is to be capable of supplying two jets of water to the satisfaction of the Society and the amount of water needed for any fixed fire-extinguishing system provided to protect the space where the main fire pumps are located.

On board cargo ships designed to carry five or more tiers of containers on or above the weather deck, the total capacity of the emergency fire pump need not exceed 72 m^3/h.

2) Pressure at hydrants

When the pump is delivering the quantity of water required by item 1) above, the pressure at any hydrants shall be not less than the minimum pressure required in Ch 4, Sec 6, [1.2.6].

3) Suction heads

The total suction head and the net positive suction head of the pump shall be determined having due regard to the requirements of Ch 4, Sec 6 and the present Article on the pump capacity and on the hydrant pressure under all conditions of list, trim, roll and pitch likely to be encountered in service. The ballast condition of a ship on entering or leaving a dry dock need not be considered a service condition.

4) Arrangement of the sea suction of the emergency fire pump

- The sea suction for the pump is to be fitted at a safe depth below the waterline at any draught under all trim and heeling conditions; the ballast condition of a ship on entering or leaving a dry dock need not be considered a service condition. The emergency fire pump is to be of the self-priming type. The location of the pump is to be such that it is capable of pumping at any draught under all trim and heeling conditions. The sea valve is to be capable of being operated from a position near the pump.
- Where it is found necessary to locate the emergency fire pump sea suction in the space containing the main fire pumps, the sea valve is to be operable from a readily accessible position not likely to be affected by a fire in the space containing the main fire pumps.

b) Diesel engines and fuel tank

1) Starting of diesel engine

Any diesel-driven power source for the pump shall be capable of being readily started in its cold condition down to the temperature of 0°C by hand (manual) cranking. Where ready starting cannot be assured, if this is impracticable, or if lower temperatures are likely to be encountered, and if the room for the diesel driven power source is not heated, electric heating of the diesel engine cooling water or lubricating oil system shall be fitted, to the satisfaction of the Society. If hand (manual) starting is impracticable, the Society may permit compressed air, electricity, or other sources of stored energy, including hydraulic power or starting cartridges to be used as a means of starting. These means shall be such as to enable the diesel-driven power source to be started at least six times within a period of 30 minutes and at least twice within the first 10 minutes.

2) Fuel tank capacity

Any service fuel tank shall contain sufficient fuel to enable the pump to run on full load for at least 3 hours and sufficient reserves of fuel shall be available outside the machinery space of category A to enable the pump to be run on full load for an additional 15 hours.

c) Prime mover and source of power of the emergency fire pump

1) The emergency fire pump and its prime mover are to be to the satisfaction of the Society.

2) The emergency fire pump prime mover is to be so arranged that an immediate start is possible under all prevailing temperature conditions. Diesel engines exceeding 15 kW are to be equipped with an approved auxiliary starting device, e.g. starting battery, independent hydraulic system or independent starting air system, having a capacity sufficient for at least six starts of the fire emergency pump. For diesel engines of 15 kW and smaller, manual means of starting are sufficient.

3) For the operation of the emergency fire pump, fuel is to be available from outside the main machinery space for at least 18h operation.

4) When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps and to be located outside the engine room, and separated from it by an A class division, and the relevant electrical cables are not to pass through the compartment containing the main fire pump.

d) Testing of the emergency fire pump and its prime mover

1) Upon completion of the installation of the emergency fire pump, a running test is to be carried out to the satisfaction of the Society.

2) The emergency generator and its prime mover and any emergency accumulator battery are to be so arranged as to ensure that they will function at full rated power when the ship is upright and when inclined at any angle of list up to and including 22,5° either way or up to and including 10° inclination either way in the fore and aft direction. The above angles of list and trim are to be considered to occur simultaneously in their most unfavourable combination (see also Ch 1, Sec 1, [2.4]).

12 Arrangement of means of escape

12.1 Passenger ships

12.1.1 Width of stairways

a) Basic requirements for stairway widths

Stairways shall not be less than 900 mm in clear width. The minimum clear width of stairways shall be increased by 10 mm for every one person provided for in excess of 90 persons. The total number of persons to be evacuated by such stairways shall be assumed to be two thirds of the crew and the total number of passengers in the areas served by such stairways. The width of the stairways shall not be inferior to those determined by item b) hereafter.

b) Calculation method of stairway widths

1) Basic principles of the calculation

- *This calculation method determines the minimum stairway width at each deck level, taking into account the consecutive stairways leading into the stairway under consideration.*
- *It is the intention that the calculation method shall consider evacuation from enclosed spaces within each main vertical zone individually and take into account all of the persons using the stairway enclosures in each zone, even if they enter that stairway from another vertical zone.*
- *For each main vertical zone the calculation shall be completed for the night-time (case 1) and daytime (case 2) and the largest dimension from either case used for determining the stairway width for each deck under consideration.*
- *The calculation of stairway widths shall be based upon the crew and passenger load on each deck. Occupant loads shall be rated by the designer for passenger and crew accommodation spaces, service spaces, control spaces and machinery spaces. For the purpose of the calculation the maximum capacity of a public space shall be defined by either of the following two values: the number of seats or similar arrangements, or the number obtained by assigning 2 m^2 of gross deck surface area to each person.*

2) Calculation method for minimum value

- *Basic formulae*

  In considering the design of stairway widths for each individual case which allow for the timely flow of persons evacuating to the assembly stations from adjacent decks above and below, the following calculation methods shall be used (see Fig 2 and Fig 1):

  - *when joining two decks:*

    $W = (N1 + N2) \times 10$ mm

  - *when joining three decks:*

    $W = (N1 + N2 + 0,5\ N3) \times 10$ mm

  - *when joining four decks:*

    $W = (N1 + N2 + 0,5\ N3 + 0,25\ N4) \times 10$ mm

  - *when joining five decks or more decks, the width of the stairways shall be determined by applying the above formula for four decks to the deck under consideration and to the consecutive deck,*

  where:

  W : *The required tread width between handrails of the stairway.*

  The calculated value of W may be reduced where available landing area S is provided in stairways at the deck level defined by subtracting P from Z, such that:

  $P = S \times 3,0$ persons/m^2; and $P_{max} = 0,25\ Z$

  where:

  Z : *The total number of persons expected to be evacuated on the deck being considered*

  P : *The number of persons taking temporary refuge on the stairway landing, which may be subtracted from Z to a maximum value of P = 0,25 Z (to be rounded down to the nearest whole number)*

  S : *The surface area (m^2) of the landing, minus the surface area necessary for the opening of doors and minus the surface area necessary for accessing the flow on stairs (see Fig 2)*

N : The total number of persons expected to use the stairway from each consecutive deck under consideration; N1 is for the deck with the largest number of persons using that stairway; N2 is taken for the deck with the next highest number of persons directly entering the stairway flow such that when sizing the stairway width at each deck level:

N1 > N2 > N3 > N4 (see Fig 1). These decks are assumed to be on or up-stream (i.e. away from the embarkation deck) of the deck being considered.

- *Distribution of persons*

The dimensions of the means of escape shall be calculated on the basis of the total number of persons expected to escape by the stairway and through doorways, corridors and landings (see Fig 3). Calculations shall be made separately for the two cases of occupancy of the spaces specified below. For each component part of the escape route, the dimension taken shall not be less than the largest dimension determined for each case:

Case 1:

- *passengers in cabins with maximum berthing capacity fully occupied*
- *members of the crew in cabins occupied to 2/3 of maximum berthing capacity, and*
- *service spaces occupied by 1/3 of the crew.*

Case 2:

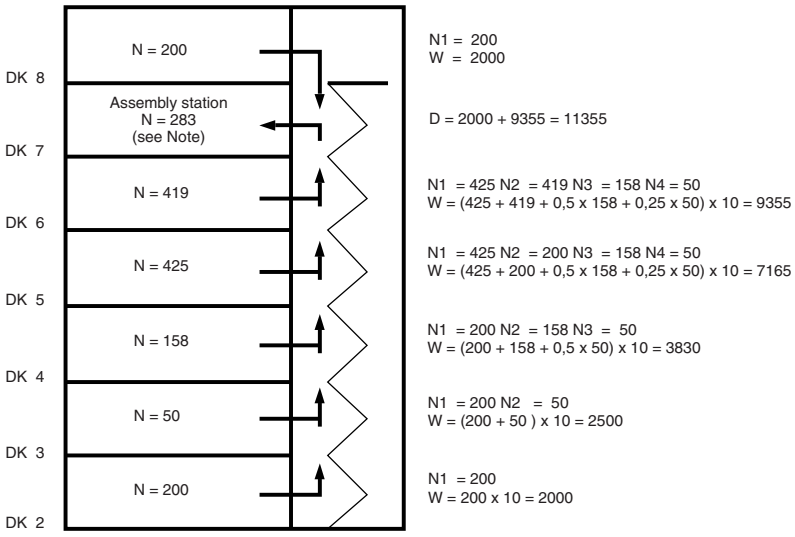
- *passengers in public spaces occupied to 3/4 of maximum capacity,*
- *1/3 of the crew distributed in public spaces*
- *service spaces occupied by 1/3 of the crew, and*
- *crew accommodation occupied by 1/3 of the crew.*

The maximum number of persons contained in a main vertical zone, including persons entering stairways from another main vertical zone, shall not be assumed to be higher than the maximum number of persons authorized to be carried on board for the calculation of stairway widths only.

c) Prohibition of decrease in width in the direction to the assembly station

The stairway shall not decrease in width in the direction of evacuation to the assembly station. Where several assembly stations are in one main vertical zone, the stairway width shall not decrease in the direction of the evacuation to the most distant assembly station.

Figure 1 : Minimum stairway width (W) calculation example



Z (pers) = number of persons expected to evacuate through the stairway

N (pers) = number of persons directly entering the stairway flow from a given deck

W (mm) = (N1 + N2 + 0,5 N3 + 0,25 N4) x 10 = calculated width of stairway

D (mm) = width of exit doors

N1 > N2 > N3 > N4 where:

N1 (pers) = the deck with the largest number of persons N entering directly the stairway

N2 (pers) = the deck with the next largest number of persons N entering directly the stairway, etc.

Note: The doors to the assembly station shall have aggregate widths of 11355 mm.

12.1.2 Details of stairways

a) *Handrails*

Stairways shall be fitted with handrails on each side. The maximum clear width between handrails shall be 1800 mm.

b) *Alignment of stairways*

All stairways sized for more than 90 persons shall be aligned fore and aft.

c) *Vertical rise and inclination*

Stairways shall not exceed 3,5 m in vertical rise without the provision of a landing and shall not have an angle of inclination greater than 45°.

d) *Landings*

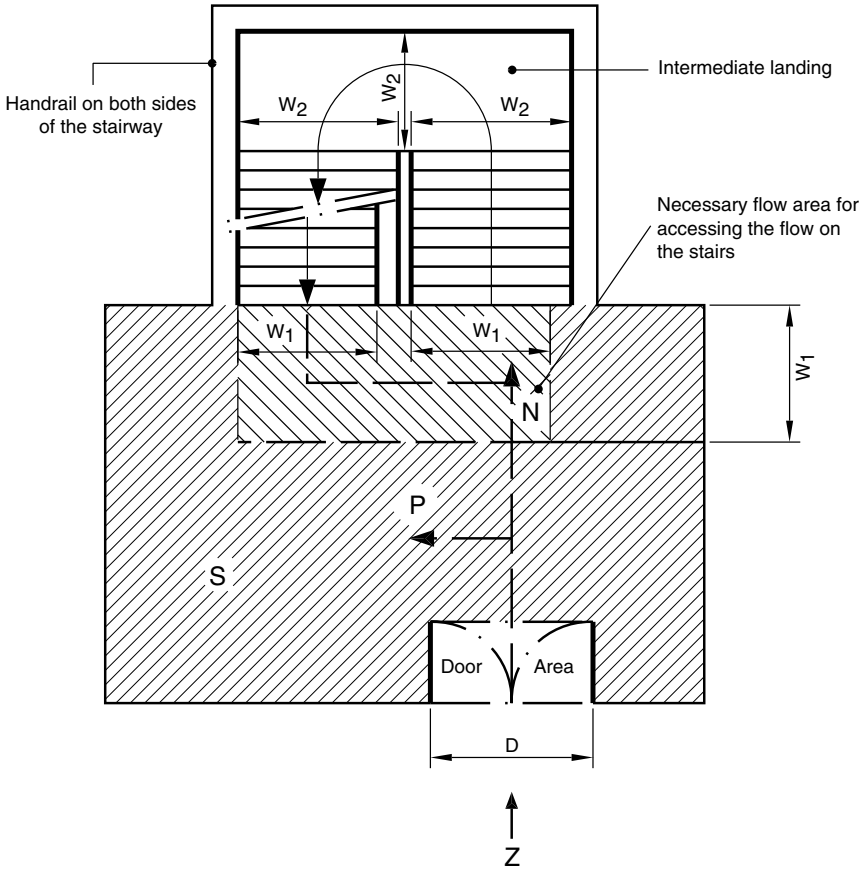
With the exception of intermediate landings, landings at each deck level shall be not less than 2 m^2 in area and shall increase by 1 m^2 for every 10 persons provided for in excess of 20 persons, but need not exceed 16 m^2, except for those landings servicing public spaces having direct access onto the stairway enclosure. Intermediate landings shall be sized in accordance with [12.1.3], item a).

12.1.3 Doorways and corridors

a) *Doorways and corridors and intermediate landings included in means of escape shall be sized in the same manner as stairways.*

b) *The aggregate width of stairway exit doors to the assembly station shall not be less than the aggregate width of stairways serving this deck.*

Figure 2 : Landing calculation for stairway width reduction



P = S x 3 persons/m^2 = the number of persons taking refuge on the landing to a maximum of P = 0,25 Z

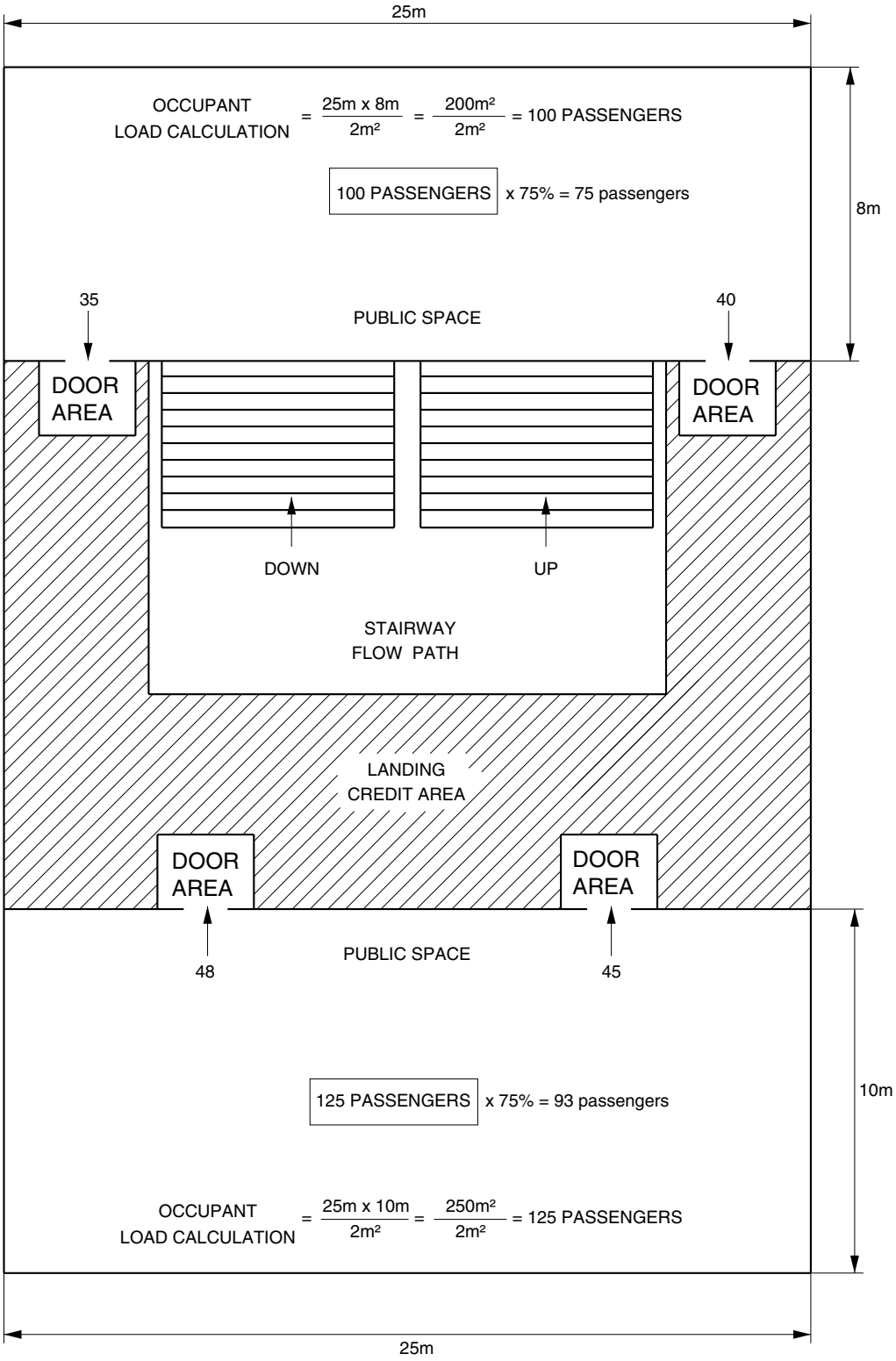
N = Z – P = the number of persons directly entering the stairway flow from a given deck

Z = number of persons to be evacuated from the deck considered

S = available landing area (m^2) after subtracting the surface area necessary for movement and subtracting the space taken by the door swing area. Landing area is a sum of flow area, credit area and door area

D = width of exit doors to the stairway landing area (mm).

Figure 3 : Occupant loading calculation example



12.1.4 Evacuation routes to the embarkation deck

a) Assembly station

It shall be recognized that the evacuation routes to the embarkation deck may include an assembly station. In this case, consideration shall be given to the fire protection requirements and sizing of corridors and doors from the stairway enclosure to the assembly station and from the assembly station to the embarkation deck, noting that evacuation of persons from assembly stations to embarkation positions will be carried out in small controlled groups.

b) Routes from the assembly station to the survival craft embarkation position

Where the passengers and crew are held at an assembly station which is not at the survival craft embarkation position, the dimension of stairway width and doors from the assembly station to this position shall be based on the number of persons in the controlled group. The width of these stairways and doors need not exceed 1500 mm unless larger dimensions are required for evacuation of these spaces under normal conditions.

12.1.5 Means of escape plans

Means of escape plans shall be provided indicating the following:

a) the number of crew and passengers in all normally occupied spaces

b) the number of crew and passengers expected to escape by stairway and through doorways, corridors and landings

c) assembly stations and survival craft embarkation positions

d) primary and secondary means of escape, and

e) width of stairways, doors, corridors and landing areas.

Means of escape plans shall be accompanied by detailed calculations for determining the width of escape stairways, doors, corridors and landing areas (see also Ch 4, Sec 8, [2.2.3], item g)).

12.2 Cargo ships

12.2.1 *Stairways and corridors used as means of escape shall be not less than 700 mm in clear width and shall have a handrail on one side. Stairways and corridors with a clear width of 1800 mm and over shall have handrails on both sides. Clear width is considered the distance between the handrail and the bulkhead on the other side or between the handrails. The angle of inclination of stairways should be, in general, 45°, but not greater than 50°, and in machinery spaces and small spaces not more than 60°. Doorways which give access to a stairway shall be of the same size as the stairway.*

13 Inert gas systems

13.1 Application

13.1.1 Specific requirements for inert gas systems are given in:

- Ch 1, Sec 13, [2] for BWMS
- Pt D, Ch 7, Sec 6, [5] for oil tankers
- Pt D, Ch 8, Sec 9, [2] for chemical tankers
- Pt D, Ch 9, Sec 9, [1] for liquefied gas carriers.

13.2 Definitions

13.2.1 *For the purposes of this Article:*

a) Cargo tanks means those cargo tanks, including slop tanks, which carry cargoes, or cargo residues, having a flashpoint not exceeding 60ºC.

b) Inert gas system includes inert gas systems using flue gas, inert gas generators, and nitrogen generators and means the inert gas plant and inert gas distribution together with means for preventing backflow of cargo gases to machinery spaces, fixed and portable measuring instruments and control devices.

c) Gas-safe space is a space in which the entry of gases would produce hazards with regard to flammability or toxicity.

d) Gas-free is a condition in a tank where the content of hydrocarbon or other flammable vapour is less than 1% of the lower flammable limit (LFL), the oxygen content is at least 21%, and no toxic gases are present.

Note 1: Refer to the Revised recommendations for entering enclosed spaces aboard ships (IMO resolution A.1050(27)).

13.3 Requirements for all systems

13.3.1 General

a) The inert gas systems shall be designed, constructed and tested to the satisfaction of the Society. It shall be designed to be capable of rendering and maintaining the atmosphere of the relevant cargo tanks non-flammable.

Note 1: Refer to the Revised standards for the design, testing and locating of devices to prevent the passage of flame into cargo tanks in tankers (MSC/Circ.677, as amended by MSC/Circ.1009 and MSC.1/Circ.1324) and the Revised factors to be taken into consideration when designing cargo tank venting and gas-freeing arrangements (MSC/Circ.731).

b) The system shall be capable of:

1) inerting empty cargo tanks and maintaining the atmosphere in any part of the tank with an oxygen content not exceeding 8% by volume and at a positive pressure in port and at sea except when it is necessary for such a tank to be gas-free;

2) eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas-free;

3) purging empty cargo tanks of hydrocarbon or other flammable vapours, so that subsequent gas-freeing operations will at no time create a flammable atmosphere within the tank;

4) *delivering inert gas to the cargo tanks at a rate of at least 125% of the maximum rate of discharge capacity of the ship expressed as a volume. For chemical tankers and chemical/product tankers, the Society may accept inert gas systems having a lower delivery capacity provided that the maximum rate of discharge of cargoes from cargo tanks being protected by the system is restricted to not more than 80% of the inert gas capacity; and*

5) *delivering inert gas with an oxygen content of not more than 5% by volume to the cargo tanks at any required rate of flow.*

c) *Materials used in inert gas systems shall be suitable for their intended purpose. In particular, those components which may be subjected to corrosive action of the gases and/or liquids are to be either constructed of corrosion-resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.*

d) *The inert gas supply may be:*

1) *treated flue gas from main or auxiliary boilers, or*

2) *gas from an oil or gas-fired gas generator, or*

3) *gas from nitrogen generators.*

The Society may accept systems using inert gases from one or more separate gas generators or other sources or any combination thereof, provided that an equivalent level of safety is achieved. Such systems shall, as far as practicable, comply with the requirements of this article. Systems using stored carbon dioxide shall not be permitted unless the Administration is satisfied that the risk of ignition from generation of static electricity by the system itself is minimized.

13.3.2 Safety measures

a) *The inert gas system shall be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank.*

b) *Automatic shutdown of the inert gas system and its components parts shall be arranged on predetermined limits being reached, taking into account the provisions of [13.3.4], [13.4.3] and [13.5.3].*

The automatic shutdown of the inert gas system and its components should involve the following:

- shutdown of fans and closing of regulating valve for the following:
  - high water level in scrubber (not applicable for N2);
  - low pressure/flow to scrubber (not applicable for N2); or
  - high-high temperature of inert gas supply.
- closing of regulating valve in the event of:
  - high oxygen content (in excess of 5% by volume); or
  - failure of blowers/fans or N2 compressors.
- activation of double-block and bleed arrangement upon:
  - loss of inert gas supply (for ships with double block and bleed replacing water seal); or
  - loss of power.

c) *Suitable shutoff arrangements shall be provided on the discharge outlet of each generator plant.*

d) *The system shall be designed to ensure that if the oxygen content exceeds 5% by volume, the inert gas shall be automatically vented to atmosphere.*

e) *Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge. If blowers are to be used for gas-freeing, their air inlets shall be provided with blanking arrangements.*

f) *Where a double block and bleed valve is installed, the system shall ensure upon of loss of power, the block valves are automatically closed and the bleed valve is automatically open.*

13.3.3 System components

a) *Non-return devices*

1) *At least two non-return devices shall be fitted in order to prevent the return of vapour and liquid to the inert gas plant, or to any gas-safe spaces.*

2) *The first non-return device shall be a deck seal of the wet, semi-wet, or dry type or a double-block and bleed arrangement. Two shut-off valves in series with a venting valve in between, may be accepted provided:*

- *the operation of the valve is automatically executed. Signal(s) for opening/closing is (are) to be taken from the process directly, e.g. inert gas flow or differential pressure; and*
- *alarm for faulty operation of the valves is provided, e.g. the operation status of "blower stop" and "supply valve(s) open" is an alarm condition.*

3) *The second non-return device shall be a non-return valve or equivalent capable of preventing the return of vapours and liquids and fitted between the deck water seal (or equivalent device) and the first connection from the inert gas main to a cargo tank. It shall be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the first connection to the cargo tanks to isolate the deck water seal, or equivalent device, from the inert gas main to the cargo tanks.*

4) *A water seal, if fitted, shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times. The audible and visual alarm on the low level of water in the water seal shall operate at all times.*

5) *The arrangement of the water seal, or equivalent devices, and its associated fittings shall be such that it will prevent backflow of vapours and liquids and will ensure the proper functioning of the seal under operating conditions.*

6) *Provision shall be made to ensure that the water seal is protected against freezing, in such a way that the integrity of seal is not impaired by overheating.*

7) *A water loop or other approved arrangement shall also be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas-safe spaces. Means shall be provided to prevent such loops from being emptied by vacuum.*

8) *Any water seal, or equivalent device, and loop arrangements shall be capable of preventing return of vapours and liquids to an inert gas plant at a pressure equal to the test pressure of the cargo tanks.*

9) *The non-return devices shall be located in the cargo area on deck.*

b) *Inert gas lines*

1) *The inert gas main may be divided into two or more branches* downstream *of the non-return devices required by [13.3.3], item a).*

2) *The inert gas main shall be fitted with branch piping leading to the cargo tank. Branch piping for inert gas shall be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they shall be provided with locking arrangements. The control system shall provide unambiguous information of the operational status of such valves to at least the control panel required in [13.3.4].*

   Unambiguous information of the operational status of stop valves in branch piping leading from the inert gas main to cargo tanks means position indicators providing open/intermediate/closed status information in the control panel required in [13.3.4]. Limit switches should be used to positively indicate both open and closed positions. Intermediate position status should be indicated when the valve is in neither open nor closed position.

3) *Each cargo tank not being inerted shall be capable of being separated from the inert gas main by:*
   - *removing spool-pieces, valves or other pipe sections, and blanking the pipe ends; or*
   - *arrangement of two spectacle flanges in series with provisions for detecting leakage into the pipe between the two spectacle flanges; or*
   - *equivalent arrangements to the satisfaction of the Society, providing at least the same level of protection.*

4) *Means shall be provided to protect cargo tanks against the effect of overpressure or vacuum caused by thermal variations and/or cargo operations when the cargo tanks are isolated from the inert gas mains.*

5) *Piping systems shall be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.*

6) *Arrangements shall be provided to enable the inert gas main to be connected to an external supply of inert gas. The arrangements shall consist of a 250 mm nominal pipe size bolted flange, isolated from the inert gas main by a valve and located* downstream *of the non-return valve. The design of the flange should conform to the appropriate class in the standards adopted for the design of other external connections in the ship's cargo piping system.*

7) *If a connection is fitted between the inert gas main and the cargo piping system, arrangements shall be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. This shall consist of two shutoff valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks.*

8) *The valve separating the inert gas main from the cargo main and which is on the cargo main side shall be a non-return valve with a positive means of closure.*

9) *Inert gas piping systems shall not pass through accommodation, service and control station spaces.*

10) *In combination carriers, the arrangement to isolate the slop tanks containing oil or oil residues from other tanks shall consist of blank flanges which will remain in position at all times when cargoes other than oil are being carried except as provided for in the relevant section of IMO Circular MSC/Circ.353, as amended by IMO Circular MSC/Circ.387.*

13.3.4 Indicators and alarms

a) *The operation status of the inert gas system shall be indicated in a control panel.*

   The operational status of the inert gas system is to be based on indication that inert gas is being supplied downstream of the gas regulating valve and on the pressure or flow of the inert gas mains downstream of the non-return devices. However, the operational status of the inert gas system is not to be considered to require additional indicators and alarms other than those specified in this requirement and [13.4.3] or [13.5.3], as appropriate.

b) *Instrumentation shall be fitted for continuously indicating and permanently recording, when inert gas is being supplied:*

1) *the pressure of the inert gas mains* downstream *of the non-return devices; and*

2) *the oxygen content of the inert gas.*

c) *The indicating and recording devices shall be placed in the cargo control room where provided. But where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.*

d) *In addition, meters shall be fitted:*

1) *in the navigation bridge to indicate at all times the pressure referred to in item b) 1) and the pressure in the slop tanks of combination carriers, whenever those tanks are isolated from the inert gas main; and*

2) *in the machinery control room or in the machinery space to indicate the oxygen content referred to in item b) 2).*

e) *Audible and visual alarms*

1) *Audible and visual alarms shall be provided, based on the system designed, to indicate:*

- *oxygen content in excess of 5% by volume (see also item e) 2));*
- *failure of the power supply to the indicating devices as referred to in item b);*
- *gas pressure less than 100 mm water gauge. The alarm arrangement shall be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times (see also item e) 2));*
- *high-gas pressure; and*
- *failure of the power supply to the automatic control system (see also item e) 2)).*

2) *The alarms required in item e) 1) for:*

- *oxygen content*
- *gas pressure less than 100 mm water gauge, and*
- *failure of the power supply to the automatic control system,*

shall be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

3) *An audible alarm system independent of that required in item e) 1) for gas pressure less than 100 mm water gauge, or automatic shutdown of cargo pumps shall be provided to operate on predetermined limits of low pressure in the inert gas main being reached.*

The term "alarm system independent" means that a second pressure sensor, independent of the sensor serving the alarms for low pressure, high pressure and pressure indicator/recorder should be provided. Notwithstanding the above, a common programmable logic controller (PLC) should, however, be accepted for the alarms in the control system. The independent sensor should not be required if the system is arranged for the shutdown of cargo pumps. If a system for shutdown of cargo pumps is arranged, an automatic system shutting down all cargo pumps should be provided. The shutdown should be alarmed at the control station. The shutdown should not prevent the operation of ballast pumps or pumps used for bilge drainage of a cargo pump room.

4) *Two oxygen sensors shall be positioned at appropriate locations in the space or spaces containing the inert gas system. If the oxygen level falls below 19%, these sensors shall trigger alarms, which shall be both visible and audible inside and outside the space or spaces and shall be placed in such a position that they are immediately received by responsible members of the crew.*

13.3.5 Instruction manuals

Detailed instruction manuals shall be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system.

Note 1: Refer to the Revised Guidelines for inert gas systems (MSC/Circ.353), as amended by MSC/Circ.387.

The manuals shall include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

13.4 Requirements for flue gas and inert gas generator systems

13.4.1 Application

In addition to the provisions in [13.3], for inert gas systems using flue gas or inert gas generators, the provisions of this sub-article shall apply.

13.4.2 System requirements

a) *Inert gas generators*

1) *Two fuel oil pumps shall be fitted to the inert gas generator. Suitable fuel in sufficient quantity shall be provided for the inert gas generators.*

2) *The inert gas generators shall be located outside the cargo tank area. Spaces containing inert gas generators shall have no direct access to accommodation service or control station spaces, but may be located in machinery spaces. If they are not located in machinery spaces, such a compartment shall be separated by a gastight steel bulkhead and/or deck from accommodation, service and control station spaces. Adequate positive-pressure-type mechanical ventilation shall be provided for such a compartment.*

b) *Gas regulating valves*

1) *A gas regulating valve shall be fitted in the inert gas main. This valve shall be automatically controlled to close, as required in [13.3.2], item b). It shall also be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the inert gas flow rate.*

2) *The gas regulating valve shall be located at the forward bulkhead of the forward most gas-safe space through which the inert gas main passes.*

c) *Cooling and scrubbing arrangement*

1) *Means shall be fitted which will effectively cool the volume of gas specified in [13.3.1], item b) and remove solids and sulphur combustion products. The cooling water arrangements shall be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision shall also be made for an alternative supply of cooling water.*

2) *Filters or equivalent devices shall be fitted to minimize the amount of water carried over to the inert gas blowers.*

d) *Blowers*

1) *At least two inert gas blowers shall be fitted and be capable of delivering to the cargo tanks at least the volume of gas required by [13.3.1], item b). For systems fitted with inert gas generators the Society may permit only one blower if that system is capable of delivering the total volume of gas required by [13.3.1], item b) to the cargo tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the ship's crew.*

2) *Where inert gas generators are served by positive displacement blowers, a pressure relief device shall be provided to prevent excess pressure being developed on the discharge side of the blower.*

3) *When two blowers are provided, the total required capacity of the inert gas system shall be divided evenly between the two and in no case is one blower to have a capacity less than 1/3 of the total required.*

e) *Inert gas isolating valves*

For systems using flue gas, flue gas isolating valves shall be fitted in the inert gas mains between the boiler uptakes and the flue gas scrubber. These valves shall be provided with indicators to show whether they are open or shut, and precautions shall be taken to maintain them gastight and keep the seatings clear of soot. Arrangements shall be made to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

f) *Prevention of flue gas leakage*

1) *Special consideration shall be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.*

2) *To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage shall be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.*

13.4.3 Indicators and alarms

a) *In addition to the requirements in [13.3.4], item b), means shall be provided for continuously indicating the temperature of the inert gas at the discharge side of the system, whenever it is operating.*

b) *In addition to the requirements [13.3.4], item e), audible and visual alarms shall be provided to indicate:*

- *insufficient fuel oil supply to the oil-fired inert gas generator;*
- *failure of the power supply to the generator;*
- *low water pressure or low water flow rate to the cooling and scrubbing arrangement;*
- *high water level in the cooling and scrubbing arrangement;*
- *high gas temperature;*
- *failure of the inert gas blowers; and*
- *low water level in the water seal.*

13.5 Requirements for nitrogen generator systems

13.5.1 Application

In addition to the provisions in [13.3], for inert gas systems using nitrogen generators, the provisions of [13.5.2] and [13.5.3] shall apply.

13.5.2 System requirements

a) *The system shall be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas required by [13.3.1], item b).*

b) *A feed air treatment system shall be fitted to remove free water, particles and traces of oil from the compressed air.*

c) *The air compressor and nitrogen generator may be installed in the engine-room or in a separate compartment. A separate compartment and any installed equipment shall be treated as an "Other machinery space" with respect to fire protection. Where a separate compartment is provided for the nitrogen generator, the compartment shall be fitted with an independent mechanical extraction ventilation system providing six air changes per hour. The compartment is to have no direct access to accommodation spaces, service spaces and control stations.*

d) *Where a nitrogen receiver or a buffer tank is installed, it may be installed in a dedicated compartment, in a separate compartment containing the air compressor and the generator, in the engine room, or in the cargo area. Where the nitrogen receiver or a buffer tank is installed in an enclosed space, the access shall be arranged only from the open deck and the access door shall open outwards. Adequate, independent mechanical ventilation, of the extraction type, shall be provided for such a compartment.*

13.5.3 Indicators and alarms

a) *In addition to the requirements in [13.3.4], item b), instrumentation is to be provided for continuously indicating the temperature and pressure of air at the suction side of the nitrogen generator.*

b) *In addition to the requirements in [13.3.4], item e), audible and visual alarms shall be provided to include:*

- *failure of the electric heater, if fitted;*
- *low feed-air pressure or flow from the compressor;*
- *high-air temperature; and*
- *high condensate level at automatic drain of water separator.*

14 Helicopter facility foam firefighting appliances

14.1 Application

14.1.1 *This Article details the specifications for foam firefighting appliances for the protection of helidecks and helicopter landing areas as required by Ch 4, Sec 10.*

14.2 Definitions

14.2.1 *D-value means the largest dimension of the helicopter used for assessment of the helideck when its rotors are turning. It establishes the required area of foam application.*

14.2.2 *Deck integrated foam nozzles are foam nozzles recessed into or edge mounted on the helideck.*

14.2.3 *Foam-making branch pipes are air-aspirating nozzles in tube shape for producing and discharging foam, usually in straight stream only.*

14.2.4 *Hose reel foam station is a hose reel fitted with a foam-making branch pipe and non-collapsible hose, together with fixed foam proportioner and fixed foam concentrate tank, mounted on a common frame.*

14.2.5 *Monitor foam station is a foam monitor, either self-inducing or together with separate fixed foam proportioner, and fixed foam concentrate tank, mounted on a common frame.*

14.2.6 *Obstacle free sector is the take-off and approach sector which totally encompasses the safe landing area and extends over a sector of at least 210°, within which only specified obstacles are permitted.*

14.2.7 *Limited obstacle sector is a 150° sector outside the take-off and approach sector that extends outward from a helideck where objects of limited height are permitted.*

14.3 Engineering specifications for helidecks and helicopter landing areas

14.3.1 *The system shall be capable of manual release, and may be arranged for automatic release.*

14.3.2 *For helidecks the foam system shall contain at least two fixed foam monitors or deck integrated foam nozzles. In addition, at least two hose reels fitted with a foam-making branch pipe and non-collapsible hose sufficient to reach any part of the helideck shall be provided. The minimum foam system discharge rate shall be determined by multiplying the D-value area by 6 l/min/m^2. The minimum foam system discharge rate for deck integrated foam nozzle systems shall be determined by multiplying the overall helideck area by 6 l/min/m^2. Each monitor shall be capable of supplying at least 50% of the minimum foam system discharge rate, but not less than 500 l/min. The minimum discharge rate of each hose reel shall be at least 400 l/min.*

The quantity of foam concentrate shall be adequate to allow operation of all connected discharge devices for at least 5 min.

14.3.3 *Where foam monitors are installed, the distance from the monitor to the farthest extremity of the protected area shall be not more than 75% of the monitor throw in still air conditions.*

14.3.4 *For helicopter landing areas, at least two portable foam applicators or two hose reel foam stations shall be provided, each capable of discharging a minimum foam solution discharge rate, in accordance with Tab 5.*

The quantity of foam concentrate shall be adequate to allow operation of all connected discharge devices for at least 10 min. For tankers fitted with a deck foam system, the Society may consider an alternative arrangement, taking into account the type of foam concentrate to be used.

Table 5 : Foam discharge rates

Cat.	Helicopter overall length (D-value)	Minimum foam solution discharge rate, in l/min
H1	up to but not including 15 m	250
H2	from 15 m up to but not including 24 m	500
H3	from 24 m up to but not including 35 m	800

14.3.5 *Manual release stations capable of starting necessary pumps and opening required valves, including the fire main system, if used for water supply, shall be located at each monitor and hose reel. In addition, a central manual release station shall be provided at a protected location. The foam system shall be designed to discharge foam with nominal flow and at design pressure from any connected discharge devices within 30 s of activation.*

14.3.6 *Activation of any manual release station shall initiate the flow of foam solution to all connected hose reels, monitors, and deck integrated foam nozzles.*

14.3.7 *The system and its components shall be designed to withstand ambient temperature changes, vibration, humidity, shock impact and corrosion normally encountered on the open deck, and shall be manufactured and tested to the satisfaction of the Society.*

14.3.8 *A minimum nozzle throw of at least 15 m shall be provided with all hose reels and monitors discharging foam simultaneously. The discharge pressure, flow rate and discharge pattern of deck integrated foam nozzles shall be to the satisfaction of the Society, based on tests that demonstrate the nozzle's capability to extinguish fires involving the largest size helicopter for which the helideck is designed.*

14.3.9 *Monitors, foam-making branch pipes, deck integrated foam nozzles and couplings shall be constructed of brass, bronze or stainless steel. Piping, fittings and related components, except gaskets, shall be designed to withstand exposure to temperatures up to 925°C.*

14.3.10 *The foam concentrate shall be demonstrated effective for extinguishing aviation fuel spill fires and* is to be approved based on IMO Circular MSC.1/Circ.1312 or International Civil Aviation Organization - Airport Services Manual, Part 1 - Rescue and Firefighting, Chapter 8 - Extinguishing Agent Characteristics, Paragraph 8.1.5 - Foam Specifications Table 8-1, Level “B” foam. *Where the foam storage tank is on the exposed deck, freeze protected foam concentrates shall be used, if appropriate, for the area of operation.*

14.3.11 *Any foam system equipment installed within the take-off and approach obstacle-free sector shall not exceed a height of 0.25 m. Any foam system equipment installed in the limited obstacle sector shall not exceed the height permitted for objects in this area.*

14.3.12 *All manual release stations, monitor foam stations, hose reel foam stations, hose reels and monitors shall be provided with a means of access that does not require travel across the helideck or helicopter landing area.*

14.3.13 *Oscillating monitors, if used, shall be pre-set to discharge foam in a spray pattern and have a means of disengaging the oscillating mechanism to allow rapid conversion to manual operation.*

14.3.14 *If a foam monitor with flow rate up to 1000 l/min is installed, it shall be equipped with an air-aspirating nozzle. If a deck integrated nozzle system is installed, then the additionally installed hose reel shall be equipped with an air-aspirating handline nozzle (foam branch pipes). Use of non-air-aspirating foam nozzles (on both monitors and the additional hose reel) is permitted only where foam monitors with a flow rate above 1000 l/min are installed. If only portable foam applicators or hose reel stations are provided, these shall be equipped with an air-aspirating handline nozzle (foam branch pipes).*

NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part D
Service Notations

Chapter 1	Ro-Ro Cargo Ships and Pure Car and/or Truck Carriers
Chapter 2	Container Ships
Chapter 3	Livestock Carriers
Chapter 4	Bulk Carriers
Chapter 5	Ore Carriers
Chapter 6	Combination Carriers
Chapter 7	Oil Tankers and FLS Tankers
Chapter 8	Chemical Tankers
Chapter 9	Liquefied Gas Carriers
Chapter 10	Tankers
Chapter 11	Passenger Ships
Chapter 12	Ro-Ro Passenger Ships
Chapter 13	Ships for Dredging Activity
Chapter 14	Non-Propelled Units
Chapter 15	Fishing Vessels
Chapter 16	Offshore Patrol Vessels
Chapter 17	Cement Carriers

July 2025

Table of Content

Chapter 1 Ro-Ro Cargo Ships and Pure Car and/or Truck Carriers

Section 1 General

1 Application 44

1.1

Section 2 Hull and Stability

1 General 45

1.1 Application
1.2 Documents to be submitted

2 Stability 45

2.1 Damage stability requirements for ship where additional class notation SDS is required

3 Structure design principles 45

3.1 Wood sheathing

4 Design loads 45

4.1 Load combinations for direct strength analysis

5 Global strength 45

5.1 Hull girder strength
5.2 Global transverse strength

6 Construction and testing 46

6.1 Special structural details

Section 3 Machinery and Systems

1 Scuppers and sanitary discharges 47

1.1 Drainage of ro-ro cargo spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion

Section 4 Electrical Installations

1 General 48

1.1 Applicable requirements
1.2 Documentation to be submitted
1.3 Safety characteristics

2 Installation 49

2.1 Installations in closed ro-ro cargo spaces
2.2 Installations in cargo spaces other than ro-ro cargo spaces but intended for the carriage of motor vehicles

3 Type approved components 49

3.1

Chapter 2 Container Ships

Section 1 General

1 General 51

1.1 Application
1.2 Definition

Table of Content

Section 2 Hull and Stability

1 General 52

1.1 Application
1.2 Documentation and information

2 Stability 53

2.1 Intact stability
2.2 Damage stability requirements for ships where the additional class notation SDS is required

3 Structure design principles 54

3.1 Ship structure
3.2 Material
3.3 Net scantling approach
3.4 Strength principles
3.5 Bottom structure
3.6 Deck structure
3.7 Bulkheads

4 Design loads 58

4.1 Still water hull girder loads
4.2 Dynamic hull girder loads

5 Load combinations for direct strength analysis based on partial three-dimensional model 61

5.1 General
5.2 Container weight
5.3 Loading conditions for cargo holds strength check
5.4 Loading conditions for fuel oil tanks
5.5 Load cases

6 Load combinations for direct strength analysis based on full length model 66

6.1 Loading condition
6.2 Load cases

7 Hull girder strength assessment 67

7.1 Section modulus and moment of inertia

8 Cargo hold structural strength analysis 67

8.1 General

9 Buckling 67

9.1 Load cases

10 Fatigue 68

10.1 Corrosion model
10.2 Design loading condition for fatigue assessment

11 Fixed cell guides 69

11.1 General
11.2 Arrangement of fixed cell guides
11.3 Strength criteria

12 Lashing bridge 70

12.1 General
12.2 Design load
12.3 Strength assessment

13 Lashing items 71

13.1 Fixed and portable container securing fittings
13.2 Lashing software

Table of Content

Section 3 Machinery and Systems

1 Open-top container ships 72

1.1

Section 4 Whipping and Springing Assessment

1 General 73

1.1 Application
1.2 Definitions
1.3 Data and documentation to be submitted

2 Loading conditions 73

2.1 General
2.2 Additional loading conditions

3 Linear spectral fatigue assessment 74

3.1 General
3.2 Ship operational profile
3.3 Fatigue computation
3.4 Criteria

4 Ultimate strength assessment 75

4.1 General
4.2 Ship operational profile
4.3 Computation of extreme vertical bending moment
4.4 Criteria

5 Non-linear fatigue assessment 76

5.1 General
5.2 Ship operational profile
5.3 Fatigue computation
5.4 Criteria

Appendix 1 Methodology for Long Term Direct Hydro-Structure Calculations including Whipping and Springing Response

1 General 78

1.1 Introduction

2 Operating conditions 78

2.1 Wave environment

3 Ship hydro-structural model 81

3.1 General
3.2 Finite elements modeling
3.3 Hydrodynamic loads
3.4 Structural ship response
3.5 General modeling considerations
3.6 Type of simulations
3.7 Statistical analysis of ship response in an irregular sea state

4 Extreme response and fatigue damage computation 86

4.1 Extreme response
4.2 Fatigue damage

5 Long term analysis methods 89

5.1 General
5.2 Fully long-term analysis
5.3 Design Sea States Approach
5.4 Single Design Sea State

Chapter 3 Livestock Carriers

Section 1 General

1 General 92

1.1 Application
1.2 Summary table

Section 2 Hull and Stability

1 General 93

1.1 Documents to be submitted

2 General arrangement 93

2.1 Livestock arrangement
2.2 Arrangement of spaces dedicated to the carriage of livestock
2.3 Means of escape and access

3 Stability 94

3.1 Intact stability

4 Design loads 94

4.1 Local loads
4.2 Load combinations for direct strength analysis

5 Hull girder strength 94

5.1 Application
5.2 Global transverse strength

6 Hull scantlings 95

6.1 Scantlings of plating, ordinary stiffeners and primary supporting members

Section 3 Systems serving Livestock Spaces

1 General 96

1.1 Application
1.2 Documents to be submitted

2 Design of the systems 96

2.1 General
2.2 Ventilation system
2.3 Fodder and fresh water systems
2.4 Washing system
2.5 Drainage system
2.6 Lighting system

Section 4 Fire-Fighting Systems in Livestock Spaces

1 General 98

1.1 Application
1.2 Documents to be submitted

2 Fire-fighting appliances 98

2.1 Fire hoses
2.2 Additional fire-fighting means

Table of Content

Chapter 4 Bulk Carriers

Section 1 General

1 General 100

1.1 Application

Section 2 Ship Arrangement

1 General arrangement design 101

1.1 General

2 Access arrangement 101

2.1 Access arrangement to double bottom and pipe tunnel
2.2 Access arrangement to and within spaces in, and forward of, the cargo area

Section 3 Hull and Stability

1 Stability 103

1.1 Definitions
1.2 Intact stability
1.3 Damage stability requirements for ships where additional class notation SDS is required

2 Structure design principles 105

2.1 Double bottom structure
2.2 Single side structure
2.3 Double side structure
2.4 Deck structure

3 Design loads 108

3.1 Loading conditions for longitudinal strength assessment
3.2 Hull girder loads in flooded conditions
3.3 Load combinations for direct strength analysis

4 Hull girder strength 110

4.1 Hull girder yield strength in flooded conditions

5 Hull scantlings of bulk carriers 110

5.1 Plating
5.2 Ordinary stiffeners
5.3 Buckling check in flooded conditions

6 Protection of hull metallic structures 111

6.1 Protection of cargo holds

7 Construction and testing 113

7.1 Welding and weld connections
7.2 Special structural details

Appendix 1 Intact Stability Criteria for Grain Loading

1 Calculation of assumed heeling moments due to cargo shifting 114

1.1 Stowage of bulk grain
1.2 General assumptions
1.3 Assumed volumetric heeling moment of a filled compartment trimmed
1.4 Assumed volumetric heeling moment of a filled compartment untrimmed
1.5 Assumed volumetric heeling moments in trunks
1.6 Assumed volumetric heeling moment of a partly filled compartment
1.7 Other assumptions
1.8 Saucers
1.9 Overstowing arrangements and securing

2 Dispensation from trimming ends of holds in certain ships 121
2.1 Calculation example

Appendix 2 Hold Mass Curves

1 General 127
1.1 Application
2 Hold mass curves 128
2.1 General

Chapter 5 Ore Carriers

Section 1 General

1 General 137
1.1 Application

Section 2 Ship Arrangement

1 General 138
1.1 Application
2 General arrangement design 138
2.1 General
3 Access arrangement 139
3.1 Access arrangement to double bottom and pipe tunnel
3.2 Access arrangement to and within spaces in, and forward of, the cargo area

Section 3 Hull and Stability

1 General 140
1.1 Loading manual and loading instruments
2 Stability 140
2.1 Intact stability
2.2 Damage stability requirements for ships where additional class notation SDS has been required
3 Structure design principles 140
3.1 Double bottom structure
3.2 Side structure
3.3 Deck structure
3.4 Longitudinal bulkhead structure
3.5 Transverse bulkhead structure
4 Design loads 141
4.1 Hull girder loads
4.2 Load combinations for direct strength analysis
5 Hull scantlings 142
5.1 Corrosion addition
5.2 Additional requirements
6 Construction and testing 142
6.1 Welding and weld connections
6.2 Special structural details

Chapter 6 Combination Carriers

Section 1 General

1 General 144

1.1 Application

Section 2 Ship Arrangement

1 General arrangement design 145

1.1 General
1.2 Double bottom tanks or compartments
1.3 Navigation position

2 Size and arrangement of cargo tanks and slop tanks 148

2.1 Cargo tanks
2.2 Oil outflow
2.3 Slop tanks

3 Size and arrangement of protective ballast tanks or compartments 150

3.1 General
3.2 Size and arrangement of ballast tanks or compartments

4 Size and arrangement of segregated ballast tanks (SBT) 151

4.1 General
4.2 Capacity of SBT

5 Access arrangement 151

5.1 Access to double bottom and pipe tunnel
5.2 Access arrangement to and within spaces in, and forward of, the cargo area
5.3 Access to dry cargo holds
5.4 Access to compartments in the oil cargo area
5.5 Access to the bow

Section 3 Hull and Stability

1 General 154

1.1 Loading manual and loading instrument

2 Stability 154

2.1 Intact stability
2.2 Damage stability - dry cargoes or ballast loading conditions - for ships where additional class notation SDS is requested
2.3 Damage stability - oil cargoes - for ships where additional class notation SDS is requested

3 Structure design principles of ships with the service notation combination carrier / OBO ESP 157

3.1 Double bottom structure
3.2 Double side structure
3.3 Deck structure

4 Structure design principles of ships with the service notation combination carrier / OOC ESP 158

4.1 Double bottom structure
4.2 Side structure
4.3 Deck structure
4.4 Longitudinal bulkhead structure
4.5 Transverse bulkhead structure

5 Design loads 159

5.1 Loading conditions for longitudinal strength assessment
5.2 Load combinations for direct strength analysis
5.3 Local loads

6 Hull scantlings 159
6.1 Strength check with respect to stresses due to the temperature gradient
7 Other structures 160
7.1 Machinery space
7.2 Opening arrangement
8 Hull outfitting 160
8.1 Equipment
9 Protection of hull metallic structures 160
9.1 Protection by aluminium coatings
10 Cathodic protection of tanks 160
10.1 General
10.2 Anodes
10.3 Impressed current systems
11 Construction and testing 161
11.1 Welding and weld connections
11.2 Special structural details

Section 4 Machinery and Cargo Systems
1 General 162
1.1 Application
1.2 Documents
2 General requirements 162
2.1 Ventilation and gas detection
2.2 Arrangement of cargo lines
2.3 Cargo openings
2.4 Cofferdam filling and draining
3 Slop tanks 163
3.1 Segregation of piping systems
3.2 Venting system
3.3 Discharge pumping and piping arrangement

Chapter 7 Oil Tankers and FLS Tankers

Section 1 General
1 General 165
1.1 Application
1.2 Specific requirements
1.3 Definitions

Section 2 Ship Arrangement
1 General 168
1.1 Application
1.2 Documents to be submitted
2 General arrangement of the ship with regard to fire prevention and crew safety 168
2.1 Location and separation of spaces
2.2 Access and openings
2.3 Ventilation

Table of Content

3 General arrangement of the ship with regard to pollution prevention 173

3.1 Application
3.2 Protection of the cargo tank length in the event of grounding or collision
3.3 Segregation of oil and water ballast
3.4 Accidental oil outflow performance
3.5 Cleaning of cargo tanks
3.6 Retention of oil on board - Slop tanks
3.7 Deck spills
3.8 Pump-room bottom protection

4 Structural arrangement of asphalt carrier independent tanks and supports 178

4.1 Supports
4.2 Inspectability of the cargo area

Section 3 Hull and Stability

1 General 182

1.1 Documents to be submitted

2 Stability 182

2.1 Application
2.2 Intact stability
2.3 Damage stability for ships where the additional class notation SDS is required

3 Structure design principles 185

3.1 Framing arrangement
3.2 Bulkhead structural arrangement

4 Design loads 185

4.1 Loading conditions for longitudinal strength assessment
4.2 Local loads
4.3 Load combinations for direct strength analysis

5 Hull scantlings 186

5.1 Strength check with respect to stresses due to the temperature gradient
5.2 Hull girder stress for independent tanks structures

6 Scantlings of independent tanks structures 187

6.1 Plating
6.2 Ordinary stiffeners
6.3 Primary supporting members

7 Supports of independent tanks 187

7.1 General
7.2 Vertical supports
7.3 Antirolling keys
7.4 Antipitching keys
7.5 Anticollision keys
7.6 Antiflotation keys
7.7 Yielding criteria

8 Independent tanks direct strength analysis 189

8.1 General
8.2 Three cargo holds model

9 Other structures 190

9.1 Machinery space
9.2 Opening arrangement

10 Hull outfitting 190

10.1 Equipment

11 Protection of hull metallic structures 190

11.1 Protection by aluminium coatings
11.2 Material and coatings of tanks

Table of Content

12 Cathodic protection of tanks 190

12.1 General
12.2 Anodes
12.3 Impressed current systems

13 Construction and testing 191

13.1 Welding and weld connections
13.2 Special structural details

Section 4 Machinery and Cargo Systems

1 General 193

1.1 Application
1.2 Documents to be submitted
1.3 Abbreviations

2 Piping systems other than cargo piping system 195

2.1 General
2.2 Bilge system
2.3 Ballast system
2.4 Air and sounding pipes of spaces other than cargo tanks
2.5 Scupper pipes
2.6 Heating systems intended for cargo
2.7 Use of crude oil as fuel

3 Cargo pumping and piping systems 199

3.1 General
3.2 Cargo pumping system
3.3 Cargo piping design
3.4 Cargo piping arrangement and installation
3.5 Arrangement of cargo pump rooms
3.6 Design of integrated cargo and ballast systems on tankers

4 Cargo tanks and fittings 204

4.1 Application
4.2 Cargo tank venting
4.3 Cargo tank inerting, purging and/or gas-freeing
4.4 Cargo tank level gauging systems
4.5 Protection against tank overfilling
4.6 Tank washing systems

5 Prevention of pollution by cargo oil 209

5.1 General
5.2 Discharge into the sea of cargo oil or oily mixtures
5.3 Oil discharge monitoring and control system
5.4 Pumping, piping and discharge arrangements

6 Certification, inspection and testing 211

6.1 Application
6.2 Workshop tests
6.3 Shipboard tests

7 Steering gear 213

7.1 General
7.2 Design of the steering gear
7.3 Alternative design for ships of less than 100 000 tonnes deadweight

8 Additional requirements for ships assigned the additional service feature asphalt carrier 215

8.1 Application
8.2 Additional requirements

9 Specific requirements for ships having the notations “FLS tanker” or “FLS tanker, flash point > 60°C” 215

9.1 Application
9.2 Design requirements

Section 5 Electrical Installations

1 General 217

1.1 Application
1.2 Documentation to be submitted
1.3 System of supply
1.4 Earth detection
1.5 Mechanical ventilation of hazardous spaces
1.6 Electrical installation precautions

2 Hazardous locations and types of equipment 218

2.1 Special requirements for oil tankers carrying flammable liquids having a flash point not exceeding 60°C and for oil tankers carrying flammable liquids having a flash point exceeding 60°C heated to a temperature within 15°C of their flash point or above their flash point
2.2 Special requirements for oil tankers carrying flammable liquids having a flash point exceeding 60°C unheated or heated to a temperature below and not within 15°C of their flash point
2.3 Special requirements for FLS tankers

Section 6 Fire Protection

1 General 220

1.1 Application
1.2 Documents to be submitted

2 General requirements 220

2.1 Sources of ignition
2.2 Electrical equipment
2.3 Pipe trunk

3 Fixed deck foam system 221

3.1 Application
3.2 System design
3.3 Arrangement and installation

4 Fire-extinguishing systems except deck foam system 223

4.1 Pressure water fire-extinguishing systems
4.2 Fire-extinguishing systems for cargo pump rooms

5 Inert gas systems 223

5.1 Application
5.2 General requirements
5.3 Additional requirements for nitrogen generator systems
5.4 Nitrogen/inert gas systems fitted for purposes other than inerting required by [5.1.1]

6 Fixed hydrocarbon gas detection systems 225

6.1 Engineering specifications

7 Gas measurement and detection 226

7.1 Provisions applicable to all ships
7.2 Additional provisions for ships having the service notation oil tanker or FLS tanker
7.3 Additional provisions for ships fitted with an inert gas system
7.4 Provisions for installation of gas analysing units

Table of Content

Appendix 1 Devices to Prevent the Passage of Flame into the Cargo Tanks

1 General 228

1.1 Application
1.2 Definitions
1.3 Instruction manual

2 Design of the devices 229

2.1 Principles
2.2 Mechanical design
2.3 Performance
2.4 Flame screens
2.5 Marking of devices

3 Sizing, location and installation of devices 231

3.1 Sizing of devices
3.2 Location and installation of devices

4 Type test procedures 231

4.1 Principles
4.2 Test procedure for flame arresters located at openings to the atmosphere
4.3 Test procedures for high velocity vents
4.4 Test rig and test procedures for detonation flame arresters located in-line
4.5 Operational test procedure
4.6 Laboratory report

Appendix 2 Design of Crude Oil Washing Systems

1 General 236

1.1 Application
1.2 Definitions
1.3 Operations and Equipment Manual

2 Design and installation 236

2.1 Piping
2.2 Tank washing machines
2.3 Pumps
2.4 Stripping system
2.5 Ballast lines

3 Inspection and testing 239

3.1 Initial survey
3.2 Piping
3.3 Tank washing machines
3.4 Stripping system

Appendix 3 Lists of Oils

1 Application 240

1.1 Scope of the lists of oils

2 Lists of products 240

2.1 List of oils

Appendix 4 List of Products for which Part D, Chapter 8 and IBC Code do not Apply

1 Application 241

1.1 Scope of the list
1.2 Safety and pollution hazards

2 List of products for which Part D, Chapter 8 and IBC Code do not apply 241

2.1

Table of Content

Appendix 5 Accidental Oil Outflow Performance

1 General 243

1.1 Purpose
1.2 Application

2 Accidental oil outflow performance 243

2.1 Mean oil outflow parameter
2.2 Calculation

3 Piping arrangements 247

3.1 Provision regarding piping arrangements

Chapter 8 Chemical Tankers

Section 1 General

1 General 249

1.1 Application
1.2 IBC Code requirements and the Society's rules
1.3 Definitions

2 Additional requirements 250

2.1 Ships assigned the additional service feature IPxxx or IPxxx-capable
2.2 Emergency towing arrangement
2.3 Steering gear

3 Documentation to be submitted 250

3.1

Section 2 Ship Survival Capability and Location of Cargo Tanks

1 Freeboard and intact stability 252

1.1 Intact stability

2 Conditions of loading 252

2.1 Additional loading conditions for ships where additional class notation SDS is requested

3 Location of cargo tanks 252

3.1 Minimum distance of cargo tanks from shell
3.2 Suction wells

4 Flooding assumptions for ships where additional class notation SDS is requested 252

4.1 Tunnels, ducts and pipes in the damaged zone

5 Standard of damage for ships where additional class notation SDS is requested 253

5.1 Damage to stepped machinery space forward bulkhead
5.2 Longitudinal extension of damage to superstructure

6 Survival requirements for ships where additional class notation SDS is requested 253

6.1 General
6.2 Intermediate stages of flooding
6.3 Definition of range of positive stability
6.4 Survival criterion
6.5 Type 3 ships less than 125 m in length

Table of Content

Section 3 Ship Arrangement

1 Cargo segregation 255

1.1 Segregation of cargoes mutually reacting
1.2 Cargo piping arrangement

2 Accommodation, service and machinery spaces and control stations 256

2.1 Location of paint lockers
2.2 Air intakes and other openings to accommodation spaces
2.3 Windows, sidescuttles and doors to accommodation spaces
2.4 Safe access to the bow

3 Cargo pump rooms 257

3.1 General requirement
3.2 Machinery driven by shafting passing through pump room bulkheads

4 Access to spaces in the cargo area 257

4.1 General
4.2 Horizontal openings
4.3 Vertical openings

5 Bilge and ballast arrangements 258

5.1 Ballast segregation
5.2 Ballast filling arrangement
5.3 Bilge

6 Integrated cargo and ballast systems 259

6.1

7 Bow or stern loading and unloading arrangements 259

7.1 Coamings

Section 4 Cargo Containment

1 General 260

1.1 Application

2 Structure design principles 260

2.1 Materials
2.2 Hull structure
2.3 Bulkhead structure

3 Hull girder loads 261

3.1 Still water loads
3.2 Load combinations for direct strength analysis

4 Hull scantlings 261

4.1 Plating

5 Scantlings of independent tank structures 262

5.1 General

6 Supports of independent tanks 262

6.1 General

7 Other structures 262

7.1 Machinery space

8 Protection of hull metallic structures 262

8.1 Aluminium coatings
8.2 Passivation treatment

9 Construction and testing 262

9.1 Welding and weld connections
9.2 Structural details

Table of Content

Section 5 Cargo Transfer

1 Piping scantlings 264

1.1 General
1.2 Pipe classes
1.3 Pipe wall thickness calculation

2 Piping fabrication and joining details 265

2.1 Pipes not required to be joined by welding
2.2 Expansion joints
2.3 Non-destructive testing of welded joints

3 Piping arrangements 265

3.1 Arrangement of cargo piping
3.2 Removable piping systems

4 Cargo transfer control systems 266

4.1 General
4.2 Control, monitoring and alarm devices and cargo control room

5 Ship's cargo hoses 266

5.1 Compatibility

6 Bonding 266

6.1 Static electricity

7 Certification, inspection and testing 267

7.1 Application
7.2 Inspection and testing
7.3 Shipboard tests

Section 6 Materials for Construction

1 General 269

1.1 Material and coating characteristics

2 Special requirements for materials 269

2.1 Miscellaneous requirements

Section 7 Cargo Temperature Control

1 General 270

1.1 Heated cargoes
1.2 Cargo heating and cooling systems
1.3 Valves and other fittings
1.4 Cargo temperature measuring system
1.5 Requirements for special products

Section 8 Cargo Tank Venting and Gas-Freeing Arrangements

1 Cargo tank venting 272

1.1 Venting system drainage

2 Types of tank venting system 272

2.1 Controlled tank venting system
2.2 Position of vent outlets

3 Cargo tank gas-freeing 272

3.1 Fans

Table of Content

Section 9 Environmental Control

1 General 273

1.1 Control by padding
1.2 Control by drying
1.3 Control by inerting
1.4 Control by ventilation

2 Inert gas systems 274

2.1 General requirements
2.2 Additional requirements for nitrogen generator systems
2.3 Nitrogen /Inert gas systems fitted for purposes other than inerting required by [1.3.1]

Section 10 Electrical Installations

1 General 276

1.1 Application
1.2 Documentation to be submitted
1.3 System of supply
1.4 Earth detection
1.5 Mechanical ventilation of hazardous spaces
1.6 Electrical installation precautions

2 Hazardous locations and types of equipment 277

2.1 Electrical equipment permitted in hazardous areas for ships carrying dangerous chemicals in bulk having a flash-point not exceeding 60°C and ships carrying dangerous chemicals in bulk having a flash point exceeding 60°C heated to a temperature within 15°C of their flash point or above their flashpoint
2.2 Electrical equipment permitted in hazardous areas for ships carrying dangerous chemicals in bulk having a flash-point exceeding 60°C unheated or heated to a temperature below and not within 15°C of their flashpoint
2.3 Electrical equipment permitted in tankers carrying cargoes (for example acids) reacting with other products/materials to evolve flammable gases

Section 11 Fire Protection and Fire Extinction

1 General 280

1.1 Application

2 Cargo pump rooms 280

2.1 Fixed fire-extinguishing systems

3 Cargo area 280

3.1 Temperature of steam and heating media within the cargo area
3.2 Monitors and foam applicators
3.3 Simultaneous use of foam and water systems
3.4 Portable fire-extinguishing equipment
3.5 Ships carrying flammable products

Section 12 Mechanical Ventilation in the Cargo Area

1 Spaces normally entered during cargo handling operations 282

1.1 Miscellaneous requirements
1.2 Additional requirements for non-sparking fans

2 Pump rooms and other enclosed spaces normally entered 283

2.1 Clarification of general requirement

3 Spaces not normally entered 284

3.1 Portable fans

Section 13 Instrumentation

1 Gauging 285

1.1 Types of gauging devices

Table of Content

2 Vapour detection 285

2.1 Vapour detection instruments
2.2 Provisions for installation of gas analysing units

Section 14 Protection of Personnel

1 Protective equipment 286

1.1 Location of protective equipment

2 Safety equipment 286

2.1 Additional equipment for ships carrying toxic products
2.2 Medical first aid equipment

Section 15 Special Requirements

1 Ammonium nitrate solution (93% or less) 287

1.1 Ammonia injection
1.2 Cargo pumps

2 Hydrogen peroxide solutions 287

2.1 Hydrogen peroxide solutions over 60% but not over 70%

3 Propylene oxide and mixtures of ethylene oxide/propylene oxide with an ethylene oxide content of not more than 30% by weight 287

3.1 Tank cleaning
3.2 Joints in cargo lines
3.3 Oxygen content in tank vapour spaces
3.4 Valves at cargo hose connections

4 Acids 288

4.1 Electrical arrangements
4.2 Leak detection system
4.3 Lining for tanks and piping

5 Toxic products 288

5.1 Position of tank vent outlets
5.2 Return line to shore installation

6 Cargoes protected by additives 289

6.1 Prevention of blockage by polymerisation

7 Cargoes with a vapour pressure greater than 0,1013 MPa (1,013 bar) absolute at 37,8°C 289

7.1 General
7.2 Return of expelled gases

8 Special cargo pump room requirements 289

8.1 Clarification

9 Overflow control 289

9.1 Independence of systems

Section 16 Operational Requirements

1 General 291

1.1

Section 17 Summary of Minimum Requirements

1 General 292

1.1

Section 18 List of Chemicals to which this Chapter Does Not Apply
1 General 293
1.1

Section 19 Index of Products Carried In Bulk
1 General 294
1.1

Section 20 Transport of Liquid Chemical Wastes
1 General 295
1.1

Section 21 Criteria for Assigning Carriage Requirements for Products Subject to the IBC Code
1 General 296
1.1

Chapter 9 Liquefied Gas Carriers

Section 1 General
1 General 299
1.1 Application
1.2 IGC Code requirements or other IMO Circulars and the Society's Rules
2 Application and implementation 300
2.1
3 Additional requirements 301
3.1 Emergency towing arrangement
3.2 Steering gear
3.3 Ships assigned the additional service feature IPxxx or IPxxx-capable
4 Definitions 302
4.1
5 Documentation to be submitted 304
5.1
6 Cargo equipment trials 306
6.1 Scope
6.2 Extent of the tests
7 Additional service features BOG-reliquefaction and subcooling 307
7.1 General
8 Additional service feature STL-SPM 307
8.1 General
8.2 Documentation to be submitted
8.3 Structural design
8.4 Mechanical installation
8.5 Electrical and automation installation

Section 2 Ship Survival Capability and Location of Cargo Tanks
1 General 310
1.1

2 Freeboard and stability 310
2.1 General
3 Damage assumptions 311
3.1 General
3.2 Other damage
4 Location of cargo tanks 312
4.1 General
5 Flood assumptions 317
5.1 General
6 Standard of damage 318
6.1 General
7 Survival requirements 318
7.1 General

Section 3 Ship Arrangement
1 General 320
1.1 Segregation of the cargo area
1.2 Accommodation, service and machinery spaces and control stations
1.3 Cargo machinery spaces and turret compartments
1.4 Cargo control rooms
1.5 Access to spaces in the cargo area
1.6 Airlocks
1.7 Bilge, ballast and oil fuel arrangements
1.8 Bow and stern loading and unloading arrangements
1.9 Emergency towing arrangements

Section 4 Cargo Containment
1 General 329
1.1 Scope
1.2 Definitions
1.3 Application
2 Cargo containment 330
2.1 Functional requirement
2.2 Cargo containment safety principles
2.3 Secondary barriers in relation to tank types
2.4 Design of secondary barriers
2.5 Partial secondary barriers and primary barrier small leak protection system
2.6 Supporting arrangements
2.7 Associated structure and equipment
2.8 Thermal insulation
2.9 Use of cargo heater to raise the cargo temperature
3 Design loads 333
3.1 General
3.2 Permanent loads
3.3 Functional loads
3.4 Environmental loads
3.5 Accidental loads
4 Structural integrity 337
4.1 General
4.2 Structural analyses
4.3 Stress categories
4.4 Design conditions
4.5 Ultimate design condition
4.6 Fatigue design condition
4.7 Accident design condition

Table of Content

5 Materials 341

5.1 General
5.2 Materials forming ship structure
5.3 Materials of primary and secondary barrier
5.4 Thermal insulation and other materials used in cargo containment systems

6 Construction processes 343

6.1 General
6.2 Weld joint design
6.3 Design for gluing and other joining processes
6.4 Testing

7 Supports 345

7.1 Supporting arrangement
7.2 Calculation of reaction forces in way of tank supports
7.3 Checking criteria
7.4 Supports of independent tanks of type A and type B primarily constructed of plane surfaces
7.5 Supports of independent tanks of type B primarily constructed of bodies of revolution
7.6 Supports of type C independent tanks

8 Type A independent tanks 347

8.1 Design basis
8.2 Structural analyses
8.3 Ultimate design condition
8.4 Accident design conditions
8.5 Testing

9 Type B independent tanks 350

9.1 Design basis
9.2 Structural analyses
9.3 Ultimate design condition
9.4 Fatigue design condition
9.5 Accident design condition
9.6 Testing
9.7 Marking

10 Type C independent tanks 356

10.1 Design basis
10.2 Shell thickness
10.3 Ultimate design condition
10.4 Fatigue design condition
10.5 Accident design condition
10.6 Testing
10.7 Marking

11 Membrane tanks 360

11.1 Design Basis
11.2 Design consideration
11.3 Loads and loads combinations
11.4 Structural analysis
11.5 Structural details
11.6 Ultimate design condition
11.7 Fatigue design condition
11.8 Accident design condition
11.9 Design development testing
11.10 Testing
11.11 Certification of materials and products

12 Integral tanks 364

12.1 Design basis
12.2 Structural analysis
12.3 Ultimate design condition
12.4 Accident design condition
12.5 Testing

13	Semi-membrane tanks	365
	13.1 Design basis 13.2 Testing	
14	Cargo containment systems of novel configuration	365
	14.1 Limit state design for novel concepts	

Section 5 Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems

1	General	366
	1.1	
2	System requirements	366
	2.1 2.2 Arrangements: General	
3	Arrangements for cargo piping outside the cargo area	367
	3.1 Emergency cargo jettisoning 3.2 Bow and stern loading arrangements 3.3 Turret compartment transfer systems 3.4 Gas fuel piping systems	
4	Design pressure	367
	4.1	
5	Cargo system valve requirements	368
	5.1 5.2 Cargo manifold connections 5.3	
6	Cargo transfer arrangements	369
	6.1 General 6.2 Vapour return connections 6.3 Cargo tank vent piping systems 6.4 Cargo sampling connections 6.5 Cargo filters	
7	Installation requirements	370
	7.1 Design for expansion and contraction 7.2 Precautions against low temperature 7.3 Water curtain 7.4 Bonding	
8	Piping fabrication and joining details	371
	8.1 General 8.2 Direct connections 8.3 Flanged connections 8.4 Expansion joints 8.5 Other connections	
9	Welding, post-weld heat treatment and non-destructive testing	371
	9.1 General 9.2 Post-weld heat treatment 9.3 Non-destructive testing	
10	Installation requirements for cargo piping outside the cargo area	372
	10.1 Bow and stern loading arrangements 10.2 Turret compartment transfer systems 10.3 Gas fuel piping	

11 Piping system component requirements 372

11.1 General
11.2 Piping scantlings
11.3 Allowable stress
11.4 High-pressure gas fuel outer pipes or ducting scantlings
11.5 Stress analysis
11.6 Flanges, valves and fittings
11.7 Ship's cargo hoses

12 Materials 376

12.1

13 Testing requirements 376

13.1 General
13.2 Cargo pumps and gas/reliquefaction/refrigeration compressors
13.3 Type testing of valves
13.4 Type testing of expansion bellows
13.5 System testing requirements
13.6 Emergency shutdown valves

Section 6 Materials of Construction and Quality Control

1 Definitions 381

1.1

2 Scope and general requirements 381

2.1

3 General test requirements and specifications 381

3.1 Tensile test
3.2 Toughness test
3.3 Bend test
3.4 Section observation and other testing

4 Requirements for metallic materials 383

4.1 General requirements for metallic materials

5 Welding of metallic materials and non-destructive testing 388

5.1 General
5.2 Welding consumables
5.3 Welding procedure tests for cargo tanks and process pressure vessels
5.4 Welding procedure tests for piping
5.5 Production weld tests
5.6 Non-destructive testing

6 Other requirements for construction in metallic materials 390

6.1 General
6.2 Independent tank
6.3 Secondary barriers
6.4 Semi-membrane tanks
6.5 Membrane tanks

7 Non-metallic materials 391

7.1 General

Section 7 Cargo Pressure / Temperature Control

1 Methods of control 392

1.1 General

2 Design of systems 392

2.1 General

3 Reliquefaction of cargo vapours 392

3.1
3.2 Refrigerating installation components
3.3 Refrigerants

4 Thermal oxidation of vapours 393

4.1 General
4.2 Thermal oxidation systems
4.3 Burners
4.4 Safety

5 Pressure accumulation systems 394

5.1 General

6 Liquid cargo cooling 394

6.1 General

7 Segregation 394

7.1 General

8 Availability 394

8.1 General

Section 8 Vent Systems for Cargo Containment

1 General 396

1.1

2 Pressure relief systems 396

2.1 General

3 Vacuum protection systems 399

3.1 General

4 Sizing of pressure relieving system 399

4.1 Sizing of pressure relief valves
4.2 Sizing of vent pipe system
4.3 Upstream pressure losses
4.4 Downstream pressure losses
4.5 Blow-down

Section 9 Cargo Containment System Atmosphere Control

1 General 402

1.1 Atmosphere control within the cargo containment system
1.2 Atmosphere control within the hold spaces (cargo containment systems other than type C independent tanks)
1.3 Environmental control of spaces surrounding type C independent tanks
1.4 Inerting
1.5 Inert gas production on board
1.6 Engineering specifications for nitrogen / inert gas systems

Section 10 Electrical Installations

1 General 405

1.1 Application
1.2 Documentation to be submitted
1.3 Definitions
1.4 General requirements
1.5 System of supply
1.6 Earth detection
1.7 Mechanical ventilation of hazardous spaces

Table of Content

2 Hazardous locations and types of equipment 408

2.1 Electrical equipment permitted in gas-dangerous spaces and zones
2.2 Submerged cargo pumps

3 Product classification 408

3.1 Temperature class and explosion group

Section 11 Fire Protection and Extinction

1 General 410

1.1 Fire safety requirements
1.2 Fire mains and hydrants
1.3 Water-spray system
1.4 Dry chemical powder fire-extinguishing systems
1.5 Enclosed spaces containing cargo handling equipment
1.6 Firefighter's outfits

Section 12 Artificial Ventilation in the Cargo Area

1 General 415

1.1 Scope
1.2 Spaces required to be entered during normal cargo handling operations
1.3 Spaces not normally entered

Section 13 Instrumentation and Automation Systems

1 General 417

1.1

2 Level indicators for cargo tanks 418

2.1 General

3 Overflow control 418

3.1 General

4 Pressure monitoring 419

4.1 General

5 Temperature indicating devices 419

5.1 General

6 Gas detection 419

6.1 General

7 Additional requirements for containment systems requiring a secondary barrier 421

7.1 Integrity of barriers
7.2 Temperature indication devices

8 Automation systems 422

8.1 General

9 System integration 422

9.1 General

Section 14 Personnel Protection

1 General 423

1.1 Protective equipment
1.2 First-aid equipment
1.3 Safety equipment
1.4 Personal protection requirements for individual products

Table of Content

Section 15 Filling Limits for Cargo Tanks

1 General 425

1.1 Definitions
1.2 General requirements
1.3 Default filling limit
1.4 Determination of increased filling limit
1.5 Maximum loading unit
1.6 Information to be provided to the Master

Section 16 Use of Cargo as Fuel

1 General 427

1.1
1.2 Documentation to be submitted

2 Use of cargo vapour as fuel 427

2.1 General

3 Arrangement of spaces containing gas consumers 427

3.1 General

4 Gas fuel supply 428

4.1 General
4.2 Leak detection
4.3 Routeing of fuel supply pipes
4.4 Requirements for gas fuel supply with pressure greater than 1 MPa
4.5 Gas consumer isolation
4.6 Spaces containing gas consumers
4.7 Piping and ducting construction
4.8 Gas detection

5 Gas fuel plant and related storage tanks 431

5.1 Provision of gas fuel
5.2 Remote stops
5.3 Compressors
5.4 Heating and cooling mediums
5.5 Piping and pressure vessels

6 Special requirements for main boilers 432

6.1 Arrangements
6.2 Combustion equipment
6.3 Safety

7 Special requirements for gas-fired internal combustion engines 433

7.1 General
7.2 Gas fuel supply to engines with fuel injection pressure greater than 1 MPa
7.3 Shut-off of gas fuel supply with pressure greater than 1 MPa
7.4 Emergency stop of dual fuel engines with fuel injection pressure greater than 1 MPa
7.5 Requirements on dual fuel engines
7.6 Arrangements
7.7 Combustion equipment
7.8 Safety

8 Special requirements for gas turbine 434

8.1 Arrangements
8.2 Combustion equipment
8.3 Safety

9 Alternative fuels and technologies 435

9.1 General
9.2 Specific requirements for the use of LPG as fuel

Table of Content

Section 17 Special Requirements

1	General	437
	1.1 Application	
2	Materials of construction	437
	2.1 General	
3	Independent tanks	437
	3.1 General	
4	Refrigeration systems	437
	4.1 General	
5	Cargoes requiring type 1G ship	438
	5.1 General	
6	Exclusion of air from vapour spaces	438
	6.1 General	
7	Moisture control	438
	7.1 General	
8	Inhibition	438
	8.1 General	
9	Flame screens on vent outlets	439
	9.1 General	
10	Maximum allowable quantity of cargo per tank	439
	10.1 General	
11	Cargo pumps and discharge arrangements	439
	11.1 General	
12	Ammonia	439
	12.1 General	
13	Chlorine	440
	13.1 Cargo containment system 13.2 Cargo piping systems 13.3 Materials 13.4 Instrumentation: safety devices 13.5 Personnel protection 13.6 Filling limits for cargo tanks	
14	Ethylene oxide	441
	14.1 General	
15	Separate piping systems	442
	15.1 General	
16	Methyl acetylene-propadiene mixtures	442
	16.1 General	
17	Nitrogen	443
	17.1 General	
18	Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide content of not more than 30% by weight	443
	18.1 General	
19	Vinyl chloride	445
	19.1 General	

20 Mixed C4 cargoes 445
20.1 General
21 Carbon dioxide: high purity 445
21.1 General
22 Carbon dioxide: reclaimed quality 446
22.1 General

Section 18 Operating Requirements
1 General 447
1.1
2 Cargo operating manual 447
2.1 General
3 Cargo emergency shutdown (ESD) system 447
3.1 General
3.2 ESD valve requirements
3.3 ESD system controls
3.4 Additional shutdowns
3.5 Pre-operations testing
3.6 Testing

Section 19 Summary of Minimum Requirements
1 General 451
1.1 Explanatory notes to the summary of minimum requirements
2 Additional information on products 451
2.1

Section 20 Hull Scantling
1 General 455
1.1 Application
2 Flooding for ships with independent tanks 455
2.1 General
3 Finite element model 455
3.1 General
3.2 Structural modeling
3.3 Load combinations for direct strength analysis
3.4 Yielding strength criteria
3.5 Buckling check
4 Membrane tanks 457
4.1 General
4.2 Sloshing loads
4.3 Collision loads
5 Structural details 458
5.1 General
5.2 Connections of inner bottom with transverse cofferdam bulkheads

Section 21 Additional Requirements for Ship carrying Liquefied Hydrogen in Bulk
1 General 459
1.1 Application
1.2 Documentation to be submitted
1.3 Definitions

Table of Content

2 Safety assessment 460

2.1 Hazard identification and risk analysis

3 Cargo containment 461

3.1 General
3.2 Independent tanks using vaccum insulation
3.3 Independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces
3.4 Membrane tanks keeping insulation spaces under vacuum

4 Process pressure vessels and liquid, vapour and pressure piping systems 463

4.1 General
4.2 Design pressure

5 Materials 463

5.1 General

6 Vent systems for cargo containment 464

6.1 General

7 Cargo containment system atmosphere control 464

7.1 Inert gas production on board

8 Electrical installations 464

8.1 Temperature class and explosion group

9 Fire protection and extinction 464

9.1 Enclosed spaces containing cargo handling equipment
9.2 Fire detection

10 Artificial ventilation in the cargo area 465

10.1 Spaces required to be entered during normal cargo handling operations

11 Instrumentation and automation systems 465

11.1 Gas detection

12 Filling limits for cargo tanks 465

12.1 Default filling limit

13 Survey at work and certification 465

13.1 General
13.2 Valves

Appendix 1 Guidance for Calculation of Pressures and Accelerations

1 Guidance to detailed calculation of internal pressure for static design purpose 466

1.1 Calculation of dynamic liquid pressure
1.2 Calculation of acceleration components

2 Internal pressure for membrane tanks 470

2.1 General
2.2 Sloshing pressure and tank areas to be checked

3 Guidance for calculation of pressures for a static heel angle of 30° 471

3.1 Internal pressure calculation
3.2 Sea pressure calculation

4 Calculation of dynamic pressure for collision loads 472

4.1 General

Appendix 2 Correspondances between Pt D, Chapter 9 and IMO Circular MSC.1/Circ.1679

1 General 473

1.1

Appendix 3 Correspondances between Part D, Chapter 9 and the IGC Code
1 General 474
1.1

Chapter 10 Tankers

Section 1 General
1 General 484
1.1 Application

Section 2 Hull and Stability
1 General 485
1.1 Documents to be submitted
2 General arrangement 485
2.1 Compartment arrangement
3 Stability 485
3.1 Intact stability
4 Design loads 485
4.1 Loading conditions for longitudinal strength assessment
4.2 Load combinations for direct strength analysis
5 Hull scantlings 486
5.1 Strength check with respect to stresses due to the temperature gradient
6 Scantlings of independent tank structures 486
6.1 General
7 Supports of independent tanks 486
7.1 General
8 Other structures 486
8.1 Machinery space
9 Construction and testing 486
9.1 Special structural details

Section 3 Machinery and Cargo Systems
1 General 487
1.1 Documents to be submitted
2 Piping systems 487
2.1 General
2.2 Cargo piping and pumping
2.3 Air pipes
2.4 Refrigerating installations
2.5 Cargo tank cleaning systems
2.6 Additional requirements for ships carrying category Z substances

Chapter 11 Passenger Ships

Section 1 General

1 General 490

1.1 Application

Section 2 Ship Arrangement

1 General 491

1.1 Definitions

2 General arrangement design 491

2.1 Openings in watertight boundaries below the bulkhead deck
2.2 Openings in bulkheads above the bulkhead deck
2.3 Doors
2.4 Ballast compartment arrangement
2.5 Machinery compartment arrangement

Section 3 Hull and Stability

1 General 497

1.1 Documents to be submitted

2 Stability 497

2.1 Definitions
2.2 Intact stability
2.3 Damage stability for ships where SDS notation has been required

3 Structure design principles 502

3.1 Hull structure

4 Design loads 502

4.1 Loads on deck
4.2 Sea pressures

5 Hull girder strength 503

5.1 Basic criteria
5.2 Global transverse strength

6 Hull scantlings 503

6.1 Balcony doors

Section 4 Machinery and Cargo System

1 Bilge system 504

1.1 General
1.2 Bilge pumps
1.3 Direct bilge suction
1.4 Control location
1.5 Provision against bilge system damage
1.6 Drainage and pumping arrangements for vehicle, special category and ro-ro spaces protected by fixed pressure water-spraying systems

2 Ballast system 506

2.1

3 Miscellaneous requirements 506

3.1 Steering gear
3.2 Oil-level gauges
3.3 Watertight doors

Table of Content

Section 5 Electrical Installations

1 General 507

1.1 Documentation to be submitted
1.2 Electrical distribution and protection
1.3 Flooding detection systems for passenger ships carrying 36 or more persons

2 Emergency source of electrical power and emergency installations 507

2.1 General
2.2 Distribution of electrical power
2.3 Low-location lighting

3 General emergency alarm and public address systems 511

3.1 General emergency alarm system
3.2 Public address system
3.3 Combined general emergency alarm - public address system

4 Installation 513

4.1 Section and distribution boards

5 Type approved components 513

5.1

Appendix 1 Calculation Method for Cross-Flooding Arrangements

1 Calculation method for cross-flooding arrangements 514

1.1 Definitions
1.2 Cross-flooding area

Chapter 12 Ro-Ro Passenger Ships

Section 1 General

1 General 521

1.1 Application

Section 2 Ship Arrangement

1 General 522

1.1 Definitions

2 General arrangement design 522

2.1 Number and disposition of transverse watertight bulkheads
2.2 Openings in watertight boundaries below the bulkhead deck
2.3 Doors
2.4 Openings in bulkheads above the bulkhead deck
2.5 Integrity of the hull and superstructure, damage prevention and control
2.6 Ballast compartment arrangement
2.7 Machinery compartment arrangement
2.8 Passenger spaces in ro-ro ships

Section 3 Hull and Stability

1 General 529

1.1 Documents to be submitted

2 Stability 529

2.1 Definitions
2.2 Intact stability
2.3 Damage stability for ships where SDS notation has been required

3 Structure design principles 535
3.1 General
3.2 Hull structure
4 Design loads 535
4.1 Loads on deck
4.2 Lowest 0,5 m of bulkheads forming vertical division along escape routes
5 Hull girder strength 535
5.1 Basic criteria
5.2 Global transverse strength
6 Hull scantlings 535
6.1 Plating
6.2 Ordinary stiffeners
6.3 Primary supporting members
7 Other structures 536
7.1 Superstructures and deckhouses
8 Construction and testing 536
8.1 Special structural details

Section 4 Electrical Installations
1 General 537
1.1 Applicable requirements
1.2 Documentation to be submitted
1.3 Safety characteristics
1.4 Flooding detection systems for passenger ships carrying 36 or more persons
2 Supplementary emergency lighting 537
2.1
3 Installation 537
3.1 Installations in special category spaces situated above the bulkhead deck
3.2 Installations in special category spaces situated below the bulkhead deck
3.3 Installations in cargo spaces other than special category spaces intended for the carriage of motor vehicles
3.4 Protection of socket outlets in vehicle spaces
4 Type approved components 539
4.1

Chapter 13 Ships for Dredging Activity
Section 1 General
1 General 541
1.1 Application
1.2 Definitions
1.3 Documentation to be submitted

Section 2 Hull and Stability
1 Stability 543
1.1 Intact stability
1.2 Damage stability where the additional class notation SDS has been requested

Table of Content

2	Structure design principles	545
	2.1 General	
	2.2 Longitudinal members in the area of the hopper well	
	2.3 Transverse members in the area of the hopper well	
	2.4 Arrangements relating to suction pipes	
	2.5 Areas subject to heavy wear	
	2.6 Reinforcements for grounding	
	2.7 Bolted structures	
3	Design loads	550
	3.1 General	
	3.2 Loading conditions	
	3.3 Hull girder loads for dredgers, hopper dredgers and hopper units of more than 65 m in length	
	3.4 Hull girder loads for split hopper dredgers and split hopper units of more than 65 m in length	
	3.5 Internal pressures in hopper well	
4	Hull girder strength of dredgers, hopper dredgers and hopper units	556
	4.1 General	
	4.2 Midship section modulus	
5	Hull girder strength of split hopper dredgers and split hopper units	557
	5.1 General	
	5.2 Definitions	
	5.3 Hull girder stress	
	5.4 Checking criteria	
6	Hull scantlings	558
	6.1 General	
	6.2 Hull girder normal stress for split hopper dredgers and split hopper units of more than 65 m in length	
	6.3 Minimum net thicknesses of plating	
	6.4 Transverse vertically corrugated bulkheads	
	6.5 Well bulkhead and cellular keel platings	
	6.6 Transversely framed bottoms	
7	Fatigue	559
	7.1 General	
8	Hopper dredgers and hopper units: checking of hopper well structure	560
	8.1 General	
	8.2 Floors, webs, trunks, strongbeams and girders	
9	Split hopper dredgers and split hopper units: superstructure hinges	560
	9.1 General	
	9.2 Arrangements	
	9.3 Materials used for the hinges	
	9.4 Forces	
	9.5 Scantlings of the hinges	
10	Split hopper dredgers and split hopper units: decks hinges, hydraulic jack connections and chocks	564
	10.1 General	
	10.2 Arrangements	
	10.3 Static forces	
	10.4 Dynamic forces	
	10.5 Scantlings	

11 Split hopper dredgers and split hopper units: hydraulic jacks and associated piping systems 567

11.1 General
11.2 Definitions
11.3 Arrangements
11.4 Scantling of jacks
11.5 Inspection and testing
11.6 Relief valve setting

12 Rudders 569

12.1 General
12.2 Additional requirements for split hopper dredgers and split hopper units

13 Equipment 569

13.1 General
13.2 Additional requirements for split hopper dredgers and split hopper units

Section 3 Machinery and Dredging Systems

1 General 570

1.1 Application

2 Dredging system 570

2.1 Attachment of dredging equipment to the hull

3 Steering gear of split hopper dredgers and split hopper units 570

3.1 General
3.2 Design of the steering gear
3.3 Synchronisation

4 Testing of dredging equipment 570

4.1 On board testing

Appendix 1 Guidance on Calculation of Transverse Strength Hopper Well Structure

1 Hopper dredgers and hopper units: checking of hopper well structure 571

1.1 General

2 Floors 571

2.1 General
2.2 Different types of bottom and valves used
2.3 Load borne by floors
2.4 Shear force diagrams
2.5 Bending moments for each elementary load
2.6 Resultant bending moment
2.7 Normal load
2.8 Differential opening valves
2.9 Buckling of upper flange

3 Strong beams at deck level 575

3.1 Forces acting on strong beams
3.2 Sectional area of strong beams

4 Brackets for trunks 576

4.1 General

5 Girders supporting the hydraulic cylinder in the hopper spaces (bottom door types 1, 2 and 3) 576

5.1

Chapter 14 Non-Propelled Units

Section 1 General

1 General 579

1.1 Application

Section 2 Hull and Stability

1 General 580

1.1 Application
1.2 Additional class notations for lifting appliances of ships with service notation pontoon - crane

2 Stability 580

2.1 Intact stability for ships with service notation pontoon or pontoon - crane
2.2 Additional intact stability criteria for ships with service notation pontoon - crane

3 Structure design principles 581

3.1 Hull structure
3.2 Lifting appliances

4 Hull girder strength 581

4.1 Yielding check

5 Hull scantlings 582

5.1 General
5.2 Hull scantlings of non-propelled units with the service notation pontoon fitted with arrangements and systems for launching operations
5.3 Hull scantlings of non-propelled units with service notation pontoon - crane

6 Hull outfitting 583

6.1 Equipment

Section 3 Machinery and Systems

1 General 584

1.1 Application
1.2 Documents to be submitted

2 Bilge system 584

2.1 Bilge system in ships having no source of electrical power
2.2 Bilge system in ships having a source of electrical power

Chapter 15 Fishing Vessels

Section 1 General

1 General 587

1.1 Application

Section 2 Ship Arrangement

1 General 588

1.1 Definitions

2 General arrangement design 588

2.1 Subdivision arrangement

Table of Content

Section 3 Hull and Stability

1 General 589

1.1 Documents to be submitted

2 Stability 589

2.1 Intact stability

3 Design loads 590

3.1 Fish holds
3.2 Working deck

4 Hull scantlings 590

4.1 Fish holds
4.2 Bottom, side and decks plating
4.3 Aft ramp

5 Arrangement for hull and superstructure openings 590

5.1 General

6 Lifting appliances and fishing devices 591

6.1 General
6.2 Design loads
6.3 Strength check

7 Hull outfitting 591

7.1 Rudder stock scantlings
7.2 Equipment

8 Protection of hull metallic structures 593

8.1 Protection of cargo sides by battens
8.2 Deck composition

Section 4 Machinery

1 General 594

1.1 Application
1.2 Documents to be submitted
1.3 Tests - Trials in ships L ≥ 24 m
1.4 Tests - Trials in ships L < 24 m
1.5 General requirements applicable to all piping systems in ships L ≥ 24 m
1.6 General requirements applicable to all piping systems in ships L < 24 m
1.7 Sea inlets and overboard discharges in ships L ≥ 24 m
1.8 Sea inlets and ship side valves in ships L < 24 m
1.9 Non-metallic rigid pipes in ships L ≥ 24m
1.10 Non-metallic rigid pipes in ships L < 24m
1.11 Flexible hoses and expansion joints
1.12 Metallic flexible pipes and joints

2 Bilge system in ships L ≥ 24 m 599

2.1 General
2.2 Design of the bilge system
2.3 Bilge pumps
2.4 Size of bilge pipes
2.5 Bilge piping arrangement
2.6 Materials

3 Bilge system in ships L < 24 m 602

3.1 General
3.2 Pumps and ejectors
3.3 Size of bilge pipes
3.4 Arrangement of bilge lines and their accessories

Table of Content

4	Scuppers and sanitary discharges	604
	4.1 Principle 4.2 General 4.3 Discharges through manned machinery spaces 4.4 Materials	
5	Air pipes and sounding devices in ships L ≥ 24 m	604
	5.1 Air pipes 5.2 Sounding and level gauging devices	
6	Air pipes and sounding devices in ships L < 24 m	606
	6.1 Air pipes 6.2 Sounding and level gauging devices	
7	Ventilation in ships ≥ 24 m	607
	7.1	
8	Ventilation in ships < 24 m	607
	8.1	
9	Engine cooling systems in ships L ≥ 24 m	607
	9.1	
10	Engine cooling systems in ships L < 24 m	607
	10.1 Principle 10.2 Motorships 10.3 Fresh water cooling system 10.4 Cooling pumps 10.5 Sea inlets 10.6 Filters 10.7 Operating control 10.8 Materials	
11	Oil fuel systems in ships L ≥ 24m	608
	11.1	
12	Oil fuel systems in ships L < 24m	608
	12.1 General 12.2 Oil fuel tanks and bunkers 12.3 Transfer pipes 12.4 Oil fuel supply to engines 12.5 Materials - Construction	
13	Lubricating oil systems in ships L ≥ 24 m	610
	13.1	
14	Lubricating oil systems in ships L < 24 m	610
	14.1 General 14.2 Lubricating pumps 14.3 Filters 14.4 Safety devices	
15	Hydraulic systems in ships L ≥ 24 m	610
	15.1	
16	Hydraulic systems in ships L < 24 m	610
	16.1 General 16.2 Safety and monitoring devices	
17	Compressed air systems in ships L ≥ 24 m	610
	17.1	

Table of Content

18 Compressed air systems in ships L < 24 m 611

18.1
18.2 Accessories for compressed air systems
18.3 Arrangement of compressed air systems
18.4 Construction - Material

19 Exhaust gas systems in ships L ≥ 24 m 611

19.1

20 Exhaust gas systems in ships L < 24 m 611

20.1 Hull outlet
20.2 Cooling and lagging
20.3 Water-cooled exhaust gas pipes

21 Refrigeration systems for the preservation of the catch 611

21.1 General
21.2 Design of refrigeration systems
21.3 Arrangement of the refrigerating machinery spaces and refrigerating rooms
21.4 Breathing apparatus

22 Propelling and auxiliary machinery in ships L ≥ 24 m 612

22.1

23 Propelling and auxiliary machinery in ships L < 24 m 612

23.1 Shafting
23.2 Shaft accessories

24 Steering gear 613

24.1 Application
24.2 General
24.3 Strength, performance and power operation of the steering gear
24.4 Control of the steering gear
24.5 Availability

Section 5 Electrical Installations

1 General 615

1.1 Application

2 Documentation to be submitted 615

2.1

3 Type approved components 615

3.1

4 General requirements for system design, location and installation 615

4.1 Design and construction
4.2 Distribution
4.3 Main source of electrical power
4.4 Emergency source of electrical power
4.5 Precaution against shock, fire and other hazards of electrical origin
4.6 Engineers' alarm
4.7 Steering gear
4.8 Fire detection and fire alarm
4.9 Alarm - Communication
4.10 Final sub-circuits
4.11 Electric cables
4.12 Switchboard
4.13 Rotating electrical machines
4.14 Batteries

5 Lightning protection 622

5.1 Application

Section 6 Fire Protection

1 General 623

1.1 Application
1.2 National regulations
1.3 Type approved products
1.4 Definitions

2 Water fire-fighting system 624

2.1 General
2.2 Number and type of fire pumps
2.3 Characteristics and arrangement of fire pumps
2.4 Fire main, hydrants and hoses

3 Fire-extinguishing appliances in machinery spaces 626

3.1 Fixed fire-extinguishing systems
3.2 Additional fire-extinguishing arrangements

4 Fire extinguishers 627

4.1 Design and installation of fire extinguishers
4.2 Arrangement of fire extinguishers in accommodation and service spaces

5 Structural fire protection 628

5.1
5.2 Ships of 45 m in length and over
5.3 Ships of 24 m in length and over but less than 45 m
5.4 Ships of less than 24 m in length

6 Ventilation systems 630

6.1

7 Prevention of fire 631

7.1

8 Means of escape 631

8.1

9 Fire detection 632

9.1

10 Storage of gas cylinders and dangerous materials 632

10.1

Chapter 16 Offshore Patrol Vessels

Section 1 General

1 General 634

1.1 Application
1.2 Number of persons on board

Section 2 Stability

1 General 636

1.1 Application

2 Intact Stability 636

2.1 Maximum turning angle
2.2 Crowding angle for offshore patrol vessels carrying more than 60 persons

3 Damage stability 636
3.1 Offshore patrol vessels carrying more than 60 persons
3.2 Bottom damages
4 Damage control documentation for ships greater than or equal to 500 GT 637
4.1

Section 3 Machinery
1 General 638
1.1 Application
1.2 Capacity of service tanks for offshore patrol vessels with GT ≥ 500
1.3 Progressive flooding
1.4 Bilge pumping after flooding

Section 4 Electricity and Automation
1 General 639
1.1 Application
1.2 General alarm for ships with GT < 500
1.3 Emergency source of electrical power for ships with GT ≥ 500
1.4 Public address system for ships with GT ≥ 500

Section 5 Fire safety
1 General 640
1.1 Application
2 Materials 640
2.1 Steel or equivalent
3 Specific requirements 640
3.1 Offshore patrol vessels carrying more than 60 persons
3.2 Ammunition storage compartments

Chapter 17 Cement Carriers

Section 1 General
1 General 642
1.1 Application

Section 2 Ship Arrangement
1 General 643
1.1 Documents to be submitted
2 General arrangement design 643
2.1 General
3 Access arrangement 643
3.1 Access arrangement to double bottom and pipe tunnel
3.2 Access arrangement to and within spaces in, and forward of, the cargo area

Section 3 Hull and Stability
1 Stability 645
1.1 Intact stability

Table of Content

2	Structure design principles	645
	2.1 Double bottom structure	
	2.2 Double side structure	
	2.3 Topside structure	
3	Design loads	646
	3.1 Hull girder loads in flooded conditions	
	3.2 Load combinations for direct strength analysis	
4	Hull girder strength	646
	4.1 Hull girder yield strength in flooded conditions	
5	Hull scantlings	647
	5.1 Buckling check in flooded conditions	
6	Protection of hull metallic structures	647
	6.1 Protection of cargo holds	
7	Construction and testing	648
	7.1 Welding and weld connections	

Part D
Service Notations

CHAPTER 1
RO-RO CARGO SHIPS AND PURE CAR AND/OR TRUCK CARRIERS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Systems

Section 4 Electrical Installations

Section 1 General

1 Application

1.1

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of one of the service notation **ro-ro cargo ship**, **PCTC** or **PCC**, as defined in Pt A, Ch 1, Sec 2, [4.2.3] and Pt A, Ch 1, Sec 2, [4.2.4].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules,
- NR216 Materials and Welding.
- applicable requirements according to Tab 1.

1.1.3 Additional guidance for arrangement and structural assessment is provided in NI640 Guidance Note for Structural Assessment of Passenger Ships and Ro-ro Ships.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B	• NR566
	L < 65 or 90 m **(1)**	• NR600	• NR566
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 1, Sec 2	• Part B • Ch 1, Sec 2
	L < 65 or 90 m **(1)**	• NR600	• NR600
Stability		• Part B • Ch 1, Sec 2	• NR566 • Ch 1, Sec 2
Machinery and cargo systems		• Part C • Ch 1, Sec 3	• NR566 • Ch 1, Sec 3
Electrical installations		• Part C • Ch 1, Sec 4	• NR566 • Ch 1, Sec 4
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Hull and Stability

1 General

1.1 Application

1.1.1 The requirements of this Section apply to multi-deck ships with double bottom and, in some cases, with wing tanks up to the lowest deck above the full load waterline, intended for the carriage of:

- vehicles which embark and disembark on their own wheels, and/or goods in or on pallets or containers which can be loaded and unloaded by means of wheeled vehicles
- railway cars, on fixed rails, which embark and disembark on their own wheels.

1.2 Documents to be submitted

1.2.1 In addition to the documentation requested in Part B, the following documents are to be submitted for information:

- operating and maintenance manual of bow, side and stern doors and ramps (see Pt B, Ch 11, Sec 6 and Pt B, Ch 11, Sec 7)
- plan of design loads on deck
- plan of arrangement of motor vehicles, railway cars and/or other types of vehicles which are intended to be carried, indicating securing and load bearing arrangements
- characteristics of motor vehicles, railways cars and/or other types of vehicles which are intended to be carried: (as applicable) axle load, axle spacing, number of wheels per axle, wheel spacing, size of tyre print.

2 Stability

2.1 Damage stability requirements for ship where additional class notation SDS is required

2.1.1 A ship, assigned a service notation **ro-ro cargo ship**, **PCTC** or **PCC**, equal to or greater than 80 m in length where additional class notation **SDS** is required (see Pt A, Ch 1, Sec 2, [6.17.1]) is to comply with the subdivision and damage stability criteria in Pt B, Ch 3, App 3.

3 Structure design principles

3.1 Wood sheathing

3.1.1 Wood sheathing is recommended for caterpillar trucks and unusual vehicles.

It is recommended that a piece of wood of suitable thickness is provided under each crutch in order to distribute the mass over the plate and the nearest stiffeners.

4 Design loads

4.1 Load combinations for direct strength analysis

4.1.1 The load combinations defined in NI640, App 1, [4] are to be considered for direct strength analysis.

5 Global strength

5.1 Hull girder strength

5.1.1 In addition to the requirements in Pt B, Ch 6, Sec 1, [1.3] and Pt B, Ch 7, Sec 6, [1.1.2], the contribution of the hull structures up to the strength deck to the longitudinal strength is to be assessed through a finite element analysis of the whole ship in the following cases:

- when the size of openings in side shell and/or longitudinal bulkheads located below the strength deck decreases significantly the capability of the plating to transmit shear forces to the strength deck
- when the ends of superstructures which are required to contribute to longitudinal strength may be considered not effectively connected to the hull structures.

5.2 Global transverse strength

5.2.1 The behaviour of the ship primary structural members under racking effects due to transverse forces induced by transverse accelerations is to be investigated according to Pt B, Ch 7, App 1, or by means of a complete ship model according to NI 640.

6 Construction and testing

6.1 Special structural details

6.1.1 The specific requirements in Pt B, Ch 13, Sec 5, [2] for ships with the service notation **ro-ro cargo ship**, **PCTC**, or **PCC**, are to be complied with.

Section 3 Machinery and Systems

1 Scuppers and sanitary discharges

1.1 Drainage of ro-ro cargo spaces, intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion

1.1.1 Prevention of build-up of free surfaces

In cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion and fitted with a fixed pressure water-spraying fire-extinguishing system, the drainage arrangement is to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effect upon stability of the added weight and free surface of water is to be taken into account to the extent deemed necessary by the Society in its approval of the stability information.

1.1.2 Scupper draining

Scuppers from cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion are not to be led to machinery or other places where sources of ignition may be present.

Section 4 Electrical Installations

1 General

1.1 Applicable requirements

1.1.1 In addition to the relevant requirements of Part C, Chapter 2 and those contained in this Section, electrical installations in spaces intended for the carriage of motor vehicles with fuel in their tanks for their propulsion are to comply with those of Part C, Chapter 4.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, Tab 1, the following is to be submitted for approval:

a) plan of hazardous areas

b) document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas.

Table 1 : Electrical equipment permitted in closed ro-ro cargo spaces

No.	Space description	Electrical equipment	Hazardous area
1	Closed ro-ro cargo spaces except areas under item 3	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 0 b) certified intrinsically safe apparatus Ex(ib) c) simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ib" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and acceptable to the appropriate authority d) certified flameproof Ex(d) e) certified pressurised Ex(p) f) certified increased safety Ex(e) g) certified encapsulated Ex(m) h) certified sand filled Ex(q) i) certified specially Ex(s) j) cables sheathed with at least one of the following: • a non-metallic impervious sheath in combination with braiding or other metallic covering • copper or stainless steel sheath (for mineral-insulated cables only)	Zone 1
2	Exhaust ventilation ducts	As stated under item 1	Zone 1
3	On condition that the ventilation system is so designed and operated as to provide continuous ventilation of the cargo spaces at the rate of at least 10 air changes per hour whenever vehicles are on board: • areas above a height of 450 mm from the deck • areas above a height of 450 mm from each platform for vehicles, if fitted, without openings of sufficient size permitting penetration of petrol gases downward • areas above platforms for vehicles, if fitted, with openings of sufficient size permitting penetration of petrol gases downward	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 1 b) tested specially for zone 2 (e.g. type "n" protection) c) pressurised, and acceptable to the appropriate authority d) encapsulated, and acceptable to the appropriate authority e) the type which ensures the absence of sparks and arcs and of "hot spots" during its normal operation (minimum class of protection IP55) f) cables sheathed with at least a non-metallic external impervious sheath	Zone 2

1.3 Safety characteristics

1.3.1 The explosion group and temperature class of electrical equipment of a certified safe type for use with explosive petrol-air mixtures are to be at least IIA and T3.

2 Installation

2.1 Installations in closed ro-ro cargo spaces

2.1.1 Except as provided for in [2.1.2], electrical equipment is to be of a certified safe type as stated in Pt C, Ch 2, Sec 3, [10.2.6] and electrical cables are to be as stated in Pt C, Ch 2, Sec 3, [10.5.2].

2.1.2 Above a height of 450 mm from the deck and from each platform for vehicles, if fitted, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment as stated in Pt C, Ch 2, Sec 3, [10.2.7] and electrical cables as stated in Pt C, Ch 2, Sec 3, [10.5.3]are permitted, on condition that the ventilation system is so designed and operated as to provide continuous ventilation of the cargo spaces at the rate of at least 10 air changes per hour whenever vehicles are on board.

2.1.3 Electrical equipment and cables in an exhaust ventilation duct are to be as stated in [2.1.1].

2.1.4 The requirements in this item are summarised in Tab 1.

2.2 Installations in cargo spaces other than ro-ro cargo spaces but intended for the carriage of motor vehicles

2.2.1 The provisions of [2.1] apply.

2.2.2 All electric circuits terminating in cargo holds are to be provided with multipole linked isolating switches located outside the holds. Provision is to be made for locking in the off position.

This requirement does not apply to safety installations such as fire, smoke or gas detection systems.

3 Type approved components

3.1

3.1.1 Alarm systems for closing devices of openings and water leakage detection systems if of electronic type, as well as television surveillance systems, are to be type approved or in accordance with [3.1.2].

3.1.2 Case-by-case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

CHAPTER 2
CONTAINER SHIPS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Systems

Section 4 Whipping and Springing Assessment

Appendix 1 Methodology for Long Term Direct Hydro-Structure Calculations including Whipping and Springing Response

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **container ship**, as defined in Pt A, Ch 1, Sec 2, [4.2.6].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1

and the requirements of Pt F, Ch 12, Sec 6, for open-top container ships, as defined in [1.2.1].

1.1.3 Ships assigned the additional service feature **equipped for carriage of containers** are to comply with the requirements of Ch 2, Sec 2 except Ch 2, Sec 2, [4.2]; Ch 2, Sec 2, [7]; Ch 2, Sec 2, [9] and Ch 2, Sec 2, [13].

1.2 Definition

1.2.1 Open-top container ships

An “open-top container ship” is defined as container ship especially designed so that one or more of the cargo holds need not be fitted with hatch covers.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• Part B	• NR566
	L < 65 m	• NR600	• NR566
Hull	L ≥ 65 m	• Part B • Ch 2, Sec 2 • Ch 2, Sec 4 **(1)**	• Part B • Ch 2, Sec 2
	L < 65 m	• NR600	• NR600
Stability		• Part B • Ch 2, Sec 2	• NR566 • Ch 2, Sec 2
Machinery and cargo systems		• Part C • Ch 2, Sec 3	• NR566 • Ch 2, Sec 3
Electrical installations		• Part C • Ch 2, Sec 3	• NR566 • Ch 2, Sec 3
Automation		• Part C • Ch 2, Sec 3	• NR566 • Ch 2, Sec 3
Fire protection, detection and extinction		• Part C • Ch 2, Sec 3	• NR566 • Ch 2, Sec 3

(1) In accordance with the applicable requirements of Ch 2, Sec 2, [1.1.3] for the assignment of notations **WhiSp1**, **WhiSp2** or **WhiSp3**.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Hull and Stability

Symbols

For symbols not defined in this Section, refer to Pt B, Ch 1, Sec 3.

C : Wave parameter, taken as follows:

- for $L \leq L_{ref}$:

$$C = 1 - 1{,}50\left(1 - \sqrt{\frac{L}{L_{ref}}}\right)^{2,2}$$

- for $L > L_{ref}$:

$$C = 1 - 0{,}45\left(\sqrt{\frac{L}{L_{ref}}} - 1\right)^{1,7}$$

L_{ref} : Reference length, in m, taken equal to:

- for the determination of the vertical wave bending moments according to [4.2.1]:

$$L_{ref} = 315C_w^{-1,3}$$

- for the determination of the vertical wave shear forces according to [4.2.2]:

$$L_{ref} = 330C_w^{-1,3}$$

$M_{sw\text{-}min}$: Minimum permissible still water bending moment as defined in Pt B, Ch 5, Sec 4, [2.2.1].

$M_{sw\text{-}max}$: Maximum permissible still water bending moment as defined in Pt B, Ch 5, Sec 4, [2.2.1].

n : Navigation coefficient, as defined in Pt B, Ch 5, Sec 3, [1.1.2]for a reference length L_{ref} calculated with:

- for the determination of the vertical wave bending moments according to [4.2.1]:

$$\alpha = \frac{315}{486} \cdot \frac{1}{C_w^{1,3}}$$

$f_\alpha = 1{,}0$

- for the determination of the vertical wave shear forces according to [4.2.2]:

$$\alpha = \frac{330}{486} \cdot \frac{1}{C_w^{1,3}}$$

$f_\alpha = 1{,}0$

$Q_{sw\text{-}min}$: Minimum permissible still water shear force as defined in Pt B, Ch 5, Sec 4, [2.3.1].

$Q_{sw\text{-}max}$: Maximum permissible still water shear force as defined in Pt B, Ch 5, Sec 4, [2.3.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to double bottom ships of double or single side skin construction, intended to carry containers in holds or on decks.

1.1.2 Open-top container ships

In addition to the requirements of this Section, open-top container ships are to comply with the requirements of Pt F, Ch 12, Sec 6.

1.1.3 Whipping and springing

In accordance with Ch 2, Sec 4, [1.1.2]:

- for ships assigned the service notation **container ship** with a rule length between 300 m and 350 m:
  - The requirements given in Ch 2, Sec 4, [3] for the assignment of the notation **WhiSp1** are to be complied with.
  - The notation **WhiSp2** may be assigned instead of **WhiSp1** for ships complying with the requirements given in Ch 2, Sec 4, [4], in addition to the requirements given in Ch 2, Sec 4, [3].
  - The notation **Whisp3** may be assigned instead of **WhiSp1** for ships complying with the requirements given in Ch 2, Sec 4, [5], in addition to the requirements given in Ch 2, Sec 4, [3] and Ch 2, Sec 4, [4].

- for ships assigned the service notation **container ship** with a rule length greater than 350 m in length:
  - The requirements given in Sec 4 [3] and Ch 2, Sec 4, [4] for the assignment of the notation **WhiSp2** are to be complied with.
  - The notation **WhiSp3** may be assigned instead of **WhiSp2** for ships complying with the requirements given in Ch 2, Sec 4, [5], in addition to the requirements given in Ch 2, Sec 4, [3] and Ch 2, Sec 4, [4].

1.2 Documentation and information

1.2.1 Documentation to be submitted

In addition to the documentation requested in Pt B, the documentation required in Pt F, Ch 12, Sec 5 is to be submitted to the Society for approval for ships assigned the service notation **container ship**.

1.2.2 Information to be submitted

The following additional information is to be included in the relevant documents:

- the distributions of still water permissible vertical bending moments, vertical shear forces, and the maximum torsional moment in seagoing and harbour conditions, as defined in Pt B, Ch 5, Sec 4, are to be included in the loading manual
- the permissible stack weights for 20′ and 40′ containers stacks in hold and on deck, as defined in [5.2.2], are to be included on the midship section drawing and in the loading manual

2 Stability

2.1 Intact stability

2.1.1 General

The stability for the loading conditions defined in Pt B, Ch 3, App 2, [1.2.4] is to be in compliance with the requirements of Pt B, Ch 3, Sec 2.

2.1.2 Additional criteria

In addition to [2.1.1], the initial metacentric height is to be equal to or greater than 0,20 m.

2.1.3 Alternative criteria for ships greater than 100 m in length

For ships greater than 100 m in length, the Society may apply the following criteria instead of those in Pt B, Ch 3, Sec 2*:*

- *the area under the righting lever curve (GZ curve), in m·rad, is to be not less than 0,009/C up to an angle of heel of 30°, and not less than 0,016/C up to 40° or the angle of flooding θ_f if this angle is less than 40°*
- *the area under the righting lever curve (GZ curve), in m·rad, between the angles of heel of 30° and 40° or between 30° and θ_f, if this angle is less than 40°, is to be not less than 0,006/C*
- *the righting lever GZ, in m, is to be at least 0,033/C at an angle of heel equal to or greater than 30°*
- *the maximum righting lever GZ, in m, is to be at least 0,042/C*
- *the total area under the righting lever curve (GZ curve), in m·rad, up to the angle of flooding θ_f is not to be less than 0,029/C*

where:

C : *Coefficient defined by:*

$$C = \sqrt{\frac{T}{KG}}\sqrt{\frac{100}{L}}\left(\frac{C_B}{C_W}\right)^2\frac{TD'}{B_m^2}$$

T : *Mean draught, in m*

KG : *Height of the centre of mass above base, in m, corrected for free surface effect, not be taken as less than T*

C_B : *Block coefficient*

C_W : *Waterplane coefficient*

D′ : *Moulded depth, in m, corrected for defined parts of volumes within the hatch coamings obtained from the following formula:*

$$D' = D + \left(\frac{2b - B_D}{B_D}\right)\left(\frac{2\Sigma\ell_H}{L}\right)h$$

h : *Mean height, in m, of hatch coamings within L/4 forward and aft from amidships (see* Fig 1*)*

b : *Mean width, in m, of hatch coamings within L/4 forward and aft from amidships (see* Fig 1*)*

B_m, B_D : *Breadths, in m, defined in* Fig 1

ℓ_H : *Length, in m, of each hatch coaming within L/4 forward and aft from amidships (see* Fig 2*).*

Figure 1 : Definition of dimensions

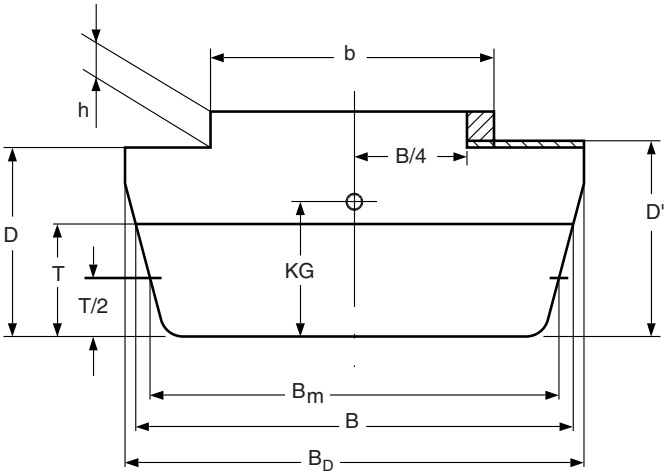
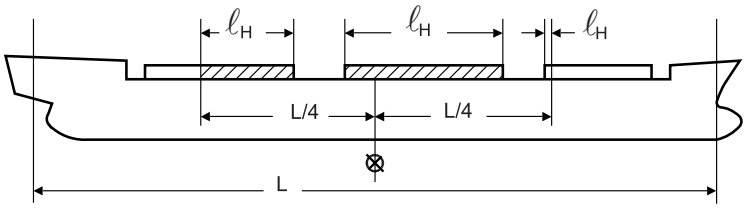


Figure 2 : Definition of dimensions



2.2 Damage stability requirements for ships where the additional class notation SDS is required

2.2.1 General

Any type of container ship with a length equal to or greater than 80 m *is to comply with the subdivision and damage stability criteria of Pt B, Ch 3, App 3.*

3 Structure design principles

3.1 Ship structure

3.1.1 Design

The ship structure is to be longitudinally or transversely framed with full transverse bulkheads and intermediate web frames.

When single side skin construction is adopted, a torsion box girder at the topsides or an equivalent structure is to be fitted. Typical midship sections are shown in Fig 3 and Fig 4.

Figure 3 : Container ship of double side skin construction

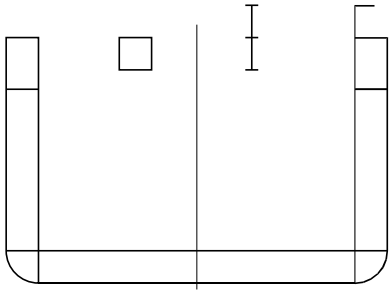
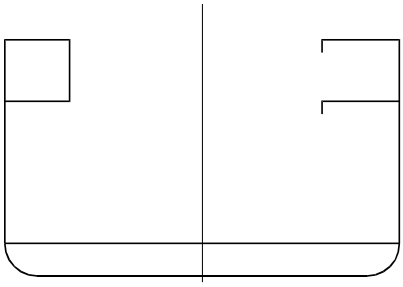


Figure 4 : Container ship of single side skin construction



3.2 Material

3.2.1 The material classes required for the strength deck plating, the sheerstrake and the torsion box girder structure within 0,4 L amidships are to be maintained in way of the entire cargo hold region.

3.2.2 When steel plates of thickness greater than 50 mm, made of material with specified minimum yield stress equal to 460 N/mm^2 are used in the upper deck region (for upper deck plating, hatch top and side coaming or their attached longitudinals stiffeners), the material grade is at least to be EH.

3.2.3 Prevention of brittle crack propagation

This requirement applies to ships for which steel with minimum specified yield stress R_{eH} of 390 or 460 N/mm^2 is used for hatch coaming plating.

It gives measures, to be applied in cargo hold region, for prevention of propagation of brittle cracks initiating in block-to-block butt joints of upper deck and hatch side coaming (including top plating and their attached longitudinals).

a) For plating with as-built thickness greater than 50 mm but not greater than 100 mm, measures are to be taken as specified in Tab 1, in which minimum specified yield stress R_{eH} and thickness t refer to hatch coaming top and side platings (not upper deck).

   Measures are defined as follows:

   - Measure 1: measure for prevention of brittle crack propagation along block-to-block butt joints, and deviation from butt joints into base metal
   - Measure 2: measure for prevention of brittle crack propagation from weld areas other than butt joints considered in Measure 1, such as fillets and attachment welds.

   When brittle crack arrest steels are used, the minimum specified yield stress of the upper deck is to be not higher than 390. Otherwise other means for preventing the crack initiation and propagation shall be agreed by the Society.

b) For plating with as-built thickness greater than 100 mm, appropriate measures are to be considered on a case-by-case basis by the Society.

c) If the as-built thickness of the hatch coaming structure is equal to or less than 50 mm, measures are not necessary, regardless of the as-built thickness and yield stress of the upper deck.

Table 1 : Measures to prevent propagation of brittle cracks

R_{eH}, in N/mm^2	As-built thickness, in mm	Measures
390	50 < t ≤ 85	N.A.
	85 < t ≤ 100	Measure 1 **(1)** and Measure 2
460 Flux cored arc welding	50 < t ≤ 100	Measure 1 **(1)** and Measure 2
460 Electrogas welding	50 < t ≤ 100	Measure 1 and Measure 2
(1) As an alternative to Measure 1, the shipbuilder may apply enhanced non-destructive testing (particularly time-of-flight diffraction technique) to all block-to-block butt joints over their full length, using stricter defect acceptance criteria, in lieu of ultrasonic testing		

The following is considered to be an acceptable example of preventive Measure 1:

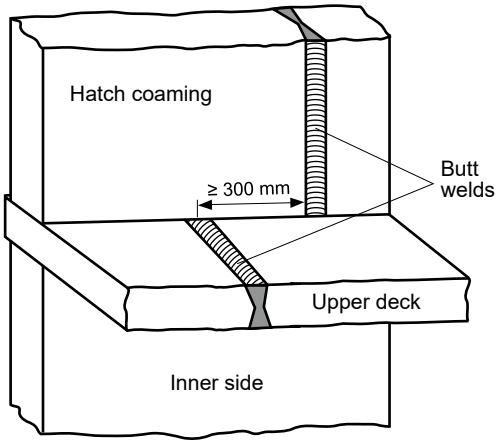
a) Use of brittle crack arrest steel for upper deck plating, in a way suitable to prevent transmission of crack propagating from hatch coaming to the structure below, and

b) Use of brittle crack arrest steel for hatch side coaming plating, and

c) One of the following arrangements, aiming at creating a discontinuity in weld line:

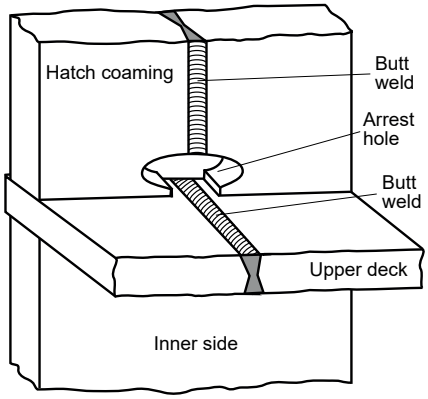
   - shifting block-to-block butt welds of the hatch side coaming and those of the upper deck. This shift is to be not less than 300 mm (see Fig 5)

Figure 5 :



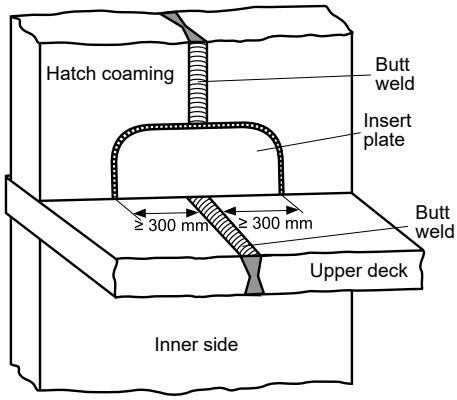
- providing crack arrest holes in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld. In this case, the fatigue strength of the lower end of the butt weld is to be assessed (see Fig 6)

Figure 6 :



- including arrest insert plates, of brittle crack arrest steel in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld (see Fig 7).

Figure 7 :



As an alternative to items b) and c), the shipbuilder may apply enhanced non-destructive testing (particularly time-of-flight diffraction technique) to all block-to-block butt joints over their full length, using stricter defect acceptance criteria, in lieu of ultrasonic testing.

The procedure and the acceptance criteria of non destructive (NDT) and ultrasonic testing (UT) are to be in accordance with Pt B, Ch 13, Sec 4.

The use of brittle crack arrest steel for upper deck plating, in a way suitable to prevent transmission of crack propagating from hatch coaming to the structure below, is considered to be an acceptable example of preventive Measure 2.

The brittle crack arrest steels used in Measure 1 and Measure 2 are to be selected according to Tab 2 where suffixes CAS1 and CAS2 are defined in NR216 Materials and Welding.

When brittle crack arrest steels are used, the weld joints between the hatch coaming side and the upper deck are to be partial penetration. In the vicinity of ship block joints, alternative weld may be used for the deck and hatch coaming side connection provided additional means for preventing the crack propagation are implemented and agreed by the Society.

Table 2 : Brittle crack arrest steel selection

Structural members plating **(1)**	Thickness (mm)	Brittle crack arrest steel
Upper deck	50 < t ≤ 100	EH36CAS1 / FH36CAS1 EH40CAS1 / FH40CAS1
Hatch coaming side	50 < t ≤ 80	EH40CAS1 / FH40CAS1 EH47CAS1 / FH47CAS1
	80 < t ≤ 100	EH40CAS2 / FH40CAS2 EH47CAS2 / FH47CAS2
(1) Excluding their attached longitudinals		

3.3 Net scantling approach

3.3.1 Net thickness approach

The applied corrosion is to be taken equal to 0 t_c in the following cases:

- calculations of stresses based on cargo hold model (standard mesh, or 3-D beam models) or complete ship model
- calculations of stresses based on local fine mesh or very fine mesh.

3.4 Strength principles

3.4.1 Reinforcement under container corners and in way of fixed cargo securing fittings and cell guides

Local reinforcement of the hull structure and hatch covers is to be provided under container corners and in way of fixed cargo securing fittings and cell guides, if fitted.

The forces applying on the fixed cargo securing fittings are to be indicated by the designer. When one of the additional class notations **LASHING** or **LASHING-RSSA( )** is assigned, these forces may be determined by the Society.

3.5 Bottom structure

3.5.1 Floor spacing

Generally, the floor spacing is to be such that floors are located in way of the container corners. Floors are also to be fitted in way of the watertight bulkheads.

The floor spacing is generally not to be greater than 3,5 m or four times the transverse frame spaces, whichever is the smaller.

3.5.2 Cell guides

The structure of the bottom and inner bottom on which cell guides rest is to be adequately stiffened with doublers, brackets or other equivalent reinforcements.

3.6 Deck structure

3.6.1 Longitudinal hatch coaming

The width of the longitudinal hatch coaming flanges is to be such as to accommodate the hatch covers and their securing arrangements.

The end connections of the longitudinal hatch coamings are to ensure a proper transmission of stresses from the hatch coaming to the supporting structure.

3.6.2 Hatch corners

The stress concentrations in way of the hatch corners are to be checked, in particular in the top part (hatch coaming, upper deck and stringers under deck).

3.6.3 Deck and hatch cover reinforcements

The deck and hatch cover structures are to be reinforced taking into account the loads transmitted by the container corners and cell guides.

3.7 Bulkheads

3.7.1 Transverse torsion box structures in way of transverse bulkheads

Transverse torsion box structures are generally to be provided at the top part of the transverse bulkheads.

They are to be provided with sufficient strength to sustain stress resulting from the shear forces induced at their ends by hull girder torsion effects.

Similar boxes might as well be provided at the bottom part of the transverse bulkheads.

3.7.2 Primary supporting members

The vertical primary supporting members of the transverse bulkheads are to be fitted in line with bottom girders.

Their flanges are to be in line with a double bottom floor.

The strength of the connection between these members and the bottom structure is to be assessed.

3.7.3 Reinforcements in way of cell guides

When cell guides are fitted on transverse or longitudinal bulkheads which form boundaries of the hold, such structures are to be reinforced, taking into account the loads transmitted by the cell guides.

4 Design loads

4.1 Still water hull girder loads

4.1.1 Permissible torsional still water moment in seagoing condition

The permissible torsional still water moment $M_{sw\text{-}t}$, in kN·m, induced by a non-uniform distribution of cargo, consumable liquids and ballast in seagoing condition, is to be considered.

When no specific data is provided by the designer, as a guidance at a preliminary stage, $M_{sw\text{-}t}$ may be obtained, from the following formula:

$$M_{sw\text{-}t} = 0{,}04\ L\ B\ (S_h\ T_h + S_d\ T_d)$$

where:

S_h : Number of container stacks over the breadth B in cargo hold amidships

T_h : Number of container tiers in cargo hold amidships

S_d : Number of container stacks over the breadth B on deck amidships

T_d : Number of container tiers on deck amidships.

4.1.2 Permissible torsional still water moment in harbour/sheltered water

The permissible torsional still water moment $M_{sw\text{-}t\text{-}h}$, in kN·m, induced by a non-uniform distribution of cargo, consumable liquids and ballast in the harbour/sheltered water condition, is to be considered.

This value is defined as a constant value over the ship length.

When no specific data is provided by the designer, a preliminary value for $M_{sw\text{-}t\text{-}h}$ may be taken equal to the permissible torsional still water moment in seagoing condition $M_{sw\text{-}t}$ as defined in [4.1.1].

4.1.3 Torsional still water moment for direct calculations in seagoing condition

For direct calculation analysis, the torsional still water moment in seagoing condition $M_{sw\text{-}t\text{-}LC}$, in kN.m, is to be taken, at any longitudinal position for the considered dynamic load case, as follows:

- for $C_{WT} \geq 0$

  $$M_{sw\text{-}t\text{-}LC} = |f_{lp}| M_{sw\text{-}t}(f_{q\text{-}a} + f_{q\text{-}f})$$

- for $C_{WT} < 0$

  $$M_{sw\text{-}t\text{-}LC} = -|f_{lp}| M_{sw\text{-}t}(f_{q\text{-}a} + f_{q\text{-}f})$$

where:

C_{WT} : Load combination factor for wave torsional moment, to be taken as specified in Pt B, Ch 5, Sec 2, for the considered dynamic load case.

f_{lp} : Factor depending on the longitudinal position, as defined in Pt B, Ch 5, Sec 2

$f_{q\text{-}a}$, $f_{q\text{-}f}$: Distribution factors, as defined in Pt B, Ch 5, Sec 4, [3.4.1]

$M_{sw\text{-}t}$: Permissible torsional still water moment in seagoing condition, as defined in [3.1.1].

4.1.4 Torsional still water moment for direct calculations in harbour/sheltered water

For direct calculation analysis, the torsional still water moment in the harbour/sheltered water condition $M_{sw\text{-}t\text{-}p}$, in kN.m, is to be taken, at any longitudinal position, as follows:

$$M_{sw\text{-}t\text{-}p} = f_{lp}\ M_{sw\text{-}t\text{-}h}\ (f_{q\text{-}a} + f_{q\text{-}f})$$

where:

f_{lp} : Factor depending on the longitudinal position, as defined in Pt B, Ch 5, Sec 2

$M_{sw\text{-}t\text{-}h}$: Permissible torsional still water moment in harbour/sheltered water, as defined in [4.1.2]

$f_{q\text{-}a}$, $f_{q\text{-}f}$: Distribution factors, as defined in Pt B, Ch 5, Sec 4, [3.4.1].

4.2 Dynamic hull girder loads

4.2.1 Vertical wave bending moments for strength assessment

The vertical wave bending moments $M_{wv\text{-}h}$ and $M_{wv\text{-}s}$, in kN·m, at any longitudinal position, are to be taken as:

- in hogging condition:

  $M_{wv\text{-}h} = 1,5\ n\ 0,85\ f_S\ f_{nl\text{-}h}\ f_{m\text{-}h}\ C\ L^3\ C_W\ f_{BL}^{0,8}$

- in sagging condition:

  $M_{wv\text{-}s} = -1,5\ n\ 0,85\ f_S\ f_{nl\text{-}s}\ f_{m\text{-}s}\ C\ L^3\ C_W\ f_{BL}^{0,8}$

where:

f_S : Speed effect coefficient as defined in Pt B, Ch 5, Sec 3

$f_{nl\text{-}h}$: Coefficient considering non-linear effects applied to hogging, to be taken equal to:

$$f_{nl-h} = 1 + n \cdot \left(0,3 \frac{C_B}{C_W} \sqrt{T_{SC}} - 1\right)$$

without being taken greater than 1,1

For OHM and OHS load cases, $f_{nl\text{-}h}$ is to be taken equal to 1,0

$f_{nl\text{-}s}$: Coefficient considering non-linear effects applied to sagging, to be taken equal to:

$$f_{nl-s} = 1 + n \cdot \left(4,5 \frac{1 + 0,2 f_{Bow}}{C_W \sqrt{C_B}\ L^{0,3}} - 1\right)$$

without being taken less than 1,0

For OHM and OHS load cases, $f_{nl\text{-}s}$ is to be taken equal to 1,0

f_{Bow} : Bow flare shape coefficient, to be taken equal to:

$$f_{Bow} = \frac{A_{DK} - A_{WL}}{0,2 L z_f}$$

A_{DK} : Projected area to the horizontal plane of deck, in m^2, including the forecastle deck, extending from 0,8 L forward (see Fig 10)

A_{WL} : Waterplane area, in m^2, at scantling draught T_{SC}, extending from 0,8 L forward

$f_{m\text{-}h}$: Distribution factor for vertical wave bending moment in hogging condition along the ship's length, to be taken as follows (see Fig 8):

- for $x \le 0$:

  $f_{m\text{-}h} = 0,0$

- for $x = 0,1$ L:

  $f_{m\text{-}h} = 0,15$

- for $0,35\ L \le x \le 0,55\ L$:

  $f_{m\text{-}h} = 1,00$

- for $x = 0,8$ L:

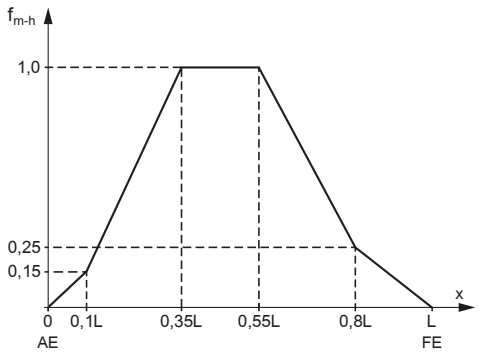
  $f_{m\text{-}h} = 0,25$

- for $x \ge L$:

  $f_{m\text{-}h} = 0,0$

Intermediate values of $f_{m\text{-}h}$ are to be obtained by linear interpolation

Figure 8 : Distribution factor $f_{m\text{-}h}$

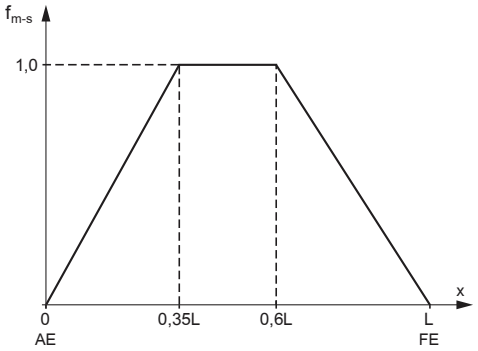


f_{m-s} : Distribution factor for vertical wave bending moment in sagging condition along the ship's length, to be taken as follows (see Fig 9):

- for $x \leq 0$:
  $f_{m-s} = 0,0$
- for $0,35\ L \leq x \leq 0,6\ L$:
  $f_{m-s} = 1,0$
- for $x \geq L$:
  $f_{m-s} = 0,0$

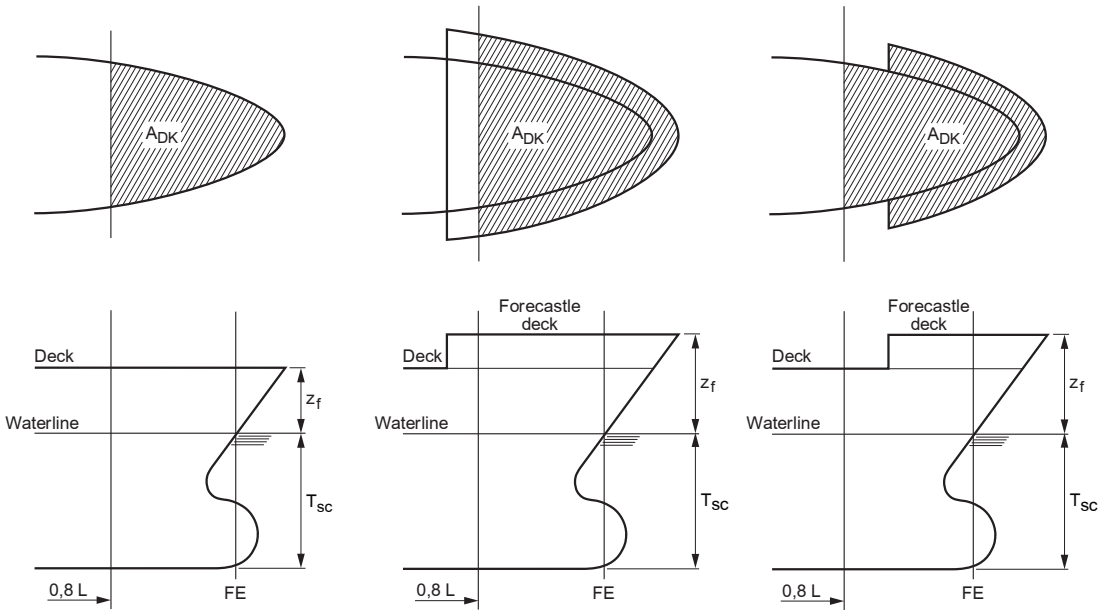
Intermediate values of f_{m-s} are to be obtained by linear interpolation

Figure 9 : Distribution factor f_{m-s}



z_f : Vertical distance, in m, from the waterline at scantling draught T_{SC} to the deck (or forecastle deck), measured at FE (see Fig 10)

Figure 10 : Projected area A_{DK} and vertical distance z_f



4.2.2 Vertical wave shear forces for strength assessment

The vertical wave shear forces Q_{wv-pos} and Q_{wv-neg}, in kN, at any longitudinal position, are to be taken as follows:

$$Q_{wv-pos} = n\ 0,85\ f_S\ f_{q-pos}\ C\ L^2\ C_W\ f_{BL}^{0,8}$$

$$Q_{wv-neg} = -\ n\ 0,85\ f_S\ f_{q-neg}\ C\ L^2\ C_W\ f_{BL}^{0,8}$$

where:

f_S : Speed effect coefficient as defined in Pt B, Ch 5, Sec 3

f_{q-pos} : Distribution factor along the ship length for positive wave shear force, to be taken as (see Fig 11):

- for $x \leq 0$:
  $f_{q-pos} = 0,0$
- for $0,15L \leq x \leq 0,3L$:
  $f_{q-pos} = 5,2\ (0,3 + 0,7 f_{nl-h})$

- for 0,4L ≤ x ≤ 0,55L:

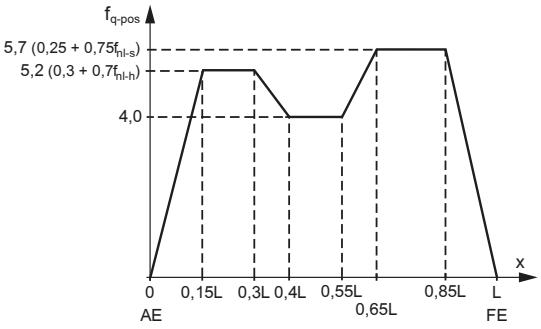
  $f_{q\text{-}pos} = 4,0$
- for 0,65L ≤ x ≤ 0,85L:

  $f_{q\text{-}pos} = 5,7\ (0,25 + 0,75f_{nl\text{-}s})$
- for x ≥ L:

  $f_{q\text{-}pos} = 0,0$

Intermediate values of $f_{q\text{-}pos}$ are to be obtained by linear interpolation

Figure 11 : Distribution factor $f_{q\text{-}pos}$



$f_{q\text{-}neg}$: Distribution factor along the ship length for negative wave shear force, to be taken as (see Fig 12):

- for x ≤ 0:

  $f_{q\text{-}neg} = 1,3\ (0,3 + 0,7f_{nl\text{-}s})$
- for 0,15L ≤ x ≤ 0,3L:

  $f_{q\text{-}neg} = 5,2\ (0,3 + 0,7f_{nl\text{-}s})$
- for 0,4L ≤ x ≤ 0,50L:

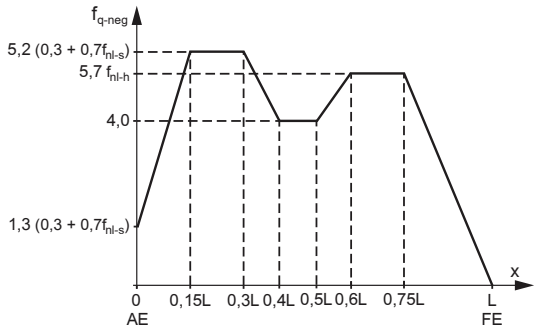
  $f_{q\text{-}neg} = 4,0$
- for 0,6L ≤ x ≤ 0,75L:

  $f_{q\text{-}neg} = 5,7\ f_{nl\text{-}h}$
- for x ≥ L:

  $f_{q\text{-}neg} = 0,0$

Intermediate values of $f_{q\text{-}neg}$ are to be obtained by linear interpolation

Figure 12 : Distribution factor $f_{q\text{-}neg}$



$f_{nl\text{-}h}$, $f_{nl\text{-}s}$: Coefficients considering non-linear effects and defined in [4.2.1]

5 Load combinations for direct strength analysis based on partial three-dimensional model

5.1 General

5.1.1 The loading conditions to be considered for three- dimensional analysis are given in:

- [5.3] for strength check of cargo holds
- [5.4] for strength check of fuel oil tanks when deep fuel oil tanks are located in the cargo hold area.

These loading conditions may be adjusted if deemed relevant by the Society.

5.1.2 The load cases to be considered for three-dimensional analysis are given in [5.5].

5.2 Container weight

5.2.1 Maximum number of tiers

It corresponds to the maximum number of tiers on deck and in hold as provided on the container stowage plan.

On a case-by-case basis, for tiers on deck, the maximum number of tiers as provided among all the loading conditions as described in the loading manual might be used, upon agreement by the Society.

5.2.2 Permissible stack weight

The permissible stack weights in hold and on deck, for 20′ and 40′ containers as referred to in [5.2.3] to [5.2.6], are to be defined in the loading manual and on the midship section, as required in [1.2.2].

5.2.3 Heavy cargo in hold

a) 40′ containers:

Heavy cargo weight of 40' containers in hold is to be calculated as the permissible stack weight, as defined in [5.2.2], divided by the maximum number of tiers, as defined in [5.2.1].

Note 1: At preliminary stage when the permissible stack weight is not available, the heavy cargo weight of 40' containers in hold may be taken equal to 30,5 T.

b) 20′ containers:

Heavy cargo weight of 20' containers in hold is to be calculated as the permissible stack weight, as defined in [5.2.2], divided by the maximum number of tiers, as defined in [5.2.1].

A specific value of uniform permissible stack weight of 20' containers might be specified in loading manual and midship section, used for FE calculation. This value should be at least equal to the maximum stack weight of 20' container stacks provided among the different loading conditions of the loading manual.

5.2.4 Heavy cargo on deck

a) 40′ containers:

Heavy cargo weight of 40' containers on deck is to be calculated as the permissible stack weight, as defined in [5.2.2], divided by the maximum number of tiers, as defined in [5.2.1].

b) 20′ containers:

Heavy cargo weight of 20' containers on deck is to be calculated as the permissible stack weight, as defined in [5.2.2], divided by the maximum number of tiers, as defined in [5.2.1].

5.2.5 Light cargo in hold

a) 40′ containers:

Light cargo weight of 40' containers in hold is to be taken as 55% of its related heavy cargo weight, as defined in [5.2.3], not exceeding 16,5 T per container.

b) 20′ containers:

Light cargo weight of 20' containers in hold is to be taken as the minimum stack weight in holds, selected among homogeneous conditions provided in the loading manual considering the holds filled up to the top, divided by the maximum number of tiers as defined in [5.2.1], without exceeding 8 T per container.

5.2.6 Light cargo on deck

Light cargo weight of 40' containers on deck is to be taken equal to 90% of its related heavy cargo weight, without exceeding 17 T per container.

5.3 Loading conditions for cargo holds strength check

5.3.1 The loading conditions to be considered for cargo hold strength check are given in [5.3.4] to [5.3.8] and are summarized in Tab 3.

5.3.2 For the loading conditions given in [5.3.5] to [5.3.8], all ballast and fuel oil tanks in way of cargo hold model are to be empty.

5.3.3 If deemed necessary by the Society, specific static harbour conditions may have to be considered in addition to the loading conditions given in [5.3.4] to [5.3.8], using permissible hull girder loads for harbour conditions.

5.3.4 Ballast loading condition

Ballast 1 (BL-1):

- all cargo holds to be empty, ballast tanks to be full
- the draught value is to be taken as the minimum ballast draught provided in the loading manual (LM) and the still water bending moment is to be taken from the same condition.

5.3.5 Homogeneous loading conditions

Homogeneous heavy (HH):

- homogeneous 40′ containers loaded on deck and in holds
- heavy cargo weight of 40′ containers is to be considered as defined in [5.2.3] and [5.2.4]
- scantling draught is to be considered together with the maximum design still water bending moment in hogging.

Homogeneous light (HL):

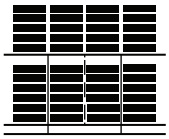
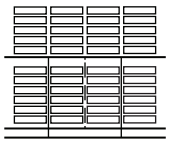
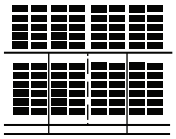
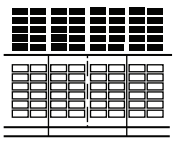
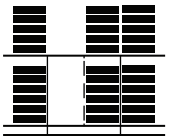
- homogeneous 40′ containers loaded on deck and in holds
- light cargo weight of 40′ containers is to be considered as defined in [5.2.5] and [5.2.6]
- scantling draught is to be considered together with the maximum design still water bending moment in hogging.

Homogeneous reduced draught (HR):

- homogeneous 20′ containers loaded on deck and in holds. Reduced draught is to be considered together with the minimum design still water bending moment
- reduced draught corresponds to the expected draught amidships when heavy cargo is loaded in the considered holds while lighter cargo is loaded in the other holds.

  Reduced draught is not to be taken more than 90% of the scantling draught
- heavy cargo weight of 20′ containers is to be considered as defined in [5.2.3].

Table 3 : Loading conditions for cargo hold strength check

Loading condition	Description	Loading pattern	Container loading **(1)**	Draught	SWBM	SWSF
BL-1	Ballast		Not loaded	T_{BAL}	from LM	Q_{sw}
HH	Homogeneous (heavy)		Heavy cargo 40′	T_{SC}	$M_{sw\text{-}max}$	Q_{sw}
HL	Homogeneous (light)		Light cargo 40′	T_{SC}	$M_{sw\text{-}max}$	Q_{sw}
HR	Homogeneous (reduced draught)		Heavy cargo 20′ If mixed stowage on deck is applicable: Max 20' and 40' stack weight	$\leq 0,9T_{SC}$	$M_{sw\text{-}min}$	Q_{sw}
DL	Maximum deck load		Heavy cargo 20′ on deck If mixed stowage on deck is applicable: Max 20, and 40' stack weight. Light cargo 20' in hold	0,9 T_{SC}	$M_{sw\text{-}min}$ **(2)**	Q_{sw}
OB-1	One bay empty		Heavy cargo 40′ One bay empty in hold and on deck **(3)**	T_{SC}	$M_{sw\text{-}max}$	Q_{sw}
FD	Flooding		Heavy cargo 40′ Any cargo hold flooded	T_{FL}	–	–

(1) Container weights are defined in [5.2]. Each stack is to be loaded with the maximum number of tiers, as defined in [5.2.1].

(2) The minimum vertical still water bending moment taken from all the homogeneous loading conditions in the loading manual may be used.

(3) A minimum list of loading patterns is defined in Tab 4.

5.3.6 Maximum deck load loading condition

Maximum deck load (DL):

- maximum stack load of 20' containers on deck and minimum stack load of 20' containers in holds
- light cargo weight of 20′ containers in hold is to be taken as defined in [5.2.5]
- heavy cargo weight of 20′ containers on deck is to be taken as defined in [5.2.3]
- scantling draught is to be considered together with the minimum still water bending moment, selected among all homogeneous loading conditions described in the loading manual.

5.3.7 One bay empty loading condition

One bay empty 1 (OB-1):

- homogeneous loading is to be considered similarly to HH, as defined in [5.3.5], except one bay to be kept empty in hold and on deck. A minimum list of loading patterns is defined in Tab 4
- scantling draught is to be considered together with the maximum design still water bending moment in hogging.

Table 4 : One bay empty loading condition

Container ship arrangement		Bays to be considered as being empty
Design	Number of bays per hold	
Twin islands	2	Bay located immediately aft of the fore island
		One of the two bays of the second cargo hold aft of the fore island
	3	Bay located immediately aft of the fore island
		Two forward bays in the second cargo hold aft of the fore island **(1)**
Single island	2	One bay among those located within 0,3 L to 0,7 L
	3	One bay among those located within 0,3 L to 0,7 L and adjacent to a watertight bulkhead
		One bay among those located within 0,3 L to 0,7 L, in the middle of the hold
(1) Two different loading conditions are to be checked, each of them with one of the bays to be considered empty.		

5.3.8 Flooding

Flooding (FD):

- homogeneous loading is to be considered similarly to HH, as defined in [5.3.5]. Dynamic loads and hull girder loads are disregarded
- draught T_{FL} is to be considered up to the deepest equilibrium waterline in damaged condition (obtained from applicable damage stability calculations). If this information is not available at design stage, the draught might be considered up to the freeboard deck. It is to be checked at a later stage that the deepest equilibrium waterline remains below the freeboard deck
- the structural analysis is limited to the transverse watertight bulkheads and to double bottom girders extending one frame aft and fore of the transverse watertight bulkheads
- the weight of immersed containers may be reduced by 30% of their buoyancy at empty stage.

5.4 Loading conditions for fuel oil tanks

5.4.1 The loading conditions to be considered for fuel oil tank strength check are given in [5.4.3] to [5.4.6] and are summarized in Tab 5.

5.4.2 The actual density of the fuel oil is to be used in the calculation.

If any deckhouse or superstructure is fitted above the fuel oil tanks, inertial loads induced by such structures are to be modelled.

5.4.3 Normal ballast loading conditions

Ballast 2 (BL-2):

- cargo holds are to be empty. All fuel oil tanks are to be fully loaded
- the draught is to be taken as the minimum ballast draught provided in the loading manual.

Ballast 3 (BL-3):

- cargo holds are to be empty. Fuel oil tanks are to be loaded alternately
- the draught is to be taken as the minimum ballast draught provided in the loading manual.

Table 5 : Loading conditions for fuel oil tanks strength check

Loading condition	Description	Container loading **(1)**	FOT loading	Draught	SWBM	SWSF
BL-2	Ballast	Not loaded	Full	T_{BAL}	from LM	Q_{sw}
BL-3			Alternate			
SL-1	Maximum stack load	Heavy cargo 40′	Empty	T_{SC}	$M_{sw\text{-}min}$	Q_{sw}
SL-2			Alternate			
OB-2	One bay empty	Heavy cargo 40′ One bay adjacent to HFO empty **(2)**	Empty	T_{SC}	$M_{sw\text{-}max}$	Q_{sw}
OB-3			Alternate			
OB-4			Full	T_L **(3)**	$M_{sw\text{-}min}$	
OB-5			Alternate			
TS	Testing	Not loaded	Testing	T_{BAL}	from LM	Q_{sw}

(1) Container weights are defined in [5.2]. Each stack is to be loaded with the maximum number of tiers as defined in [5.2.1].

(2) If the arrangement and scantling of the bays forward and aft of the FOT are symmetrical, either bay is to be empty and the other to be full. Otherwise, both conditions are to be considered.

(3) The lightest load draught taken from the loading manual.

5.4.4 Maximum stack load loading conditions

Maximum stack load 1 (SL-1):

- cargo holds are to be loaded as per HH condition described in [5.3.5]. Fuel oil tanks are to be empty
- scantling draught is to be considered together with the minimum still water bending moment, selected among all homogeneous loading conditions described in the loading manual.

Maximum stack load 2 (SL-2):

- cargo holds are to be loaded as per HH condition described in [5.3.5]. Fuel oil tanks are to be loaded alternately through ship's breadth
- Scantling draught is to be considered together with the minimum still water bending moment, selected among all homogeneous loading conditions described in the loading manual.

5.4.5 One bay empty loading conditions

One bay empty 2 (OB-2):

- cargo holds are to be loaded as per HH condition described in [5.3.5] except one bay adjacent to the fuel oil tanks to be kept empty. Fuel oil tanks are to be empty
- scantling draught is to be considered together with the maximum design still water bending moment in hogging.

One bay empty 3 (OB-3):

- cargo holds are to be loaded as per HH condition described in [5.3.5] except one bay adjacent to the fuel oil tanks to be kept empty. Fuel oil tanks are to be loaded alternately
- scantling draught is to be considered together with the maximum design still water bending moment in hogging.

One bay empty 4 (OB-4):

- cargo holds are to be loaded as per HH condition described in [5.3.5] except one bay adjacent to the fuel oil tanks to be kept empty. All fuel oil tanks are to be fully loaded
- the draught is to be taken as the lightest load draught provided in loading manual.

One bay empty 5 (OB-5):

- cargo holds are to be loaded as per HH condition described in [5.3.5] except one bay adjacent to the fuel oil tanks to be kept empty. Fuel oil tanks are to be loaded alternately
- the draught is to be taken as the lightest load draught provided in loading manual, without being taken greater than 0,75 D.

5.4.6 Testing loading conditions

Testing (TS):

- fuel oil tank testing condition is to be checked considering the test pressure as defined for deep tanks in Pt B, Ch 5, Sec 6, [10]. No dynamic pressure is to be considered. Each tank is to be filled separately
- the draught is to be taken as the minimum ballast draught from the loading manual, and the still water bending moment is to be taken from the same condition.

5.5 Load cases

5.5.1 To obtain the FE load combinations as defined in Pt B, Ch 8, App 1, [3], each loading condition is to be associated with all dynamic load cases as given in Pt B, Ch 5, Sec 2, [2] except the BP load cases.

6 Load combinations for direct strength analysis based on full length model

6.1 Loading condition

6.1.1 A single loading condition complying with the following criteria is to be selected from the loading manual:

- the resulting draught is equal to the scantling draught, as far as practicable
- the resulting still water bending moment is at least equal to 95% of the maximum permissible still water bending moment ($M_{sw\text{-}max}$)
- the ship is homogeneously loaded, as far as practicable
- the cargo holds are loaded up to their top, as far as practicable
- the minimum ballast water is carried.

6.1.2 The full length model is generally to be loaded with 40' containers; 20' containers might be used to fill holds that cannot be entirely filled in with 40' containers.

The selection criteria for the loading condition generally leads to a nominal container weight of 28 t / FEU (14 t / TEU). Any significant deviation to this value shall be discussed with the Society.

Note 1:

TEU : Twenty-foot Equivalent Unit, used to define a standard container of 20 feet in length

FEU : Forty-foot Equivalent Unit, used to define a standard container of 40 feet in length

6.2 Load cases

6.2.1 Load case definition

The wave heading β, in deg, which maximises each dominant load effect is specified in Tab 6.

The peak period T_p, in s, which maximises each dominant load effect is to be taken as:

$$T_p = (T_0)^{0,5}\left(\frac{2\pi L_c}{g}\right)^{0,25}$$

where:

T_0 : Wave period providing the maximum RAO, in s, to be taken as:

$$T_0 = 2,2\left(\frac{L}{\alpha g}\right)^{0,5}$$

L_c : Length, in m, as defined in Pt B, Ch 5, Sec 3

α : Parameter for the considered load case, as defined in Tab 6.

6.2.2 Design value of dominant load effect

The design values of dominant load effects are specified in Tab 6.

When deemed relevant by the Society, the design values may be derived on the basis of a direct long-term linear seakeeping analysis. The long-term value for vertical bending moment is to be corrected for Froude-Krylov non-linearities. Long-term values are to be derived for a return period of 25 years, considering a North-Atlantic scatter diagram. The routing factor as defined in Pt B, Ch 5, Sec 3 is also to be considered.

6.2.3 Combined load effects

When the design value of the dominant load effect is not based on the rule value, the heading and amplitude of waves is to be selected such that the amplitude of the other combined load effects is not to exceed their rule reference value multiplied by a factor C_{max} given in Tab 7.

Table 6 : Load cases definition

Load case	EDW (1)	Dominant load effect	Location	Wave heading β (2)	α	Reference of design value D
1	HVM	Vertical wave bending moment M_{wv-h} or M_{wv-s}	Midship section	180°	0,65 $C_{W-LC}^{-1,3}$	M_{wv-h} and M_{wv-s} defined in [4.2.1]
2	FVM	Vertical wave bending moment M_{wv-h} or M_{wv-s}	Vicinity of 0,25L	0°	0,65 $C_{W-LC}^{-1,3}$	
3	BR	Roll motion θ	Midship section	90°	4,60 T_R^{-2}	θ defined in Pt B, Ch 5, Sec 3, [2.1.1]
4	BP	Wave pressure at the waterline P_W	Midship section	90°	0,55 $f_{TL}^{-0,4}$	P_W defined in Pt B, Ch 5, Sec 5, [1.3.1] for BP
5	OHM	Horizontal wave bending moment M_{wh}	Midship section	120°	0,65 $f_{TL}^{-0,3}$	M_{wh} defined in Pt B, Ch 5, Sec 4, [3.3]
6	OHS	Horizontal wave shear force Q_{wh} and torsion M_{wt}	Vicinity of 0,75L	60°	0,68 $f_{TL}^{-0,3}$	Q_{wh} defined in Pt B, Ch 5, Sec 4, [3.4] M_{wt} defined in Pt B, Ch 5, Sec 4, [3.5]
7	OVA	Vertical acceleration a_Z	Vicinity of L	120°	0,24 $f_{BL}^{-0,8}$	a_Z defined in Pt B, Ch 5, Sec 3, [3.2.4]

(1) Equivalent Design Wave as defined in Pt B, Ch 5, Sec 2

(2) The forward ship speed is to be taken equal to 5 knots

Note 1:

C_{W-LC} : Waterplane coefficient at considered loading condition draught T_{LC}

T_R : Dimensionless roll period as defined in Pt B, Ch 5, Sec 2

f_{TL} : Ratio between draught at the considered loading condition and rule length as defined in Pt B, Ch 5, Sec 3

f_{BL} : Ratio between moulded breadth and rule length as defined in Pt B, Ch 5, Sec 3

Table 7 : Values of factor C_{max}

Load component	C_{max}
Wave bending moments and wave torque	1,10
Wave shear forces	1,40
Roll angle, vertical and horizontal accelerations	1,10
Wave pressure	1,20

7 Hull girder strength assessment

7.1 Section modulus and moment of inertia

7.1.1 Minimum net moment of inertia

For both hogging and sagging conditions, the net moment of inertia I_{y-n50}, in m^4, of the hull transverse section is to be not less than I_{y-min}, obtained from the following formula:

$$I_{y-min} = 1,55\ L\ |M_{sw} + M_{wv}|\ 10^{-7}$$

7.1.2 Within the longitudinal extend as defined in Pt B, Ch 6, Sec 1, [3.2.1], the scantlings of all continuous longitudinal members are to be maintained based on the modulus requirement at the midship.

8 Cargo hold structural strength analysis

8.1 General

8.1.1 As an alternative to Pt B, Ch 8, App 1, [1.1.3], the extent of the cargo hold structural analysis may be limited to the midship area at the discretion of the Society.

9 Buckling

9.1 Load cases

9.1.1 HVM and FVM load cases are replaced by S11A1 and S11A2 head sea load cases, where all load components are to be applied simultaneously with the hull girder still water load values as defined in Tab 8 and the load combination factors (LCF) for the hull girder wave loads and accelerations as defined in Tab 9.

Table 8 : Hull girder still water loads for buckling strength assessment

Load component		S11A1		S11A2	
		Hogging	Sagging	Hogging	Sagging
Hull girder still water loads	M_{sw}	$M_{sw\text{-}max}$	$M_{sw\text{-}min}$	0,7 $M_{sw\text{-}max}$	0,7 $M_{sw\text{-}min}$
	Q_{sw}	0,7 Q_{hog}	0,7 Q_{sag}	Q_{hog}	Q_{sag}
	$M_{sw\text{-}t}$	0	0	0	0

Note 1:

- For x / L ≤ 0,5 : $Q_{hog} = Q_{sw\text{-}max}$ and $Q_{sag} = Q_{sw\text{-}min}$
- For x / L > 0,5 : $Q_{hog} = Q_{sw\text{-}min}$ and $Q_{sag} = Q_{sw\text{-}max}$

Table 9 : Load combination factors for buckling strength assessment

Load component		LCF	S11A1		S11A2	
			Hogging	Sagging	Hogging	Sagging
Hull girder wave loads	M_{wv}	C_{WV}	1,0	–1,0	0,7	–0,7
	Q_{wv}	C_{QV}	0,7 f_{lq}	–0,7 f_{lq}	f_{lq}	$-f_{lq}$
	M_{wh}	C_{WH}	0	0	0	0
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	10 f_{TL} – 0,60	0,60 – 10 f_{TL}	10 f_{TL} – 0,60	0,60 – 10 f_{TL}
	$a_{pitch\text{-}x}$	C_{XP}	0,38	–0,38	0,38	–0,38
	$a_{yaw\text{-}x}$	C_{XY}	0	0	0	0
	g sinφ	C_{XG}	–0,36	0,36	–0,36	0,36
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	$a_{roll\text{-}y}$	C_{YR}	0	0	0	0
	$a_{yaw\text{-}y}$	C_{YY}	0	0	0	0
	g sinθ	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	–0,10 – 5,70 f_{TL}	0,10 + 5,70 f_{TL}	–0,10 – 5,70 f_{TL}	0,10 + 5,70 f_{TL}
	$a_{roll\text{-}z}$	C_{ZR}	0	0	0	0
	$a_{pitch\text{-}z}$	C_{ZP}	0,38	–0,38	0,38	–0,38

Note 1:

f_{lq} = 1 for x/L ≤ 0,5 and f_{lq} = –1 for x/L > 0,5

f_{TL} : Ratio between draught at the considered loading condition and rule length, to be taken as $f_{TL} = T_{LC} / L$

T_{LC} : Draught amidships, in m, at the considered loading condition

10 Fatigue

10.1 Corrosion model

10.1.1 The following values of stress correction factor as defined in NI611 are to be considered:

a) For analytical approach for longitudinal stiffeners:

- f_{c_a} = 0,95
- f_{c_b} = 1,0

b) For FEA calculations:

- f_{c_FEA} = 1,0

10.2 Design loading condition for fatigue assessment

10.2.1 A single loading condition at 0,85 T_{SC} is to be considered for fatigue analysis.

When a finite element analysis is requested, the design fatigue loading condition is to be selected according to the criteria defined in [6.1], in particular with respect to the minimum value for still water bending moment, except for the resulting draught to be taken equal to 0,85 T_{SC}. Loading conditions based on deeper draught may also be accepted.

10.2.2 For spectral fatigue analysis a second loading condition may be requested if deemed necessary. This loading condition takes into account the effect of specific local loads, typically for large fuel tanks (oil or gas).

This second loading condition is to be taken similar to the one described in [10.2.1], with only an adjustment on the local loads as necessary.

When a second loading condition is considered, the contribution to the global damage of each loading condition is to be adjusted as relevant.

11 Fixed cell guides

11.1 General

11.1.1 Containers may be secured within fixed cell guides, permanently connected by welding to the hull structure, which prevent horizontal sliding and tipping.

11.1.2 When containers are secured by fixed cell guides, the scantlings of such cell guides and supports are to comply with the criteria in [11.2] and [11.3].

11.2 Arrangement of fixed cell guides

11.2.1 Vertical guides generally consist of sections with equal sides, not less than 12 mm in thickness, extended over a height sufficient to give uniform support to containers.

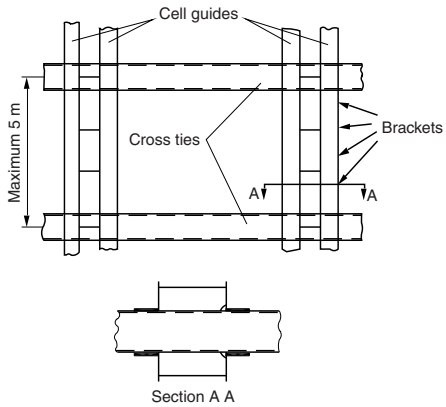
11.2.2 Guides are to be connected to each other and to the supporting structures of the hull by means of cross-ties and longitudinal members such as to prevent deformation due to the action of the forces transmitted by containers.

In general, the spacing between cross-ties connecting the guides may not exceed 5 metres and their position is to coincide as nearly as possible with that of the container corners (see Fig 13).

Cross-ties are to be longitudinally restrained at one or more points so that their elastic deformation due to the action of the longitudinal thrust of containers does not exceed 20 mm at any point.

11.2.3 The upper end of the guides is to be fitted with a block to facilitate entry of the containers. Such appliance is to be of robust construction so as to withstand impact and chafing.

Figure 13 : Typical structure of cell guides



11.3 Strength criteria

11.3.1 The local stresses in the elements of cell guides, transverse and longitudinal cross-ties, and connections with the hull structure are to be less than the following values:

- normal stress: 150/k N/mm^2
- shear stress: 100/k N/mm^2
- Von Mises equivalent stress: 175/k N/mm^2,

where:

k : Material factor, defined in Pt B, Ch 4, Sec 1, [2.2].

12 Lashing bridge

12.1 General

12.1.1 Container securing

Containers on deck may be secured by means of lashing bridges permanently connected by welding to the ship structure. Lashing bridges allow lashing at a higher level.

12.1.2 Material

Materials used are to comply with Pt B, Ch 4, Sec 1. The manufacturing processes and testing are to comply with the applicable requirements of NR216 Materials and Welding.

12.1.3 Strength verification

Drawings of the lashing bridge structure and details of the supporting structure are to be submitted to the Society for approval together with details on the calculations carried out.

12.1.4 Structural modelling

Calculations are to be based at least on three-dimensional beam analysis or on finite element analysis.

A finite element model is to be used in all cases where a beam model is deemed insufficient, in particular when vertical plain bulkheads are fitted.

A finite element model is to be built in accordance with relevant requirements from Pt B, Ch 8, App 1, [2.3] and Pt B, Ch 8, App 1, [2.4].

The finite element mesh size is to be adjusted in accordance with Pt B, Ch 8, App 1, [2.4.3] in order to properly model the displacements and resulting stresses in the lashing bridge structure. At least 3 elements are to be used along the width of horizontal deck strips and vertical webs (sizes from 200 mm by 200 mm to 250 mm by 250 mm are generally adequate mesh sizes).

Adjacent ship structure is to be included in the model, vertically down to the second deck level and horizontally up to one web frame fore and aft of the transverse bulkhead.

Recommended boundary conditions are given in Tab 10.

Calculations are to be based on gross scantlings.

The connection of the container securing fitting to the lashing bridge is to be located in way of high stiffness structure. The Society may require a detailed finite element analysis in case of container securing fitting attached to a structure with limited stiffness.

Table 10 : Boundary conditions for FE model of lashing bridge

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
End of the model (e.g. top part of the hull, from second deck to hatch coaming)	fix	–	–	–	fix	fix
Elements linked to continuous vertical plating (e.g. linked to vertical frames of a bulkhead or to the inner hull and side shell)	–	fix	fix	–	–	–
Note 1: [–] means no constraint applied (free).						

12.1.5 Arrangement

Overall stiffness of the lashing bridge is to be sufficient to sustain the lashing loads. Stiffness reinforcement such as shear plates or diagonal bars are recommended below the level where the lashing rods can be attached.

Structural continuity is to be ensured at the connections of

the vertical supports of the lashing bridge to the ship structure.

12.2 Design load

12.2.1 Forces applied on lashing bridge

The lashing bridge is to be loaded by forces corresponding to 70% of the SWL (Safe Working Load) of the container securing fitting, taken as 250 kN.

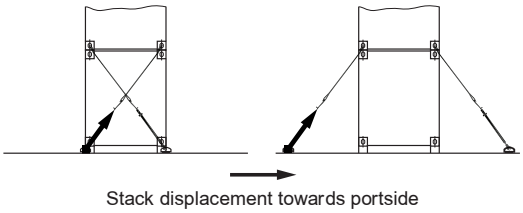
The forces defined in Tab 11 are to be applied to lashing eyes loaded by a container securing fitting in maximum tension, with an assumed displacement of the stacks towards portside.

A container securing fitting in external or internal lashing is considered in maximum tension when the fitting restrains both the container racking and lifting (see Fig 14).

Table 11 : Forces towards portside

Longitudinal direction	Transverse direction	Upward
20 kN (fore bay) –20 kN (aft bay)	119 kN	126 kN

Figure 14 : Loaded lashing eye



12.2.2 Loading conditions

The following loading conditions are to be considered for the calculation of lashing bridges:

a) Both fore and aft bays of the lashing bridge are loaded with containers

b) Fore bay of the lashing bridge is loaded with containers while the aft bay is empty

c) Aft bay of the lashing bridge is loaded with containers while the fore bay is empty.

Loading condition a) is intended to maximize vertical and transverse forces acting on the lashing bridge. Loading conditions b) and c) are intended to maximize the longitudinal forces acting on the lashing bridge.

12.3 Strength assessment

12.3.1 Allowable stress

Allowable stresses for the design loads as defined in [12.2]] are to be in accordance with:

- Pt B, Ch 7, Sec 6, [5.1.4] for beam analysis
- Pt B, Ch 8, App 1, [5.2.3] or Pt B, Ch 8, App 2, [4.1.3] for finite element analysis.

12.3.2 Lashing bridge stiffness

In order to sustain the loads transmitted by the container securing fittings and to have enough rigidity with limited deformations, the lashing bridge stiffness is to be assessed.

The displacement in the transverse direction at each lashing level i of the lashing bridge is to satisfy the following criteria:

$(d_{trans,i} - d_{bot}) \leq 1,85\ h_i$

where:

i : Lashing level depending on the vertical location of attachment of the container securing fittings to the lashing bridge. The level of reference (level 0) is defined as the lowest level where it is possible to attach the container securing fittings over the full width of the lashing bridge (see Pt F, Ch 12, Sec 5)

$d_{trans,i}$: Average transverse displacement, in mm, of the lashing eyes for the considered lashing level i

d_{bot} : Average transverse displacement, in mm, of the lashing bridge at the bottom of the stack

h_i : Average height, in m, of the lashing eyes with regard to the bottom of the stack, for the considered lashing level i

When the lashing bridge is not compliant with the above criteria, standard values for the effective stiffness factors of container securing fittings as defined in Pt F, Ch 12, Sec 5, are to be replaced by values obtained with direct calculations.

13 Lashing items

13.1 Fixed and portable container securing fittings

13.1.1 All fixed and portable container securing fittings are to comply with the requirements of Pt F, Ch 12, Sec 5.

13.1.2 The deck stanchions are to be checked according to the criteria for pillars defined in Pt B, Ch 7, Sec 6, [2.6] with design loads submitted by the manufacturer.

13.2 Lashing software

13.2.1 The ship is to be equipped with a lashing software complying with the requirements given in Pt F, Ch 12, Sec 5, [7].

Section 3 Machinery and Systems

1 Open-top container ships

1.1

1.1.1 Open-top container ships are to comply with the requirements of Pt F, Ch 12, Sec 6.

Section 4 Whipping and Springing Assessment

1 General

1.1 Application

1.1.1 This Section specifies the requirements for performing fatigue and ultimate strength assessments based on direct hydro-structure calculations taking into account the springing and whipping structural responses.

1.1.2 In accordance with Pt A, Ch 1, Sec 2, [4.2.6] or Pt A, Ch 1, Sec 2, [6.18.4], ships complying with the requirements of this Section may be assigned one of the following notations:

- **WhiSp1** when the fatigue damage assessment takes into account the effects of linear springing. The requirements of Article [3] are applicable to these ships.
- **WhiSp2** when, in addition to the requirements for the notation **WhiSp1**, the ultimate strength assessment takes into account the non-linear effects of whipping. The requirements of Articles [3] and [4] are applicable to these ships.
- **WhiSp3** when, in addition to the requirements for the notation **WhiSp2**, the fatigue damage assessment takes into account the non-linear effects of whipping. The requirements of Articles [3], [4] and [5] are applicable to these ships.

1.2 Definitions

1.2.1 Springing

Springing is the resonant structural vibration as defined in NI691, Sec. 7, [3.1.2].

1.2.2 Whipping

Whipping is the transient structural vibration as defined in NI691, Sec. 7, [3.1.3].

1.3 Data and documentation to be submitted

1.3.1 The data and documentation to be submitted are listed in Tab 1.

Table 1 : Data and documentation to be submitted

No.	I/A **(1)**	Item
1	A	Detailed description of the loading conditions listed in [2]
2	I	Provisional lightship distribution
3	I	Complete ship finite element model, as described in Ch 2, App 1, [3.2.1]
4	A	List of structural details which will be considered for fatigue calculations
5	I	Local very fine mesh models for all considered structural details, as described in Ch 2, App 1, [3.2.2]
(1) A: to be submitted for approval; I: to be submitted for information.		

2 Loading conditions

2.1 General

2.1.1 Fatigue assessment

Fatigue analysis is to be carried out for a single loading condition, selected so as to maximise the still water bending moment in hogging.

2.1.2 Ultimate strength assessment

Extreme response analysis is to be carried out for a single loading condition, selected so as to maximise the still water bending moment in hogging.

2.2 Additional loading conditions

2.2.1 Additional loading conditions may be considered for these calculations on a case-by-case basis, if deemed relevant by the Society.

3 Linear spectral fatigue assessment

3.1 General

3.1.1 The linear fatigue assessment is computed as shown in Tab 2, with and without springing. The difference between the two computed fatigue damages represents the effect of linear springing on fatigue damage.

Table 2 : Linear fatigue assessment

		Hydrodynamic loads		
		Linear	Weakly non-linear	Slamming
Structural response	Quasi-static	X		
	Dynamic	X		

3.2 Ship operational profile

3.2.1 Operating conditions

a) For ships assigned the navigation notation **unrestricted navigation**, the following wave scatter diagram is to be used:

- In general: worldwide scatter diagram as given in Ch 2, App 1, Tab 2. The sea states are to be modelled by a Jonswap spectrum with γ equal to 1,5 and a "cos n" spreading function with n equal to 3.
- If the additional class notation **spectral fatigue( )** is assigned: wave scatter diagram corresponding to the routes or areas indicated between brackets.

b) Ships assigned a navigation notation other than **unrestricted navigation** are to be considered on a case-by-case basis.

3.2.2 Loading conditions

The fatigue analysis is to be carried out for the loading conditions defined in Article [2]. Additional loading conditions which could significantly contribute to the fatigue damage may be contemplated on a case-by-case basis.

3.2.3 Wave heading

Wave headings are considered uniformly distributed from 0° to 360°.

A different distribution may be used if accurate information is available. The probability of each wave heading (relative angle between the ship route and the wave direction) is then to be defined before running the computations.

3.2.4 Speed profile

The ship speed is to be taken as 75% of the maximum ahead service speed in all sea states.

Different speed profiles may be used if accurate information is available. They may be based on full-scale measurement data. The speed dependance on the sea states is then to be defined before running the computations.

3.3 Fatigue computation

3.3.1 Linear quasi-static fatigue damage

The linear quasi-static stress RAO is computed for each structural detail (defined in [1.3]) according to Ch 2, App 1, [3.3.1] and Ch 2, App 1, [3.4.1]. The linear fatigue damage and the corresponding fatigue life are then derived using sea state statistics from the considered scatter diagram and the appropriate S-N curve (see Ch 2, App 1, [4.2.2]). The damage is to be computed for a return period of 25 years, or xx years when the additional class notation **VeriSTAR-HULL FLM FAT xx years** is assigned.

3.3.2 Linear dynamic fatigue damage

The linear stress RAO including dynamic structural response is computed for each structural detail (defined in [1.3]) according to Ch 2, App 1, [3.3.1] Ch 2, App 1, [3.4.2]. The fatigue damage and the corresponding fatigue life are then derived using sea state statistics from the considered scatter diagram and the appropriate S-N curve. The damage shall be computed for a return period of 25 years, or xx years when the additional class notation **VeriSTAR-HULL FLM FAT xx years** is assigned.

3.3.3 Impact of whipping on damage

For ships above 300m in length, the linear fatigue damage is to be corrected using the following partial safety factor α_{whip} to be taken:

- α_{whip} = 1 for ships assigned the notation **WhiSp3**
- α_{whip} = 1,15 otherwise.

3.4 Criteria

3.4.1 Linear quasi-static fatigue life

A minimum of 25 years fatigue life is to be achieved for each of the considered details.

When the additional class notation **VeriSTAR-HULL FLM FAT xx years** is assigned, the fatigue life for each of the considered details is to reach a minimum of xx years.

3.4.2 Linear dynamic fatigue life

A minimum of 25 years fatigue life is to be achieved for each of the considered details.

When the additional class notation **VeriSTAR-HULL FLM FAT xx years** is assigned, the fatigue life for each of the considered details is to reach a minimum of xx years.

4 Ultimate strength assessment

4.1 General

4.1.1 Ultimate strength is checked as shown in Tab 3, using a fully non-linear dynamic structural response including whipping and springing effects.

Table 3 : Ultimate strength assessment

		Hydrodynamic loads		
		Linear	Weakly non-linear	Slamming
Structural response	Quasi-static	X	(X)	
	Dynamic			X
Note 1: Optional calculations steps are displayed within brackets.				

4.2 Ship operational profile

4.2.1 Operating conditions

For ships assigned the navigation notation **unrestricted navigation**, the wave scatter diagram for North Atlantic from IACS Recommendation No. 34 Rev. 2 is to be used. This scatter diagram is given in Ch 2, App 1, Tab 2.

The sea states are to be modelled by a Jonswap spectrum with g equal to 1,5 and a “cos n” spreading function with n equal to 3, as defined in IACS Recommendation No. 34 Rev.2.

Ships assigned a navigation notation other than **unrestricted navigation** are to be considered on a case-by-case basis.

4.2.2 Loading conditions

The extreme response analysis is to be carried out for the loading conditions defined in Article [2], depending on the ship type and on the way she is operated. Additional loading conditions may be contemplated on a case-by-case basis.

4.2.3 Wave heading

Wave headings are considered uniformly distributed from 0° to 360°.

A different distribution may be used if accurate information is available. The probability of each wave heading (relative angle between the ship route and the wave direction) is then to be defined before runing the computations.

4.2.4 Speed profile

The ship speed is to be taken as 5 knots in all sea states.

Different speed profiles may be used if accurate information is available. They may be based on full-scale measurement data. The speed dependance on the sea states is then to be defined before runing the computations.

4.3 Computation of extreme vertical bending moment

4.3.1 Linear extreme bending moment

A list of longitudinal locations where the vertical bending moment will be computed is to be defined. This list of cross-sections is to include at least a calculation point in each hold, plus any additional locations deemed necessary.

The vertical bending moment RAO at each cross-section is to be computed using the linear hydrodynamic loads defined in Ch 2, App 1, [3.3.1]. A linear long-term analysis is performed and the extreme value corresponding to a return period of 25 years is computed with a probability of exceedance $\alpha = 0,63$ (see Ch 2, App 1, [5.2.2]).

Note 1: Vertical bending moment means total vertical bending moment, i.e. it includes the still water bending moment and the wave bending moment.

4.3.2 Weakly non-linear loads

This calculation step is optional but can be useful to separate the non-linear effects induced by wave non-linearities and those induced by pure whipping.

The extreme vertical bending moment, corresponding to a return period of 25 years with a probability of exceedance $\alpha = 0,63$, is computed at each cross-section, using a Design Sea State approach (see Ch 2, App 1, [5.3]) together with a weakly non-linear time domain hydro-structure model (see Ch 2, App 1, [3.3.2]). The Design Sea State is based on the most contributive sea state to the linear extreme vertical bending moment amidships computed in [4.3.1].

4.3.3 Whipping simulations

The extreme minimum and maximum vertical wave bending moments, corresponding to a return period of 25 years with a probability of exceedance $\alpha = 0,63$, is computed at each cross-section, using a Design Sea State approach (see Ch 2, App 1, [5.3]) together with a non-linear time domain hydro-structure model including slamming forces (see Ch 2, App 1, [3.3.3]). The Design Sea State is based on the most contributive sea state to the linear extreme vertical bending moment amidships computed in [4.3.1].

4.4 Criteria

4.4.1 It is to be checked that the hull girder ultimate bending capacity at any cross-section between 0,2L and 0,75L is in compliance with the following formula for both minimum and maximum extreme vertical bending moments:

$$\frac{M_U}{\gamma_R} \geq M$$

where:

M_U : Ultimate bending capacity of the hull transverse section defined in Pt B, Ch 6, Sec 2, [2]

M : Extreme vertical bending moment computed in [4.3.3] defined as follows:

$M = M_{sw} + M_{wv}$

where:

M_{sw} : Permissible minimum and maximum vertical still water bending moments in seagoing conditions defined in Pt B, Ch 5, Sec 4, [2.2.1]

M_{wv} : Extreme minimum and maximum vertical wave bending moment computed in [4.3.3].

γ_R : Partial safety factor taken equal to 1,1

L : Rule length defined in Pt B, Ch 1, Sec 3, [2.1.1].

5 Non-linear fatigue assessment

5.1 General

5.1.1 The non-linear fatigue assessment includes the whipping contribution to the fatigue damage, as shown in Tab 4.

Table 4 : Non-linear fatigue assessment

		Hydrodynamic loads		
		Linear	Weakly non-linear	Slamming
Structural response	Quasi-static	(X)		
	Dynamic	(X)		X
Note 1: Intermediate calculations steps are displayed within brackets.				

5.2 Ship operational profile

5.2.1 Operating conditions, loading conditions, wave headings and speed profile are to be the same as for a linear fatigue assessment (refer to [3.2]).

5.3 Fatigue computation

5.3.1 Design Sea States and headings definition

A linear fatigue damage computation, including springing, is to be achieved as a first step (see [3.3]). Design Sea States and headings are then chosen among those showing the highest contribution to the linear dynamic fatigue damage. A set of Design Sea States is defined for each structural detail.

5.3.2 Whipping simulations

The fatigue damage and the corresponding fatigue life including whipping effects are derived for each structural detail using a Design Sea States approach (see Ch 2, App 1, [5.3]) used in conjunction with a non-linear time domain hydro-structure model including slamming forces (see Ch 2, App 1, [3.3.3]).

5.4 Criteria

5.4.1 The fatigue life for each of the considered details is to reach a minimum of 25 years.

When the additional class notation **VeriSTAR-HULL FLM FAT xx years** is assigned, the fatigue life for each of the considered details is to reach a minimum of xx years.

Appendix 1 Methodology for Long Term Direct Hydro-Structure Calculations including Whipping and Springing Response

1 General

1.1 Introduction

1.1.1 The present Appendix describes the various methods and tools to be used for the direct calculation of the hydro-structural response of ships, including whipping and springing response.

1.1.2 The following tools and methods are needed to determine the extreme stress or the total fatigue damage corresponding to the ship life:

- a description of the operating conditions during all the ship life, including the wave environment and the ship operational profile (see Article [2])
- a hydro-structure model of the ship, which is able to compute the ship response on any type of wave conditions, including hydroelastic effects (see Article [3])
- methods to derive extreme responses and the fatigue damage from the results of the previous computations (see Article [4])
- a long-term analysis methodology that is able to define the optimal number of computations to be run, in order to derive the extreme response and the total fatigue damage (see Article [5]).

1.1.3 There is not a single methodology to compute the extreme response and the total fatigue damage. This appendix presents a list of methods and tools. Depending on what is to be simulated, a given long-term methodology is to be used in conjunction with a specific hydro-structure model.

2 Operating conditions

2.1 Wave environment

2.1.1 Wave scatter diagram

A wave scatter diagram is a description of the joint probabilities of wave heights and wave periods. This description is made for a given geographical area. Usually there is no information about the direction of the waves. The scatter diagrams are usually based on hindcast data, which are extrapolated using some analytical functions.

2.1.2 Fatigue assessment

For the fatigue assessment, the following scatter diagram is to be used:

- In general:
  Worldwide scatter diagram as given in Tab 1. The sea states are to be modelled by a Jonswap spectrum with γ equal to 1,5 and a “cos n” spreading function with n equal to 3.
- For ships assigned the additional class notation **spectral fatigue( )**:
  Wave scatter diagram corresponding to the routes or areas indicated between brackets.

2.1.3 Ultimate strength assessment

For the ultimate strength assessment, the North Atlantic scatter diagram as given in Tab 2 is to be used.

Table 1 : World wide scatter diagram

Significant wave height H_s (m)	Mean wave period T_{0m1} (s)														TOTAL
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	
0,5	2338,65	3563,56	3800,17	2897,50	1545,29	665,75	307,22	173,51	111,92	72,85	24,85	7,43	2,87	1,10	15512,68
1,5	2,13	1630,28	6819,92	12013,79	10751,72	6835,47	3406,90	1506,03	592,08	199,17	57,72	14,79	3,36	0,67	43834,03
2,5	0,00	0,05	452,30	3368,52	6898,39	6198,03	4171,89	2375,47	1175,70	503,31	190,22	65,62	20,98	6,19	25426,68
3,5	0,00	0,00	0,15	212,75	1827,53	2665,07	2045,61	1277,18	703,85	345,98	153,78	64,41	26,63	11,06	9333,99
4,5	0,00	0,00	0,00	0,61	176,52	990,51	1002,12	683,96	376,79	179,01	76,00	29,67	11,18	4,27	3530,63
5,5	0,00	0,00	0,00	0,00	1,66	175,23	458,07	381,68	227,12	106,51	42,80	15,47	5,20	1,67	1415,43
6,5	0,00	0,00	0,00	0,00	0,01	6,11	136,30	190,18	134,02	66,92	26,21	8,87	2,75	0,80	572,18
7,5	0,00	0,00	0,00	0,00	0,00	0,05	13,88	74,52	71,21	41,35	16,94	5,49	1,57	0,43	225,45
8,5	0,00	0,00	0,00	0,00	0,00	0,00	0,37	16,78	32,44	23,88	11,18	3,73	1,00	0,25	89,63
9,5	0,00	0,00	0,00	0,00	0,00	0,00	0,01	1,41	11,49	12,41	7,05	2,62	0,70	0,16	35,85
10,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	2,29	5,29	4,05	1,79	0,52	0,11	14,12
11,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,19	1,73	2,03	1,17	0,40	0,09	5,63
12,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,34	0,86	0,69	0,29	0,07	2,27
13,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,28	0,34	0,19	0,05	0,90
14,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,14	0,11	0,04	0,35
15,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,04	0,05	0,03	0,13
16,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,05
17,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01
18,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
TOTAL	2340,79	5193,89	11072,55	18493,16	21201,13	17536,22	11542,37	6680,78	3439,14	1558,80	614,04	222,30	77,83	27,01	100000

Note 1:

The H_s and T_{0m1} values are class midpoints.

$$T_{0m1} = 2\pi\frac{m_{-1}}{m_0}$$

where m_n is the spectral moment of order n

Table 2 : North Atlantic scatter diagram

Significant wave height H_s (m)	Mean wave period T_{0m1} (s)																			TOTAL
	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5	19,5	
0,5	0,00	0,00	6,82	202,00	333,61	187,76	45,59	4,74	0,21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	780,73
1,5	0,00	0,00	0,33	2028,35	12750,81	11693,38	7215,76	3006,80	846,07	160,77	20,63	1,79	0,10	0,00	0,00	0,00	0,00	0,00	37724,79
2,5	0,00	0,00	0,00	3,38	2805,81	8517,73	7835,85	5887,37	3608,30	1805,81	737,71	246,00	66,96	14,88	2,70	0,40	0,05	0,00	31530,95
3,5	0,00	0,00	0,00	0,00	23,06	2742,51	4666,81	4100,83	2936,41	1713,38	814,68	315,65	99,66	25,64	5,38	0,92	0,13	0,01	17445,07
4,5	0,00	0,00	0,00	0,00	0,00	82,06	1759,81	2069,19	1715,42	1151,29	625,51	275,12	97,96	28,24	6,59	1,24	0,19	0,02	7812,64
5,5	0,00	0,00	0,00	0,00	0,00	0,08	149,74	811,81	791,81	609,66	375,67	185,26	73,12	23,09	5,84	1,18	0,19	0,02	3027,47
6,5	0,00	0,00	0,00	0,00	0,00	0,00	1,02	147,59	305,37	271,71	190,23	104,79	45,42	15,49	4,16	0,88	0,15	0,02	1086,83
7,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,77	88,62	107,20	86,26	53,35	25,36	9,27	2,60	0,56	0,09	0,01	378,09
8,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	9,40	38,70	36,80	25,95	13,63	5,33	1,55	0,34	0,05	0,01	131,78
9,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	9,34	15,15	12,51	7,39	3,12	0,94	0,20	0,03	0,00	48,88
10,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,81	5,73	5,96	4,08	1,90	0,60	0,13	0,02	0,00	19,23
11,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	1,29	2,68	2,23	1,18	0,40	0,08	0,01	0,00	7,89
12,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,11	1,01	1,14	0,72	0,27	0,06	0,01	0,00	3,32
13,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,22	0,51	0,42	0,18	0,04	0,00	0,00	1,37
14,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,19	0,21	0,12	0,03	0,00	0,00	0,57
15,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,09	0,07	0,02	0,00	0,00	22
16,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,04	0,01	0,00	0,00	0,06
17,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,01	0,00	0,00	0,04
18,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,02
TOTAL	0,00	0,00	7,15	2233,73	15913,29	23223,52	21674,58	16031,12	10301,81	5868,69	2909,77	1230,31	437,79	129,62	31,47	6,11	0,92	0,09	100000

Note 1:

The H_s and T_{0m1} values are class midpoints.

$$T_{0m1} = 2\pi\frac{m_{-1}}{m_0}$$

where m_n is the spectral moment of order n

3 Ship hydro-structural model

3.1 General

3.1.1 A good evaluation of the structural response of a ship in waves needs a proper coupling between a hydrodynamic model, which describes the hydrodynamic interaction between the ship and the waves, and a structural model, which describes the structural response to wave loads and inertia loads. Several levels of assumptions can be chosen for the hydrodynamic model and the structural model, depending on which physical behaviour is expected to be reproduced.

The ship structural response can be considered as:

- quasi-static, which means that the structural response is strictly proportional to the applied loads. This model is described in [3.4.1]
- dynamic, if dynamic amplification occurs. This model is described in [3.4.2].

Three types of hydrodynamic loads may be considered to be applied to the ship:

- linear loads (valid only for the smallest sea states), described in [3.3.1]
- weakly non-linear loads (Froude-Krylov forces), described in [3.3.2]
- slamming loads, described in [3.3.3].

3.2 Finite elements modeling

3.2.1 Complete ship model

Complete ship model is to be built in accordance with Pt B, Ch 8, App 3, [2].

3.2.2 Local detail models

Local structural details are to be assessed according to Pt B, Ch 13, Sec 5, [2.5].

Fine mesh and very fine mesh models are to be built in accordance with:

- for fine mesh: Pt B, Ch 8, App 2, [2.3.1]
- for very fine mesh: NI611 Guidelines for Fatigue Assessment of Ships and Offshore Units, Sec 5, [2.3.4].

3.3 Hydrodynamic loads

3.3.1 Linear

The linear part of the hydrodynamic loading is calculated by a validated numerical seakeeping code. The use of codes based on the Boundary Element Method (BEM) is recommended. In the case of linear calculations the mesh contains the mean underwater part only. The mesh size is to be chosen so that the minimal wave length (defined on the basis of encounter frequency) is covered by at least 6 panels. Alternatively, a special treatment of the high frequency calculations can be used in order to avoid the numerical inaccuracies inherent to the BEM method. In any case, the problem of irregular frequencies is to be properly solved.

The hydrodynamic problem is solved for every degree of freedom: at least the 6 rigid body motions and the first natural elastic modes if a dynamic structural response is considered. The equation of motion is then solved in the frequency domain for all the generalized motions (rigid body modes and elastic modes).

The outputs of a linear hydro-structure computation are the Response Amplitude Operators (RAO). Ship motions RAOs and internal hull girder loads RAOs are directly computed by the seakeeping software (the internal loads are calculated simply by integration of the external inertia and pressure loads between the ship end and the considered section). Stress RAOs are computed from the structural analysis.

RAOs are to be computed for:

- at least 36 headings (10° step)
- frequencies in the range [0,1: 2] rad/s
- a frequency step of $0,3(g/L)^{0,5}$

  where:

  $g = 9,81$ m/s^2

  L : Length between perpendiculars.

3.3.2 Weakly non-linear

The minimum non-linearities that should be included are based on the so called Froude-Krylov approximation. The pressure of the undisturbed incoming wave is applied to the hull on every wet panel, and not only under the mean waterline as it is done in the linear computation. The mesh that is used to integrate the pressure loading has to include the part above the mean waterline. The non-linear hydrostatic restoring forces are also included by taking into account the real position of the ship in the integration of the hydrostatic pressure.

The motion equation is solved using a time domain seakeeping program. The radiation forces are included through the memory functions, whereas the diffraction forces remain linear. All extra forces needed in the time domain simulation to ensure course-keeping and to avoid low frequency motions should be properly included in the loading of the structural mesh. For each time-step a loading case is built and the corresponding structural response is calculated by 3D FEM analysis. If the dynamic structural

response is included, the stress response might be computed by modal summation if it is justified that the modal convergence is achieved.

The outputs of a weakly non-linear hydro-structure computation are time traces. Ship motions and internal hull girder loads are directly computed by the seakeeping software (the internal loads are calculated simply as the sum of the inertial and pressure loads at each section). Time histories of stresses are computed by a structural analysis performed for each time step of the simulation.

3.3.3 Slamming

The slamming pressures are to be computed using either a CFD code or a Boundary Element Method provided that they are properly validated and coupled with the seakeeping code. The slamming pressures are to be properly transferred to the FE model at each time step of the time domain simulation.

The outputs of a non-linear hydro-structure computation are time traces. Ship motions and internal hull girder loads are directly computed by the seakeeping software (the internal loads are calculated simply as the sum of the inertial and pressure loads at each section).

Time histories of stresses are computed by a structural analysis performed for each time step of the simulation. If duly justified a modal approach can be used to reconstruct the stress history without performing a FE calculation at each time step.

3.4 Structural ship response

3.4.1 Quasi-static ship response

Once the hydrodynamic seakeeping problem is solved, the different loading cases for FE model analysis need to be constructed. Each loading case is composed of the hydrodynamic pressure loading on the wet panels, the inertial and the gravity loading on each finite element and the additional damping loading. The perfect equilibrium of the overall loading needs to be ensured. In case of important differences between the hydrodynamic and the structural meshes, special care is to be given to the pressure transfer. Both pressure and nodal forces approaches for pressure transfer are acceptable.

The structural problem is solved using FEA software for each loading case. The structural response is supposed to be static and linear. In the case of top-down modeling, once the problem is solved for the coarse mesh, the corresponding problem is solved for every fine mesh. The stresses obtained from this analysis are then used for fatigue, yielding or buckling computation. This computational scheme is depicted in Fig 1.

3.4.2 Dynamic ship response

The first step of the dynamic analysis is the modal FE model analysis in dry (vacuum) condition, which is to be done with care. Local structural modes are to be removed. The first 10 dry distortion modes are normally considered enough. Once the dry modes are obtained, the modal displacements are to be transfered from the structural model to the hydrodynamic model and the corresponding hydrodynamic problems are to be defined. Once the hydrodynamic problem is solved, a fully coupled dynamic equation is solved, giving the modal amplitudes.

Special care is to be given to the separation of the quasi-static and dynamic parts (as illustrated in Fig 3) of the response to ensure a proper convergence of the results. The quasi-static part of the response is calculated using the quasi-static method explained in [3.4.1]. The dynamic part of the response is calculated by summing up the dynamic contribution of each mode. Special attention is to be given to the fine mesh analysis for the dynamic part. The total response is obtained by summing the quasi-static part and the dynamic part as shown in Fig 2.

Figure 1 : Computational scheme for Quasi-static analysis

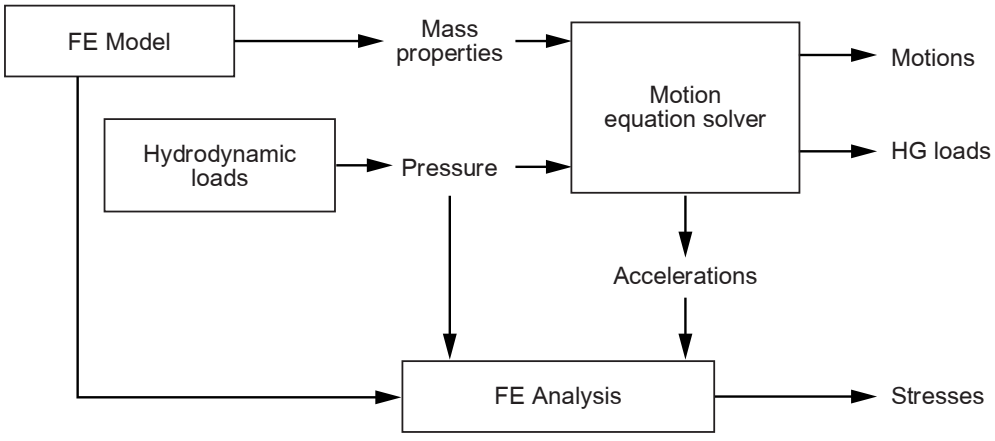


Figure 2 : Computational scheme for Dynamic analysis

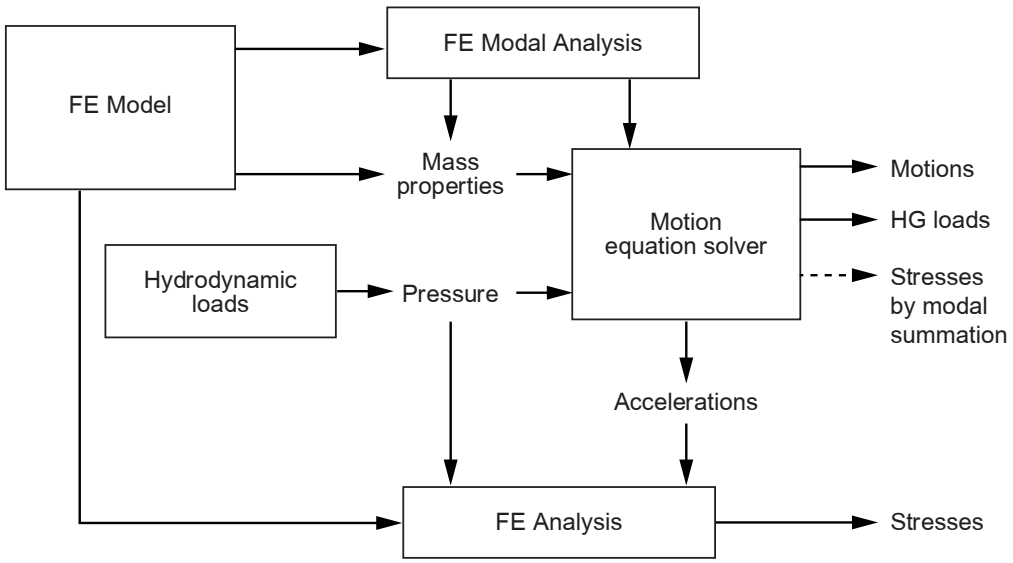
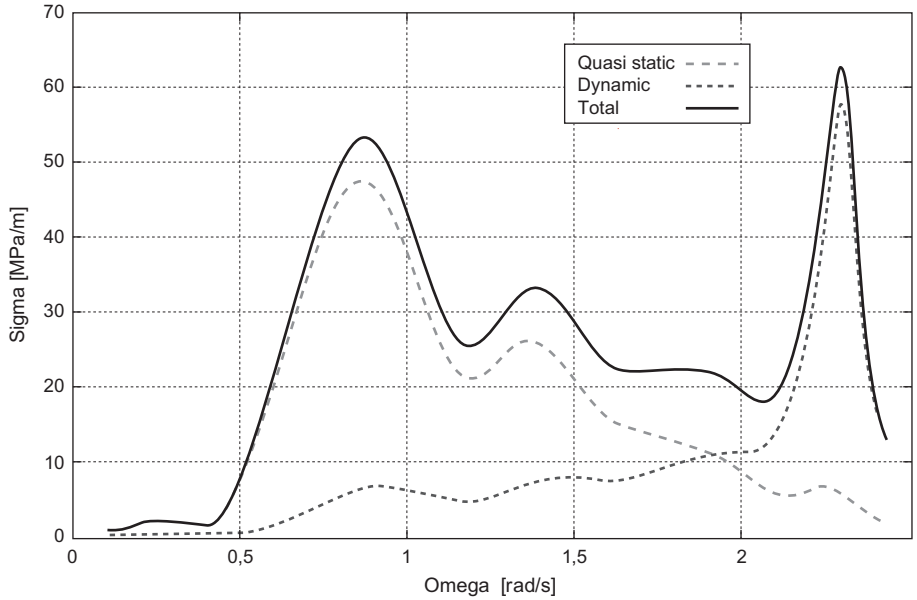


Figure 3 : Typical springing response and its decomposition into quasi static and dynamic part.



3.5 General modeling considerations

3.5.1 Mass properties

For each loading condition the following mass properties computed from the FE model should be verified according to the values from the trim and stability booklet:

- mass
- radii of gyration
- longitudinal distribution
- location of the center of gravity.

3.5.2 Hydrostatic balance

For each loading condition, the computed values of displacement, trim, and vertical still water bending moment are to be checked and compared to the values of the trim and stability booklet. The following tolerances are considered acceptable:

- 2% of the displacement
- 0,1° of the trim angle
- 10% of the still water bending moment.

It is also worth checking the following hydrostatic properties:

- draft at aft perpendicular and forward perpendicular
- location of the center of buoyancy (LCB)
- transverse and longitudinal metacentric height (GMt and GMl).

3.5.3 Roll damping

Additional damping forces are to be added to the motion equation in order to take into account the viscous damping and damping due to rudders, bilge keels, and other existing appendages. This additional damping is to be added to the wave damping computed by the hydrodynamic program. This damping could be based on experimental data or empirical methods. This damping is essentially non-linear and may be modeled by a linear and a quadratic damping coefficient. An equivalent linearised damping coefficient may be used when the problem is solved in linear frequency domain. If no information is available a linear damping of 5% of the critical damping is to be applied using the following formula:

$$B_{44} = 0,05 \cdot \frac{\Delta \cdot g \cdot GM_t \cdot T_{44}}{\pi}$$

where:

B_{44} : Roll damping

Δ : Mass of the ship, in kg

g : 9,81 m/s²

GM_t : Transverse metacentric height, in m

T_{44} : Roll natural period, in s.

These damping forces should be applied to the FE model as nodal forces to ensure a perfect equilibrium between the forces applied to the FE model and the acceleration solution of the motion equation.

3.5.4 Structural damping

Extra damping taking into account structural damping and cargo damping is to be added to the wave damping computed by the hydrodynamic program for the flexible modes. The structural damping may vary between 1% and 3% of the critical damping and tends to increase for the higher vibration modes.

$$B_{ii} = \eta_{ii} \cdot \frac{K_{ii} \cdot T_{ii}}{\pi}$$

where:

B_{ii} : Additional damping of flexible mode i

K_{ii} : Total stiffness (hydrostatic + structural) of the flexible mode i

T_{ii} : Natural period of mode i

h_{ii} : Fraction of the critical damping for the flexible mode i.

These damping forces should be applied to the FE model as nodal forces to ensure a perfect equilibrium between the forces applied to the FE model and the acceleration solution of the motion equation.

3.6 Type of simulations

3.6.1 General

The type of hydro-structural simulations depends on which hydrodynamic loads and which structural model are used. Possible simulations are shown in Tab 3.

Table 3 : Types of hydro-structural simulations loads

		Hydrodynamic loads		
		Linear	Weakly non-linear	Slamming
Structural response	Quasi-static	Linear seakeeping	Non-linear seakeeping	Local slamming effect
	Dynamic	Linear springing	Non-linear springing and wave induced whipping	Non-linear springing and slamming induced whipping

3.6.2 Linear seakeeping

Rigid body linear seakeeping response can be simulated using the quasi-static structural model with linear hydrodynamic loads. This model is used for linear fatigue assessment without springing effects in Ch 2, Sec 4, [3].

3.6.3 Linear springing

Linear springing response can be simulated using the dynamic structural model with the linear seakeeping loads. This model is used for linear fatigue assessment including springing effects in Ch 2, Sec 4, [3].

3.6.4 Non-linear seakeeping

Non-linear hull girder loads, such as hogging and sagging bending moment, can be evaluated using this model.This model can be used for intermediate results of the ultimate strength assessment in Ch 2, Sec 4, [4].

3.6.5 Local slamming effect

Local structural deformations due to slamming pressures can be computed using this model.

3.6.6 Non-linear springing and wave induced whipping

Because this model is taking into account non-linear wave loads and a structural dynamic response, it can simulate linear and non-linear springing as well as wave-induced whipping. It is to be noted that it is not possible to separate the whipping response from the springing response.

3.6.7 Non-linear springing and slamming induced whipping

This model is the most complex as it includes all non-linear loads, including slamming loads, coupled with a structural dynamic response. It can simulate linear and non-linear springing as well as slamming-induced whipping. It is to be noted that it is not possible to separate the whipping response from the springing response. This model is used for ultimate strength assessment Ch 2, Sec 4, [4] and non-linear fatigue assessment Ch 2, Sec 4, [5].

3.7 Statistical analysis of ship response in an irregular sea state

3.7.1 Linear frequency domain simulations

In case of linear hydrodynamic loads ([3.3.1]) and linear structure response, the ship behavior is defined by its RAOs. On a given irregular sea state, the ship response is characterized by the response spectrum defined as:

$$S_R(\omega) = \int_0^{360} RAO^2(\omega,\mu) S_\omega(\omega,\mu) d\mu$$

The spectral moments of the response are defined as:

$$m_n = \int_0^{\infty}\int_0^{360} \omega_e^n RAO^2(\omega,\mu) S_\omega(\omega,\mu) d\mu\, d\omega$$

Where the encounter frequency ω_e is defined as:

$$\omega_e = \omega - \frac{\omega^2 U}{g}\cos\mu$$

The mean up-crossing period is defined as:

$$Tz = 2\pi\sqrt{\frac{m_0}{m_2}}$$

The probability density of response range follows the Rayleigh distribution. Its cumulative distribution function is:

$$P_{Range}(x) = 1 - \exp\left(\frac{-x^2}{8m_0}\right)$$

The cumulative distribution function of the cycles amplitudes (maxima or minima) is:

$$P_{Amp}(x) = 1 - \exp\left(\frac{-x^2}{2m_0}\right)$$

3.7.2 Non-linear time domain simulations

In case of non-linear hydrodynamic loads ([3.3.2] and [3.3.3]), the simulation of the ship response is done in time domain. From a statistical point of view, this time domain signal can be analyzed with two different counting methods.

The up-crossing counting method consists in dividing the response into cycles (one cycle being defined between two consecutive mean level up-crossing), and to keep the maximum and the minimum of each cycle. The mean up-crossing period is defined as the mean period of all the cycles. The maxima and minima are sorted and used to define an empirical cumulative distribution function of the response. This distribution may be different from a Rayleigh distribution, because of the non-linearity of the simulation. The up-crossing counting method is used to define the extreme response on a sea state, or a set of sea states.

An analytical function (Weibull distribution for instance) can be fitted to the empirical cumulative distribution function, in order to be able to extrapolate the results to a lower probability level. Special care should be taken to the fitting procedure, and to the possible error introduced by an extrapolation.

If a linear result if available, it might be useful to compare the empirical distribution of the non-linear response with the empirical distribution of the linear response (which should converge to a Rayleigh distribution), and to fit a relationship between the non-

linear response and the linear response having the same probability. Hence the cumulative distribution function of the non-linear response can be defined from the linear cumulative distribution function of the equivalent linear response.

The rainflow counting method consists in dividing the responses into cycles, taking into account all the local maxima and minima. The mean period of all the cycles may be different from the up-crossing period. This counting method is used to compute fatigue damage.

4 Extreme response and fatigue damage computation

4.1 Extreme response

4.1.1 Definition

The extreme response associated to a return period Tr is the maximum response the ship will see while sailing during a period Tr with given environmental conditions. The extreme response is associated to a given exceedance probability or risk.

It can be an extreme load response (bending moment, torsion, acceleration...) or an extreme stress response.

4.1.2 Short term extreme

For a given short term condition (sea state and heading), the maximum short term response, corresponding to a duration T, exceeded with a risk α is defined by:

$$\alpha = 1 - P(x)^N$$

$$N = \frac{T}{T_z}$$

where:

N : Number of response cycles in the duration of the sea state

T_z : Zero up-crossing period of the response in seconds

T : Duration of the sea state in seconds

$P(x)$: Cumulative distribution function of the response.

Note 1: Usually the extreme short term response is defined as the response where the cumulative distribution function is equal to 1-1/N:

$$P(x) = 1 - \frac{1}{N}$$

For N larger than 100, the risk α corresponding to this extreme response is 63%.

If the response is computed from a frequency domain linear computation, the cumulative distribution function is to be based on a Rayleigh distribution ([3.7.1]). Hence the extreme short term response is perfectly known, whatever the duration of the sea state and the associated risk are.

On the other hand, the use of the cumulative distribution function based on the results of a time domain simulation of finite duration ([3.7.2]) is more complex. The empirical distribution is only known up to the value of the maximum response achieved during the time domain simulation, and the tail of this distribution does not statistically converge. Hence it is not possible to compute a short term extreme corresponding to a longer duration T and/or a lower risk α. For a good statistical convergence of the short term maxima, it is advised to run a time domain simulation at least $(10/\alpha)$ longer than the desired reference duration T of the short term maxima.

If an analytical fitting function is used, the short term extreme can be computed for any duration and risk, but special care should be given to the results, depending on the extrapolation procedure.

Another solution can be to increase the significant wave height of the short term condition, in order to increase the probability of exceedance of a given response. From a linear simulation, the cumulative distribution functions in two short term conditions of wave height Hs and λ Hs are linked by the following relation:

$$P(x) = 1 - (1 - P'(x))^{\lambda^2}$$

where:

$P(x)$: Cumulative distribution function of the response in a significant wave height Hs

$P'(x)$: Cumulative distribution function of the response in a significant wave height λ Hs.

The same relationship can be considered as valid for a for non-linear response. This validity is only based on the assumption that the ratio between the non-linear response and the linear response corresponding to the same probability of exceedance is the same on both sea states. Using this assumption, it is interesting to compute the empirical cumulative distribution function $P'(x)$ on a higher sea state, in order to define the tail of the distribution $P(x)$, and to be able to compute the short term extreme for a long duration T and/or a low risk α. This method should only be used for the tail of the distribution $P'(x)$ (for $P'(x) > 0,8$).

4.1.3 Long term extreme

For a long-term condition, defined as a list of short-term conditions (scatter diagram or list of sea states), the maximum long-term response, corresponding to a return period Tr, exceeded with a risk α, is defined by:

$$\alpha = 1 - \prod_i P_i(x)^{N_i}$$

$$N_i = \frac{p_i Tr}{T_i}$$

where:

Tr : Return period in seconds

i : Index of the short term condition

N_i : Number of response cycles in the return period, corresponding to the short term condition i

T_i : Zero up-crossing period of the response in the short term condition i in seconds

p_i : Probability of the short term condition i

$P_i(x)$: Cumulative distribution function of the response in the short term condition i.

The contribution of all short term conditions to the extreme value can be defined by:

$$1 - P_i(x)^{N_i}$$

The most contributive conditions are the short term conditions having the highest contribution to the extreme value.

When the short term cumulative distribution functions are defined from linear computations, the cumulative distribution functions are based on Rayleigh distributions ([3.7.1]). Hence the extreme long term response is perfectly known, whatever the reference duration and the associated risk is. However it is to be checked that the wave data from the scatter diagram are sufficiently detailed in the highest sea states: the most contributive sea states should be inside the scatter diagram, and not at its edge.

When the short term cumulative distribution functions are based on empirical distributions from time domain simulations, extrapolation is needed to compute the long term extreme. The techniques explained in [4.1.2] should be applied. It is to be checked that all the short term conditions having a significant contribution to the long term extreme have been extrapolated correctly, and that the statistical convergence is achieved.

Note 1: Usually the extreme long term response is defined as:

$$\sum_i N_i P_i(x) = 1$$

For a return period larger than a few days, the risk α corresponding to this extreme response is 63%.

Note 2: The total number of response cycles in the return period Tr is given by:

$$N_{Tr} = \sum_i N_i$$

For return periods of the order of 25 years, this number of response cycles is often of the order of 10^8. That is why the life time extreme response is often called the 10^{-8} response. However the number of response cycles in 25 years depends on the ship length, and on the load type or stress RAO. It is therefore more relevant to define the different extreme loads or stress response at the same return period Tr, rather than at the same probability 10^{-8} , corresponding to different return periods.

4.2 Fatigue damage

4.2.1 Definition

The fatigue damage is computed from a time history of stress cycles and a S-N curve which is the characteristic of the structural detail.

Fatigue damage can not be computed from a load response, except in a simplified case, when the stress response is supposed to be proportional to a single load response.

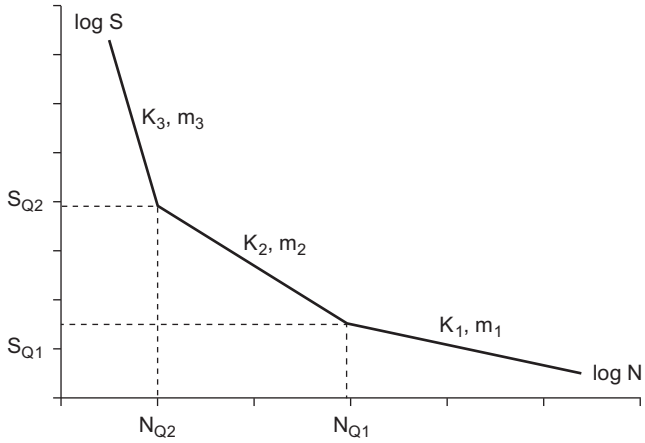
4.2.2 Short term fatigue damage

In a short term condition of duration T, the fatigue damage can be computed from the cumulative distribution function of stress ranges, and from the S-N curve.

A S-N curve is defined by the parameters m_i and K_i as illustrated in Fig 4. The maximum number of cycles until the rupture is given by:

$$N(\Delta\sigma) = \frac{K_i}{\Delta\sigma^{m_i}} \ldots\ldots (S_{Q_{i-1}} < \Delta\sigma < S_{Q_i})$$

Figure 4 : S-N curve



The fatigue damage is computed using the assumption of linear cumulative damage proposed by Palmgreen-Miner:

$$D = \int_0^{\infty} \frac{n(\Delta\sigma)}{N(\Delta\sigma)} d\Delta\sigma$$

$$n(\Delta\sigma) = \frac{T}{T_{\Delta\sigma}} \cdot \frac{d}{dx} P(\Delta\sigma)$$

where:

T_{Ds} : Mean stress range period

T : Duration of the sea state in seconds

$P(\Delta\sigma)$: Cumulative distribution function of the stress range.

The cumulative distribution function can be based on a Rayleigh distribution ([3.7.1]) or an empirical distribution based on a Rainflow count ([3.7.2]). In case of empirical distribution, this distribution should be based on a time domain simulation of at least 1h to 3h, for a good statistical convergence of the hourly fatigue damage.

When the density function is a Rayleigh distribution, the fatigue damage can be computed analytically:

$$D = \frac{T}{T_{\Delta\sigma}} \sum_{k=1}^{Nslope} \frac{1}{K_k} (2\sqrt{2m_0})^{m_k} \left(\Gamma\left(1 + \frac{m_k}{2}; \frac{S_{Q_k}^2}{8m_0}\right) - \Gamma\left(1 + \frac{m_k}{2}; \frac{S_{Q_{k-1}}^2}{8m_0}\right) \right)$$

$$S_{Q_0} = \infty \; S_{Q_{Nslope}} = Threshold$$

4.2.3 Long term fatigue damage

For a long-term condition, defined as a list of short-term conditions (scatter diagram or list of sea states), the fatigue damage corresponding to a return period Tr is defined as the sum of the damage accumulated in all the short term conditions.

$$D = \sum_i \int_0^{\infty} \frac{n_i(\Delta\sigma)}{N(\Delta\sigma)} d\Delta\sigma$$

$$n_i(\Delta\sigma) = p_i \frac{Tr}{T_{\Delta\sigma i}} \cdot \frac{d}{dx} P_i(\Delta\sigma)$$

where:

Tr : Return period in seconds

i : Index of the short term condition

T_{Dsi} : Mean stress range period in the short term condition i in seconds

p_i : Probability of the short term condition i

$P_i(x)$: Cumulative distribution function of the response in the short term condition i.

The contribution of each short term condition to the total damage can be defined by:

$$\int_0^{\infty} \frac{n_i(\Delta\sigma)}{N(\Delta\sigma)} d\Delta\sigma$$

The most contributive conditions are the short term conditions having the highest contribution to the total damage.

Another way to compute the long term fatigue damage is first to compute the long term distribution of stress ranges by summing the stress ranges distributions over all the short term conditions, and in a second step to compute the damage using the Miner sum:

$$n(\Delta\sigma) = \sum_i n_i(\Delta\sigma)$$

$$D = \int_0^{\infty} \frac{n(\Delta\sigma)}{N(\Delta\sigma)} d\Delta\sigma$$

5 Long term analysis methods

5.1 General

5.1.1 Definition

A long term analysis consists in simulating the ship behavior over a very long period of time (usually 25 years), where the ship will encounter many different environmental conditions. The objective of the long term analysis is to compute:

- the extreme response over that period of time (extreme stress, motion or load)
- the fatigue damage.

5.1.2 Input data

In order to do a long-term analysis a complete description of the environmental conditions is needed. This description can come from some hindcast data, or from a scatter diagram (see [2.1]).

To compute the hydro-structure ship response on every sea state of the environmental conditions, a proper model of the ship should be chosen (see Article [3]) and its operational profile should be given (see Ch 2, Sec 4, [4.2]).

5.1.3 Output data

The output of a long-term analysis is the distribution of stress cycles, or load cycles, in all the short term conditions composing the long term environmental conditions. From these distributions of cycles, it is possible to compute:

- the extreme response in term of stress, or load
- the fatigue damage.

A secondary output of the long-term analysis is the list of the most contributive conditions (heading, sea state) to the extreme response or to the fatigue damage.

5.1.4 Analysis methods

Several methods can be employed to perform a long term analysis. The most complex ones simulate all the life time ship response, while the simplified methods, under given assumptions, focus on a limited number of simulations cases. All these methods are described hereafter.

5.2 Fully long-term analysis

5.2.1 General case

A fully long-term analysis consists in simulating the ship response in all the sea states of the environmental conditions. This analysis may be very time consuming if the model chosen for calculating the ship hydro structure response is not very time efficient (time domain model, including non-linearity).

5.2.2 Linear long-term analysis

If the ship response is considered to be linear, the long-term analysis is done very easily. The ship behavior is characterized by its linear RAOs defined in [3.3.1]. It can be a load RAO (Vertical Bending Moment, Torsion Moment, Acceleration...) or a stress RAO. A load RAO only needs the results of a seakeeping computation, while a stress RAO needs in addition the results of FE analysis.

The extreme response corresponding to any return period and any risk can be computed with the procedure described in [4.1.3].

The fatigue damage corresponding to any return period can be computed from the procedure described in [4.2.3].

Both for extreme and fatigue, a very useful result is the identification of the most contributive short term condition, in terms of heading and sea state.

5.3 Design Sea States Approach

5.3.1 Principle

The principle of the Design Sea States approach is to focus the computation on a limited number of short term conditions (sea states and heading). These conditions are the ones having the highest contribution to the extreme response, or to the fatigue damage.

5.3.2 Choice of Design Sea States based on a linear long term analysis results

When the non-linear ship response is supposed to be partly governed by the linear ship response, it may be useful to choose the Design Sea States among the short term conditions having the highest contributions to the linear extreme response or total linear fatigue damage.

5.3.3 Computation of extreme response and fatigue damage

The Design Sea States approach is an iterative process:

- a first set of sea states and headings is chosen, and short term computation is done on these conditions.
- the extreme response, or the fatigue damage, is then computed using only these sea states, and neglecting the contribution of all the other conditions ([4.1.3] and [4.2.3]).
- the contribution of each computed condition to the extreme response, or total fatigue damage is computed. It is to be checked that the contribution on the edge of the chosen conditions can be neglected. If not, new short term conditions are added, and the process is started again.

5.4 Single Design Sea State

5.4.1 Principle

Under certain conditions, when it can be assumed than the non-linear ship response is just a correction of its linear response, it might be enough to compute the non-linear ship response for a single short term condition, and to use the results of this short term condition to correct the linear result.

5.4.2 Choice of the Design Sea State

For extreme response analysis, the Single Design Sea State should be the short term condition having the highest contribution to the linear extreme response.

For fatigue damage analysis, the Single Design Sea State should be the short term condition having the highest contribution to the linear fatigue damage.

5.4.3 Computation of the extreme response

The linear extreme response is computed at first using the linear long term analysis method ([5.2.2]). On the chosen Design Sea State, the risk of exceeding this linear extreme response is computed (see [4.1.2]). The short term non-linear extreme response corresponding to the same risk is then derived from the non-linear simulation. To limit the duration of the non-linear simulation, a fitting function may be used, or the Design Sea State significant wave height may be increased, as explained in [4.1.2].

This short term extreme response is considered to be the long term extreme response.

5.4.4 Computation of the fatigue damage

The linear fatigue damage is first computed using the linear long term analysis method ([5.2.2]). On the chosen Design Sea State, the linear fatigue damage and the non-linear fatigue damage are computed (see [4.2.2]). A correction factor is defined as the increase of fatigue damage due to non-linear effects.

This correction factor is applied to the long term linear fatigue damage to compute the long term non-linear fatigue damage.

CHAPTER 3
LIVESTOCK CARRIERS

Section 1 General

Section 2 Hull and Stability

Section 3 Systems Serving Livestock Spaces

Section 4 Fire-Fighting Systems in Livestock Spaces

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **livestock carrier**, as defined in Pt A, Ch 1, Sec 2, [4.2.6].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.2 Summary table

1.2.1 Requirements applicable to ships having the service notation **livestock carrier** are summarized in Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B • Ch 3, Sec 2	• NR566 • Ch 3, Sec 2
	L < 65 or 90 m **(1)**	• NR600	• NR566 • Ch 3, Sec 2
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 3, Sec 2	• Part B • Ch 3, Sec 2
	L < 65 or 90 m **(1)**	• NR600	• NR600
Stability		• Part B • Ch 3, Sec 2	• NR566 • Ch 3, Sec 2
Machinery and cargo systems		• Part C • Ch 3, Sec 3	• NR566 • Ch 3, Sec 3
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C • Ch 3, Sec 4	• NR566 • Ch 3, Sec 4

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Hull and Stability

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the following documents are to be submitted for information:

- livestock arrangement
- distribution of fodder and consumable liquid on the various decks and platforms.

2 General arrangement

2.1 Livestock arrangement

2.1.1 The livestock are to be kept in pens. The dimensions of these pens are to be suitable for the livestock carried. In general, the breadth and the length of the pen may not be greater than 4,5 m and 9 m, respectively.

The livestock may not be carried on hatch covers unless the latter are effectively protected.

2.2 Arrangement of spaces dedicated to the carriage of livestock

2.2.1 General

The requirements of this item apply to the arrangement of the spaces dedicated to the carriage of livestock. When deemed necessary by the Society, such spaces may need to be adapted or complemented depending on the species of animals which are to be carried.

2.2.2 Protection of livestock

Arrangements for protecting the livestock from injury, avoidable suffering and exposure to weather, sea or hot parts are to be provided.

2.2.3 Livestock arrangement

Livestock may not be carried, or loaded for carriage, in any part of a ship where the livestock, livestock fittings, livestock equipment or carrying arrangements may:

- obstruct access to any accommodation space or working space necessary for the safe running of the ship, or the means of egress from any hold or under deck space
- interfere with life-saving or fire-fighting appliances
- interfere with the tank sounding equipment or bilge pumping
- interfere with the operation of closing appliances
- interfere with the operation of freeing ports
- interfere with the lighting or ventilation of other parts of the ships
- interfere with the proper navigation of the ship.

2.3 Means of escape and access

2.3.1 General

In each space in which livestock is carried, not less than two means of escape for persons are to be fitted, widely separated and giving access to an open deck.

Access to livestock space for persons is to be safe. Where it is combined with a ramp used for moving livestock between decks, it is to be separated from the livestock ramp by protective fencing.

2.3.2 Closing arrangement

Pens, stalls and similar fittings are to be provided with a means of access for persons with secure closing arrangement which structural strength is to be considered by the Society on a case-by-case basis.

2.3.3 Passageway width

If access between a ship side and a pen, stall or similar fitting is required for purposes of safe and proper operation of ship, a passageway not less than 550 mm wide is to be provided between the ship's rail or bulwark and the rails or receptacles of the pen, stall or fitting.

3 Stability

3.1 Intact stability

3.1.1 General

The stability of the ship for the loading conditions reported in the trim and stability booklet is to be in compliance with the requirements of Pt B, Ch 3, Sec 2.

3.1.2 Additional requirements

Where national or international rules apply, the Society reserves the right to adopt the rules in force in the country in which the ship is registered or in which the ship trades.

4 Design loads

4.1 Local loads

4.1.1 Cargo deck

The static pressure $P_{dl\text{-}s}$, in kN/m^2, due to livestock on decks to be considered for the assessment of plating and stiffeners is to be defined by the Designer.

When no value is specified, the following may be considered:

- 15 kN/m^2 for cattle, horses and camels
- 8 kN/m^2 for sheep, goats and pigs.

For the assessment of primary supporting members, $P_{dl\text{-}s}$ is to be taken equal to 0,3 times the value defined above for plating and stiffeners.

4.2 Load combinations for direct strength analysis

4.2.1 Loading condition

One loading condition is to be selected among those presented in the loading manual considering the following criteria:

- it represents the maximum draught
- it results in the highest vertical bending moment.

4.2.2 Load cases

The loading condition defined in [4.2.1] is to be associated to the following dynamic load cases:

- HVM
- FVM
- OVA1
- BP2
- OHM
- OHS
- BR1

5 Hull girder strength

5.1 Application

5.1.1 Strength deck

In addition to the requirements in Pt B, Ch 6, Sec 1, [1.3], the contribution of the hull structures up to the strength deck to the longitudinal strength is to be assessed through a finite element analysis of the whole ship in the following cases:

- when the size of openings in the side shell and/or longitudinal bulkheads located below the deck assumed by the Designer as the strength deck decrease significantly the capability of the plating to transmit shear forces to the strength deck.
- when the ends of superstructures which are required to contribute to longitudinal strength may be considered not effectively connected to the hull structures in way.

Alternatively, finite element analysis may be replaced by beam analysis on a case-by-case basis.

5.2 Global transverse strength

5.2.1 The behaviour of the ship primary structural members under racking effects due to transverse forces induced by transverse accelerations is to be investigated according to Pt B, Ch 7, App 1, or by means of a complete ship model according to Pt B, Ch 8, App 3.

6 Hull scantlings

6.1 Scantlings of plating, ordinary stiffeners and primary supporting members

6.1.1 Movable or collapsible structural elements above the strength deck

In general, the movable or collapsible structural elements used for the stocking and the distribution of livestock on decks or platform decks are not considered for classification purpose.

Nevertheless, where deemed necessary by the shipyard they may be designed and constructed according to the criteria in Part B, Chapter 7. In this case, the scantlings of the barriers surrounding each pen are to take into account the loads applied by the livestock as a result of roll and pitch of the ship.

Section 3 Systems serving Livestock Spaces

1 General

1.1 Application

1.1.1 The provisions of this Section cover the systems installed on ships having the service notation **livestock carrier** and intended for:

- the supply of food, water and fresh air to the livestock
- the cleaning of the livestock spaces
- the draining of the sewage effluents produced by the livestock.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

Item No.	Description of the document **(1)**
1	Diagram of the ventilation system, with indication of the gross volume of the enclosed spaces
2	Diagram of storage and distribution systems for fodder and water
3	Diagram of the water cleaning system
4	Diagram of the drainage system
(1) Diagrams are also to include, where applicable: • the (local and remote) control and monitoring systems and automation systems • the instructions for the operation and maintenance of the piping system concerned (for information).	

2 Design of the systems

2.1 General

2.1.1 The piping systems covered by this Section are to be designed, constructed and tested in accordance with the applicable provisions of Pt C, Ch 1, Sec 10.

2.2 Ventilation system

2.2.1 General

Mechanical ventilation is to be provided for the following spaces containing livestock:

- enclosed spaces
- partially closed spaces arranged with pens on more than one deck level and having a breadth greater than 20 m.

2.2.2 Capacity of the mechanical ventilation

The capacity of the mechanical ventilation is not to be less than:

- 20 air changes per hour of each enclosed space
- 15 air changes per hour of each partially closed space,

based on the gross volume of the space, deduced, if possible, from the volume of any tank or trunk within that space.

Note 1: Where the clear height of the space is less than 2,30 m, the Society may require higher air change rates, with a maximum of:

- 30 changes per hour for enclosed spaces
- 22,5 changes per hour for partially closed spaces.

2.2.3 Fans

a) Ventilation circuits are to be supplied by at least two independent fans of such a capacity as to maintain normal ventilation of all the spaces with one fan out of action.

b) Fans driven by electric motors are to be considered as essential auxiliaries. Their electrical supply is to comply with the provisions of Pt C, Ch 2, Sec 3.

2.3 Fodder and fresh water systems

2.3.1 General

a) Spaces intended for livestock are to be provided with receptacles for feeding and watering the animals concerned.

b) The capacity of the receptacles is not to be less than 33% of the daily consumption of the animals concerned, except when the feed system is automatic.

2.3.2 Fresh water system

a) The fresh water system serving the livestock spaces is to be totally independent from the fresh water system serving the spaces intended for the crew.

b) All livestock spaces are to be provided with fresh water service.

c) The fresh water system is to include at least:

- one main supply pump, of a capacity sufficient to continuously supply fresh water to the livestock
- one standby pump of at least the same capacity.

Note 1: When the water supply system is not automatic, the standby pump may be replaced by a portable pump ready to be connected to at least one fresh water tank.

d) When the water supply is automatic, water receptacles are to be fitted with:

- means of automatic water level control
- devices to avoid the return of water from the receptacle to the fresh water tank.

2.4 Washing system

2.4.1 A water washing system is to be provided with appropriate connections to wash the livestock spaces.

2.5 Drainage system

2.5.1 General

a) Each space intended for the livestock is to be fitted with a pipe or gutter of sufficient size to drain the sewage and the washing effluents.

b) The drainage system serving the livestock spaces is to be independent from any piping system serving the other spaces of the ship, and in particular from the bilge system.

2.5.2 Materials

The pipes and other components of the draining system are to be made of a material resistant to the corrosion due to the effluents.

2.5.3 Draining pipes and discharges

a) Discharges from livestock spaces are to comply with the provisions of Pt C, Ch 1, Sec 10, [8].

b) Where necessary, drainage gutters and upper parts of the draining pipes are to be covered by a strainer plate.

c) Draining pipes from livestock spaces are to discharge into a holding tank, wells or overboard.

Note 1: Overboard discharge is subject to the provisions of MARPOL Annex IV - Regulations for the Prevention of Pollution by Sewage.

d) Means are to be provided to stop the overboard discharge when the ship is in port.

2.5.4 Drainage tanks

a) Drainage tanks are to be fitted with means to indicate visually the amount of their content.

b) Drainage tanks and wells are to be accessible from outside livestock pens for inspection and cleaning.

2.5.5 Pumps and ejectors

Pumps and ejectors serving the drainage tanks or wells are to be capable of conveying semi-solid matter.

2.6 Lighting system

2.6.1 Permanently fixed adequate lighting is to be provided to give a sufficient level of illumination in passage ways between pens and access routes between or from those parts.

2.6.2 An emergency permanently fixed lighting system is to be provided in case of failure of the main electrical system required in [2.6.1]. This lighting system is to comply with the requirements in Part C, Chapter 2 for emergency lighting.

2.6.3 In addition to those required in [2.6.1], fixed or portable lightings are to be provided to give a sufficient level of illumination so that livestock can be inspected in each pen.

Section 4 Fire-Fighting Systems in Livestock Spaces

1 General

1.1 Application

1.1.1 This Section provides, for ships having the service notation **livestock carrier**, specific requirements for fire-fighting in the livestock spaces.

Such requirements supplement those given in Part C, Chapter 4.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document
1	Drawing showing the location of the fire-fighting appliances fitted in the livestock spaces
2	Specification of the fire-fighting appliances

2 Fire-fighting appliances

2.1 Fire hoses

2.1.1 The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant may reach any part of the spaces intended for the livestock. At least one of these jets is to be from a single length of hose.

2.1.2 Fire hoses are to be provided for:

- each hydrant located in an enclosed space, and
- for each 50 m length, or part thereof, of open deck spaces.

2.1.3 Fire hoses are to be located in conspicuous locations, near the hydrants and close to the entrances or access to the spaces.

2.2 Additional fire-fighting means

2.2.1 Livestock spaces containing hay or straw

If hay or straw is carried or used in a livestock space, one of the following fire-fighting means is to be provided:

- a fixed water fire-fighting system, or
- portable water extinguishers spaced no more than 18 m apart, one of these extinguishers being positioned at the entrance of the space concerned.

2.2.2 Livestock spaces containing electrical equipment other than lighting systems

If electrical equipment other than that referred to in Ch 3, Sec 3, [2.6] is located in an enclosed livestock space, suitable fire-fighting means are to be provided in this respect.

CHAPTER 4
BULK CARRIERS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Appendix 1 Intact Stability Criteria for Grain Loading

Appendix 2 Hold Mass Curves

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of one of the service notations:

- **bulk carrier ESP**, **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP** or **bulk carrier CSR BC-C ESP**, as defined in Pt A, Ch 1, Sec 2, [4.3.2]
- **Self-unloading bulk carrier ESP**, as defined in Pt A, Ch 1, Sec 2, [4.3.6]
- **bulk carrier**, as defined in Pt A, Ch 1, Sec 2, [4.3.1].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Ships assigned the additional service feature **CSR**	Ships not assigned the additional service feature **CSR**	
			Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 90	• NR606 • Ch 4, Sec 2, [2]	• Part B • Ch 4, Sec 2	• NR566 • Ch 4, Sec 2
	65 ≤ L < 90	N.A.	• Part B • Ch 4, Sec 2	• NR566 • Ch 4, Sec 2
	L < 65	N.A.	• NR600	• NR566 • Ch 4, Sec 2
Hull	L ≥ 90	• NR606 **(1)**	• Part B • Ch 4, Sec 3	• Part B • Ch 4, Sec 3
	L ≥ 65	N.A.	• Part B • Ch 4, Sec 3	• Part B • Ch 4, Sec 3
	L < 65	N.A.	• NR600	• NR600
Stability		• Part B • Ch 4, Sec 3, [1]	• Part B • Ch 4, Sec 3, [1]	• NR566 • Ch 4, Sec 3, [1]
Machinery and cargo systems		Part C	Part C	NR566
Electrical installations		Part C	Part C	NR566
Automation		Part C	Part C	NR566
Fire protection, detection and extinction		Part C	Part C	NR566

(1) IACS Recommendation No.167 "Guidelines for the Identification of Vibration Issues and Recommended Remedial Measures on Ships" is to be applied on ships assigned additional service feature **CSR**.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

NR606: Common Structural Rules for Bulk Carriers and Oil Tankers.

Section 2 Ship Arrangement

1 General arrangement design

1.1 General

1.1.1 Forecastle

Ships with the service notation **bulk carrier ESP** or **bulk carrier** are to be fitted with an enclosed forecastle on the freeboard deck, with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Fig 1.

However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the International Convention on Load Lines 1966 and its Protocol 1988.

The forecastle height H_F above the main deck is to be not less than:

- the standard height of a superstructure as specified in Pt B, Ch 1, Sec 3, [2.2]
- $H_C + 0,5$ m, where H_C is the height of the forward transverse hatch coming of the foremost cargo hold, i.e. cargo hold No. 1,

whichever is the greater.

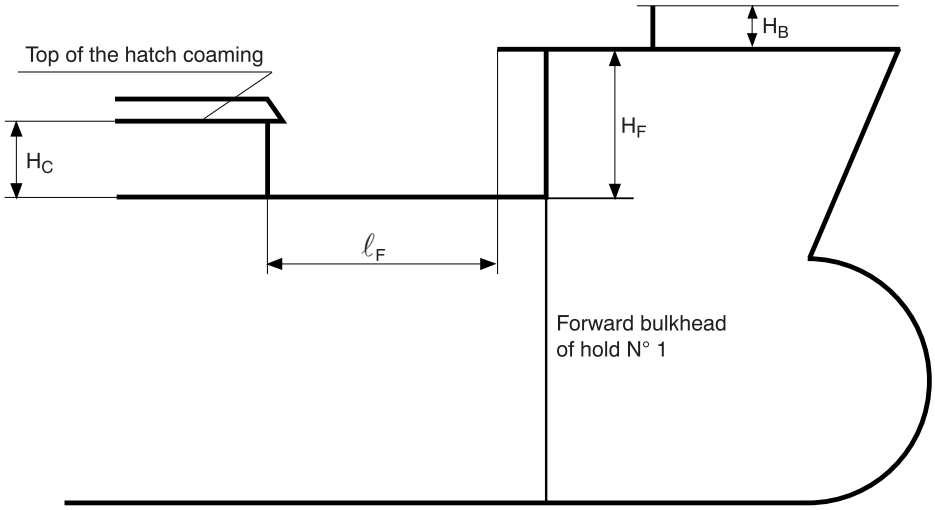
All points of the aft edge of the forecastle deck are to be located at a distance ℓ_F:

$$\ell_F \leq 5\sqrt{H_F - H_C}$$

from the hatch coming plate in order to apply the reduced loading to the No. 1 forward transverse hatch coaming and No. 1 hatch cover in applying Pt B, Ch 11, Sec 9, [4.1.3], and Pt B, Ch 11, Sec 9, [8.3.9].

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B / tan20° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Fig 1).

Figure 1 : Forecastle arrangement



2 Access arrangement

2.1 Access arrangement to double bottom and pipe tunnel

2.1.1 Means of access

Adequate means of access to the double bottom and the pipe tunnel are to be provided.

2.1.2 Manholes in the inner bottom, floors and girders

Manholes cut in the inner bottom are to be located at a minimum distance of one floor spacing from the lower stool, or transverse bulkhead if no stool is fitted.

The location and size of manholes in floors and girders are to be determined to facilitate the access to double bottom structures and their ventilation. However, they are to be avoided in the areas where high shear stresses may occur.

2.2 Access arrangement to and within spaces in, and forward of, the cargo area

2.2.1 Means of access

Ships with the service notation **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP**, are to comply with the relevant requirements of NR606 Common structural rules for bulk carriers and oil tankers.

Ships with the service notation **bulk carrier ESP** or **bulk carrier** of less than 150 m in length and of 20,000 gross tonnage and over, are to comply with SOLAS, Ch II-1, Reg 3-6.

Ships with the service notation **bulk carrier ESP** or **bulk carrier** are to comply with [2.2.2] and [2.2.3]. In addition, as far as practicable, permanent or movable means of access stored on board are to be provided to ensure proper survey and maintenance of cargo holds and, in particular, of the lower part of cargo hold side frames.

2.2.2 Hatches of cargo holds

If separate hatches are used as access to the ladders as required in [2.2.3], each hatch is to have a clear opening of at least 600 mm x 600 mm.

When the access to the cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming.

Accesses and ladders are to be so arranged that personnel equipped with self-contained breathing apparatus may readily enter and leave the cargo hold.

Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with cargo hold ladders.

2.2.3 Ladders within cargo holds

Each cargo hold is to be provided with at least two ladders as far apart as practicable longitudinally. If possible these ladders are to be arranged diagonally, e.g. one ladder near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side, from the ship's centreline.

Ladders are to be so designed and arranged that the risk of damage from the cargo handling gear is minimised.

Vertical ladders may be permitted provided they are arranged above each other in line with other ladders to which they form access and resting positions are provided at not more than 9 metres apart.

Tunnels passing through cargo holds are to be equipped with ladders or steps at each end of the hold so that personnel may get across such tunnels.

Where it may be necessary for work to be carried out within a cargo hold preparatory to loading, consideration is to be given to suitable arrangements for the safe handling of portable staging or movable platforms.

Section 3 Hull and Stability

Symbols

D_p : Propeller diameter, in m

L_{LL} : Load line length, in m, defined in Pt B, Ch 1, Sec 3, [2.1.2]

λ_0 , λ_{40} : Heeling levers illustrated in Fig 1 and taken equal to:

λ_0 = Assumed volumetric heeling moment due to transverse shift / (stowage factor · Δ)

$\lambda_{40} = 0,8\ \lambda_0$

Where the assumed volumetric heeling moment due to transverse shift is calculated in Ch 4, App 1and the stowage factor defined in [1.1.5].

Δ : Moulded displacement, as defined in Pt B, Ch 1, Sec 3

ℓ : Span, in m, of side frames; see [2.2.2]

M_{Full} , M_H , M_{HD} : Cargo mass, in t, in a cargo hold, as defined in Pt B, Ch 5, Sec 6

t_c : Corrosion addition, in mm, defined in Pt B, Ch 4, Sec 2, [1.1.1]

ℓ_p : Distance from propeller centreline to the waterline, in m.

P : Design pressure in kN/m², for the design load set being considered according to Pt B, Ch 7, Sec 2, [2] and calculated at the load calculation point defined in Pt B, Ch 4, Sec 6, [3.2].

1 Stability

1.1 Definitions

1.1.1 Grain

The term grain covers wheat, maize (corn), oats, rye, barley, rice, pulses, seeds and processed forms thereof, whose behaviour is similar to that of grain in its natural state.

1.1.2 Filled compartment trimmed

The term filled compartment trimmed refers to any cargo space in which, after loading and trimming as specified in Ch 4, App 1, the bulk grain is at its highest possible level.

1.1.3 Filled compartment untrimmed

The term filled compartment untrimmed refers to a cargo space which is filled to the maximum extent possible in way of the hatch opening but which has not been trimmed outside the periphery of the hatch opening.

1.1.4 Partially filled compartment

The term partly filled compartment refers to any cargo space where the bulk grain is not loaded in the manner prescribed in [1.1.2] or [1.1.3].

1.1.5 Stowage factor

The term stowage factor, for the purposes of calculating the grain heeling moment caused by a shift of grain, means the volume per unit weight of the cargo as attested by the loading facility, i.e. no allowance is to be made for lost space when the cargo space is nominally filled.

1.1.6 Specially suitable compartment

The term specially suitable compartment refers to a cargo space which is constructed with at least two vertical or sloping, longitudinal, grain-tight divisions which are coincident with the hatch side girders or are so positioned as to limit the effect of any transverse shift of grain. If sloping, the divisions are to have an inclination of not less than 30° to the horizontal.

1.2 Intact stability

1.2.1 General

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.5] is to be in compliance with the requirements of Pt B, Ch 3, Sec 2. In addition, the requirements in [1.2.2] and [1.2.3] are to be complied with.

1.2.2 Grain Loading Manual

Information in printed booklet form is to be provided on board to enable the Master to ensure that the ship complies with the stability requirements reported in the Rules *when carrying grain in bulk*. This booklet is commonly referred to as Grain Loading Manual and *is to include the following information:*

- *ship's particulars*
- *lightship displacement and the vertical distance from the intersection of the moulded base line and midship section to the centre of gravity (KG)*
- *table of liquid free surface corrections*
- *capacities and centres of gravity*
- *curve or table of angle of flooding, where less than 40°, at all permissible displacements*
- *curves or tables of hydrostatic properties suitable for the range of operating drafts*
- *cross curves of stability which are sufficient for the purpose of the requirements in [1.2.3] and which include curves at 12° and 40°*
- *curves or tables of volumes, vertical centres of volumes, and assumed volumetric heeling moments for every hold, filled or partly filled, or combination thereof, including the effects of temporary fittings*
- *tables or curves of maximum permissible heeling moments for varying displacements and varying vertical centres of gravity to allow the Master to demonstrate compliance with* the requirements specified in [1.2.3]
- *loading instructions in the form of notes summarising the requirements of* these Rules
- *a worked example for the guidance of the Master*
- *typical loaded service departure and arrival conditions and, where necessary, intermediate worst service conditions.*

  It is recommended that loading conditions should be provided for at least three representative stowage factors.

The Grain Loading Manual may be drawn up in the official language or languages of the Administration of the issuing country; if the language used is neither English nor French, the text is to include a translation into one of these languages.

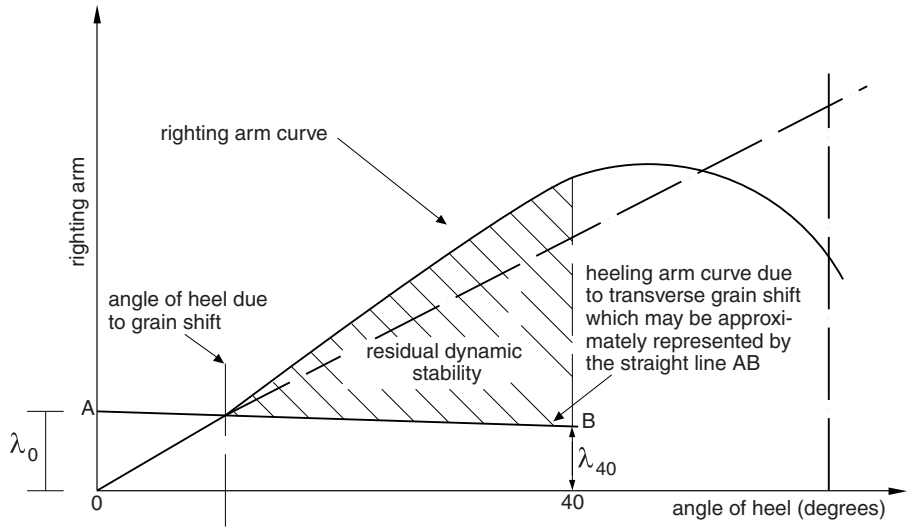
1.2.3 Intact stability criteria for grain loading

The intact stability characteristics of any ship carrying bulk grain are to be shown to meet, throughout the voyage, at least the following criteria after taking into account in the manner described in Ch 4, App 1 and in Fig 1, the heeling moments due to grain shift:

- *the angle of heel due to the shift of grain is to be not greater than 12° or the angle at which the deck edge is immersed, whichever is the lesser*
- *in the statical stability diagram, the net or residual area between the heeling arm curve and the righting arm curve up to the angle of heel of maximum difference between the ordinates of the two curves, or 40° or the angle of flooding, whichever is the least, is in all conditions of loading to be not less than 0,075 m·rad*
- *the initial metacentric height, after correction for the free surface effects of liquids in tanks, as specified in Pt B, Ch 3, Sec 2, [4], is to be not less than 0,30 m.*

After loading, the Master is to ensure that the ship is upright before proceeding to sea.

Figure 1 : Stability curve



1.3 Damage stability requirements for ships where additional class notation SDS is required

1.3.1 General

Ships with the service notation **bulk carrier ESP**, **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP** or **bulk carrier** where additional class notation **SDS** is required (see Pt A, Ch 1, Sec 2, [6.17.1]), equal to or greater than 80 m in length, are subjected to the probabilistic approach reported in Pt B, Ch 3, Sec 3, [2.1.3] and are to comply with the requirements in Pt B, Ch 3, App 3.

1.3.2 Freeboard reduction

Ships with the service notation **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP** or **bulk carrier** greater than 100 m in length which have been assigned reduced freeboard as permitted by Regulation 27 of the International Convention on Load Lines, 1966, as referenced in Pt B, Ch 3, Sec 3, [2.1.2] are to comply with the requirements specified in Pt B, Ch 3, App 4. Therefore, compliance with the requirements in [1.3.1] is not required.

1.3.3 Additional requirements

The requirements specified in [1.3.4] to [1.3.6] apply where additional class notation **SDS** is required, to bulk carriers equal to or greater than 150 m in length, intended for the carriage of bulk cargoes having dry bulk density of 1,0 t/m^3, or above and of one of the following designs:

- single side skin construction
- double side skin construction in which any part of longitudinal bulkhead is located within B/5 or 11,5 m, whichever is less, inboard from the ship's side at right angle to the centerline at the assigned summer load line.

Ships complying with the requirements in [1.3.2] are not required to comply with those in [1.3.4] to [1.3.6].

1.3.4 Flooding of cargo holds

Bulk carriers specified in [1.3.3], when loaded to the summer load line, are to be able to withstand flooding of any one cargo hold in all loading conditions and remain afloat in satisfactory condition as specified in [1.3.5].

1.3.5 Flooding criteria

After flooding, the vessel is to comply with the requirements laid down in Pt B, Ch 3, App 4.

The assumed flooding need only take into account flooding of the cargo hold space, considering the permeability values specified in [1.3.6].

1.3.6 Flooding assumptions

The permeability of a loaded hold is to be assumed as 0,9, unless a permeability relevant to a particular cargo is assumed for the volume of a flooded hold occupied by cargo and a permeability of 0,95 is assumed for the remaining empty volume of the hold. In the latter case, the permeabilities and the corresponding cargo densities specified in [3.2.2] are to be assumed.

The permeability of an empty hold is to be assumed as 0,95.

2 Structure design principles

2.1 Double bottom structure

2.1.1 Longitudinally framed double bottom

In ships greater than 120 m in length, the double bottom and the sloped bulkheads of hopper tanks are to be longitudinally framed.

The girder spacing is to be not greater than 4 times the spacing of bottom or inner bottom ordinary stiffeners and the floor spacing is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, depending on the results of the analysis carried out according to Part B, Chapter 8 for the primary supporting members in the cargo holds.

2.1.2 Transversely framed double bottom

The double bottom and the sloped bulkheads of hopper tanks may be transversely framed in ships equal to or less than 120 m in length, when this is deemed acceptable by the Society on a case-by-case basis. In this case, however, the floor spacing is to be not greater than 2 frame spaces.

2.1.3 Floors in way of transverse bulkheads

The thickness and material properties of the supporting floors and pipe tunnel beams are to be not less than those required for the bulkhead plating or, when a stool is fitted, of the stool side plating.

2.2 Single side structure

2.2.1 Frame spacing

In general, the frame spacing in cargo holds bounded by the side shell only is to be not greater than the values obtained, in m, from the following formulae:

$$s = 0,6 + \frac{L}{320} \qquad \text{for } L < 90\,m$$

$$s = 0,9 + 1,25\left(\frac{L}{100}\right)^{0,25} \qquad \text{for } L \geq 90\,m$$

2.2.2 Frame span and web height

Frame span ℓ and web height d are to be measured as indicated in Fig 2.

2.2.3 Symmetrical frame sections

Frames are to be fabricated symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

The web depth to thickness ratio is to be not greater than 60 $k^{0,5}$. The outstanding flange is to be not greater than 10 $k^{0,5}$ times the flange thickness. The end of the flange is to be sniped.

The frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature (see Fig 2) is to be not less than the value obtained, in mm, from the following formula:

$$r = \frac{0,4 b_f^2}{t_f}$$

where b_f and t_f are, in mm, the flange width and thickness, respectively.

2.2.4 Asymmetrical frame sections

In ships less than 190 m in length, mild steel frames may be asymmetrical and fitted with overlapped welded brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

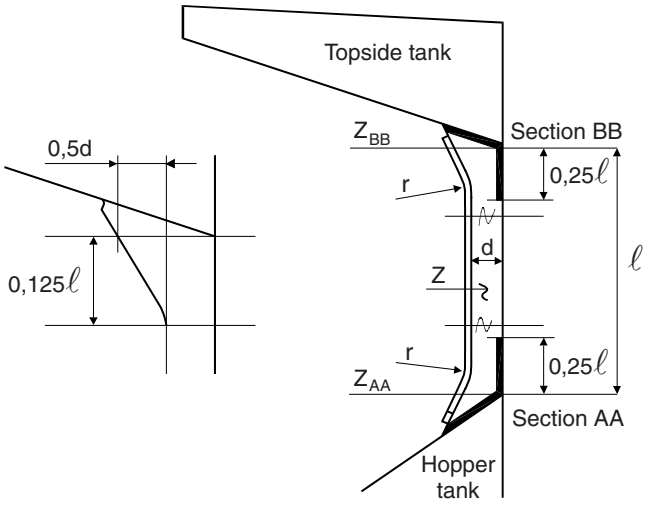
The web to thickness ratio is to be not greater than 50 $k^{0,5}$. The outstanding flange is to be not greater than 10 $k^{0,5}$ times the flange thickness.

2.2.5 Lower and upper end brackets

The section modulus of the frame end bracket or integral bracket, calculated, with an attached side plating according to Pt B, Ch 4, Sec 6, [1.3], at the end sections of the span ℓ (sections AA and BB in Fig 2), is to be not less than twice the section modulus required for the frame midspan area according to Pt B, Ch 7, Sec 6 or NR600, as applicable.

The dimensions of the lower and upper end brackets are to be not less than those shown in Fig 2.

Figure 2 : Frame and end bracket geometry



2.2.6 Connecting brackets within hopper and topside tanks

Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in Fig 3.

The net connection area of the lower or upper connecting bracket to the supporting longitudinal stiffener is to comply with the following formula:

$$\sum_i A_i d_i R_{eH,bkt-i} \geq 0,02\,\alpha_T P s \ell_{SF}^2 10^{-3}$$

The net section modulus of the:

- Side shell and hopper tank longitudinals supporting the lower connecting brackets.
- Side shell and topside tank longitudinals supporting the upper connecting brackets.

is to comply with the following formula:

$$\sum_n Z_{pli} d_i \geq \alpha_T \frac{P \ell_{SF}^{\ 2} \ell_1^{\ 2}}{16 R_{eH}}$$

where:

A_i : The offered net connection area of the bracket connecting with the i-th longitudinal stiffener, in cm^2.

d_i : Distance, in m, of the above i-th longitudinal stiffener from the intersection point of the side shell and hopper/topside tank.

ℓ_1 : Spacing, in m, of transverse supporting webs in hopper/topside tank, as applicable.

ℓ_{SF} : Side frame span, in m, not to be taken less than 0,25 D.

n : Number of the longitudinal stiffeners on the side shell and hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

R_{eH} : Lowest value of specified yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper/topside tanks that support the lower/upper end connecting bracket of the side frame.

$R_{eH,bkt-i}$: The specified minimum yield stress of the bracket connecting with the i-th longitudinal stiffener, in N/mm^2.

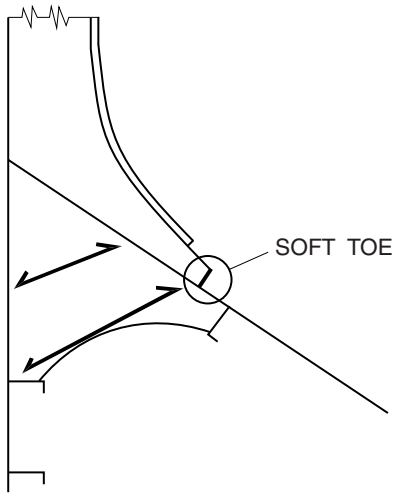
Z_{pli} : Net plastic section modulus, in cm^3, of the i-th longitudinal stiffener on the side shell or hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

α_T : Coefficient taken as:

- α_T = 150 for the longitudinal stiffeners supporting the lower connecting brackets.
- α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets.

s : Spacing between side frames, in m.

Figure 3 : Connection with bracket within hopper and topside tanks

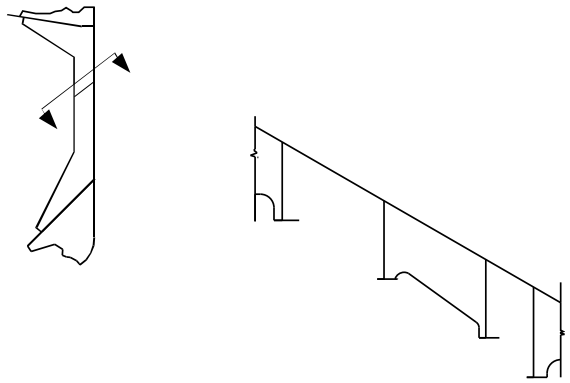


2.2.7 Tripping brackets

In way of the foremost cargo hold, side frames of asymmetrical section are to be fitted with sloped tripping brackets every two frames, as shown in Fig 4.

In way of the other holds, side frames of asymmetrical sections are to be fitted with sloped tripping brackets every two frames where the web height d is greater than 600 mm or the span ℓ is greater than 6 m.

Figure 4 : Tripping brackets



2.3 Double side structure

2.3.1 Side primary supporting members

The spacing of transverse side primary supporting members is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Part B, Chapter 8 for the primary supporting members in the cargo holds.

In any case, transverse side primary supporting members are to be fitted in line with web frames in hopper and topside tanks.

2.4 Deck structure

2.4.1 Topside tank sloping plates

The spacing of web frames in topside tanks is to be not greater than 6 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Part B, Chapter 8 for the primary supporting members in the cargo holds.

2.4.2 Deck between hatches

The cross decks between hatches are generally to be transversely framed.

Connection of the strength deck at side with the deck between hatches is to be ensured by a plate of intermediate thickness.

2.4.3 Connection of hatch end beams with deck structures

The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the topside tanks additional web frames or brackets.

2.4.4 Topside tank structure

Topside tank structures are to extend as far as possible within the machinery spaces and are to be adequately tapered.

3 Design loads

3.1 Loading conditions for longitudinal strength assessment

3.1.1 Seagoing conditions

In addition to the loading conditions specified in Pt B, Ch 5, Sec 8, the following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Cargo loading conditions defined in [3.1.2], as applicable.

b) Ballast conditions with all ballast tanks 100% full,

c) Heavy ballast condition, mandatory only for ships assigned the navigation notation **unrestricted navigation**, where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in Pt B, Ch 5, Sec 8, [3.1.1] are to be complied with
- at least one cargo hold adapted for the carriage of water ballast at sea, where required or provided, is to be full
- The propeller immersion ℓ_p / D_p is to be at least 60%
- The trim is to be by the stern and is not to exceed $0{,}015L_{LL}$
- The moulded forward draught is not to be taken less than the smaller of $0{,}03L_{LL}$ or 8 m.

3.1.2 Cargo loading conditions

- Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at scantling draught with all ballast tanks empty.

- Homogeneous cargo loaded condition where the cargo density is taken equal to 3,0 t/m^3, and all cargo holds are taken with the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at scantling draught with all ballast tanks empty.

  In cases where the cargo density applied for this design loading condition is different from 3,0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated.
- Non-homogeneous cargo loaded condition, for ships which service notation is completed by the additional service feature **nonhomload**. These conditions are to include cases where some holds may be empty, at a draught up to the scantling draught, if such conditions are intended to be operated.

3.2 Hull girder loads in flooded conditions

3.2.1 Application

These requirements apply to all types of bulk carriers of length greater than or equal to 150 m intended for the carriage of bulk cargoes having dry bulk cargo density of 1,0 t/m^3 or above and having the service notation **bulk carrier** or **self-unloading bulk carrier ESP** where the unloading system maintains the watertightness during seagoing operations.

3.2.2 Flooding assumptions

Each cargo hold is to be considered individually flooded up to the equilibrium waterline. For ships assigned the service notation **self-unloading bulk carrier ESP** and equipped with unloading systems that do not maintain watertightness, the longitudinal strength in the flooded conditions are to be considered using the extent to which the flooding may occur.

Appropriate permeabilities and bulk densities are to be used for any cargo carried. For iron ore, a minimum permeability of 0,3 with a corresponding bulk density of 3,0 t/m^3 is to be used. For cement, a minimum permeability of 0,3 with a corresponding bulk density of 1,3 t/m^3 is to be used. In this respect, “permeability” for dry bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of the cargo, to the gross volume of the bulk cargo.

The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken equal to 0,95.

For packed cargo conditions (such as in the case of steel mill products), the actual density of the cargo is to be used with a permeability of zero.

3.2.3 Still water hull girder loads

The permissible still water loads $M_{sw,f}$ and $Q_{sw,f}$ in flooded conditions are to be calculated for each of the cargo and ballast conditions considered in the intact longitudinal strength calculations, as specified in [3.1] except that harbour conditions, docking condition afloat, loading and unloading transitory conditions in port and loading conditions encountered during ballast water exchange need not be considered.

3.2.4 Wave hull girder loads

The wave loads in flooded conditions are taken as follows:

$M_{wv,f}$: Vertical wave bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, to be taken equal to 0,8 M_{wv}

M_{wv} : Vertical wave bending moment in seagoing operation, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 4, [3.1.1]

$Q_{wv,f}$: Vertical wave shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be taken equal to 0,8 Q_{wv}

Q_{wv} : Vertical wave shear force in seagoing condition, in kN, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 4, [3.2.1].

3.3 Load combinations for direct strength analysis

3.3.1 Applicable general load combinations

The following loading conditions are to be considered for direct strength analysis:

- Full load and scantling draught T_{SC}, the loaded holds being completely filled with cargo.

  Unless otherwise specified, this loading condition is to be associated with the BP dynamic load cases
- Full load, the cargo density taken equal to 3 t/m^3 unless otherwise specified in the loading manual, and scantling draught T_{SC}.

  Unless otherwise specified, this loading condition is to be associated with the BP dynamic load cases
- Heavy ballast condition and minimum design heavy ballast draught T_{BAL-H}.

  Unless otherwise specified, this loading condition is to be associated with the HVM, FVM and BR dynamic load cases
- Multi-port (MP) loading conditions, if allowed by the loading manual, and draught amidships corresponding to these conditions in the loading manual.

  Unless otherwise specified, these loading conditions are to be associated with the all the dynamic load cases

- Alternate loading conditions, if allowed by the loading manual, and draught amidships corresponding to these conditions in the loading manual.

  Unless otherwise specified, these loading conditions are to be associated with the all dynamic load cases.

In addition, harbour conditions covering the loading/unloading sequences and associated draughts amidships as defined in the loading manual are to be considered.

4 Hull girder strength

4.1 Hull girder yield strength in flooded conditions

4.1.1 Application

These requirements apply to all types of bulk carriers of length greater than or equal to 150 m intended for the carriage of bulk cargoes having dry bulk cargo density of 1,0 t/m^3 or above.

Such ships are also to have their hull girder strength checked for the flooded conditions specified in [3.2].

The damaged structure is assumed to remain fully effective in resisting the applied loads.

4.1.2 Stresses

The normal stresses in flooded conditions $\sigma_{L,f}$ at any point are to be obtained, in N/mm^2, according to the requirements given in Pt B, Ch 6, Sec 1, [2.1.1], in which M_{sw} and M_{wv} are to be replaced respectively by $M_{sw,f}$ and $M_{wv,f}$ as defined in [3.2].

The shear stresses $\tau_{L,f}$ of the side shell and the inner hull (longitudinal bulkhead) if any, at any point, are to be obtained, in N/mm^2, according to the requirements given in Pt B, Ch 6, Sec 1, [2.2.1], in which Q_{sw} and Q_{wv} are to be replaced respectively by $Q_{sw,f}$ and $Q_{wv,f}$ as defined in [3.2].

The equivalent Von Mises stresses $\sigma_{eq,f}$ are to be obtained, in N/mm^2, according to the requirements given in Pt B, Ch 6, Sec 1, [3.5.1], in which σ_L and τ_L are to be replaced respectively by $\sigma_{L,f}$ and $\tau_{L,f}$.

4.1.3 Checking criteria

It is to be checked that the equivalent Von Mises stresses $\sigma_{eq,f}$ calculated according to [4.1.2] is in compliance with the acceptance criteria Pt B, Ch 6, Sec 1, [3.5.1] for seagoing operations.

5 Hull scantlings of bulk carriers

5.1 Plating

5.1.1 Minimum net thickness of side plating

The net thickness of the side plating located between hopper and topside tanks is to be not less than the value obtained, in mm, from the following formula: $t_{MIN} = L^{0,5} - t_C$

5.2 Ordinary stiffeners

5.2.1 Minimum net thicknesses of side frames

The net thicknesses of side frames and their brackets, in way of cargo holds, are to be not less than the values given in Tab 1.

Table 1 : Minimum net thicknesses of side frames

Item	Minimum net thickness, in mm
Side frame webs	$C_L\,(7,0 + 0,03L_1) - t_C$
Lower end bracket	The greater of: • $C_L\,(7,0 + 0,03L_1) + 2 - t_C$ • as fitted net thickness of side frame web
Upper end bracket	The greater of: • $C_L\,(7,0 + 0,03L_1) - t_C$ • as fitted net thickness of side frame web
Note 1: C_L : Coefficient equal to: • 1,15 for side frames in way of the foremost cargo hold • 1,0 for side frames in way of other cargo holds L_1 : Ship's length, in m, defined in Pt B, Ch 1, Sec 3, Tab 1.	

5.2.2 Scantlings of side frames abaft the collision bulkhead

The net moment of inertia I, in cm^4, of the three side frames located immediately abaft the collision bulkhead is not to be taken less than:

$$I = 0,18\frac{P\ell_{SF}^4}{n}$$

where:

n : Frame number of considered side frame counted from the collision bulkhead to the frame in question, taken equal to 1, 2 or 3.

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of the forepeak stringers within the foremost hold.

5.2.3 Hopper and topside tank ordinary stiffeners

These requirements apply to the ordinary stiffeners of side and sloped longitudinal bulkheads, within hopper and topside tanks, which support the connecting brackets fitted in way of the side frame brackets, according to [2.2.6].

The scantlings of these ordinary stiffeners are to be determined according to Pt B, Ch 7, Sec 4, with their span measured according to Pt B, Ch 4, Sec 6, [1.1] between hopper or topside tank primary supporting members.

Alternative arrangements may be considered by the Society on a case-by-case basis. In these cases, the scantlings of the above ordinary stiffeners are to be determined for the purpose of effectively supporting the connecting brackets.

5.3 Buckling check in flooded conditions

5.3.1 Application

These requirements apply to all types of bulk carriers of length greater than or equal to 150 m intended for the carriage of bulk cargoes having dry bulk cargo density 1,0 t/m^3 or above.

5.3.2 General

The following elements are to be checked in the flooded conditions specified in [3.2] according to Pt B, Ch 9, Sec 1, considering the hull girder stresses defined in [4.1.2]:

- Plating and ordinary stiffeners contributing to the hull girder longitudinal strength
- Web plate of transverse corrugated bulkhead.

6 Protection of hull metallic structures

6.1 Protection of cargo holds

6.1.1 Coating

It is the responsibility of the shipbuilder and of the Owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo, and to see that they are applied in accordance with the Manufacturer's requirements.

6.1.2 Application

All internal and external surfaces of hatch coamings and hatch covers and all internal surfaces of cargo holds (side and transverse bulkheads) are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the Manufacturer's recommendations.

The side (single and double skin) and transverse bulkhead areas to be coated are specified in [6.1.3] to [6.1.5].

6.1.3 Single side areas to be coated

The areas to be coated are:

- the internal surfaces of the side plating
- the side frames with end brackets
- the internal surfaces of the topside tank sloping plates and, for a distance of 300 mm below, of the hopper tank sloping plates.

These areas are shown in Fig 5.

6.1.4 Double side areas to be coated

The areas to be coated are the internal surfaces of:

- the inner side plating
- the internal surfaces of the topside tank sloping plates and the hopper tank sloping plates for a distance of 300 mm below their upper ends.

These areas are shown in Fig 6.

6.1.5 Transverse bulkhead areas to be coated

The areas to be coated are the upper parts down to 300 mm below the top of the lower stool. Where there is no lower stool, the area to be coated is the whole transverse bulkhead.

These areas are shown in Fig 7.

Figure 5 : Single side - Areas to be coated

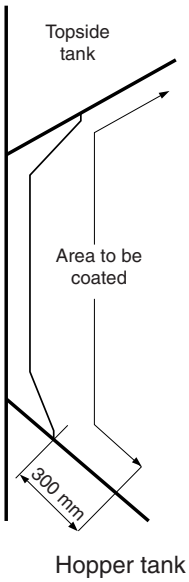


Figure 6 : Double side - Areas to be coated

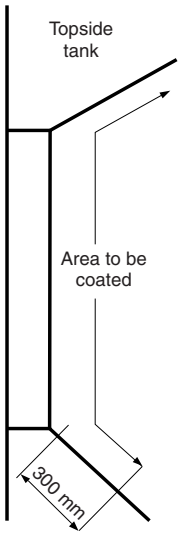
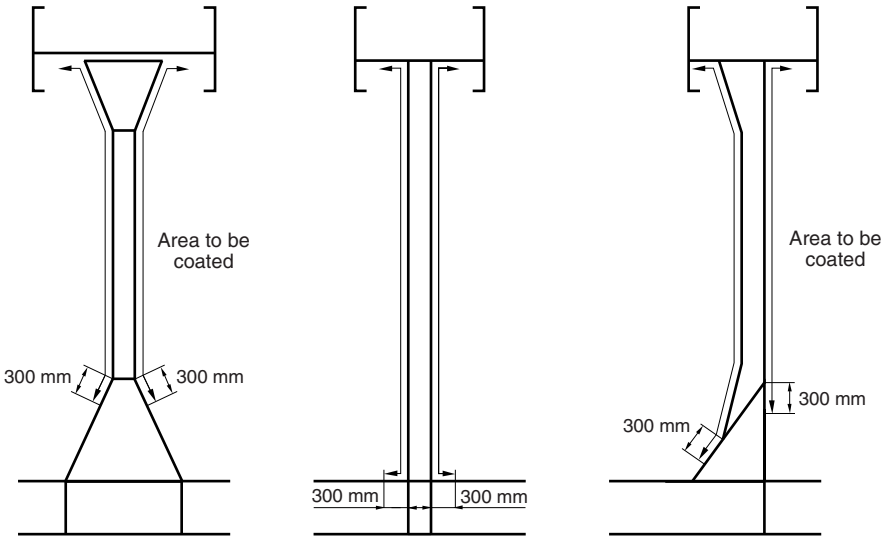


Figure 7 : Transverse bulkheads - Areas to be coated



7 Construction and testing

7.1 Welding and weld connections

7.1.1 The weld factors for some hull structural connections are specified in Tab 2. These weld factors are to be used, in lieu of the corresponding factors specified in Pt B, Ch 13, Sec 3, Tab 2, to calculate the leg length of fillet weld T connections according to Pt B, Ch 13, Sec 3, [3.2].

7.1.2 For the connections in Tab 2, continuous fillet welding is to be adopted.

7.2 Special structural details

7.2.1 The specific requirements in Pt B, Ch 13, Sec 5, [2] are to be complied with.

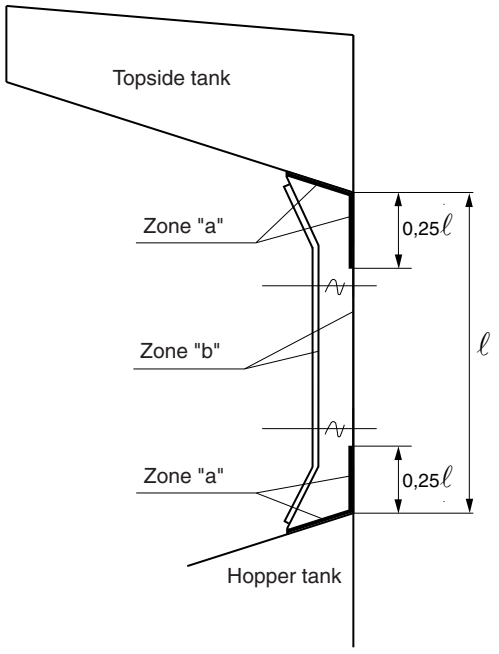
Table 2 : Weld factor w_F

Hull area	Connection			Weld factor w_F
	of	to		
Double bottom in way of cargo holds	girders	bottom and inner bottom plating		0,48
		floors (interrupted girders)		
	floors	bottom and inner bottom plating		
		girders (interrupted floors)		
Side	web of side frames and brackets	side plating, hopper and topside tank sloping plates, face plates	in zone "a" **(1)**	0,63 **(2)**
			in zone "b" **(1)**	0,56 **(2)**

(1) Zones "a" and "b" are defined in Fig 8.

(2) Where the hull form is such as to prohibit an effective fillet weld, the Society may require edge preparation of the web of side frame and bracket to be carried out in order to ensure the same efficiency as the required weld connections.

Figure 8 : Zones "a" and "b" of weld connections of side frames



Appendix 1 Intact Stability Criteria for Grain Loading

1 Calculation of assumed heeling moments due to cargo shifting

1.1 Stowage of bulk grain

1.1.1 General

All necessary and reasonable trimming is to be performed to level all free grain surfaces and to minimise the effect of grain shifting.

1.1.2 Filled compartment trimmed

In any filled compartment trimmed, as defined in Ch 4, Sec 3, [1.1.2], the bulk grain is to be trimmed so as to fill all spaces under the decks and hatch covers to the maximum extent possible.

1.1.3 Filled compartment untrimmed

In any filled compartment untrimmed, as defined in Ch 4, Sec 3, [1.1.3], the bulk grain is to be filled to the maximum extent possible in way of the hatch opening but may be at its natural angle of repose outside the periphery of the hatch opening. A filled compartment may qualify for this classification if it falls into one of the following categories:

a) the Society may, under [1.7], grant dispensation from trimming in those cases where the underdeck void geometry resulting from free flowing grain in a compartment, which may be provided with feeder ducts, perforated decks or other similar means, is taken into account when calculating the void depths, or

b) the compartment is "specially suitable" as defined in Ch 4, Sec 3, [1.1.6], in which case dispensation may be granted from trimming the ends of that compartment.

1.1.4 Grain in partially filled compartments

If there is no bulk grain or other cargo above a lower cargo space containing grain, the hatch covers are to be secured in an approved manner having regard to the mass and permanent arrangements provided for securing such covers.

When bulk grain is stowed on top of closed 'tweendeck hatch covers which are not grain-tight, such covers are to be made grain-tight by taping the joints, covering the entire hatchway with tarpaulins or separation cloths, or other suitable means.

After loading, all free grain surfaces in partly filled compartments are to be level.

1.1.5 Cargo securing

Unless account is taken of the adverse heeling effect due to the grain shift according to these Rules, the surface of the bulk grain in any partly filled compartment is to be secured so as to prevent a grain shift by overstowing as described in [1.9.1] to [1.9.3]. Alternatively, in partly filled compartments, the bulk grain surface may be secured by strapping or lashing as described in [1.9.4] or [1.9.5].

Lower cargo spaces and 'tweendeck spaces in way thereof may be loaded as one compartment provided that, in calculating transverse heeling moments, proper account is taken of the flow of grain into the lower spaces.

1.1.6 Longitudinal division

In filled compartments trimmed, filled compartments untrimmed and partly filled compartments, longitudinal divisions may be installed as a device to reduce the adverse heeling effect of grain shift provided that:

a) the division is grain-tight,

b) the construction meets the requirements in Part B for longitudinal bulkheads; if no particular requirement is foreseen see MSC Res. 23(59)sect 11-14); and

c) in 'tweendecks, if fitted, the division extends from deck to deck and in other cargo spaces the division extends downwards from the underside of the deck or hatch covers, as described in [1.3.2] a) (second bullet)*, Note 2, [1.3.2] b), Note 7,or [1.6.1] b), as applicable.*

1.2 General assumptions

1.2.1 Voids in spaces loaded with grain

For the purpose of calculating the adverse heeling moment due to a shift of cargo surface in ships carrying bulk grain it is to be assumed that:

a) in filled compartments which have been trimmed in accordance with [1.1.2], a void exists under all boundary surfaces having an inclination to the horizontal less than 30° and that void is parallel to the boundary surface having an average depth calculated according to the formula:

$V_d = V_{d1} + 0,75\ (d - 600)$

where:

V_d : *Average void depth, in mm*

V_{d1} : *Standard void depth, in mm, from Tab 1*

d : *Actual girder depth, in mm.*

In any case, V_d is to be assumed equal to or greater than 100 mm.

b) within filled hatchways and in addition to any open void within the hatch cover there is a void of average depth of 150 mm measured down to the grain surface from the lowest part of the hatch cover or the top of the hatch side coaming, whichever is the lower.

c) in a filled compartment untrimmed which is exempted from trimming outside the periphery of the hatchway by the provisions of [1.1.3] a), it is to be assumed that the surface of the grain after loading will slope into the void space underdeck, in all directions, at an angle of 30° to the horizontal from the edge of the opening which establishes the void.

d) In a filled compartment untrimmed which is exempted from trimming in the ends of the compartment under the provisions of [1.1.3] b), it is to be assumed that the surface of the grain after loading will slope in all directions away from the filling area at an angle of 30° from the lower edge of the hatch end beam. However, if feeding holes are provided in the hatch end beams in accordance with Tab 2, then the surface of the grain after loading is to be assumed to slope in all directions, at an angle of 30° from a line on the hatch end beam which is the mean of the peaks and valleys of the actual grain surface as shown in Fig 1.

The description of the pattern of grain surface behaviour to be assumed in partly filled compartments is contained in [1.6].

Table 1 : Standard void depth

Distance, in m, from hatch end or hatch side to boundary of compartment	Standard void depth V_{d1} in mm
0,5	570
1,0	530
1,5	500
2,0	480
2,5	450
3,0	440
3,5	430
4,0	430
4,5	430
5,0	430
5,5	450
6,0	470
6,5	490
7,0	520
7,5	550
8,0	590

Note 1: For boundary distances greater than 8,0 m, the standard void depth V_{d1} is to be linearly extrapolated with 80 mm increases for each 1,0 m increase in length.

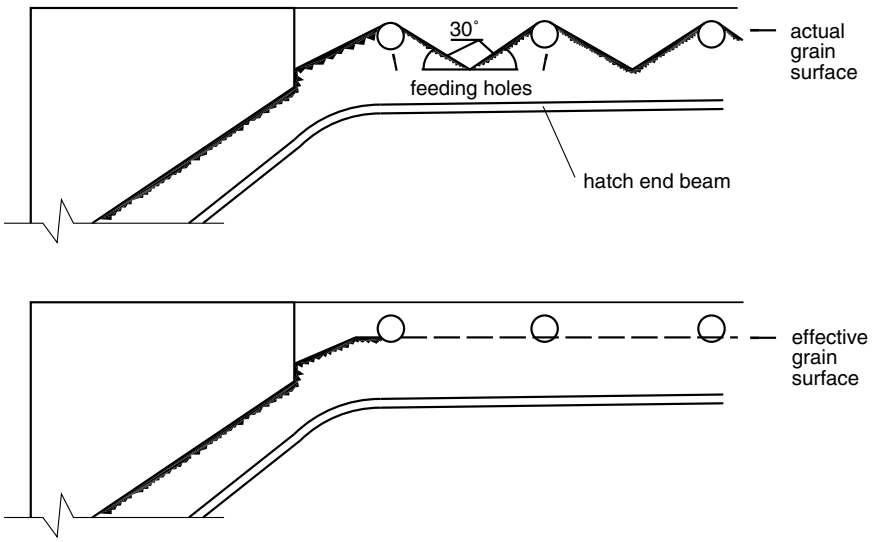
Note 2: In the corner area of a compartment, the boundary distance is to be the perpendicular distance from the line of the hatch side girder or the line of the hatch end beam to the boundary of the compartment, whichever is the greater. The girder depth d is to be taken as the depth of the hatch side girder or the hatch end beam, whichever is the lesser.

Note 3: Where there is a raised deck clear of the hatchway, the average void depth measured from the underside of the raised deck is to be calculated using the standard void depth in association with a girder depth of the hatch end beam plus the height of the raised deck.

Table 2 : Requirements for feeding holes

Minimum diameter, in mm	Area, in cm^2	Maximum spacing, in m
90	63,6	0,60
100	78,5	0,75
110	95,0	0,90
120	113,1	1,07
130	133,0	1,25
140	154,0	1,45
150	177,0	1,67
160	201,0	1,90
170 or above	227,0	2,00

Figure 1 : Effective grain surface to be assumed



1.2.2 Assumptions in filled compartments trimmed

For the purpose of demonstrating compliance with the stability criteria specified in Ch 4, Sec 3, [1.2.3], the ship's stability calculations are normally to be based upon the assumption that the centre of gravity of cargo in a filled compartment trimmed is at the volumetric centre of the whole cargo space. In those cases where the Society authorises account to be taken of the effect of assumed underdeck voids on the vertical position of the centre of gravity of the cargo in filled compartments trimmed, it is necessary to compensate for the adverse effect of the vertical shift of grain surfaces by increasing the assumed heeling moment due to the transverse shift of grain as follows:

$M_{H,T} = 1,06\ M_{H,C}$

where:

$M_{H,T}$: *Total heeling moment, in t.m*

$M_{H,C}$: *Calculated transverse heeling moment, in t.m.*

In all cases the weight of cargo in a filled compartment trimmed is to be the volume of the whole cargo space divided by the stowage factor.

1.2.3 Assumptions in filled compartments untrimmed

The centre of gravity of cargo in a filled compartment untrimmed is to be taken to be the volumetric centre of the whole cargo compartment with no account being allowed for voids. In all cases the weight of cargo is to be the volume of the cargo (resulting from the assumptions stated in [1.2.1] c) or [1.2.1] d)) divided by the stowage factor.

1.2.4 Assumptions in partially filled compartments

In partly filled compartments the adverse effect of the vertical shift of grain surfaces is to be taken into account as follows:

$M_{H,T} = 1,12\ M_{H,C}$

where $M_{H,T}$ and $M_{H,C}$ are defined in [1.2.2].

1.2.5 Equivalent methods

Any other equally effective method may be adopted to make the compensation required in [1.2.2] and [1.2.4].

1.3 Assumed volumetric heeling moment of a filled compartment trimmed

1.3.1 General

The pattern of grain surface movement relates to a transverse section across the portion of the compartment being considered and the resultant heeling moment is to be multiplied by the length to obtain the total moment for that portion.

The assumed transverse heeling moment due to grain shifting is a consequence of final changes of shape and position of voids after grain has moved from the high side to the low side.

The resulting grain surface after shifting is to be assumed to be at 15° to the horizontal.

In calculating the maximum void area that can be formed against a longitudinal structural member, the effects of any horizontal surfaces, e.g. flanges or face bars, are to be ignored.

The total areas of the initial and final voids are to be equal.

Longitudinal structural members which are grain-tight may be considered effective over their full depth except where they are provided as a device to reduce the adverse effect of grain shift, in which case the provisions of [1.1.6] are to apply.

A discontinuous longitudinal division may be considered effective over its full length.

1.3.2 Assumptions

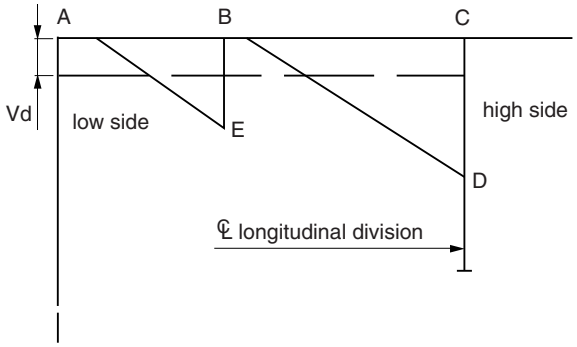
In the following paragraphs it is assumed that the total heeling moment for a compartment is obtained by adding the results of separate consideration of the following portions:

a) before and abaft hatchways:

- *if a compartment has two or more main hatchways through which loading may take place, the depth of the underdeck void for the portion or portions between such hatchways is to be determined using the fore and aft distance to the mid-point between the hatchways*
- *after the assumed shift of grain the final void pattern is to be as shown in Fig 2.*

b) In and abreast of hatchways without longitudinal division, after the assumed shift of grain the final void pattern is to be as shown in Fig 3 or Fig 4.

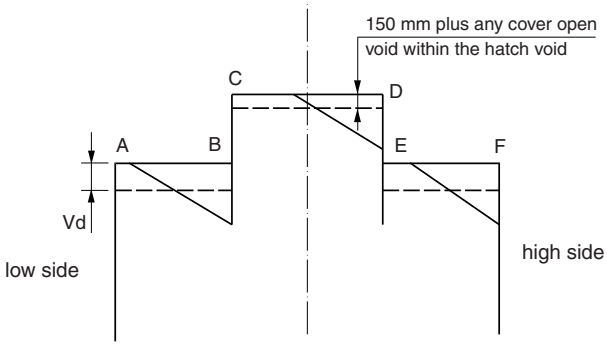
Figure 2 : Final void pattern



Note 1: If the maximum void area which can be formed against the girder at B is less than the initial area of the void under AB, i.e. AB.Vd, the excess area is to be assumed to transfer to the final void on the high side.

Note 2: If, for example, the longitudinal division at C is one which has been provided in accordance with [1.1.6], it is to extend to at least 0,6 m below D or E, whichever gives the greater depth.

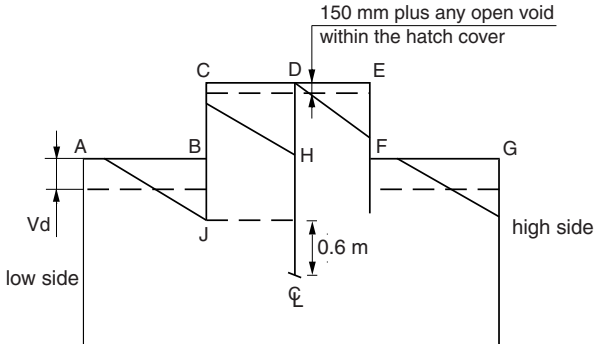
Figure 3 : Final void pattern



Note 3: AB: Any area in excess of that which can be formed against the girder at B is to transfer to the final void area in the hatchway.

Note 4: CD: Any area in excess of that which can be formed against the girder at E is to transfer to the final void area on the high side.

Figure 4 : Final void pattern



Note 5: The excess void area from AB is to transfer to the low side half of the hatchway in which two separate final void areas are formed: one against the centreline division and the other against the hatch side coaming and girder on the high side.

Note 6: If a bagged saucer or bulk bundle is formed in a hatchway it is to be assumed for the purpose of calculating the transverse heeling moment that such a device is at least equivalent to the centreline division.

Note 7: If the centreline division is one which has been provided in accordance with [1.1.6], it is to extend to at least 0,6 m below H or J, whichever gives the greater depth.

1.3.3 Compartment loaded in combination

The following paragraphs describe the patterns of void behaviour which are to be assumed when compartments are loaded in combination:

a) without effective centreline divisions:

- *under the upper deck:*

  as for the single deck arrangement described in [1.3.2] a) (second bullet) and [1.3.2] b).

- *under the second deck (if applicable):*

  the area of void available for transfer from the low side, i.e. original void area less area against the hatch side girder, is to be assumed to transfer as follows: one half to the upper deck hatchway and one quarter each to the high side under the upper and second deck.

- *under the third and lower decks (if applicable):*

  the void areas available for transfer from the low side of each of these decks are to be assumed to transfer in equal quantities to all the voids under the decks on the high side and the void in the upper deck hatchway.

b) with effective centreline divisions which extend into the upper deck hatchway:

- *at all deck levels abreast of the division the void areas available for transfer from the low side are to be assumed to transfer to the void under the low side half of the upper deck hatchway*
- *at the deck level immediately below the bottom of the division the void area available for transfer from the low side is to be assumed to transfer as follows: one half to the void under the low side half of the upper deck hatchway and the remainder in equal quantities to the voids under the decks on the high side*
- *at deck levels lower than those described above, the void area available for transfer from the low side of each of those decks is to be assumed to transfer in equal quantities to the voids in each of the two halves of the upper deck hatchway on each side of the division and the voids under the decks on the high side.*

c) with effective centreline divisions which do not extend into the upper deck hatchway:

Since no horizontal transfer of voids may be assumed to take place at the same deck level as the division, the void area available for transfer from the low side at this level is to be assumed to transfer above the division to voids on the high side in accordance with the principles of a) and b).

1.4 Assumed volumetric heeling moment of a filled compartment untrimmed

1.4.1 General

All the provisions for filled compartments trimmed set forth in [1.3] are to also apply to filled compartments untrimmed, except as reported in [1.4.2].

1.4.2 Additional requirements

In filled compartments untrimmed which are exempted from trimming outside the periphery of the hatchway under the provisions of [1.1.3] a), the following assumptions apply:

a) The resulting grain surface after shifting is to be assumed to be at an angle of 25° to the horizontal. However, if in any section of the compartment, forward, aft, or abreast of the hatchway the mean transverse area of the void in that section is equal to or less than the area which would be obtained by application of [1.2.1] a), then the angle of grain surface after shifting in that section is to be assumed to be 15° to the horizontal.

b) The void area at any transverse section of the compartment is to be assumed to be the same both before and after the grain shift, i.e. it is to be assumed that additional feeding does not occur at the time of the grain shift.

In filled compartments untrimmed which are exempted from trimming in the ends, forward and aft of the hatchway, under the provisions of [1.1.3] b), the following assumptions apply:

a) the resulting grain surface abreast of the hatchway after shifting is to be assumed to be at an angle of 15° to the horizontal

b) the resulting grain surface in the ends, forward and aft of the hatchway after shifting is to be assumed to be at an angle of 25° to the horizontal.

1.5 Assumed volumetric heeling moments in trunks

1.5.1 *After the assumed shift of grain the final void pattern is to be as shown in Fig 5.*

Note 1: If the wing spaces in way of the trunk cannot be properly trimmed in accordance with [1.1], it is to be assumed that a 25° surface shift takes place.

1.6 Assumed volumetric heeling moment of a partly filled compartment

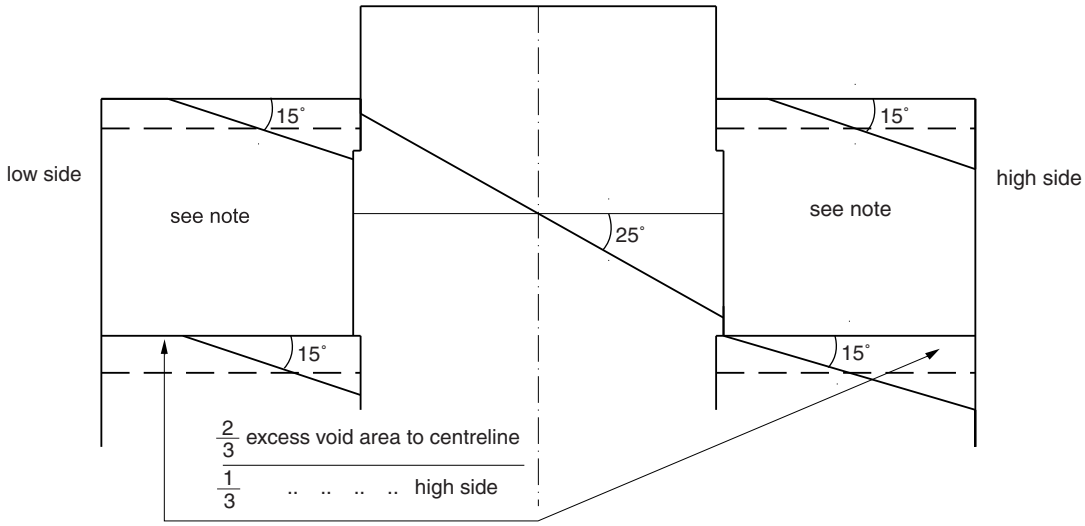
1.6.1

a) *When the free surface of the bulk grain has not been secured in accordance with [1.9.1] to [1.9.3], [1.9.4], or [1.9.5], it is to be assumed that the grain surface after shifting is at 25° to the horizontal.*

b) *In a partly filled compartment, a division, if fitted, is to extend from one eighth of the maximum breadth of the compartment above the level of the grain surface and to the same distance below the grain surface.*

c) *In a compartment in which the longitudinal divisions are not continuous between the transverse boundaries, the length over which any such divisions are effective as devices to prevent full width shifts of grain surfaces is to be taken to be the actual length of the portion of the division under consideration less two sevenths of the greater of the transverse distances between the division and its adjacent division or ship side. This correction does not apply in the lower compartments of any combination loading in which the upper compartment is either a filled compartment or a partly filled compartment.*

Figure 5 : Assumed volumetric heeling moment in trunks



1.7 Other assumptions

1.7.1 *The Society may authorise departure from the assumptions contained in these Rules in those cases where it considers this to be justified having regard to the provisions for loading or the structural arrangements, provided the stability criteria in Ch 4, Sec 3, [1.2.3] are met.*

Where such authorisation is granted under this regulation, particulars shall be included in the grain loading manual.

These particulars include the additional calculation of heeling moments for filled holds with untrimmed ends, an example of which is reported in [2.1].

1.8 Saucers

1.8.1 *For the purpose of reducing the heeling moment a saucer may be used in place of a longitudinal division in way of a hatch opening only in a filled trimmed compartment as defined in Ch 4, Sec 3, [1.1.2], except in the case of linseed and other seeds having similar properties, where a saucer may not be substituted for a longitudinal division. If a longitudinal division is provided, it is to meet the requirements of [1.1.6].*

1.8.2 *The depth of the saucer, measured from the bottom of the saucer to the deck line, is to be as follows:*

- *for ships with a moulded breadth of up to 9,1 m, not less than 1,2 m*
- *for ships with a moulded breadth of 18,3 m or more, not less than 1,8 m*
- *for ships with a moulded breadth between 9,1 m and 18,3 m, the minimum depth of the saucer is to be calculated by interpolation.*

1.8.3 *The top (mouth) of the saucer is to be formed by the underdeck structure in way of the hatchway, i.e. hatch side girders or coamings and hatch end beams. The saucer and hatchway above are to be completely filled with bagged grain or other suitable cargo laid down on a separation cloth or its equivalent and stowed tightly against adjacent structure so as to have a bearing contact with such structure to a depth equal to or greater than one half of the depth specified in [1.8.2].*

If hull structure to provide such bearing surface is not available, the saucer is to be fixed in position by steel wire rope, chain, or double steel strapping as specified in [1.9.4] d) and spaced not more than 2,4 m apart.

1.8.4 *As an alternative to filling the saucer in a filled trimmed compartment with bagged grain or other suitable cargo, a bundle of bulk grain may be used provided that:*

a) the dimensions and means for securing the bundle in place are the same as specified for a saucer in [1.8.2] and [1.8.3]

b) the saucer is lined with a material acceptable to the Society having a tensile strength of not less than 2,687 N per 5 cm strip and which is provided with suitable means for securing at the top

c) as an alternative to b), a material acceptable to the Society having a tensile strength of not less than 1,344 N per 5 cm strip may be used if the saucer is constructed as follows:

- *athwartship lashings acceptable to the Society are to be placed inside the saucer formed in the bulk grain at intervals of not more than 2,4 m. These lashings are to be of sufficient length to permit being drawn up tight and secured at the top of the saucer.*
- *dunnage not less than 25 mm in thickness or other suitable material of equal strength and between 150 mm and 300 mm in width is to be placed fore and aft over these lashings to prevent the cutting or chafing of the material which is to be placed thereon to line the saucer*

d) the saucer is to be filled with bulk grain and secured at the top except that when using material approved under c) further dunnage is to be laid on top after lapping the material before the saucer is secured by setting up the lashings

e) if more than one sheet of material is used to line the saucer they are to be joined at the bottom either by sewing or by a double lap

f) the top of the saucer is to be coincidental with the bottom of the beams when these are in place and suitable general cargo or bulk grain may be placed between the beams on top of the saucer.

1.9 Overstowing arrangements and securing

1.9.1 Bagged grain

Where bagged grain or other suitable cargo is utilised for the purpose of securing partly filled compartments, the free grain surface is to be level and is to be covered with a separation cloth or equivalent or by a suitable platform. Such platform is to consist of bearers spaced not more than 1,2 m apart and 25 mm boards laid thereon spaced not more than 100 mm apart. Platforms may be constructed of other materials provided they are deemed by the Society to be equivalent.

1.9.2 Separating platform

The platform or separation cloth is be topped off with bagged grain tightly stowed and extending to a height of not less than one sixteenth of the maximum breadth of the free grain surface or 1,2 m, whichever is the greater.

1.9.3 Equivalent cargo

The bagged grain is to be carried in sound bags which are to be well filled and securely closed.

Instead of bagged grain, other suitable cargo tightly stowed and exerting at least the same pressure as bagged grain stowed in accordance with [1.9.2] may be used.

1.9.4 Strapping or lashing

When, in order to eliminate heeling moments in partly filled compartments, strapping or lashing is utilised, the securing is to be accomplished as follows:

a) the grain is to be trimmed and levelled to the extent that it is very slightly crowned and covered with burlap separation cloths, tarpaulins or the equivalent

b) the separation cloths and/or tarpaulins are to overlap by at least 1,8 m

c) two solid floors of rough 25 mm by 150 mm to 300 mm lumber are to be laid with the top floor running longitudinally and nailed to an athwartship bottom floor. Alternatively, one solid floor of 50 mm lumber, running longitudinally and nailed over the top of a 50 mm bottom bearer not less than 150 mm wide, may be used. The bottom bearers are to extend the full breadth of the compartment and are to be spaced not more than 2,4 m apart. Arrangements utilising other materials and deemed by the Society to be equivalent to the foregoing may be accepted.

d) Steel wire rope (19 mm diameter or equivalent), double steel strapping (50 mm x 1,3 mm and having a breaking load of at least 49 kN), or chain of equivalent strength, each of which is to be set tightly by means of a 32 mm turnbuckle, may be used for lashings. A winch tightener, used in conjunction with a locking arm, may be substituted for the 32 mm turnbuckle when steel strapping is used, provided suitable wrenches are available for setting up as necessary.

When steel strapping is used, not less than three crimp seals are to be used for securing the ends. When wire is used, not less than four clips are to be used for forming eyes in the lashings.

e) Prior to the completion of loading the lashings are to be positively attached to the framing at a point approximately 450 mm below the anticipated final grain surface by means of either a 25 mm shackle or beam clamp of equivalent strength

f) the lashings are to be spaced not more than 2,4 m apart and each is to be supported by a bearer nailed over the top of the fore and aft floor. This bearer is to consist of lumber of not less than 25 mm by 150 mm or its equivalent and is to extend the full breadth of the compartment.

g) During the voyage the strapping is to be regularly inspected and set up where necessary.

1.9.5 Securing with wire mesh

When, in order to eliminate grain heeling moments in partly filled compartments, strapping or lashing is utilised, the securing may, as an alternative to the method described in [1.9.4], be accomplished as follows:

a) the grain is to be trimmed and levelled to the extent that it is very slightly crowned along the fore and aft centreline of the compartment

b) the entire surface of the grain is to be covered with burlap separation cloths, tarpaulins, or the equivalent. The covering material is to have a tensile strength of not less than 1,344 N per 5 cm strip.

c) Two layers of wire reinforcement mesh are to be laid on top of the burlap or other covering. The bottom layer is to be laid athwartship and the top layer is to be laid longitudinally. The lengths of wire mesh are to be overlapped at least 75 mm. The top layer of mesh is to be positioned over the bottom layer in such a manner that the squares formed by the alternate layer measure approximately 75 mm by 75 mm. The wire reinforcement mesh is the type used in reinforced concrete construction. It is fabricated of 3 mm diameter steel wire having a breaking strength of not less than 52 kN/cm^2, welded in 150 mm x 150 mm squares. Wire mesh having mill scale may be used but mesh having loose, flaking rust may not be used.

d) The boundaries of the wire mesh, at the port and starboard side of the compartment, are to be retained by wood planks 150 mm x 50 mm,

e) hold-down lashings, running from side to side across the compartment, are to be spaced not more than 2,4 m apart except that the first and the last lashing are not to be more than 300 mm from the forward or after bulkhead, respectively. Prior to the completion of the loading, each lashing is to be positively attached to the framing at a point approximately 450 mm below the anticipated final grain surface by means of either a 25 mm shackle or beam clamp of equivalent strength. The lashing is to be led from this point over the top of the boundary plank described in d), which has the function of distributing the downward pressure exerted by the lashing. Two layers of 150 mm x 25 mm planks are to be laid athwartship centred beneath each lashing and extending the full breadth of the compartment.

f) The hold-down lashings are to consist of steel wire rope (19 mm diameter or equivalent), double steel strapping (50 mm x 1,3 mm and having a breaking load of at least 49 kN), or chain of equivalent strength, each of which is to be set tight by means of a 32 mm turnbuckle. A winch tightener, used in conjunction with a locking arm, may be substituted for the 32 mm turnbuckle when steel strapping is used, provided suitable wrenches are available for setting up as necessary. When steel strapping is used, not less than three crimp seals are to be used for securing the ends. When wire rope is used, not less than four clips are to be used for forming eyes in the lashings.

g) During the voyage the hold-down lashings are to be regularly inspected and set up where necessary.

2 Dispensation from trimming ends of holds in certain ships

2.1 Calculation example

2.1.1 General

As a result of the provisions in [1.1.3] and [1.7.1], *dispensation may be granted from trimming the ends of holds in specially suitable ships, when requested, provided that an additional entry of heeling moments for filled holds with untrimmed ends is approved and included in the* grain loading manual required in Ch 4, Sec 3, [1.2.2]. *Untrimmed ends are to be treated as partly filled spaces and, accordingly, the grain surface in these portions of the hold is to be assumed to shift to an angle of 25° from the horizontal.*

After taking into account the heeling moments due to the shift of grain in the untrimmed ends, dispensation may be granted provided the ship meets the stability criteria specified in Ch 4, Sec 3, [1.2.3].

This dispensation may be granted only to ships which are arranged with sloping bulkheads, port and starboard forming the longitudinal inner boundaries of topside tanks and which slope at an angle of 30° or more to the horizontal.

When calculating the geometry of the void beyond the hatch end, allowance may be made for feeding holes in the hatch and beam provided they meet the requirements reported in Tab 2.

The effective depth is to be taken as the distance from the underside of the deck to a horizontal line on the hatch end beam which is the mean between the peaks and valleys of the actual grain surface as shown in Fig 1.

2.1.2 Assumptions

In performing the calculation of the volumetric heeling moment, the grain in the hatchway is assumed to be filled to the maximum and the resulting surface shifted to an angle of 15° to the horizontal.

In the untrimmed end the surface of the grain will slope in all directions away from the filling area at an angle of 30° to the horizontal from the lower edge of the hatch end beam or, in certain cases from a higher level where feeding holes are provided.

The sum of the moments calculated for the ends and the moments for the hatchway give the total volumetric heeling moment for the compartment "filled - ends not trimmed" and is to be listed for any such compartment in the grain loading manual.

The information concerning full holds assumed to be trimmed and partly filled holds is to remain the same as at present.

2.1.3 Calculation of void areas

In ships having sloping topside tanks in each hold, the grain surface leans against topside tank bulkheads if its slope is equal to or greater than 30° to the horizontal; in this case no void occurs.

In the zone forward and abaft the hatch, the grain surface is located so as that the standard void depth V_d increases with the distance from the hatch.

For the void depth calculation, three different transversal sections, AA, BB and CC are taken into account, and for each of these sections, three different points (A_1, A_2, A_3, B_1, B_2, B_3 and C_1, C_2, C_3) are to be considered, as illustrated in Fig 6.

The distance between the points C_3 and B_2, in m, is as follows:

$$C_3B_2 = \sqrt{(3^2 + 2^2)} = 3,61$$

and the void depth V_{d2}, in m, measured in B_2 is:

$$V_{d2} = 3,61 \tan 30^o + 0,60 = 2,68$$

The topside tank area A_W, in m², (I + II) is as follows:

$$A_W = (6 \cdot 0,60) + \frac{6(\tan 30^o)6}{2} = 13,98$$

The void depth V_{d3}, V_{d2}, V_{d1}, in m, relevant to points A3, A2, A1 of section AA is:

$$V_{d3} = 4 \tan 30^o + 0,60 = 2,91$$

$$V_{d2} = (\sqrt{3^2 + 4^2}) \tan 30^o + 0,60 = 3,49$$

$$V_{d1} = (\sqrt{6^2 + 4^2}) \tan 30^o + 0,60 = 4,76$$

The area $A_{V,AA}$, in m², of the void in transversal section AA (calculated according to Simpson's integration rule) is as follows:

$$A_{V,AA} = \frac{A_3 . A_2}{3} \cdot (V_{d3} + 4 \cdot V_{d2} + V_{d1}) = 21,63$$

With reference to Fig 7 and Fig 8 the following areas are calculated:

- area $A_1A_3G_3G_1$ (which is the area $A_{V,AA}$ calculated above), in m², equal to: 21,63
- topside tank area A_W, in m², equal to: 13,98
- area $A_{V,I}$, in m², relevant to void I, equal to:
  $A_{V,I} = 21,63 - 13,98 = 7,65$
- area $A_{V,II}$, in m², relevant to void II, equal to:
  $A_{V,II} = 5 \cdot 2,91 = 14,55$
- total area $A_{T,AA}$ of void, port and starboard, in m², in section AA, equal to:
  $A_{T,AA} = 2\ (7,65 + 14,55) = 44,40$

With the same procedure the void relevant to the BB section is calculated, as follows:

- total area $A_{T,BB}$ of void, port and starboard, in m², in section BB:
  $A_{T,BB} = 22,98$
- total area $A_{T,CC}$ of void, port and starboard, in m², in section CC:
  $A_{T,CC} = 2\ (5 \cdot 0,60) = 6,00$

Figure 6 : Geometry for void depth calculation

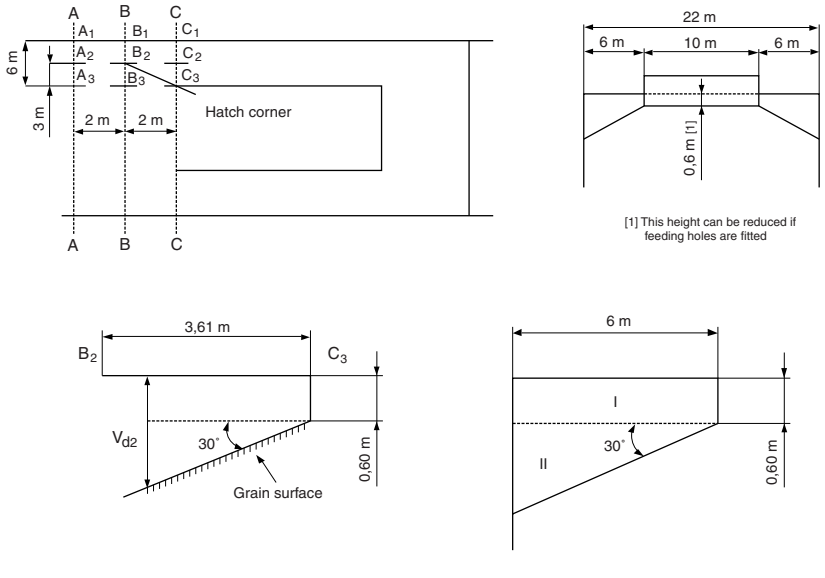


Figure 7 : Geometry for void depth calculation

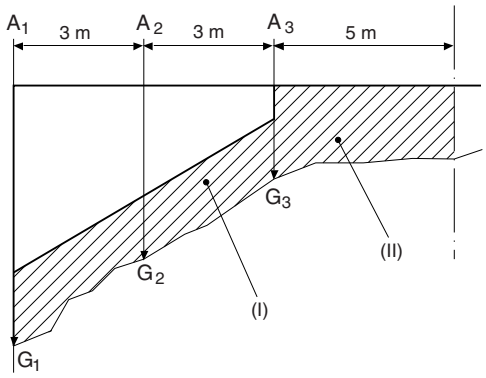
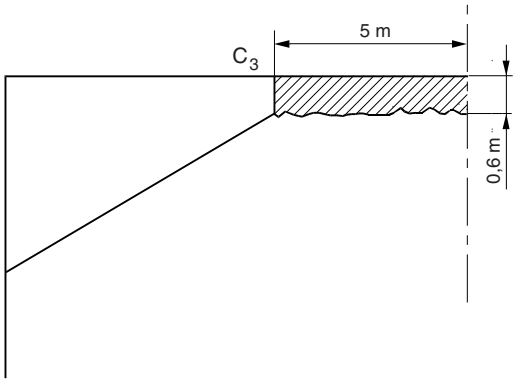


Figure 8 : Geometry for void depth calculation



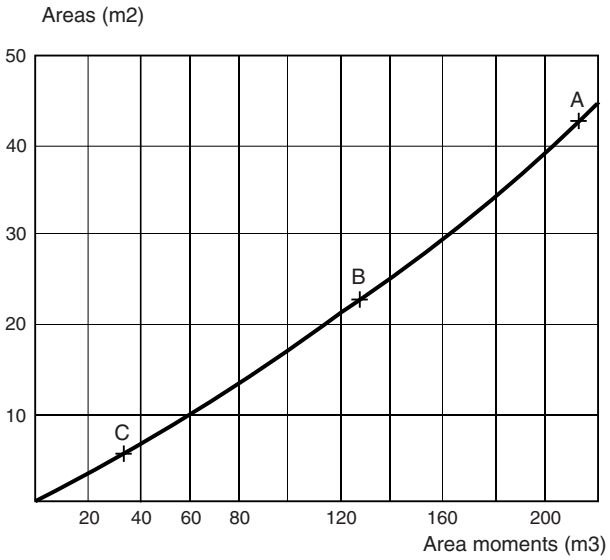
2.1.4 Calculation of areas and area moments

Finding the surface at each station after shift which establishes a void area exactly equal to that at the station before shift is a complicated calculation if done directly.

However, if the areas and corresponding area moments are calculated for random shifts from the horizontal to 25°, and a plot is made of areas versus area moments, then by entering the plot with the actual void area at any position before shift, a close approximation to the area moment after shift can be obtained. Such a plot is provided in Fig 9.

Another advantage of this method lies in the fact that while the lengths of the end sections may vary, the cross-sectional dimensions are usually uniform throughout most of the ship. Therefore the same plot of areas versus area moments can be used for several locations.

Figure 9 : Plot of areas versus area moments



With reference to Fig 10, the areas relevant to the zones 1, 2, 3 are as follows:

- area A_1, in m^2, relevant to zone 1:

$$A_1 = \frac{8,74(\tan 25^\circ)8,74}{2} - 13,98 = 3,83$$

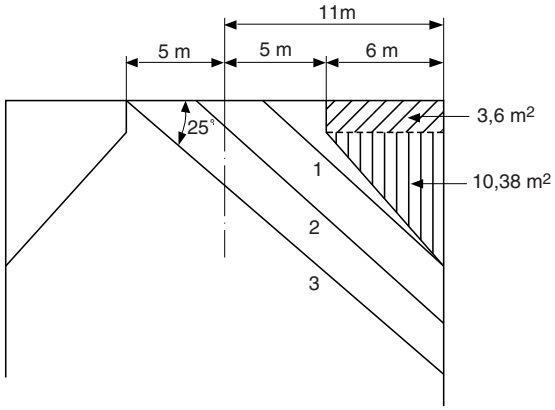
- area A_2, in m^2, relevant to zone 2:

$$A_2 = \frac{13(\tan 25^\circ)13}{2} - 13,98 = 25,41$$

- area A_3, in m^2, relevant to zone 3:

$$A_3 = \frac{16(\tan 25^\circ)16}{2} - 13,98 = 45,70$$

Figure 10 : Geometry for void depth calculation



The area moments M_1, M_2, M_3, in m^3, relevant to areas A_1, A_2, A_3, referred to the centreline are as follows:

- area moment M_1:

$$M_1 = 17,81\left(\frac{2}{3}.8,74 + 2,26\right) - 3,6(3+5) - 10,38\left(\frac{2}{3}.6 + 5\right)$$
$$= 21,80$$

- area moment M_2:

$$M_2 = 39,39\left(\frac{2}{3}.13 - 2\right) - 3,6(3+5) - 10,38\left(\frac{2}{3}.6 + 5\right)$$
$$= 140,38$$

- area moment M_3:

$$M_3 = 59,68\left(\frac{2}{3}.16 - 5\right) - 3,6(3+5) - 10,38\left(\frac{2}{3}.6 + 5\right)$$
$$= 215,97$$

A summary of the values obtained is reported in Tab 3.

Table 3 : Areas and area moments

Zone	Area, in m^2	Area moment in m^3
1	3,83	21,80
2	25,41	140,38
3	45,70	215,97

2.1.5 Calculation of volumetric heeling moment

a) Volumetric heeling moment in untrimmed end

Tab 4 gives the values of areas and area moments derived from the plot in Fig 9.

Therefore, the longitudinal distance between points A, B, C being equal to 2 m, the volumetric heeling moment in the untrimmed end M^I, in m^4, is as follows:

$$M^I = \frac{2}{3}[1 \cdot 34 + 4 \cdot 128 + 1 \cdot 212] = 505,33$$

b) Volumetric heeling moment in hatch

The following calculation is valid for void spaces within the hatch (see Fig 11):

- void area A_H, in m^2:

$$A_H = 10(0,4 + 0,15) = 5,5$$

- centre of gravity x, in m, relevant to A_H:

$$x = \sqrt{\frac{5,5 \cdot 2}{\tan 15^\circ}} = 6,41$$

- area moment M_H, in m^3:

$$M_H = 5,5\left(5 - \frac{6,41}{3}\right) = 15,75$$

The hatch length being equal to 15 m, the volumetric heeling moment in hatch M^{II}, in m^4, is as follows:

$M^{II} = 17,75 \cdot 15 = 236,25$

In addition, the possible void relevant to a longitudinal deck girder as described in Fig 12, as well as the possible void relevant to the topside tank geometry as described in Fig 13, are to be taken into account; on the contrary, the possible void relevant to topside tank longitudinal stiffeners as described in Fig 14 may not be taken into account.

c) Volumetric heeling moment

The total volumetric heeling moment in a hold, as reported in Tab 4, is the sum of the contribution of a) and b) above.

Figure 11 : Volumetric heeling moment in hatch

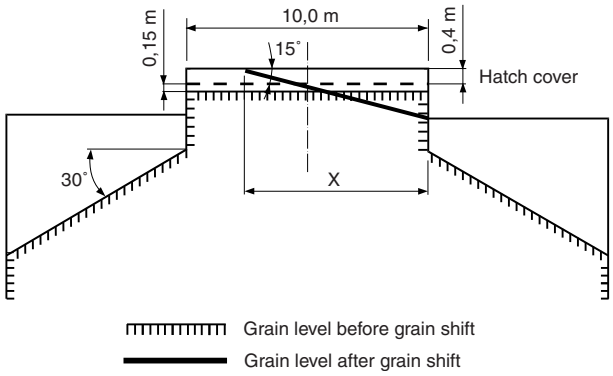


Figure 12 : Possible void relevant to a longitudinal deck girder

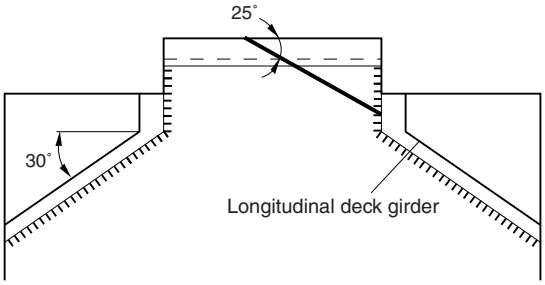


Figure 13 : Possible void relevant to the topside tank geometry

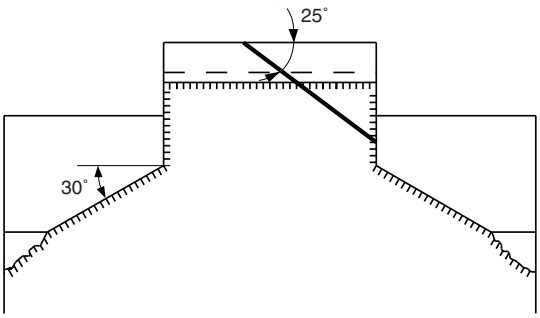


Figure 14 : Possible void relevant to topside tank longitudinal stiffeners

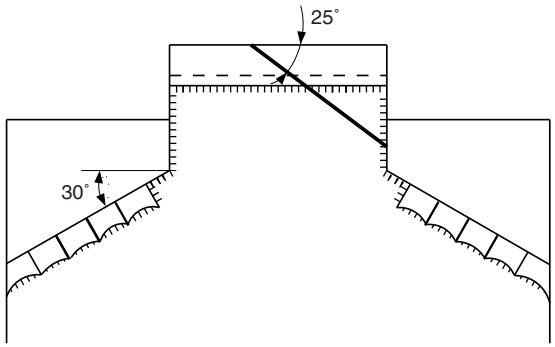


Table 4 : Total volumetric heeling moment in a hold, with untrimmed ends

Hold zone	Heeling moment, in m^4
Fore end	505,33
Hatch	236,25
Aft end	505,33
Total	1246,91

Appendix 2 Hold Mass Curves

Symbols

h : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline, in m

h_a : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the aft cargo hold of two adjacent cargo holds, in m

h_f : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the fore cargo hold of two adjacent cargo holds, in m

M_H : Cargo mass, in t, as defined in Pt B, Ch 5, Sec 6.

M_{Full} : Cargo mass, in t, as defined in Pt B, Ch 5, Sec 6.

M_{HD} : Cargo mass, in t, as defined in Pt B, Ch 5, Sec 6

M_{BLK} : The maximum cargo mass in a cargo hold of two adjacent cargo holds according to the block loading condition in the loading manual, in t

T_i : In loading condition No. i, draught, in m, at mid-hold position of single cargo hold length or at mid-length of the two adjacent cargo holds considered

T_{min} : 0,75 T_{SC} or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater, in m

T_{H1} : Minimum permissible draught, in m, in harbour condition with M_{Full} in each of the two adjacent holds to be taken as defined in Tab 1

T_{H2} : Minimum permissible draught, in m, in harbour condition with M_{Full} in holds intended to be empty in alternate loading conditions or in any hold of ships always loaded homogeneously, to be taken as defined in Tab 1

T_{H3} : Minimum permissible draught, in m, in harbour condition in case of block loading with M_{BLK} in each of the two adjacent holds of ships intended to be loaded in alternate conditions, to be taken as defined in Tab 1

T_{H4} : Minimum permissible draught, in m, in harbour condition with M_{HD} in holds intended to be full in alternate conditions, to be taken as defined in Tab 1

V_H : Volume in m^3, as defined in Pt B, Ch 5, Sec 6

V_a : Volume of the after cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3

V_f : Volume of the forward cargo hold of two adjacent cargo holds excluding volume of the hatchway part, in m^3

Σ : The sum of masses of two adjacent cargo holds.

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply to bulk carriers of 150 m in length L and above.

1.1.2 This appendix describes the procedure to be used for determination of:

- The maximum and minimum mass of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold.
- The maximum and minimum mass of cargo in any two adjacent holds as a function of the draught at mid-length of these two adjacent cargo holds.

Results of these calculations are to be included in the reviewed Loading Manual which has also to indicate the maximum permissible mass of cargo at scantling draught in each hold or in any two adjacent holds, as obtained from the design review.

1.1.3 General

The cargo mass curves of single cargo hold or of two adjacent cargo holds in seagoing and harbour conditions as defined in Tab 2 to Tab 9 are based on the loading conditions considered in Ch 4, Sec 3, [3.3]. However if the ship structure is checked for more severe loading conditions, the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

1.1.4 Loading/unloading conditions in harbour

For any bulk carrier, the maximum permissible cargo mass and the minimum required cargo mass of single cargo hold or of two adjacent cargo holds, corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

1.1.5 Maximum and minimum permissible mass expression

The maximum and minimum permissible mass in seagoing conditions, ($W_{maxS}(T_i)$, $W_{minS}(T_i)$) and in harbour condition ($W_{maxH}(T_i)$, $W_{minH}(T_i)$) at various draughts (T_i) are obtained, in t, by the following formulae given in Tab 2 to Tab 9 for the followings cases:

- ships intended to be loaded in alternate conditions not completed by the **(No MP)** indication
- ships intended to be loaded in alternate conditions completed by the **(No MP)** indication
- ships always loaded homogeneously not completed by the **(No MP)** indication
- ships always loaded homogeneously completed by the **(No MP)** indication.

2 Hold mass curves

2.1 General

2.1.1 Maximum permissible mass and minimum required mass of single cargo hold

See Tab 2 to Tab 5.

2.1.2 Maximum permissible mass and minimum required mass of two adjacent holds

See Tab 6 to Tab 9.

Table 1 : Minimum permissible draught, in m

	For ships having **(No MP)** notation assigned	For ships not having **(No MP)** notation assigned
T_{H1}	$T_{H1} = \min\left(\begin{array}{l} 0,67T_{SC} \\ T_{SC} - \dfrac{0,15\sum M_{Full}}{1,025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)} \end{array}\right)$	$T_{H2} = 0,67T_{SC} - \dfrac{0,15M_{Full}}{1,025\dfrac{V_H}{h}}$
T_{H2}	$T_{H2} = \min\left(\begin{array}{l} 0,67T_{SC} \\ T_{SC} - \dfrac{0,15M_{Full}}{1,025\dfrac{V_H}{h}} \end{array}\right)$	$T_{H2} = 0,67T_{SC} - \dfrac{0,15M_{Full}}{1,025\dfrac{V_H}{h}}$
T_{H3}	$T_{H3} = T_{SC} - \dfrac{\sum(0,15M_{BLK} + 0,1M_H)}{1,025\left(\dfrac{V_f}{h_f} + \dfrac{V_a}{h_a}\right)}$	
T_{H4}	$T_{H4} = \min\left(\begin{array}{l} 0,67T_{SC} \\ T_{SC} - \dfrac{0,15M_{HD} + 0,1M_H}{1,025\dfrac{V_H}{h}} \end{array}\right)$	

Table 2 : Ships intended to be loaded in alternate conditions not having {No MP} notation assigned

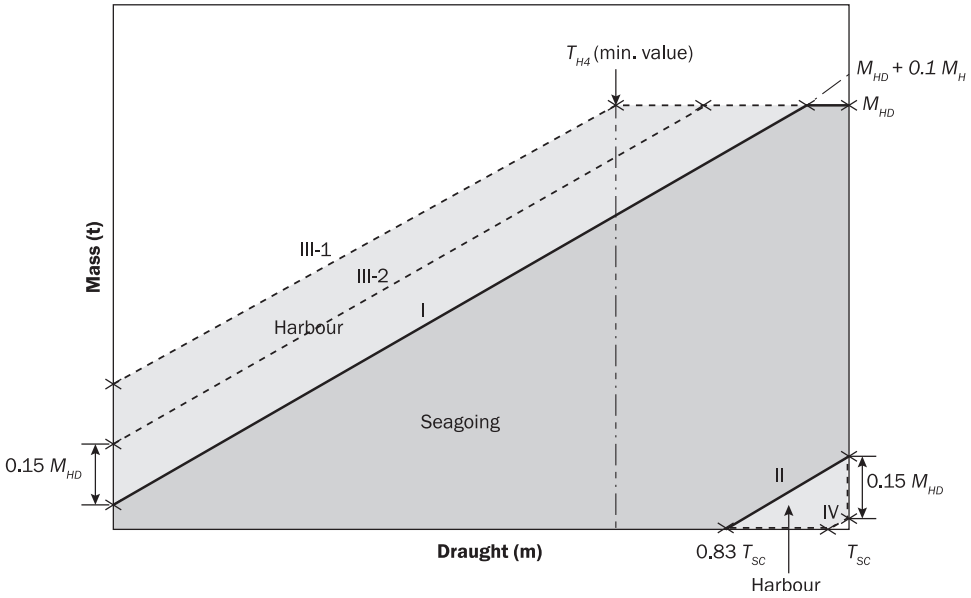
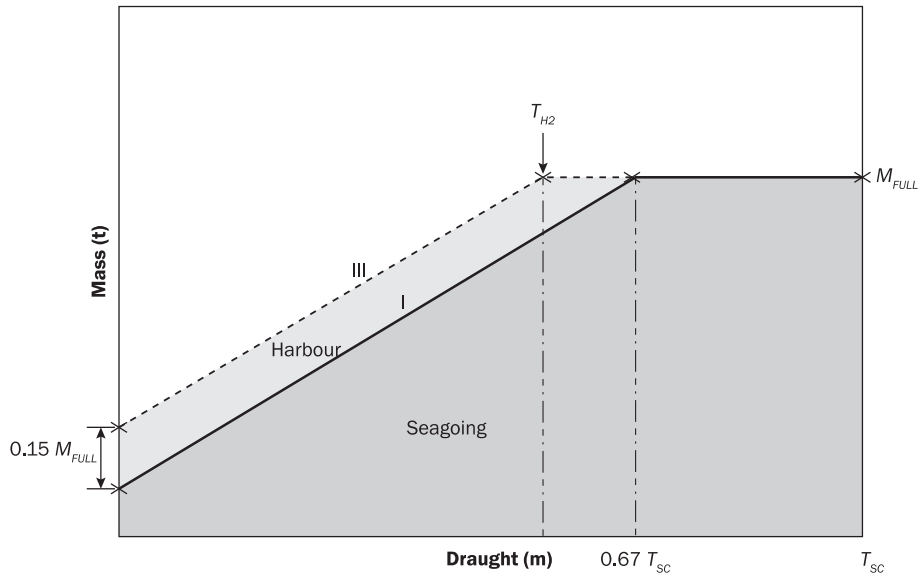
Hold	Loading conditions	Max / Min curves		Curve Ref
Full	Seagoing	Maximum:	$W_{maxS}(T_i) = M_{HD} + 0,1\ M_H - 1,025\ V_H \frac{(T_{SC} - T_i)}{h} \le M_{HD}$	I
		Minimum:	$W_{minS}(T_i) = 1,025\ V_H \frac{(T_i - 0,83T_{SC})}{h} \ge 0$	II
	Harbour	Maximum:	$W_{maxH}(T_i) = \max\left\{ \begin{array}{l} M_{HD} - 1,025\ V_H \frac{(0,67T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}(T_i) + 0,15M_{HD} \le M_{HD} \end{array} \right.$	III-1 III-2
		Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0,15M_{HD} \ge 0$	IV
				
Empty	Seagoing	Maximum:	$W_{maxS}(T_i) = M_{Full} - 1,025\ V_H \frac{(0,67T_{SC} - T_i)}{h} \le M_{Full}$	I
		Minimum:	$W_{minS}(T_i) = 1,025\ V_H \frac{(T_i - T_{SC})}{h} \ge 0$	II
	Harbour	Maximum:	$W_{maxH}(T_i) = W_{maxS}(T_i) + 0,15M_{Full} \le M_{Full}$	III
		Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0,15M_{Full} \ge 0$	IV
				

Table 3 : ships intended to be loaded in alternate conditions having {No MP} notation assigned

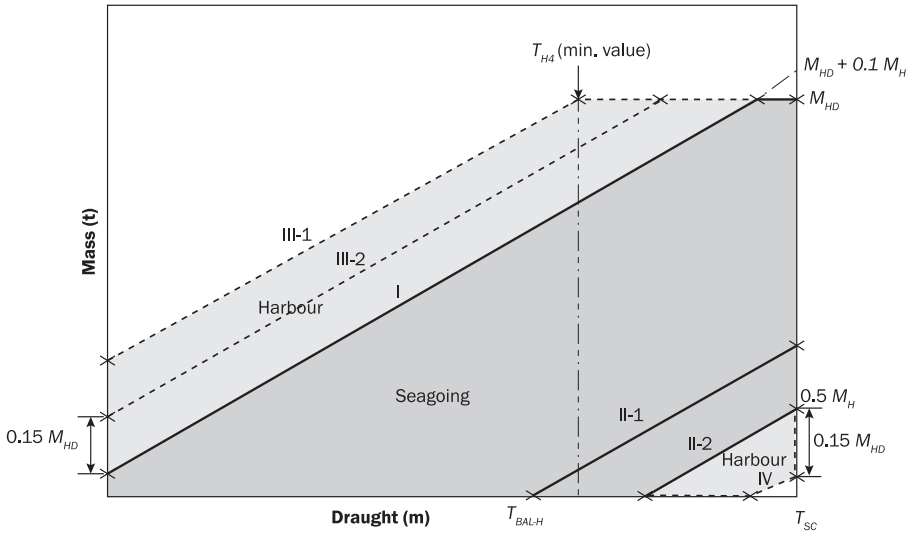
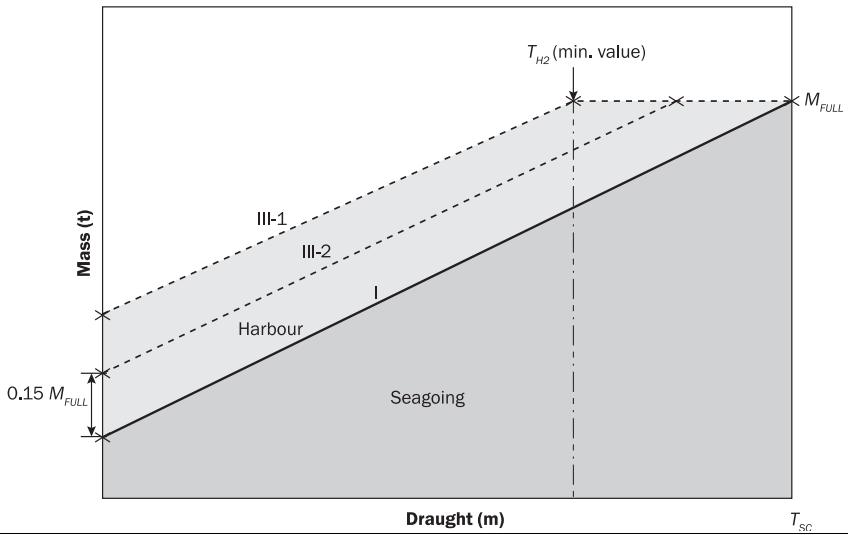
Hold	Loading conditions	Max / Min curves		Curve Ref
Full	Seagoing	Maximum:	$W_{maxS}(T_i) = M_{HD} + 0,1\ M_H - 1,025\ V_H \frac{(T_{SC} - T_i)}{h} \le M_{HD}$	I
		Minimum:	$W_{minS}(T_i) = \min \begin{cases} 1,025 V_H \frac{(T_i - T_{BAL-H})}{h} \ge 0 \\ 0,5 M_H - 1,025\ V_H \frac{(T_{SC} - T_i)}{h} \ge 0 \end{cases}$	II-1 II-2
	Harbour	Maximum:	$W_{maxH}(T_i) = \max \begin{cases} M_{HD} - 1,025\ V_H \frac{(0,67 T_{SC} - T_i)}{h} \le M_{HD} \\ W_{maxS}(T_i) + 0,15 M_{HD} \le M_{HD} \end{cases}$	III-1 III-2
		Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0,15 M_{HD} \ge 0$	IV
				
Empty	Seagoing	Maximum:	$W_{maxS}(T_i) = M_{Full} - 1,025\ V_H \frac{(T_{SC} - T_i)}{h} \le M_{Full}$	I
		Minimum:	$W_{minS}(T_i) = 1,025\ V_H \frac{(T_i - T_{SC})}{h} \ge 0$	II
	Harbour	Maximum:	$W_{maxH}(T_i) = \max \begin{cases} M_{Full} - 1,025\ V_H \frac{(0,67 T_{SC} - T_i)}{h} \le M_{Full} \\ W_{maxS}(T_i) + 0,15 M_{Full} \le M_{Full} \end{cases}$	III-1 III-2
		Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0,15 M_{Full} \ge 0$	IV
				

Table 4 : ships always loaded homogeneously not having {No MP} notation assigned

Loading conditions	Max / Min curves		Curve Ref
Seagoing	Maximum:	$W_{maxS}(T_i) = M_{Full} - 1{,}025\ V_H \frac{(0{,}67T_{SC} - T_i)}{h} \le M_{Full}$	I
	Minimum:	$W_{minS}(T_i) = 1{,}025\ V_H \frac{(T_i - 0{,}83T_{SC})}{h} \ge 0$	II
Harbour	Maximum:	$W_{maxH}(T_i) = W_{maxS}(T_i) + 0{,}15M_{Full} \le M_{Full}$	III
	Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0{,}15M_{Full} \ge 0$	IV

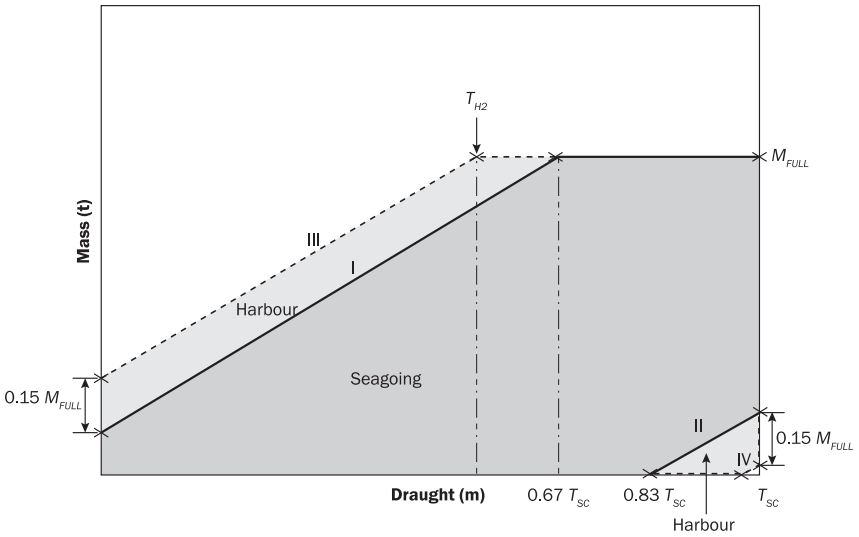


Table 5 : ships always loaded homogeneously having {No MP} notation assigned

Loading conditions	Max / Min curves		Curve Ref
Seagoing	Maximum:	$W_{maxS}(T_i) = M_{Full} - 1{,}025\ V_H \frac{(T_{SC} - T_i)}{h} \le M_{Full}$	I
	Minimum:	$W_{minS}(T_i) = \min\left\{ 1{,}025V_H \frac{(T_i - T_{BAL-H})}{h} \ge 0 \;;\; 0{,}5M_H - 1{,}025\ V_H \frac{(T_{SC} - T_i)}{h} \ge 0 \right\}$	II-1 II-2
Harbour	Maximum:	$W_{maxH}(T_i) = \max\left\{ M_{Full} - 1{,}025\ V_H \frac{(0{,}67T_{SC} - T_i)}{h} \le M_{Full} \;;\; W_{maxS}(T_i) + 0{,}15M_{Full} \le M_{Full} \right\}$	III-1 III-2
	Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0{,}15M_{Full} \ge 0$	IV

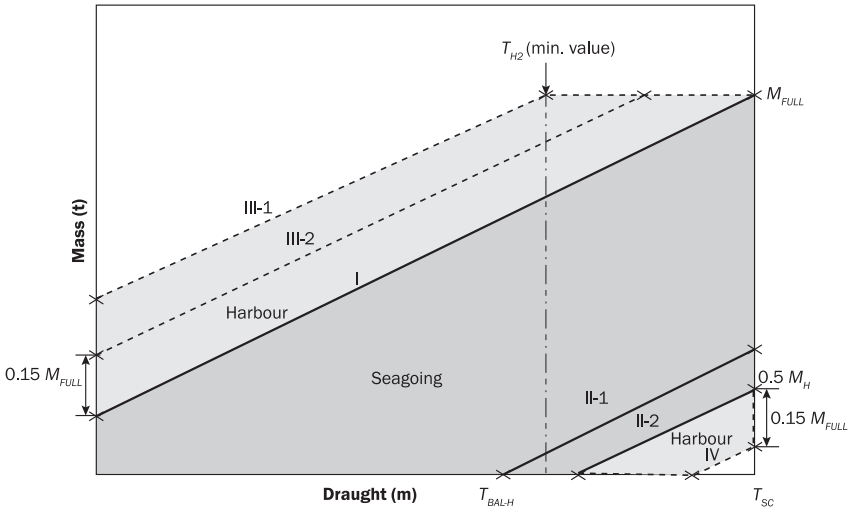


Table 6 : ships intended to be loaded in alternate conditions not having {No MP} notation assigned

Loading conditions	Max / Min curves		Curve Ref
Seagoing	Maximum:	$W_{maxS}(T_i) = \max \begin{cases} \sum (M_{BLK} + 0{,}1\ M_H) - 1{,}025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le \sum M_{BLK} \\ \sum M_{Full} - 1{,}025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0{,}67 T_{SC} - T_i) \le \sum M_{Full} \end{cases}$	I-1 **(1)** I-2
	Minimum:	$W_{minS}(T_i) = 1{,}025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0{,}75 T_{SC}) \ge 0$	II
Harbour	Maximum:	$W_{maxH}(T_i) = \max \begin{cases} W_{maxS}(T_i) + 0{,}15 \sum M_{BLK} \le \sum M_{BLK} \\ W_{maxS}(T_i) + 0{,}15 \sum M_{Full} \le \sum M_{Full} \end{cases}$	III-1 **(1)** III-2
	Minimum:	$W_{minH}(T_i) = \min \begin{cases} W_{minS}(T_i) - 0{,}15 \sum M_{BLK} \ge 0 \\ W_{minS}(T_i) - 0{,}15 \sum M_{Full} \ge 0 \end{cases}$	IV-1 **(1)** IV-2

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

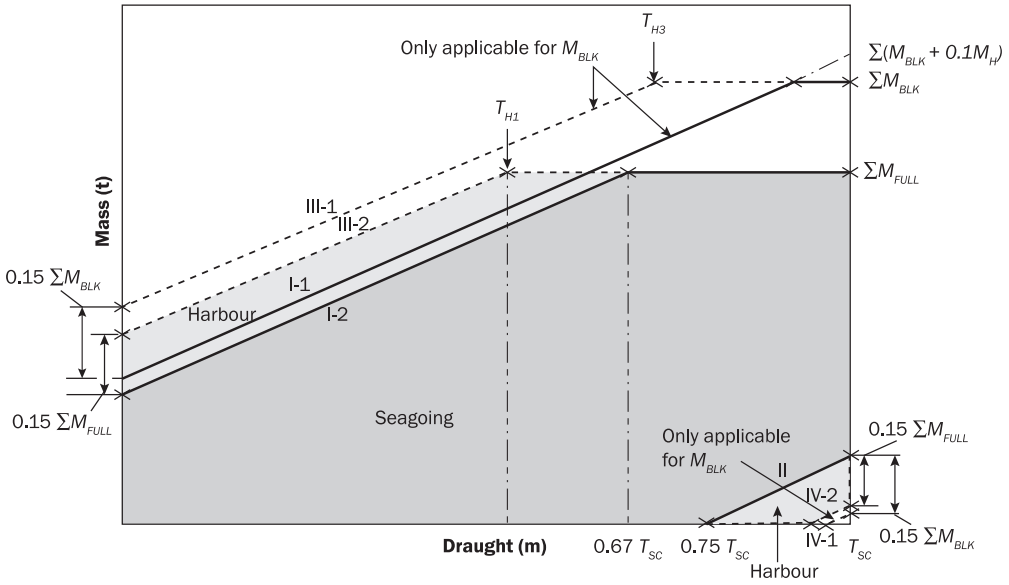


Table 7 : ships intended to be loaded in alternate conditions having {No MP} notation assigned

Loading conditions	Max / Min curves		Curve Ref
Seagoing	Maximum:	$W_{maxS}(T_i) = \max \begin{cases} \sum(M_{BLK} + 0{,}1\ M_H) - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le \sum M_{BLK} \\ \sum M_{Full} - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \le \sum M_{Full} \end{cases}$	I-1 **(1)** I-2
	Minimum:	$W_{minS}(T_i) = \min \begin{cases} 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{BAL-H}) \ge 0 \\ 0{,}5\sum M_H - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \ge 0 \end{cases}$	II-1 II-2
Harbour	Maximum:	$W_{maxH}(T_i) = \max \begin{cases} W_{maxS}(T_i) + 0{,}15\sum M_{BLK} \le \sum M_{BLK} \\ \sum M_{Full} - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0{,}67T_{SC} - T_i) \le \sum M_{Full} \\ W_{maxS}(T_i) + 0{,}15\sum M_{Full} \le \sum M_{Full} \end{cases}$	III-1 **(1)** III-2 III-3
	Minimum:	$W_{minH}(T_i) = \min \begin{cases} W_{minS}(T_i) - 0{,}15\sum M_{BLK} \ge 0 \\ W_{minS}(T_i) - 0{,}15\sum M_{Full} \ge 0 \end{cases}$	IV-1 **(1)** IV-2

(1) This limit curve is only applicable when block loading condition is included in the loading manual.

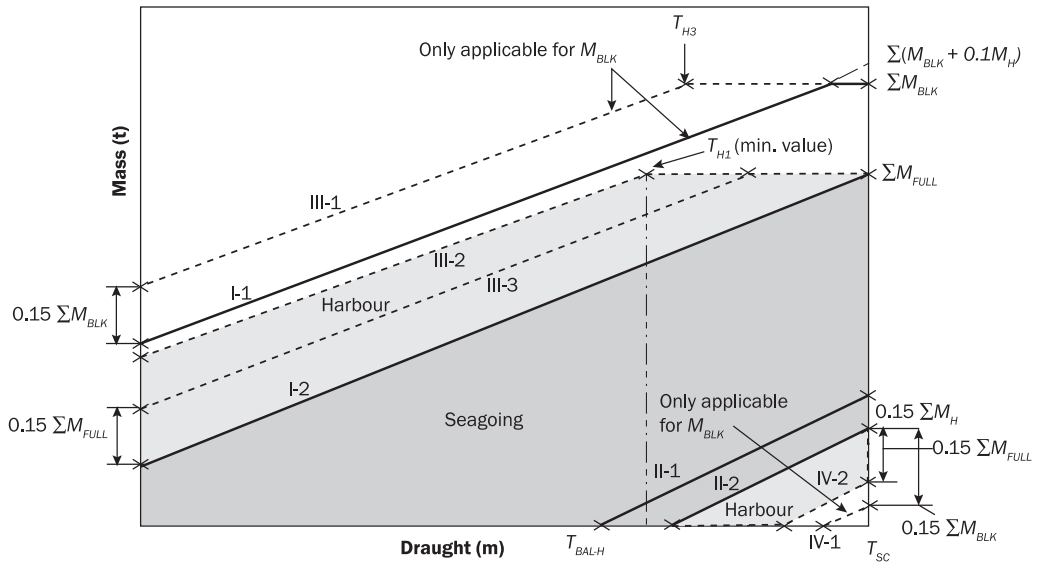


Table 8 : ships always loaded homogeneously not having {No MP} notation assigned

Loading conditions	Max / Min curves		Curve Ref
Seagoing	Maximum:	$W_{maxS}(T_i) = \sum M_{Full} - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0{,}67T_{SC} - T_i) \leq \sum M_{Full}$	I
	Minimum:	$W_{minS}(T_i) = 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0{,}75T_{SC}) \geq 0$	II
Harbour	Maximum:	$W_{maxH}(T_i) = W_{maxS}(T_i) + 0{,}15\sum M_{Full} \leq \sum M_{Full}$	III
	Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0{,}15\sum M_{Full} \geq 0$	IV

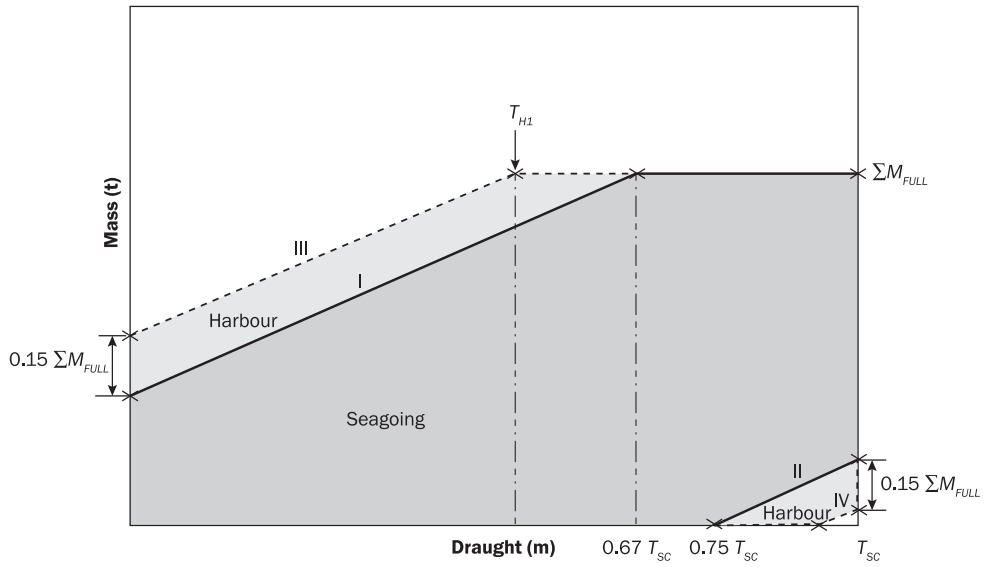
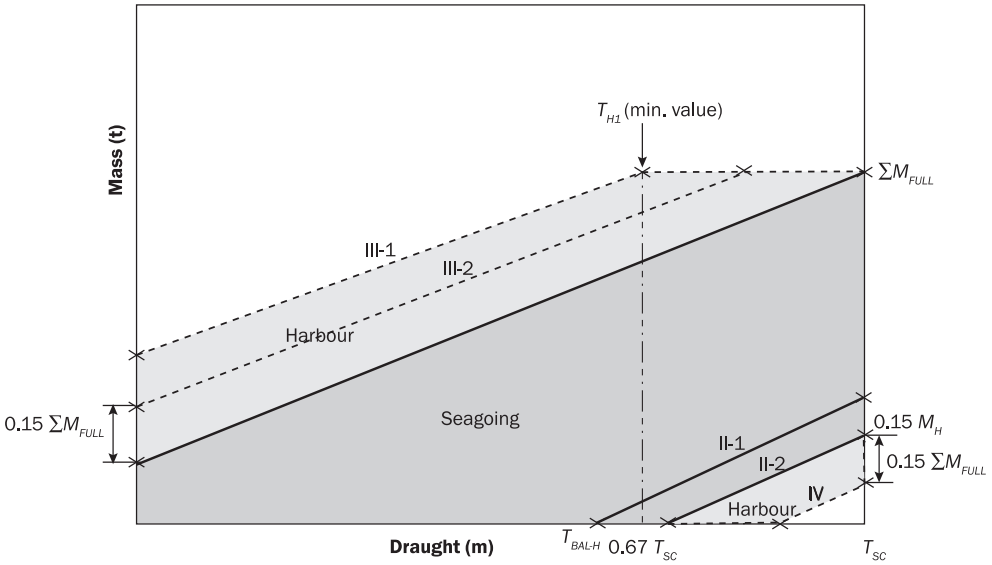


Table 9 : ships always loaded homogeneously having {No MP} notation assigned

Loading conditions	Max / Min curves		Curve Ref
Seagoing	Maximum:	$W_{maxS}(T_i) = \sum M_{Full} - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \leq \sum M_{Full}$	I
	Minimum:	$W_{minS}(T_i) = \min\left\{\begin{array}{l} 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{BAL-H}) \geq 0 \\ 0{,}5\sum M_H - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_{SC} - T_i) \geq 0 \end{array}\right.$	II-1 II-2
Harbour	Maximum:	$W_{maxH}(T_i) = \max\left\{\begin{array}{l} \sum M_{Full} - 1{,}025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0{,}67T_{SC} - T_i) \leq \sum M_{Full} \\ W_{maxS}(T_i) + 0{,}15\sum M_{Full} \leq \sum M_{Full} \end{array}\right.$	III-1 III-2
	Minimum:	$W_{minH}(T_i) = W_{minS}(T_i) - 0{,}15\sum M_{Full} \geq 0$	IV



CHAPTER 5
ORE CARRIERS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **ore carrier**, as defined in Pt A, Ch 1, Sec 2, [4.3.3].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• Part B • Ch 5, Sec 2	• NR566 • Ch 5, Sec 2
	L < 65 m	• NR600	• NR566 • Ch 5, Sec 2
Hull	L ≥ 65 m	• Part B • Ch 5, Sec 3	• Part B • Ch 5, Sec 3
	L < 65 m	• NR600	• NR600
Stability		• Part B • Ch 5, Sec 3	• NR566 • Ch 5, Sec 3
Machinery and cargo systems		• Part C	• NR566
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566

Note 1:
NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.
NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Ship Arrangement

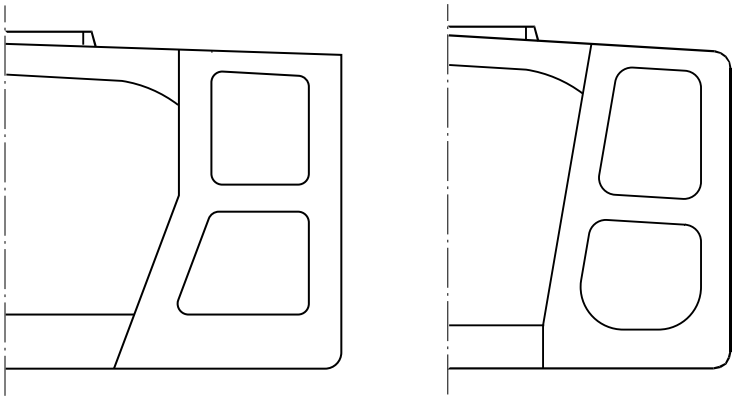
1 General

1.1 Application

1.1.1 The requirements of Ch 5, Sec 2 and Ch 5, Sec 3 apply to single deck ships with two longitudinal bulkheads and a double bottom throughout the cargo region and intended to carry dry cargoes in bulk, including ore cargo, in the centre holds only. A typical midship section is shown in Fig 1.

The application of these requirements to other ship types is to be considered by the Society on a case-by-case basis.

Figure 1 : Ore carrier



2 General arrangement design

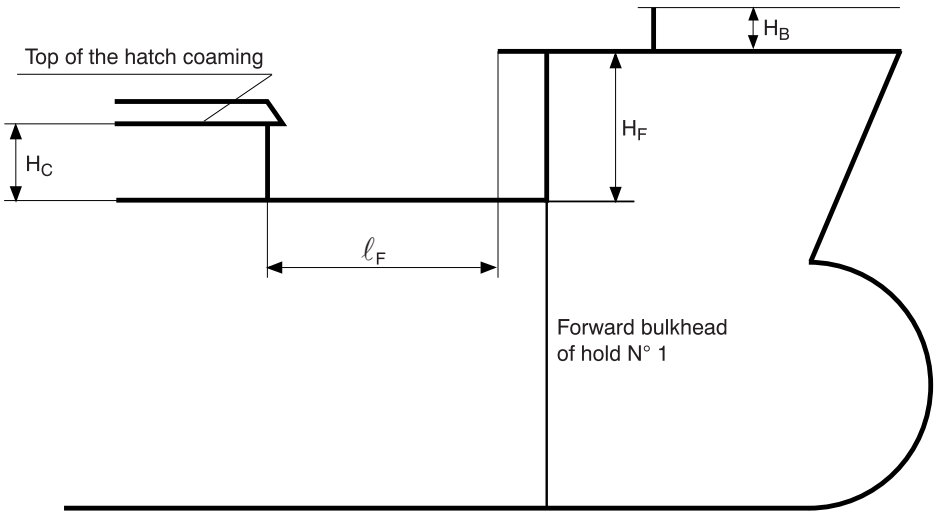
2.1 General

2.1.1 Forecastle

Ships with the service notation **ore carrier ESP** are to be fitted with an enclosed forecastle on the freeboard deck, with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Fig 2.

However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the International Convention on Load Lines 1966 and its Protocol 1988.

Figure 2 : Forecastle arrangement



The forecastle height H_F above the main deck is to be not less than:

- the standard height of a superstructure as specified in Pt B, Ch 1, Sec 3, [2.2]
- $H_C + 0,5$ m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No. 1,

whichever is the greater.

All points of the aft edge of the forecastle deck are to be located at a distance ℓ_F:

$$\ell_F \leq 5\sqrt{H_F - H_C}$$

from the hatch coaming plate in order to apply the reduced loading to the No. 1 forward transverse hatch coaming and No. 1 hatch cover in applying Pt B, Ch 11, Sec 9, [4.1.3], and Pt B, Ch 11, Sec 9, [8.3.9].

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B / tan20° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Fig 2).

3 Access arrangement

3.1 Access arrangement to double bottom and pipe tunnel

3.1.1 Means of access

Adequate means of access to the double bottom and pipe tunnel are to be provided.

3.1.2 Manholes in the inner bottom, floors and girders

Manholes cut in the inner bottom are to be located at a minimum distance of one floor spacing from the lower stool.

The location and size of manholes in floors and girders are to be determined to facilitate the access to double bottom structures and their ventilation. However, they are to be avoided in the areas where high shear stresses may occur.

3.2 Access arrangement to and within spaces in, and forward of, the cargo area

3.2.1 Means of access

Ships with the service notation **ore carrier ESP,** of 20,000 gross tonnage and over, are to comply with the International Convention for the Safety of Life at Sea, 1974, as amended, Chapter II-1, Part A-1, Regulation 3-6, for details and arrangements of openings and attachments to the hull structure.

Ships with the service notation **ore carrier ESP**, of less than 20,000 gross tonnage, are to comply with [3.2.2] and [3.2.3]. In addition, as far as practicable, permanent or movable means of access stored on board are to be provided to ensure proper survey and maintenance of cargo holds.

3.2.2 Hatches of large cargo holds

If separate hatches are used as access to the ladders as required in [3.2.3], each hatch is to have a clear opening of at least 600 mm x 600 mm.

When the access to the cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming.

Accesses and ladders are to be so arranged that personnel equipped with self-contained breathing apparatus may readily enter and leave the cargo hold.

Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with cargo hold ladders.

3.2.3 Ladders within large cargo holds

Each cargo hold is to be provided with at least two ladders as far apart as practicable longitudinally. If possible these ladders are to be arranged diagonally, e.g. one ladder near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side, from the ship's centreline.

Ladders are to be so designed and arranged that the risk of damage from the cargo handling gear is minimised.

Vertical ladders may be permitted provided they are arranged above each other in line with other ladders to which they form access and resting positions are provided at not more than 9 metres apart.

Tunnels passing through cargo holds are to be equipped with ladders or steps at each end of the hold so that personnel may get across such tunnels.

Where it may be necessary for work to be carried out within a cargo hold preparatory to loading, consideration is to be given to suitable arrangements for the safe handling of portable staging or movable platforms.

Section 3 Hull and Stability

Symbols

R_{eH} : Minimum yield stress, in N/mm^2, of the material

k : Material factor for steel, defined in Pt B, Ch 4, Sec 1, [2.2]

E : Young's modulus, in N/mm^2, to be taken equal to:

- E = 2,06.10^5 N/mm^2 for steels in general
- E = 1,95.10^5 N/mm^2 for stainless steels.

b : Breadth of plate panel, in mm, as defined in Pt B, Ch 4, Sec 6, [2.1.1].

1 General

1.1 Loading manual and loading instruments

1.1.1 The specific requirements in Pt B, Ch 1, Sec 5 for ships with the service notation **ore carrier ESP** and equal to or greater than 150 m in length are to be complied with.

2 Stability

2.1 Intact stability

2.1.1 General

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.5] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2. Where the ship is intended also for the carriage of grain, the requirements in Ch 4, Sec 3, [1.2.2] and Ch 4, Sec 3, [1.2.3] are to be complied with.

2.2 Damage stability requirements for ships where additional class notation SDS has been required

2.2.1 General

Ore carriers equal to or greater than 80 m in length are subjected to the probabilistic approach reported in Pt B, Ch 3, Sec 3, [2.1.3] and are to comply with the requirements in Pt B, Ch 3, App 3.

2.2.2 Freeboard reduction

Ore carriers greater than 100 m in length which have been assigned reduced freeboard as permitted by Regulation 27 of the International Convention on Load Lines, 1966, as referenced in Pt B, Ch 3, Sec 3, [2.1.2] are to comply with the requirement specified in Pt B, Ch 3, App 4. Therefore, compliance with the requirements in [2.2.1] is not required.

3 Structure design principles

3.1 Double bottom structure

3.1.1 The double bottom is to be longitudinally framed.

The girder spacing is to be not greater than 4 times the spacing of bottom or inner bottom ordinary stiffeners and the floor spacing is to be not greater than 3 frame spaces.

Solid floors are to be fitted in line with the transverse primary supporting members in wing tanks and intermediate floors are to be added at mid-span between primary supporting members.

3.1.2 Other arrangements may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 8, Sec 1 for the primary supporting members in the cargo holds.

3.1.3 Scarfing of the double bottom structure into the wing tanks is to be properly ensured. The inner bottom plating is generally to be prolonged within the wing tanks by adequately sized horizontal brackets in way of floors.

3.2 Side structure

3.2.1 In ships greater than 120 m in length, the side shell is to be longitudinally framed.

In general, the spacing of vertical primary supporting members is to be not greater than 6 times the frame spacing.

3.2.2 Other arrangements may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 8, Sec 1 for the primary supporting members in the cargo hold.

3.3 Deck structure

3.3.1 The deck outside the line of hatches is to be longitudinally framed.

3.3.2 The cross decks between hatches are generally to be transversely framed.

3.3.3 The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the wing tanks additional web frames or brackets.

3.4 Longitudinal bulkhead structure

3.4.1 Longitudinal bulkheads are to be plane, but they may be knuckled in the upper and lower parts to form a hopper. In such cases, the design of the knuckles and the adjacent structures is to be considered by the Society on a case-by-case basis.

3.4.2 In ships greater than 120 m in length, longitudinal bulkheads are to be longitudinally framed.

3.4.3 Other arrangements may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 8, Sec 1 for the primary supporting members in the cargo hold.

3.5 Transverse bulkhead structure

3.5.1 Where the structural arrangement of transverse bulkheads in wing tanks is different from that in centre holds, arrangements are to be made to ensure continuity of the transverse strength through the longitudinal bulkheads.

4 Design loads

4.1 Hull girder loads

4.1.1 Still water loads

In addition to the requirements in Pt B, Ch 5, Sec 4, [2.1.1], still water loads are to be calculated for the following loading conditions, subdivided into departure and arrival conditions as appropriate:

- alternate light and heavy cargo loading conditions at maximum draught
- homogeneous light and heavy cargo loading conditions at maximum draught
- ballast conditions. Partial filling of the peak tanks is not acceptable in the design ballast conditions, unless effective means are provided to prevent accidental overfilling.
- short voyage conditions where the ship is to be loaded to maximum draught but with a limited amount of bunkers
- Multi-port (MP) loading/unloading conditions, if allowed by the loading manual (see definition in Pt B, Ch 1, Sec 3, [2.6.1])
- deck cargo conditions, where applicable
- typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are also to be developed so as not to exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to the loading rate and deballasting capability.
- typical sequences for change of ballast at sea, where applicable.

4.2 Load combinations for direct strength analysis

4.2.1 The following sea-going loading conditions are to be considered for direct strength analysis:

- full load and scantling draught T, the loaded holds being completely filled with cargo
- full load, the cargo density being the maximum obtained from the loading booklet, but taken not less than 3 t/m^3, and scantling draught T
- ballast condition and ballast draught corresponding to this condition in the loading manual, or the lesser value of 0,04 L and 10 m
- Multi-Port (MP) loading conditions, if allowed by the loading manual, at draught amidships considered in the loading manual.

Unless otherwise specified, these loading conditions are to be associated with the HVM and FVM dynamic load cases.

In addition, harbour conditions covering the loading/ unloading sequences as defined in the loading manual are to be considered.

5 Hull scantlings

5.1 Corrosion addition

5.1.1 Value of corrosion addition for tank top

The corrosion addition for tank top of void/dry spaces is to be taken equal to 0 mm.

5.2 Additional requirements

5.2.1 Minimum net thicknesses

The net thickness of the inner bottom plating in holds is to be not less than the value given in Tab 1.

Table 1 : Minimum net thickness of the inner bottom plating in holds

Plating	Minimum net thickness, in mm	
Inner bottom in holds	Longitudinal framing	$2,15\ (L^{1/3}\ k^{1/6}) + 0,0045\ b$
	Transverse framing	$2,35\ (L^{1/3}\ k^{1/6}) + 0,0045\ b$

6 Construction and testing

6.1 Welding and weld connections

6.1.1 The weld factors for some hull structural connections are specified in Tab 2. These weld factors are to be used in lieu of the corresponding factors specified in Pt B, Ch 13, Sec 3, Tab 2 to calculate T connections fillet weld leg length according to Pt B, Ch 13, Sec 3, [3.2.6]. For the connections in Tab 2, continuous fillet welding is to be adopted.

6.2 Special structural details

6.2.1 The specific requirements in Pt B, Ch 13, Sec 5, [2] for ships with the service notation **ore carrier ESP** are to be complied with.

Table 2 : Weld factor w_F

Hull area	Connection		w_F
	of	to	
Double bottom in way of cargo holds	girders	bottom and inner bottom plating	0,48
		floors (interrupted girders)	
	floors	bottom and inner bottom plating	
		girders (interrupted floors)	
Bulkheads in cargo holds	structures of watertight bulkheads	longitudinal bulkheads	

CHAPTER 6
COMBINATION CARRIERS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 4 Machinery and Cargo Systems

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **combination carrier**, as defined in Pt A, Ch 1, Sec 2, [4.3.4] and Pt A, Ch 1, Sec 2, [4.3.5].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules,
- NR216 Materials and Welding,
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• Part B • Ch 6, Sec 2	• NR566 • Ch 6, Sec 2
	L < 65 m	• NR600	• NR566 • Ch 6, Sec 2
Hull	L ≥ 65 m	• Part B • Ch 6, Sec 3	• Part B • Ch 6, Sec 3
	L < 65 m	• NR600	• NR600
Stability		• Part B • Ch 6, Sec 3	• NR566 • Ch 6, Sec 3
Machinery and cargo systems		• Part C • Ch 6, Sec 4	• NR566 • Ch 6, Sec 4
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT. NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.			

Section 2 Ship Arrangement

1 General arrangement design

1.1 General

1.1.1 Forecastle

Ships with the service notation **combination carrier/OBO ESP** or **combination carrier/OOC ESP** are to be fitted with an enclosed forecastle on the freeboard deck, with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Fig 1.

However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the International Convention on Load Lines 1966 and its Protocol 1988.

The forecastle height H_F above the main deck is to be not less than:

- the standard height of a superstructure as specified in Pt B, Ch 1, Sec 3, [2.2.9]
- $H_C + 0,5$ m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No. 1,

whichever is the greater.

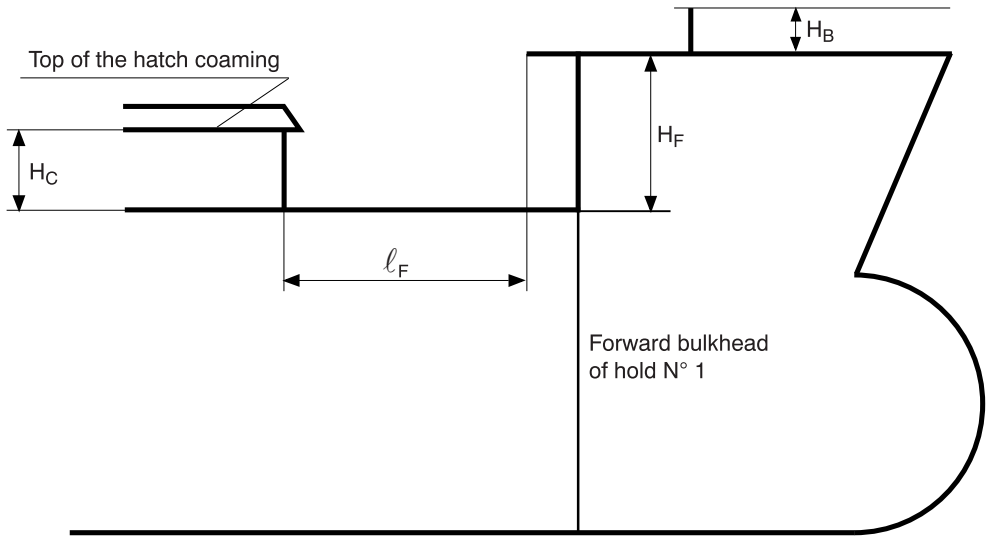
All points of the aft edge of the forecastle deck are to be located at a distance ℓ_F:

$$\ell_F \leq 5\sqrt{H_F - H_C}$$

from the hatch coaming plate in order to apply the reduced loading to the No. 1 forward transverse hatch coaming and No. 1 hatch cover in applying Pt B, Ch 11, Sec 9, [4.1.3], and Pt B, Ch 11, Sec 9, [8.3.9].

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B / tan20° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Fig 1).

Figure 1 : Forecastle arrangement



1.1.2 Cofferdams

A cofferdam or similar compartment of width not less than 760 mm is to be provided at the aft end of the oil cargo tank area. Its bulkheads are to extend from keel to deck across the full breadth of the ship.

For the purpose of this requirement, the term “cofferdam” is intended to mean an isolating compartment between two adjacent steel bulkheads or decks. The minimum distance between the two bulkheads or decks is to be sufficient for safe access and inspection.

For continuity reason, in the particular case when a corner-to-corner situation occurs, welding a diagonal plate across the corner may be accepted.

Cofferdams are also to be constructed so as to enable adequate ventilation.

1.1.3 Cargo segregation

Unless expressly provided otherwise, tanks containing oil cargoes or oil cargo residues are to be segregated from accommodation, service and machinery spaces, drinking water and stores for human consumption by means of a cofferdam, or any other similar compartment.

Where accommodation and service compartments are arranged immediately above the compartments containing flammable liquids, the cofferdam may be omitted only where the deck is not provided with access openings and is coated with a layer of material recognised as suitable by the Society. The cofferdam may also be omitted where such compartments are adjacent to a passageway, subject to the following conditions:

- the thicknesses of common boundary plates of adjacent tanks are increased with respect to those obtained from the applicable requirements in Part B and Ch 6, Sec 3, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of such plates is not less than the thickness of the plates themselves
- the hydrostatic test is carried out with a head increased by 1 m with respect to that required in Pt B, Ch 13, Sec 6.

Combination carriers of 600 t deadweight and above are not allowed to carry oil in any compartment extending forward of a collision bulkhead located in accordance with Pt B, Ch 2, Sec 1, [3].

1.1.4 Location of fuel tanks in cargo area

On ships carrying liquid cargoes having a flashpoint not exceeding 60°C, fuel tanks located with a common boundary to cargo or slop tanks are not to be situated within, nor extend partly into, the cargo tank block as defined in Ch 7, Sec 1, [1.3.4]. Such tanks may, however, be situated aft and/or forward of the cargo tank block. They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, may be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements applicable to hazardous area classification must however be met.

1.1.5 Slop tanks

The slop tanks are to be surrounded by cofferdams except where the boundaries of the slop tanks are part of the hull, main cargo deck, cargo pump room bulkhead or fuel oil bunker tank. These cofferdams are not to be open to a double bottom, pipe tunnel, pump room or other enclosed space, nor they are to be used for cargo or ballast and they are not to be connected to piping systems serving oil cargo or ballast. Means are to be provided for filling the cofferdams with water and for draining them.

Where the boundary of a slop tank is part of the cargo pump room bulkhead, the pump room is not to be open to the double bottom, pipe tunnel or other enclosed space; however, openings provided with gas-tight bolted covers may be permitted.

1.1.6 Deck spills

Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by providing a permanent continuous coaming of a height of at least 300 mm, extending from side to side.

Where gutter bars are installed on the weather decks of combination carriers in way of cargo manifolds and are extended aft as far as the aft bulkhead of superstructures for the purpose of containing cargo spills on deck during loading and discharge operations, the free surface effects caused by containment of a cargo spill during liquid transfer operations or of boarding seas while underway are to be considered with respect to the vessel's available margin of positive initial stability (GM_o).

Where the gutter bars installed are higher than 300 mm, they are to be treated as bulwarks with freeing ports arranged in accordance with Pt B, Ch 11, Sec 12, [6] and provided with effective closures for use during loading and discharge operations. Attached closures are to be arranged in such a way that jamming is prevented while at sea, enabling the freeing ports to remain effective.

An assessment of the initial stability (GM_o) for compliance with the relevant intact stability requirements taking into account the free surface effect caused by liquids contained by the gutter bars is to be undertaken on:

- tankers having cargo tanks exceeding 60% of the vessel's maximum beam at midships regardless of gutter bar height
- ships without deck camber
- ships where the height of the installed gutter bars exceeds the camber.

1.1.7 Piping

Oil cargo lines below deck are to be placed in special ducts.

1.1.8 Opening in watertight bulkheads and decks

Openings intended to be used for dry cargo handling are not permitted in bulkheads and decks separating oil cargo tanks from other compartments not designed and equipped for the carriage of oil cargoes unless such openings are equipped with alternative means approved by the Society to ensure an equivalent integrity.

1.1.9 Tank cleaning openings

Hatches and tank cleaning openings to slop tanks are only permitted on the open deck and are to be fitted with closing arrangements.

Except where they consist of bolted plates with bolts at watertight spacing, these closing arrangements are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.

1.2 Double bottom tanks or compartments

1.2.1 General

Double bottom tanks adjacent to cargo tanks are not to be used as fuel oil tanks.

1.2.2 Combination carriers of 5000 t deadweight and above

At any cross-section, the depth of each double bottom tank or compartment is to be such that the distance h between the bottom of the cargo tanks and the moulded line of the bottom shell plating measured at right angles to the bottom shell plating, as shown in Fig 2, is not less than B/15, in m, or 2,0 m, whichever is the lesser. h is to be not less than 1,0 m.

1.2.3 Combination carriers of less than 5000 t but at least 600 t deadweight

At any cross-section, the depth of each double bottom tank or compartment is to be such that the distance h between the bottom of the cargo tanks and the moulded line of the bottom shell plating measured at right angles to the bottom shell is not less than B/15, in m, with a minimum value of 0,76 m.

In the turn of the bilge area and at locations without a clearly defined turn of the bilge, the cargo tank boundary line is to run parallel to the line of the midship flat bottom as shown in Fig 3.

1.3 Navigation position

1.3.1 When it is proven necessary to provide a navigation station above the cargo area, such station is to be for navigation purposes only and is to be separated from the cargo tank deck by an open space of at least 2 m in height.

Figure 2 : Cargo tank boundary lines

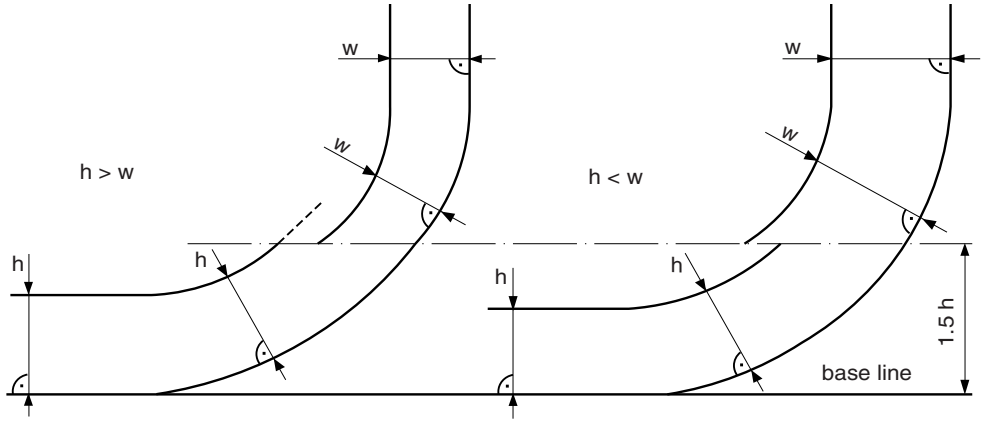
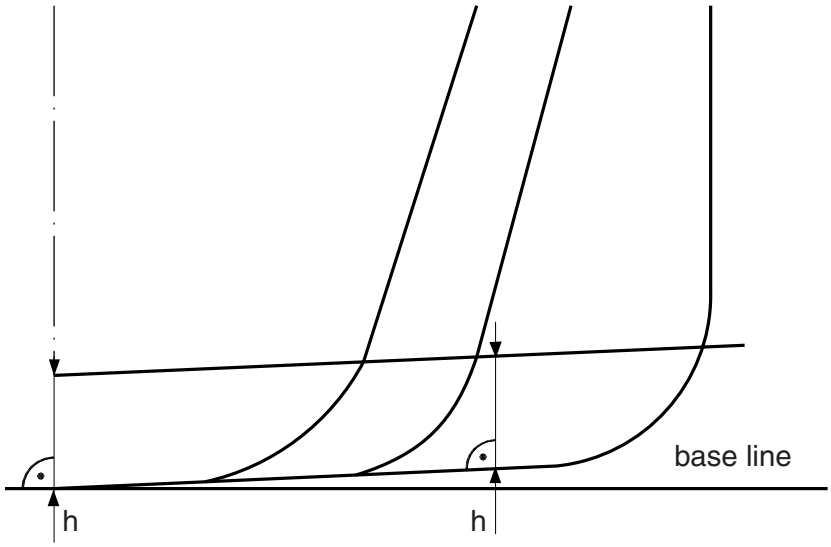


Figure 3 : Cargo tank boundary lines



2 Size and arrangement of cargo tanks and slop tanks

2.1 Cargo tanks

2.1.1 *Cargo tanks of combination carriers are to be of such size and arrangements that the hypothetical outflow O_C or O_S calculated in accordance with the provisions of [2.2] anywhere in the length of the ship does not exceed:*

- *30000 m^3, or*
- $400\sqrt[3]{DW}$

  where DW is the deadweight, in t,

whichever is the greater, but subject to a maximum of 40000 m^3.

2.1.2 *The length of each cargo tank is not to exceed 10 metres or one of the values of Tab 1, as applicable, whichever is the greater.*

Table 1 : Length of cargo tanks

Longitudinal bulkhead arrangement	Condition **(1)**	Length of cargo tanks, in m
No bulkhead (**combination carrier/OBO ESP**)	–	$(0,5\ b_i / B + 0,1)\ L_{LL}$ **(2)**
Two bulkheads (**combination carrier/OOC ESP**)	$b_i / B \geq 1/5$	$0,2\ L_{LL}$
	$b_i / B < 1/5$	$(0,5\ b_i / B + 0,1)\ L_{LL}$

(1) b_i is the minimum distance from the ship side to the outer longitudinal bulkhead of the -th tank, measured inboard at right angles to the centreline at the level corresponding to the assigned summer freeboard.

(2) Not to exceed $0,2\ L_{LL}$.

2.1.3 Cargo transfer system

In order not to exceed the volume limits established by [2.1.1] and irrespective of the accepted type of cargo transfer system installed, when such system interconnects two or more cargo tanks, valves or other similar closing devices are to be provided for separating the tanks from each other.

2.1.4 Piping through cargo tanks

Lines of piping which run through oil cargo tanks in a position less than t_C from the ship side or less than v_C from the ship's bottom are to be fitted with valves or similar closing devices at the point at which they open into any cargo tank. These valves are to be kept closed at sea at any time when the tanks contain cargo oil, except that they may be opened only for cargo transfer needed for the purpose of trimming of the ship.

t_C and v_C are, respectively, the transverse and the vertical extent of side damage as defined in Ch 6, Sec 3, [2.3.2].

2.1.5 Suction wells in cargo tanks

Suction wells in cargo tanks may protrude into the double bottom below the boundary line defined by the distance h in [1.2.2] or [1.2.3], as applicable, provided that such wells are as small as practicable and the distance between the well bottom and bottom shell plating is not less than 0,5 h.

2.2 Oil outflow

2.2.1 General

In order to limit the oil pollution from combination carriers due to side and bottom damages, the hypothetical oil outflows O_C and O_S as referred to in [2.1.1] are to be calculated by the formulae of [2.2.2] with respect to compartments breached by damage to all conceivable locations along the length of the ship to the extent as defined in Ch 6, Sec 3, [2.3.2].

In calculating the hypothetical oil outflows, the following is to be considered:

- *the volume of an oil cargo tank is to include the volume of the hatchway up to the top of the hatchway coamings, regardless of the construction of the hatch, but may not include the volume of any hatch cover; and*
- *for the measurement of the volume to moulded lines, no deduction is to be made for the volume of internal structures.*

2.2.2 General calculation of oil outflow

The oil outflow for side and bottom damages is calculated by the following formulae:

a) for side damages:

$$O_C = \Sigma W_i + \Sigma K_i C_i$$

b) for bottom damages:

$$O_S = \frac{1}{3}(\Sigma Z_i W_i + \Sigma Z_i C_i)$$

where:

W_i : *Volume of a wing tank in cubic metres assumed to be breached by the damage as specified in Ch 6, Sec 3, [2.3.2]; W_i for a segregated ballast tank may be taken equal to zero*

C_i : *Volume of a centre tank in cubic metres assumed to be breached by the damage as specified in Ch 6, Sec 3, [2.3.2]; C_i for a segregated ballast tank may be taken equal to zero*

K_i : *Coefficient defined as:*

- $1 - b_i / t_C$ for $b_i < t_C$
- 0 for $b_i \geq t_C$

Z_i : *Coefficient defined as:*

- $1 - h_i / v_S$ for $h_i < v_S$
- 0 for $h_i \geq v_S$

b_i : *Width, in m, of wing tank under consideration measured inboard from the ship side at right angles to the centreline at the level corresponding to the assigned summer freeboard. In a case where the width b_i is not constant along the length of a particular wing tank, the smallest b_i value in the tank is to be used for the purposes of assessing the hypothetical outflows of oil O_C and O_S*

h_i : *Minimum depth, in m, of the double bottom under consideration; where no double bottom is fitted, h_i is to be taken equal to zero*

t_C : *Transverse extent of side damage as defined in Ch 6, Sec 3, [2.3.2]*

v_S : *Vertical extent of bottom damage as defined in Ch 6, Sec 3, [2.3.2].*

2.2.3 Bottom damage involving simultaneously four centre tanks

In the case where bottom damage simultaneously involves four centre tanks, the value of O_S may be calculated according to the formula:

$$O_S = \frac{1}{4}(\Sigma Z_i W_i + \Sigma Z_i C_i)$$

where Z_i , W_i and C_i are defined in [2.2.2].

2.2.4 Assumptions

For the purpose of calculating O_S, *credit is only to be given in respect of double bottom tanks which are either empty or carrying clean water when cargo is carried in the tanks above.*

Suction wells may be neglected in the determination of the value h_i provided such wells are not excessive in area and extend below the tank for a minimum distance and in no case more than half the height of the double bottom. If the depth of such a well exceeds half the height of the double bottom, hi is to be taken equal to the double bottom height minus the well height.

Piping serving such wells if installed within the double bottom is to be fitted with valves or other closing arrangements located at the point of connection to the tank served to prevent oil outflow in the event of damage to the piping.

2.2.5 Reduction of oil outflow

The Society may credit as reducing oil outflow in the event of bottom damage, an installed cargo transfer system having an emergency high suction in each cargo oil tank, capable of transferring from a breached tank or tanks to segregated ballast tanks or to available cargo tankage if it can be ensured that such tanks will have sufficient ullage. Credit for such a system would be governed by ability to transfer in two hours of operation oil equal to one half of the largest of the breached tanks involved and by availability of equivalent receiving capacity in ballast or cargo tanks. The credit is to be confined to permitting calculation of O_s according to the formula in [2.2.3]. The pipes for such suctions are to be installed at least at a height not less than the vertical extent of the bottom damage v_s.

v_s is the vertical extent of bottom damage as defined in Ch 6, Sec 3, [2.3.2].

2.2.6 Alternative methods for calculating oil outflow

As an alternative to the formulae indicated in [2.2.2] or [2.2.3], the probabilistic methodology for calculating oil outflow as described in IMO Resolution MEPC.110(49) may be applied.

2.3 Slop tanks

2.3.1 Combination carriers of 150 gross tonnage and above

The arrangements of the slop tank or combination of slop tanks are to have a capacity necessary to retain the slop generated by tank washings, oil residues and dirty ballast residues. The total capacity of the slop tank or tanks is to be not less than 3 per cent of the oil carrying capacity of the ships, except that the Society may accept:

- *2% for such combination carriers where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for ejectors, without the introduction of additional water into the system*

- *2% where segregated ballast tanks are provided in accordance with Article [4]. This capacity may be further reduced to 1,5% for such combination carriers where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for ejectors, without the introduction of additional water into the system.*
- *1% for combination carriers where oil cargo is only carried in tanks with smooth walls. This capacity may be further reduced to 0,8% where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for ejectors, without the introduction of additional water into the system.*

  The term "tanks with smooth walls" includes the main oil cargo tanks of combination carriers which may be constructed with vertical framing of a small depth. Vertically corrugated bulkheads are considered smooth walls.

2.3.2 Combination carriers of 70000 t deadweight and above

Combination carriers of 70000 t deadweight and above are to be provided with at least two slop tanks.

3 Size and arrangement of protective ballast tanks or compartments

3.1 General

3.1.1 This requirement applies to combination carriers of 600 t deadweight and above.

3.2 Size and arrangement of ballast tanks or compartments

3.2.1 General

The entire oil cargo tank length is to be protected by ballast tanks or compartments other than oil cargo and fuel oil tanks as indicated in [3.2.2] to [3.2.5] for combination carriers of 5000 t deadweight and above, or [3.2.6] for combination carriers less than 5000 t deadweight.

3.2.2 Wing tanks or compartments

Wing tanks or compartments are to extend either for the full depth of the ship side or from the top of the double bottom to the uppermost deck, disregarding a rounded gunwale where fitted. They are to be arranged such that the oil cargo tanks are located inboard of the moulded line of the side shell plating, nowhere less than the distance w which, as shown in Fig 2, is measured at any cross-section at right angles to the side shell, as specified below:

- *w = 0,5 + DW / 20000, or*
- *w = 2,0 m*

whichever is the lesser.

The value of w is to be at least 1,0 m.

3.2.3 Double bottom tanks or compartments

The requirements of [1.2.1] and [1.2.2] apply.

3.2.4 Aggregate capacity of ballast tanks

On combination carriers of 20000 t deadweight and above, the aggregate capacity of wing tanks, double bottom tanks, fore peak tanks and after peak tanks is to be not less than the capacity of segregated ballast tanks necessary to meet the requirements of [4]. Wing tanks or compartments and double bottom tanks used to meet the requirements of [4] are to be located as uniformly as practicable along the oil cargo tank length. Additional segregated ballast capacity provided for reducing longitudinal hull girder bending stress, trim, etc., may be located anywhere within the ship.

In calculating the aggregate capacity, the following is to be taken into account:

- *the capacity of engine-room ballast tanks is to be excluded from the aggregate capacity of ballast tanks*
- *the capacity of ballast tanks located inboard of double hull is to be excluded from the aggregate capacity of ballast tanks (see Fig 4)*
- *spaces such as void spaces located in the double hull within the cargo tank length should be included in the aggregate capacity of ballast tanks*

Any ballast carried in localised inboard extensions, indentation or recesses of the double hull, such as bulkhead stools, should be considered as excess ballast above the minimum requirement for segregated ballast capacity according to [4].

3.2.5 Alternative methods of design and construction

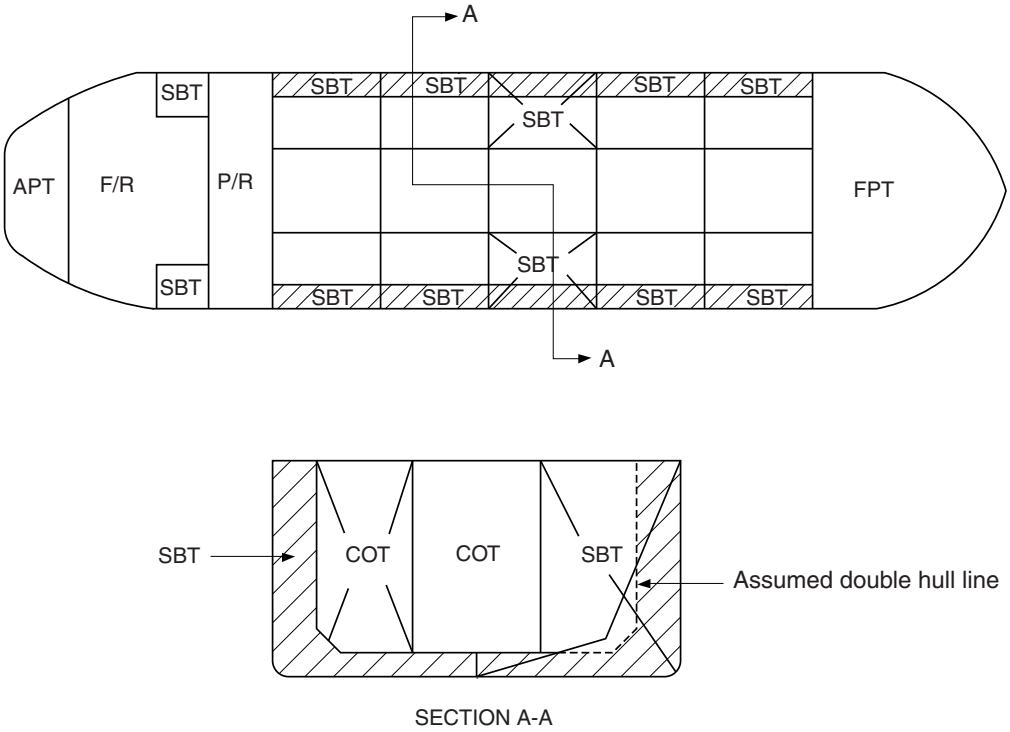
Other methods of design and construction of combination carriers may also be accepted as alternatives to the requirements prescribed in [3.2.2] to [3.2.4], provided that such methods ensure at least the same level of protection against oil pollution in the event of collision or stranding. Such methods are to be acceptable to the Society.

Note 1: The Society considers the method described in IMO Resolution MEPC.110(49) as being acceptable.

3.2.6 Combination carriers of less than 5000 t deadweight

Combination carriers of less than 5000 t deadweight are to comply with [1.2.3].

Figure 4 : Segregated ballast tanks located inboard of double hull



SECTION A-A

4 Size and arrangement of segregated ballast tanks (SBT)

4.1 General

4.1.1 *Every combination carrier of 20000 t deadweight and above is to be provided with segregated ballast tanks and to comply with [4.2].*

4.2 Capacity of SBT

4.2.1 Combination carriers equal to or greater than 150 m in length

The capacity of the segregated ballast tanks is to be so determined that the ship may operate safely on ballast voyages without recourse to the use of oil cargo tanks for water ballast. In all cases, however, the capacity of segregated ballast tanks is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballast only, the ship's draughts and trim can meet each of the following requirements:

- *the moulded draught amidships, d_m in metres (without taking into account any ship's deformation), is to be not less than 2,0 + 0,02 L_{LL}*
- *the draughts at the forward and after perpendicular are to correspond to those determined by the draught amidships d_m as specified above, in association with the trim by the stern of not greater than 0,015 L_{LL}*
- *in any case the draught at the after perpendicular is to be not less than that which is necessary to obtain full immersion of the propeller(s)*
- *in no case is ballast water to be carried in oil cargo tanks, except:*
  - *on those rare voyages when weather conditions are so severe that, in the opinion of the Master, it is necessary to carry additional ballast water in oil cargo tanks for the safety of the ship*
  - *in exceptional cases where the particular character of the operation of a combination carrier renders it necessary to carry ballast water in excess of the quantity required to comply with the requirements above, provided that such operation of the combination carrier falls under the category of exceptional cases.*

4.2.2 Combination carriers less than 150 m in length

The capacity of the segregated ballast tanks is to be considered by the Society on a case-by-case basis.

5 Access arrangement

5.1 Access to double bottom and pipe tunnel

5.1.1 Means of access

Adequate means of access to the double bottom and the pipe tunnel are to be provided.

5.1.2 Manholes in the inner bottom, floors and girders

Manholes are not to be cut in the inner bottom in way of oil cargo holds; access to the double bottom is, in general, to be provided by trunks leading to the upper deck.

The location and size of manholes in longitudinal girders and floors are determined to facilitate the access to double bottom structures and their ventilation. However, they are to be avoided in the areas where high shear stresses may occur.

5.1.3 Access to pipe tunnels under oil cargo tanks

The pipe tunnel in the double bottom under oil cargo tanks is to comply with the following requirements:

- it is not to communicate with the engine room
- provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.

5.1.4 Doors between pipe tunnel and main pump room

Where there is a permanent access from a pipe tunnel to the main pump room, a watertight door is to be fitted complying with the requirements in Pt B, Ch 2, Sec 1, [6.3.1]. In addition the following is to be complied with:

- *in addition to bridge operation, the watertight door is to be capable of being manually closed from outside the main pump room entrance*
- *the watertight door is to be kept closed during normal operations of the ship except when access to the pipe tunnel is required.* A notice is to be affixed to the door to this effect.

5.2 Access arrangement to and within spaces in, and forward of, the cargo area

5.2.1 Means of access

Ships with the service notation **combination carrier/OBO ESP** or **combination carrier/OOC ESP** of 20,000 gross tonnage and over, are to comply with provisions of [5.5] and with the International Convention for the Safety of Life at Sea, 1974, as amended, Chapter II-1, Part A-1, Regulation 3-6, as amended, Chapter II-1, Part A-1, Regulation 3-6, for details and arrangements of openings and attachments to the hull structure.

Ships with the service notation **combination carrier/OBO ESP** or **combination carrier/OOC ESP** of less than 20,000 gross tonnage, are to comply with [5.3], [5.4] and [5.5].

5.3 Access to dry cargo holds

5.3.1 Means of access

As far as practicable, permanent or movable means of access stored on board are to be provided to ensure proper survey and maintenance of dry cargo holds.

5.3.2 Hatches of large cargo holds

When the access to the dry cargo hold is arranged through the cargo hatch, the top of the ladder, as required in [5.3.3], is to be placed as close as possible to the hatch coaming.

Accesses and ladders are to be so arranged that personnel equipped with self-contained breathing apparatus may readily enter and leave the dry cargo hold.

Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with dry cargo hold ladders.

5.3.3 Ladders within large cargo holds

Each dry cargo hold is to be provided with at least two ladders as far apart as practicable longitudinally. If possible these ladders are to be arranged diagonally, e.g. one ladder near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side, from the ship's centreline.

Ladders are to be so designed and arranged that the risk of damage from the cargo handling gear is minimised.

Vertical ladders may be permitted provided they are arranged above each other in line with other ladders to which they form access and resting positions are provided at not more than 9 metres apart.

Tunnels passing through dry cargo holds are to be equipped with ladders or steps at each end of the hold so that personnel may get across such tunnels.

Where it may be necessary for work to be carried out within a dry cargo hold preparatory to loading, consideration is to be given to suitable arrangements for the safe handling of portable staging or movable platforms.

5.4 Access to compartments in the oil cargo area

5.4.1 General

Access to cofferdams, ballast tanks, dry cargo holds, oil cargo tanks and other compartments in the oil cargo area is to be direct from the open deck and such as to ensure their complete inspection.

5.4.2 Access through horizontal openings

For access through horizontal openings the dimensions are to be sufficient to allow a person wearing a self-contained, air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the compartment. The minimum clear opening is to be not less than 600 mm by 600 mm.

5.4.3 Access through vertical openings

For access through vertical openings the minimum clear opening is to be not less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

5.5 Access to the bow

5.5.1 *Combination carriers are to be provided with the means to enable the crew to gain safe access to the bow even in severe weather conditions. Such means are to be accepted by the Society.*

Note 1: The Society considers means in compliance with the Guidelines adopted by the Maritime Safety Committee of IMO with Resolution MSC.62(67) on 5/12/1996 as being acceptable.

Section 3 Hull and Stability

1 General

1.1 Loading manual and loading instrument

1.1.1 The specific requirements in Pt B, Ch 1, Sec 5 for ships with either of the service notations **combination carrier / OBO ESP** or **combination carrier / OOC ESP** and equal to or greater than 150 m in length are to be complied with.

2 Stability

2.1 Intact stability

2.1.1 General

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.5] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2. Where the ship is intended also for the carriage of grain, the requirements in Ch 4, Sec 3, [1.2.2] and Ch 4, Sec 3, [1.2.3] are to be complied with.

In addition, for the carriage of liquids, the requirements in [2.1.3] are to be complied with.

2.1.2 Liquid transfer operations

Ships with certain internal subdivision may be subjected to lolling during liquid transfer operations such as loading, unloading or ballasting. In order to reduce the effect of lolling, the design of combination carriers of 5000 t deadweight and above is to be such that the following criteria are complied with:

a) *The intact stability criteria reported in b) are to be complied with for* the worst possible condition of loading and ballasting as defined in c), *consistent with good operational practice, including the intermediate stages of liquid transfer operations. Under all conditions the ballast tanks are to be assumed slack.*

b) *The initial metacentric height GMo, in m, corrected for free surface measured at 0° heel, is to be not less than 0,15. For the purpose of calculating GMo, liquid surface corrections are to be based on the appropriate upright free surface inertia moment.*

c) *The vessel is to be loaded with:*

- *all cargo tanks filled to a level corresponding to the maximum combined total of vertical moment of volume plus free surface inertia moment at 0° heel, for each individual tank*
- *cargo density corresponding to the available cargo deadweight at the displacement at which transverse KM reaches a minimum value*
- *full departure consumable*
- *1% of the total water ballast capacity. The maximum free surface moment is to be assumed in all ballast tanks.*

2.1.3 Alternative requirements for liquid transfer operation

As an alternative to the requirements in [2.1.2], simple supplementary operational procedures are to be followed when the ship is carrying oil cargoes or during liquid transfer operations.

Simple supplementary operational procedures for liquid transfer operations means written procedures made available to the Master which:

- *are approved by the Society,*
- *indicate those cargo and ballast tanks which may, under any specific condition of liquid transfer and possible range of cargo densities, be slack and still allow the stability criteria to be met. The slack tanks may vary during the liquid transfer operations and be of any combination provided they satisfy the criteria,*
- *are to be readily understandable to the officer-in-charge of liquid transfer operations,*
- *provide for planned sequences of cargo/ballast transfer operations,*
- *allow comparisons of attained and required stability using stability performance criteria in graphical or tabular form,*
- *require no extensive mathematical calculations by the officer-in-charge,*
- *provide for corrective actions to be taken by the officer-in-charge in the event of departure from the recommended values and in case of emergency situations, and*
- *are prominently displayed in the approved trim and stability booklet and at the cargo/ballast transfer control station and in any computer software by which stability calculations are performed.*

2.2 Damage stability - dry cargoes or ballast loading conditions - for ships where additional class notation SDS is requested

2.2.1 General

Combination carriers equal to or greater than 80 m in length are subjected to the probabilistic approach reported in Pt B, Ch 3, Sec 3, [2.1.3] and are to comply with the requirements in Pt B, Ch 3, App 3, for the loading conditions which entail the carriage of dry cargoes or ballast, unless they comply with the requirements in [2.2.2] or [2.3].

2.2.2 Freeboard reduction

Combination carriers greater than 100 m in length which have been assigned reduced freeboard as permitted by Regulation 27 of the International Convention on Load Lines, 1966, as referenced in Pt B, Ch 3, Sec 3, [2.1.2] are to comply with the requirement specified in Pt B, Ch 3, App 4. Therefore, compliance with the requirements in Ch 5, Sec 3, [2.2.1] is not required.

2.3 Damage stability - oil cargoes - for ships where additional class notation SDS is requested

2.3.1 General

In the loading conditions which entail the carriage of oil cargoes, combination carriers *are to comply with the subdivision and damage stability criteria as specified in [2.3.8], after the assumed side or bottom damage as specified in [2.3.2], for the standard of damage described in [2.3.3], and for any operating draught reflecting actual partial or full load conditions consistent with trim and strength of the ship as well as specific gravities of the cargo.*

The actual partial or full load conditions to be considered are those specified in Pt B, Ch 3, App 2, [1.2.6], *but ballast conditions where the ship is not carrying oil in cargo tanks, excluding any oil residues, are not to be considered.*

2.3.2 Damage dimensions

The assumed extent of damage is to be as defined in Tab 1.

The transverse extent of damage is measured inboard the ship side at right angles to the centreline at the level of the summer load line.

The vertical extent of damage is measured from the moulded line of the bottom shell plating at centreline.

For the purpose of determining the extent of assumed damage, suction wells may be neglected, provided such wells are not excessive in areas and extend below the tank for a minimum distance and in no case more than half the height of the double bottom.

If any damage of a lesser extent than the maximum extent of damage specified in Tab 1 would result in a more severe condition, such damage is to be considered.

Table 1 : Extent of damage

Damage		Longitudinal extent	Transverse extent	Vertical extent
Side		• $l_C = 1/3\ L_{LL}^{2/3}$ or • 14,5 m whichever is the lesser	t_C = B/5 11,5 m whichever is the lesser	v_C = without limit
Bottom	for 0,3 L_{LL} from the forward perpendicular	• $l_S = 1/3\ L_{LL}^{2/3}$ • 14,5 m whichever is the lesser	• t_S = B/6 • 10 m whichever is the lesser	• v_S = B/15 • 6 m whichever is the lesser
	any other part	• $l_S = 1/3\ L_{LL}^{2/3}$ • 5 m whichever is the lesser	• t_S = B/6 • 5 m whichever is the lesser	• v_S = B/15 • 6 m whichever is the lesser

2.3.3 Standard of damage

The damage in [2.3.2] is to be applied to all conceivable locations along the length of the ship, according to Tab 2.

Table 2 : Standard of damage

Ship's length, in m	Damage anywhere in ship's length	Damage between transverse bulkheads	Machinery space flooded alone
$L_{LL} \leq 100$	No	Yes **(1) (2)**	No
$100 < L_{LL} \leq 150$	No	Yes **(1)**	No
$150 < L_{LL} \leq 225$	Yes	No	Yes
$L_{LL} > 225$	Yes	No	No

(1) Machinery space not flooded.
(2) Exemptions from the requirements of [2.3.8] may be accepted by the Society on a case-by-case basis.

2.3.4 Calculation method

The metacentric heights (GM), the stability levers (GZ) and the centre of gravity positions (KG) for judging the final survival conditions are to be calculated by the constant displacement method (lost buoyancy).

2.3.5 Flooding assumptions

The requirements of [2.3.8] are to be confirmed by calculations which take into consideration the design characteristics of the ship, the arrangements, configuration and contents of the damaged compartments and the distribution, specific gravities and free surface effect of liquids.

Where the damage involving transverse bulkheads is envisaged as specified in [2.3.3], transverse watertight bulkheads are to be spaced at least at a distance equal to the longitudinal extent of assumed damage specified in [2.3.2] in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage is to be assumed as non-existent for the purpose of determining flooded compartments.

Where the damage between adjacent transverse watertight bulkheads is envisaged as specified in [2.3.3], no main transverse bulkhead bounding side tanks or double bottom tanks is to be assumed damaged, unless:

- *the spacing of the adjacent bulkheads is less than the longitudinal extent of assumed damage specified in [2.3.2] or,*
- *there is a step or a recess in a transverse bulkhead of more than 3,05 metres in length, located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and after peak tank top is not to be regarded as a step.*

2.3.6 Progressive flooding

If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in [2.3.2], arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.

2.3.7 Permeabilities

The specific gravity of cargoes carried, as well as any outflow of liquid from damaged compartments, are to be taken into account for any empty or partially filled tank.

The permeability of compartments assumed to be damaged is to be as indicated in Tab 3.

Table 3 : Permeability

Compartments	Permeability
Appropriated for stores	0,60
Occupied by accommodation	0,95
Occupied by machinery	0,85
Void compartments	0,95
Intended for consumable liquids	0 to 0,95 **(1)**
Intended for other liquids	0 to 0,95 **(1)**
(1) The permeability of partially filled compartments is to be consistent with the amount of liquid carried in the compartment.	

2.3.8 Survival requirements

Combination carriers, in the damage case of [2.3], are to be regarded as complying with the damage stability criteria if the requirements of [2.3.9] and [2.3.10] are met.

2.3.9 Final stage of flooding

*a) The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place.*The progressive flooding is to be considered in accordance with Pt B, Ch 3, Sec 3, [3.3].

b) The angle of heel due to unsymmetrical flooding may not exceed 25°, except that this angle may be increased up to 30° if no deck edge immersion occurs.

c) The stability is to be investigated and may be regarded as sufficient if the righting lever curve has at least a range of 20° beyond the position of equilibrium in association with a maximum residual righting lever, in m, of at least 0,1 within the 20° range; the area, in m·rad, under the curve within this range is to be not less than 0,0175.

2.3.10 Intermediate stage of flooding

The Society is to be satisfied that the stability is sufficient during the intermediate stages of flooding. To this end the Society applies the same criteria relevant to the final stage of flooding also during the intermediate stages of flooding.

2.3.11 Bottom raking damage

This requirement applies to combination carriers of 20000 t deadweight and above.

The damage assumptions relative to the bottom damage prescribed in [2.3.2] are to be supplemented by the assumed bottom raking damage of Tab 4.

The requirements of [2.3.8] are to be complied with for the assumed bottom raking damage.

Table 4 : Bottom damage extent

Deadweight	Longitudinal extent	Transverse extent	Vertical extent
< 75000 t	0,4 L_{LL} **(1)**	B/3	**(2)**
≥ 75000 t	0,6 L_{LL} **(1)**	B/3	**(2)**

(1) Measured from the forward perpendicular.
(2) Breach of the outer hull.

2.3.12 Equalisation arrangements

Equalisation arrangements requiring mechanical aids such as valves or cross levelling pipes, if fitted, may not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of [2.3.9] and sufficient residual stability is to be maintained during all stages where equalisation is used. Compartments which are linked by ducts of a large cross-sectional area may be considered to be common.

2.3.13 Information to the Master

The Master of every combination carrier is to be supplied in an approved form with:

- *information relative to loading and distribution of cargo necessary to ensure compliance with the requirements relative to stability, and*
- *data on the ability of the ship to comply with damage stability criteria as determined in [2.3.8] including the effect of relaxation that may have been allowed as specified in Tab 2.*

3 Structure design principles of ships with the service notation combination carrier / OBO ESP

3.1 Double bottom structure

3.1.1 Longitudinally framed double bottom

In ships greater than 120 m in length, the double bottom and the sloped bulkheads of hopper tanks are to be longitudinally framed.

The girder spacing is to be not greater than 4 times the spacing of bottom or inner bottom ordinary stiffeners and the floor spacing is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

3.1.2 Transversely framed double bottom

The double bottom and the sloped bulkheads of hopper tanks may be transversely framed in ships less than or equal to 120 m in length, when this is deemed acceptable by the Society on a case-by-case basis. In this case, however, the floor spacing is to be not greater than 2 frame spaces.

3.1.3 Floors in way of transverse bulkheads

The thickness and material properties of the supporting floors and pipe tunnel beams are to be not less than those required for the bulkhead plating or, when a stool is fitted, of the stool side plating.

3.2 Double side structure

3.2.1 General

The side within the hopper and topside tanks is, in general, to be longitudinally framed. It may be transversely framed when this is accepted for the double bottom and the deck according to [3.1.2] and [3.3.1], respectively.

3.2.2 Side primary supporting members

The spacing of transverse side primary supporting members is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

In any case, transverse side primary supporting members are to be fitted in line with transverse primary supporting members in hopper and topside tanks.

3.3 Deck structure

3.3.1 Deck outside the line of hatches and topside tank sloping plates

In ships greater than 120 m in length, the deck outside the line of hatches and the topside tank sloping plates are to be longitudinally framed.

The spacing of transverse primary supporting members in topside tanks is to be not greater than 6 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

3.3.2 Deck between hatches

The cross decks between hatches are generally to be transversely framed.

3.3.3 Connection of hatch end beams with deck structures

The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the topside tanks additional web frames or brackets.

3.3.4 Topside tank structure

Topside tank structures are to extend as far as possible within the machinery space and are to be adequately tapered.

4 Structure design principles of ships with the service notation combination carrier / OOC ESP

4.1 Double bottom structure

4.1.1 The double bottom is to be longitudinally framed.

The girder spacing is to be not greater than 4 times the spacing of bottom or inner bottom ordinary stiffeners and the floor spacing is to be not greater than 3 frame spaces.

Solid floors are to be fitted in line with the transverse primary supporting members in wing tanks and intermediate floors are to be added at mid-span between primary supporting members.

4.1.2 Other arrangements may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

4.1.3 Scarfing of the double bottom structure into the wing tanks is to be properly ensured. The inner bottom plating is generally to be prolonged within the wing tanks by adequately sized horizontal brackets in way of floors.

4.2 Side structure

4.2.1 In ships greater than 120 m in length, the side shell is to be longitudinally framed.

In general, the spacing of vertical primary supporting members is to be not greater than 6 times the frame spacing.

4.2.2 Other arrangements may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo hold.

4.3 Deck structure

4.3.1 The deck outside the line of hatches is to be longitudinally framed.

4.3.2 The cross decks between hatches are generally to be transversely framed.

4.3.3 The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the wing tanks additional web frames or brackets.

4.4 Longitudinal bulkhead structure

4.4.1 Longitudinals bulkheads are to be plane, but they may be knuckled in the upper part and in the lower part to form a hopper. In these cases, the design of the knuckles and the adjacent structures is to be considered by the Society on a case-by-case basis.

4.4.2 In ships greater than 120 m in length, longitudinal bulkheads are to be longitudinally framed.

4.4.3 Other arrangements may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo hold.

4.5 Transverse bulkhead structure

4.5.1 Where the structural arrangement of transverse bulkheads in wing tanks is different from that in centre holds, arrangements are to be made to ensure continuity of the transverse strength through the longitudinal bulkheads.

5 Design loads

5.1 Loading conditions for longitudinal strength assessment

5.1.1 In addition to the requirements in Pt B, Ch 5, Sec 4, [2.1.1], still water loads are to be calculated for the following loading conditions, subdivided into departure and arrival conditions as appropriate:

- alternate light and heavy cargo (dry or oil) loading conditions at maximum draught, where applicable
- homogeneous light and heavy cargo (dry or oil) loading conditions at maximum draught
- ballast conditions. For ships having ballast holds adjacent to topside wing, hopper and double bottom tanks, it may be acceptable in terms of strength that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty. Partial filling of the peak tanks is not acceptable in the design ballast conditions, unless effective means are provided to prevent accidental overfilling
- short voyage conditions where the ship is to be loaded to maximum draught but with a limited amount of bunkers
- Multi-port (MP) loading/unloading conditions, if allowed by the loading manual (see Pt B, Ch 1, Sec 5, [2])
- deck cargo conditions, where applicable
- typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable.

  Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are also to be developed so as not to exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to the loading rate and deballasting capability
- typical sequences for change of ballast at sea, where applicable.

5.2 Load combinations for direct strength analysis

5.2.1 Applicable general load combinations

The following load combinations are to be considered as defined in:

- Ch 5, Sec 3, [4.2] and Ch 7, Sec 3, [4.3] for ships assigned with the service notation **combination carrier / OOC ESP**
- Ch 4, Sec 3, [3.3] and Ch 7, Sec 3, [4.3] for ships assigned with the service notation **combination carrier / OBO ESP**.

5.3 Local loads

5.3.1 Bottom impact pressure

For combination carriers of 20000 t deadweight and above, the draught T_F, to be considered in the calculation of the bottom impact pressure according to Pt B, Ch 5, Sec 5, [4.2.1], is that calculated by using the segregated ballast tanks only.

5.3.2 Oil cargo mass density

In the absence of more precise values, an oil cargo mass density of 0,9 t/m^3 is to be considered for calculating the internal pressures and forces in cargo tanks according to Pt B, Ch 5, Sec 6 or NR600, as applicable.

6 Hull scantlings

6.1 Strength check with respect to stresses due to the temperature gradient

6.1.1 General

Direct calculations of stresses induced in the hull structures by the temperature gradient are to be performed:

- for ships intended to carry cargoes at temperatures exceeding 90°C
- and when part of the hull structures temperature exceeds 90°C

In these calculations, the water temperature is to be assumed equal to 0°C.

The calculations are to be submitted to the Society for review.

6.1.2 Material

For steels used at a temperature θ between 90°C and 300°C, and unless other information is specified, their minimum yield stress R_{eH} and Young's modulus E are to be taken as specified in Pt B, Ch 4, Sec 1, [2.1.1].

The material factor is to be adjusted accordingly.

6.1.3 Thermal stress for integral tanks

The stresses induced in the hull structures by the temperature gradient are to comply with the checking criteria in Pt B, Ch 8, App 1, [5.2.3].

6.1.4 Thermal stress for independent tanks

Where a thermal elongation is made possible due to the design of the tank supports, the thermal stress may be neglected provided the cargo temperature distribution is rather uniform.

In addition, precautions are to be taken, upon loading of any hot cargo, by pre-heating the tanks in order to minimize the temperature gradients within the cargo hold.

7 Other structures

7.1 Machinery space

7.1.1 Extension of hull structures within the machinery space

Longitudinal bulkheads or inner side, as applicable, carried through cofferdams are to continue within the machinery space and are to be used preferably as longitudinal bulkheads for liquid cargo tanks. In any case, such extension is to be compatible with the shape of the structures of the double bottom, deck and platforms of the machinery space.

Where topside tanks are fitted, their structures are to extend as far as possible within the machinery space and to be adequately tapered.

7.2 Opening arrangement

7.2.1 Cargo shore connection

Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations may not face the cargo shore connection location of bow or stern loading and unloading arrangements. They are to be located on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the ship's length but not less than 3 m from the end of the deckhouse facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Sidescuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above are to be of the fixed (non-opening) type. All doors, ports and other openings on the corresponding superstructure or deckhouse side are to be fitted so that they can be kept closed during the use of the bow or stern loading and unloading arrangements. The Society may permit departures from these requirements in the case of small ships when, at its discretion, compliance with them is not possible.

Air pipes and other openings to enclosed compartments not listed above are to be shielded from spray which may come from a leaking hose or connection.

7.2.2 Deck foam system room

An access to a deck foam system room (including the foam tank and the control station) may be permitted within the limits mentioned in Pt C, Ch 4, Sec 6, [3.3.1], provided that the door is located flush with the bulkhead.

7.2.3 Tanks covers

Covers fitted on all cargo tank openings are to be of sturdy construction, and to ensure tightness for hydrocarbon and water.

Aluminium is not permitted for the construction of tank covers. The use of reinforced fibreglass covers is to be specially examined by the Society.

8 Hull outfitting

8.1 Equipment

8.1.1 Emergency towing arrangement

The specific requirements in Pt B, Ch 12, Sec 4, [3] for ships with either of the service notations **combination carrier / OBO ESP** or **combination carrier / OOC ESP** and of 20000 t deadweight and above are to be complied with.

9 Protection of hull metallic structures

9.1 Protection by aluminium coatings

9.1.1 The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in the cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate.

10 Cathodic protection of tanks

10.1 General

10.1.1 Internal structures in spaces intended to carry liquids may be provided with cathodic protection.

Cathodic protection may be fitted in addition to the required corrosion protective coating, if any.

10.1.2 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to the Society for approval.

10.2 Anodes

10.2.1 Magnesium or magnesium alloy anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks.

10.2.2 Aluminium anodes are only permitted in cargo tanks and tanks adjacent to cargo tanks in locations where the potential energy does not exceed 28 kg m. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts.

However, where aluminium anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface.

Aluminium anodes are not to be located under tank hatches or washing holes, unless protected by the adjacent structure.

10.2.3 There is no restriction on the positioning of zinc anodes.

10.2.4 Anodes are to have steel cores and are to be declared by the Manufacturer as being sufficiently rigid to avoid resonance in the anode support and designed so that they retain the anode even when it is wasted.

10.2.5 The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

10.2.6 The supports at each end of an anode may not be attached to separate items which are likely to move independently.

10.2.7 Where anode inserts or supports are welded to the structure, they are to be arranged by the Shipyard so that the welds are clear of stress peaks.

10.2.8 As a general rule, the requirements Ch 7, Sec 3, [12.2.3] to Ch 7, Sec 3, [12.2.7] apply also to spaces or compartments adjacent to cargo or slop tanks.

10.3 Impressed current systems

10.3.1 Impressed current cathodic protections are not accepted in cargo or slop tanks, unless specially authorized by the Society.

11 Construction and testing

11.1 Welding and weld connections

11.1.1 The weld factors for some hull structural connections are specified in Tab 5. These weld factors are to be used, in lieu of the corresponding factors specified in Pt B, Ch 13, Sec 3, Tab 2, to calculate the leg length of fillet weld T connections according to Pt B, Ch 13, Sec 3, [3.2.6]. For the connections of Tab 5, continuous fillet welding is to be adopted.

Table 5 : Weld factor w_F

Hull area	Connection		Weld factor w_F
	of	to	
Double bottom in way of cargo holds and tanks	girders	bottom and inner bottom plating	0,48
		floors (interrupted girders)	
	floors	bottom and inner bottom plating	
		girders (interrupted floors)	
Bulkheads in oil cargo tanks	ordinary stiffeners	bulkhead plating	0,48

11.2 Special structural details

11.2.1 The specific requirements in Pt B, Ch 13, Sec 5, [2.7] for ships with either of the service notations **combination carrier / OBO ESP** or **combination carrier / OOC ESP** are to be complied with.

Section 4 Machinery and Cargo Systems

1 General

1.1 Application

1.1.1 Ships having the service notation **combination carrier** are to comply with the requirements of Ch 7, Sec 4 applicable to oil tankers or oil tankers flashpoint > 60°C, as appropriate.

In addition, they are to comply with the provisions of this Section.

1.2 Documents

1.2.1 Documents to be submitted

In addition to those listed in Ch 7, Sec 4, Tab 1, the following documents are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document **(1)**
1	Diagram of the ventilation systems serving cargo spaces and enclosed spaces adjacent to cargo spaces
3	Diagram of the gas measurement system for cargo pump rooms, pipe ducts and cofferdams adjacent to slop tanks
4	Diagram of water filling and draining systems for cofferdams
5	Diagram of discharge pumping and piping systems for slop tanks
(1) Diagrams are also to include, where applicable: • the (local and remote) control and monitoring systems and automation systems • the instructions for the operation and maintenance of the piping system concerned (for information).	

1.2.2 Instruction manual

A manual is to be kept on board giving instructions for the carriage of contaminated sludge in slop tanks when the ship is in the dry cargo mode.

2 General requirements

2.1 Ventilation and gas detection

2.1.1 Ventilation

Cargo spaces and enclosed spaces adjacent to cargo spaces are to be capable of being mechanically ventilated. The mechanical ventilation may be provided by portable fans. See also Pt C, Ch 4, Sec 2, [2.1.2].

2.1.2 Gas detection

a) An approved fixed gas warning system capable of monitoring flammable vapours is to be provided in cargo pump rooms and pipe ducts and cofferdams adjacent to slop tanks.

b) Audible and visual alarms for the gas detection equipment are to be located on the bridge or in other suitable continually manned spaces.

2.2 Arrangement of cargo lines

2.2.1

a) Where cargo wing tanks are provided, cargo oil lines below deck are to be installed inside these tanks. However, the Society may permit cargo oil lines to be placed in special ducts which are to be capable of being adequately cleaned and ventilated and to the satisfaction of the Society.

If connected to a cargo pump room, such ducts are to be considered as cargo pump rooms for the purposes of safety.

b) Where cargo wing tanks are not provided, cargo oil lines below deck are to be placed in special ducts.

2.3 Cargo openings

2.3.1 Openings which may be used for cargo operations are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless alternative approved means provide equivalent integrity.

2.4 Cofferdam filling and draining

2.4.1 Means are to be provided for filling the cofferdams surrounding the slop tanks with water and for draining them. See Ch 6, Sec 2, [1.1.5].

3 Slop tanks

3.1 Segregation of piping systems

3.1.1

a) Pipes serving the slop tanks are to be segregated from other parts of the cargo pumping and piping system by means of isolation complying with b) or c) below.

b) Arrangements to isolate slop tanks containing oil or oil residues from other cargo tanks are to consist of blank flanges which are to remain in position at all times when cargoes other than liquid cargoes referred to in Ch 7, Sec 1, [1.1.3] are carried.

c) Means are to be provided for isolating the piping connecting the pump room with the slop tanks. The means of isolation are to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable, it may be located within the pump room directly after the piping penetrates the bulkhead.

3.2 Venting system

3.2.1 Slop tanks are to be provided with a separate venting system complying with the provisions of Ch 7, Sec 4, [4.2].

3.3 Discharge pumping and piping arrangement

3.3.1 A separate pumping and piping arrangement incorporating a manifold is to be provided for discharging the contents of the slop tanks directly to the open deck for disposal to shore reception facilities when the ship is in the dry cargo mode.

CHAPTER 7
OIL TANKERS AND FLS TANKERS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 4 Machinery and Cargo Systems

Section 5 Electrical Installations

Section 6 Fire Protection

Appendix 1 Devices to Prevent the Passage of Flame into the Cargo Tanks

Appendix 2 Design of Crude Oil Washing Systems

Appendix 3 Lists of Oils

Appendix 4 List of Products for which Part D, Chapter 8 and IBC Code do not Apply

Appendix 5 Accidental Oil Outflow Performance

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **oil tanker**, as defined in Pt A, Ch 1, Sec 2, [4.4.2].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1
- requirements as defined in [1.1.3] and [1.1.4], as applicable.

Table 1 : Applicable requirements

Item		Ships assigned the additional service feature **CSR**	Ships not assigned the additional service feature **CSR**	
			Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• NR606 **(1)** • Ch 7, Sec 2	• Part B • Ch 7, Sec 2	• NR566 • Ch 7, Sec 2
	L < 65 m	N.A.	• NR600	• NR566 • Ch 7, Sec 2
Hull	L ≥ 65 m	• NR606 **(1) (3)**	• Part B • Ch 7, Sec 3	• Part B • Ch 7, Sec 3
	L < 65 m	N.A.	• NR600	• NR600
Stability		• Part B • Ch 7, Sec 3	• Part B • Ch 7, Sec 3	• NR566 • Ch 7, Sec 3
Machinery and cargo systems		• Part C • Ch 7, Sec 4 **(2)**	• Part C • Ch 7, Sec 4 **(2)**	• NR566 • Ch 7, Sec 4 **(2)**
Electrical installations		• Part C • Ch 7, Sec 5	• Part C • Ch 7, Sec 5	• NR566 • Ch 7, Sec 5
Automation		• Part C	• Part C	• NR566
Fire protection, detection and extinction		• Part C • Ch 7, Sec 6	• Part C • Ch 7, Sec 6	• NR566 • Ch 7, Sec 6

(1) Refer to the scope of application of NR606.

(2) Ch 7, Sec 4 contains a table summarising the relaxations applying to certain service notations.

(3) IACS Recommendation No.167 "Guidelines for the Identification of Vibration Issues and Recommended Remedial Measures on Ships" is to be applied on ships assigned additional service feature **CSR**.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

NR606: Common Structural Rules for Bulk Carriers and Oil Tankers.

1.1.3 Service notation oil tanker

a) The requirements of this Chapter apply to ships having the service notation **oil tanker**, as defined in Pt A, Ch 1, Sec 2, [4.4.2]. They also apply to ships assigned the additional service feature **flash point > 60°C** and **asphalt carrier**, taking into account the specific provisions given in the different Sections.

Note 1: The specific provisions referred to in a) above do not apply to ships intended for the carriage of bulk cargoes at a temperature above the flash point of the product carried.

b) Departures from these requirements are given for ships that have the service notation **oil tanker-flash point > 60°C** and are intended only for the carriage of bulk cargoes at a temperature below and not within 15°C of their flash point.

c) Ch 7, Sec 4, [8] provides additional requirements for ships having the service notation **oil tanker-asphalt carrier**.

d) The list of substances the carriage in bulk of which is covered by the service notations **oil tanker**, **oil tanker- flash point > 60°C** and **oil tanker-asphalt carrier** is given in Ch 7, App 3, Tab 1.

1.1.4 Service notation FLS tanker

a) The requirements of this Chapter apply to ships having the service notation **FLS tanker**, as defined in Pt A, Ch 1, Sec 2, [4.4.5]. They also apply to ships assigned the additional service feature **FLS tanker-flash point > 60°C**, taking into account the specific provisions given in Ch 7, Sec 4.

Note 1: The specific provisions referred to in a) above do not apply to ships intended for the carriage of bulk cargoes at a temperature above the flash point of the product carried.

b) Ch 7, Sec 4, [9] provides additional requirements for ships having the service notations **FLS tanker** and **FLS tanker-flash point > 60°C** in the case of carriage of pollution category Z products.

c) The list of substances the carriage in bulk of which is covered by the service notations **FLS tanker** and **FLS tanker-flash point > 60°C** is given in Ch 7, App 4.

Note 2: The service notation **FLS tanker** does not cover cargoes containing 10% of benzene or more. Ships carrying such cargoes are to comply with the relevant requirements of Part D, Chapter 8.

Note 3: Where the provisions of this Chapter applicable to the service notation **oil tanker** and those applicable to the service notation **FLS tanker** are simultaneously complied with, a ship may be granted both service notations **oil tanker-FLS tanker** or **oil tanker-FLS tanker-flash point > 60°C**, as applicable.

1.2 Specific requirements

1.2.1 Ships assigned the additional service feature IPxxx or IPxxx-capable

Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** are to comply with the following requirements in addition to the applicable requirements of this Chapter:

- carriage of oil or noxious liquid substances with a flashpoint not exceeding 60°C is not permitted when the total number of persons on board exceeds 60
- for the purpose of carrying industrial personnel, the areas and spaces where industrial personnel are not permitted to enter are to be clearly marked
- the arrangements for personnel transfer are to be located outside the cargo area
- the access to the arrangements for personnel transfer are to be, as far as practicable, located outside the cargo area.

1.3 Definitions

1.3.1 Cargo area

The cargo area is that part of the ship that contains cargo tanks as well as slop tanks, cargo pump rooms including pump rooms, cofferdams, ballast or void spaces adjacent to cargo tanks or slop tanks as well as deck areas throughout the entire length and breadth of the part of the ship above these spaces.

When independent tanks are installed in hold spaces, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space are excluded from the cargo area.

1.3.2 Cargo pump room

Cargo pump room is a space containing pumps and their accessories for the handling of products covered by the service notation granted to the ship.

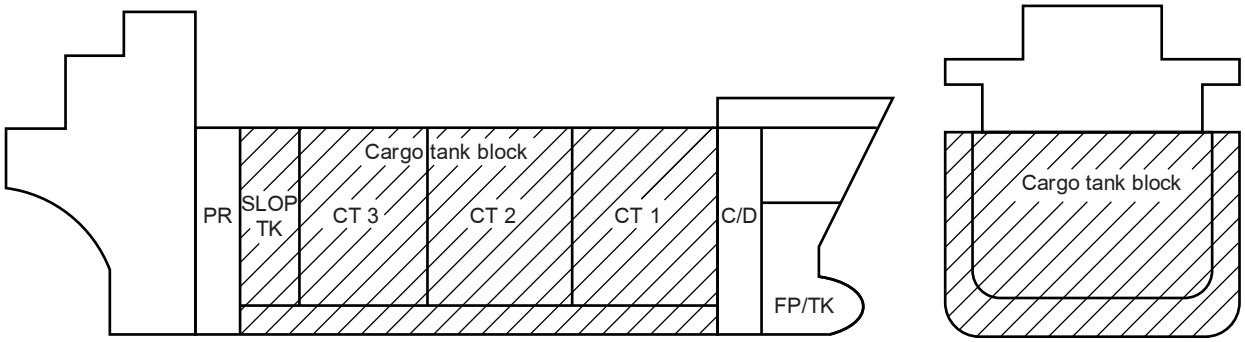
1.3.3 Cargo service spaces

Cargo service spaces are spaces within the cargo area used for workshops, lockers and storerooms of more than 2 m^2 in area, intended for cargo handling equipment.

1.3.4 Cargo tank block

The cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank (See Fig 1).

Figure 1 : Cargo tank block definition



1.3.5 Clean ballast

Clean ballast means the ballast in a tank which since oil was last carried therein, has been so cleaned that the effluent therefrom if it were discharged from a ship which is stationary into clean calm water on a clear day would not produce visible traces of oil on the surface of the water or on adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines. If the ballast is discharged through an oil discharge monitoring and control system approved by the Society, evidence based on such a system to the effect that the oil content of the effluent did not exceed 15 parts per million is to be determinative that the ballast was clean, notwithstanding the presence of visible traces.

1.3.6 Cofferdam

For the purpose of Ch 7, Sec 2, [2], a cofferdam is an isolating space between two adjacent steel bulkheads or decks. It is to meet the following criteria:

a) The minimum distance between the two bulkheads or decks is to be sufficient for safe access and inspection.

b) In order to meet the single failure principle, in the particular case when a corner-to-corner situation occurs, this principle may be met by welding a diagonal plate across the corner.

1.3.7 Crude oil

Crude oil is any oil occurring naturally in the earth whether or not treated to render it suitable for transportation and includes:

a) Crude oil from which certain distillate fractions have been removed, and

b) Crude oil to which certain distillate fractions may have been added.

1.3.8 Crude oil tanker

Crude oil tanker means an oil tanker engaged in the trade of carrying crude oil.

1.3.9 Expansion bends

Expansion bends means expansion loops such as an omega bend ("Ω") in piping system to counteract excessive stresses or displacement caused by thermal expansion or hull deformation which could be fabricated from straight lengths of pipe.

1.3.10 Fuel oil

Fuel oil means any oil used as fuel in connection with the propulsion and auxiliary machinery of the ship on which such oil is carried.

1.3.11 Heavy flanges joints

Heavy flanges joints means welded flange joints rated at least PN10 or one pressure rating higher than required design pressure, whichever is greater.

1.3.12 Hold space

Hold space is the space enclosed by the ship's structure in which an independent cargo tank is fitted.

1.3.13 Oil-like substances

Oil-like substances are those substances listed in Ch 7, App 3, Tab 2.

1.3.14 Oil mixture

Oil mixture means a mixture with any oil content.

1.3.15 Product carrier

Product carrier means an oil tanker engaged in the trade of carrying oil other than crude oil.

1.3.16 Pump room

Pump room is a space, located in the cargo area, containing pumps and their accessories for the handling of ballast and fuel oil, or cargoes other than those covered by the service notation granted to the ship.

1.3.17 Segregated ballast

Segregated ballast means the ballast water introduced into a tank which is completely separated from the cargo oil and fuel oil system and which is permanently allocated to the carriage of ballast or to the carriage of ballast or cargoes other than oil or noxious substances as variously defined in Part D, Chapter 7 and Part D, Chapter 8.

1.3.18 Slop tank

Slop tank means a tank specifically designated for the collection of tank draining, tank washings and other oily mixtures.

1.3.19 Void space

Void space is an enclosed space in the cargo area external to a cargo tank, except for a hold space, ballast space, fuel oil tank, cargo pump room, pump room, or any space normally used by personnel.

Section 2 Ship Arrangement

Symbols

L_{LL} : Load line length, in m, defined in Pt B, Ch 1, Sec 3, [2.1.2].

1 General

1.1 Application

1.1.1 Except otherwise specified, the requirements of this Section apply to the ships having one of the following service notations:

oil tanker

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker

FLS tanker, flash point > 60°C.

1.1.2 The requirements of this Section apply to ships having a propelling machinery located at the aft part of the ship. Ships with other arrangements are to be specially considered by the Society.

1.2 Documents to be submitted

1.2.1 Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document
1	General arrangement drawing with indication of: • access and openings • capacity and size of the cargo tanks, slop tanks and ballast tanks
2	Diagram of the mechanical and natural ventilation with indication of the ventilation inlets and outlets

2 General arrangement of the ship with regard to fire prevention and crew safety

2.1 Location and separation of spaces

2.1.1 Application

a) The provisions of [2.1.2] to [2.1.5] apply only to ships having the service notations **oil tanker** or **FLS tanker**.

b) Ships having one of the following service notations:

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker, flash point > 60°C

are to comply with the provisions of [2.1.6].

2.1.2 Cargo tank area

a) Fore and aft peaks are not to be used as cargo tanks.

b) Double bottom tanks adjacent to cargo tanks are not to be used as oil fuel tanks.

c) On ships having the service notation **oil tanker** or **FLS tanker** without the additional service feature **flash point > 60°C** or **asphalt carrier**, fuel tanks located with a common boundary to cargo or slop tanks are not to be situated within, nor extend partly into, the cargo tank block. Such tanks may, however, be situated aft and/or forward of the cargo tank block. They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, may be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements applicable to hazardous area classification must however be met.

2.1.3 Cargo pump rooms

a) The cargo pump rooms are to be separated from the other spaces of the ship by oiltight bulkheads and are not to have, in particular, any direct communications with the machinery spaces.

b) Where glazed ports are provided on the bulkhead separating the cargo pump room from the machinery compartment, they are to satisfy the following conditions:

- they are to be efficiently protected from mechanical damage
- strong covers are to be permanently secured on the machinery compartment side
- glazed ports are to be so constructed that glass and sealing are not impaired by the working of the ship
- the glazed ports are to be so constructed as to maintain the structural integrity and the bulkheads resistance to fire and smoke.

2.1.4 *Cargo pump rooms, cargo tanks, slop tanks and cofferdams are to be positioned forward of machinery spaces. However, oil fuel bunker tanks need not be forward of machinery spaces.*

Cargo tanks and slop tanks are to be isolated from machinery spaces by cofferdams, cargo pump rooms, oil bunker tanks or ballast tanks.

Pump-rooms containing pumps and their accessories for ballasting those spaces situated adjacent to cargo tanks and slop tanks and pumps for oil fuel transfer are to be considered as equivalent to a cargo pump room within the context of this article provided that such pump rooms have the same safety standard as that required for cargo pump rooms. Pump rooms intended solely for ballast or oil fuel transfer, however, need not comply with the requirements of Ch 7, Sec 6, [4.2].

The lower portion of the pump room may be recessed into machinery spaces of category A to accommodate pumps, provided that the deck head of the recess is in general not more than one third of the moulded depth above the keel, except that in the case of ships of not more than 25000 tonnes deadweight, where it can be demonstrated that for reasons of access and satisfactory piping arrangements this is impracticable, the Society may permit a recess in excess of such height, but not exceeding one half of the moulded depth above the keel.

Note 1: Pump rooms intended solely for ballast transfer need not comply with the requirements of Ch 7, Sec 4, [3.5.2]. The requirements of Ch 7, Sec 4, [3.5.2] are only applicable to the pump rooms, regardless of their location, where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided.

"Similar pumps" includes pumps intended for transfer of fuel oil having a flashpoint of less than 60°C. Pump-rooms intended for transfer of fuel oil having a flashpoint of not less than 60°C need not comply with the requirements of Ch 7, Sec 4, [3.5.2].

2.1.5 Accommodation spaces, service spaces and control stations

a) Accommodation spaces, main cargo control stations, control stations and service spaces (excluding isolated cargo handling gear lockers) are to be positioned aft of cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces but not necessarily aft of the fuel oil bunker tanks and ballast tanks, but be arranged in such a way that a single failure of a deck or bulkhead not permit the entry of gas or fumes from the cargo tanks into an accommodation space, main cargo control stations, control station, or service spaces. A recess provided in accordance with [2.1.4] need not be taken into account when the position of these spaces is being determined.

b) However, where deemed necessary, the Society may permit accommodation spaces, main cargo control stations, control stations, and service spaces forward of the cargo tanks, slop tanks and spaces which isolate cargo and slop tanks from machinery spaces, but not necessarily forward of fuel oil bunker tanks or ballast tanks. Machinery spaces, other than those of category A, may be permitted forward of the cargo tanks and slop tanks provided they are isolated from the cargo tanks and slop tanks by cofferdams, cargo pump rooms, fuel oil bunker tanks or ballast tanks. All of the above spaces are to be subject to an equivalent standard of safety and appropriate availability of fire-extinguishing arrangements being provided to the satisfaction of the Society. *Accommodation spaces, main cargo control spaces, control stations and service spaces are to be arranged in such a way that a single failure of a deck or bulkhead not permit the entry of gas or fumes from the cargo tanks into such spaces. In addition, where deemed necessary for the safety or navigation of the ship, the Society may permit machinery spaces containing internal combustion machinery not being main propulsion machinery having an output greater than 375 kW to be located forward of the cargo area provided the arrangements are in accordance with the provisions of this paragraph.*

c) Where the fitting of a navigation position above the cargo area is shown to be necessary, it is to be for navigation purposes only and it is to be separated from the cargo tank deck by means of an open space with a height of at least 2 m. The fire protection of such navigation position is to be in addition as required for control spaces in Ch 7, Sec 6 and other provisions, as applicable, of this Chapter.

d) Means be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of a height of at least 300 mm, extending from side to side. Special consideration be given to the arrangements associated with stern loading.

Note 1: The provisions of paragraph d) above also apply to bow and stern cargo loading stations.

e) Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation, is to be constructed of steel and insulated to A-60 standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. The distance of 3 m is to be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation is to be carried up to the underside of the deck of the navigation bridge.

Note 2: Service spaces and control stations (except the wheelhouse) located in superstructures and deckhouses enclosing accommodation are to comply with the provisions of item e).

f) The location and arrangement of the room where foods are cooked are to be selected such as to minimize the risk of fire.

g) Paint lockers, regardless of their use, cannot be located above the tanks and spaces defined in item a).

2.1.6 Case of ships having the service notations oil tanker, flash point > 60°C, oil tanker, asphalt carrier or FLS tanker, flash point > 60°C

On ships having one of the following service notations:

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker, flash point > 60°C,

the location and separation of spaces is not required to comply with requirements [2.1.2] to [2.1.5].

However, the following provisions are to be complied with:

a) Tanks containing cargo or cargo residues are to be segregated from accommodation, service and machinery spaces, tanks containing drinking water and stores for human consumption by means of a cofferdam or similar space.

b) Double bottom tanks adjacent to cargo tanks are not to be used as fuel oil tanks.

c) Means are to be provided to keep deck spills away from accommodation and service areas.

2.2 Access and openings

2.2.1 Application

a) Ships with the service notation **oil tanker ESP** of less than 500 gross tonnage, and ships with the service notation **oil tanker** or **FLS tanker** are to comply with the provisions of [2.2.2] to [2.2.6].

b) Ships having one of the following service notations:

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker, flash point > 60°C,

are to comply with the provisions of [2.2.7].

c) Ships with the service notation **oil tanker ESP** of 500 gross tonnage and over, are to comply with the provisions of [2.2.2], [2.2.4], [2.2.5] and [2.2.6] and with the International Convention for the Safety of Life at Sea, 1974, as amended, Chapter II-1, Part A-1, Regulation 3-6, for details and arrangements of openings and attachments to the hull structure.

2.2.2 Access and openings to accommodation spaces, service spaces, control stations and machinery spaces

a) Except as permitted in paragraph b), access doors, air inlets, air outlets and openings to accommodation spaces, service spaces, control stations and machinery spaces are not to face the cargo area. They are to be located on the transverse bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the length of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance need not exceed 5 m.

b) The Society may permit access doors in boundary bulkheads facing the cargo area or within the 5 m limits specified in paragraph a), to main cargo control stations and to such service spaces used as provision rooms, store-rooms and lockers, provided they do not give access directly or indirectly to any other space containing or providing for accommodation, control stations or service spaces such as galleys, pantries or workshops, or similar spaces containing sources of vapour ignition. The boundary of such a space is to be insulated to "A-60" class standard, with the exception of the boundary facing the cargo area. Bolted plates for the removal of machinery may be fitted within the limits specified in paragraph a). Wheelhouse doors and windows may be located within the limits specified in paragraph a) so long as they are designed to ensure that the wheelhouse can be made rapidly and efficiently gas tight and vapour tight.

Note 1: An access to a deck foam system room (including the foam tank and the control station) can be permitted within the limits mentioned in paragraph a), provided that the conditions listed in paragraph b) are satisfied and that the door is located flush with the bulkhead.

Note 2: The navigation bridge door and windows are to be tested for gas tightness. If a water hose test is applied, the following test conditions are deemed acceptable by the Society:

- nozzle diameter: minimum 12 mm
- water pressure just before the nozzle: not less than 2 bar,
- distance between the nozzle and the doors or windows: maximum 1,5 m.

c) Windows and sidescuttles facing the cargo area and on the side of the superstructures and deckhouses within the limits specified in paragraph a) are to be of the fixed (non-opening) type. Such windows and sidescuttles, except wheelhouse windows, are to be constructed to "A-60" class standard.

d) Air intakes and air outlets of machinery spaces are to be located as far aft as practicable and, in any case, outside the limits stated in a) above.

e) Where the ship is designed for bow or stern loading and unloading, entrance, air inlets and openings to accommodation, service and machinery spaces and control stations are not to face the cargo shore connection location of bow or stern loading or unloading arrangements. They are to be located on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the length of the ship but not less than 3 m from the end of the deckhouse facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Sidescuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above are to be of the fixed (non-opening) type. In addition, during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side are to be kept closed.

Note 3: Where, in the case of small ships, compliance with the provisions of paragraph e) is not possible, the Society may permit departures.

2.2.3 Access to spaces in the cargo area

a) Access to cofferdams, ballast tanks, cargo tanks and other compartments in the cargo area is to be direct from the open deck and such as to ensure their complete inspection. Access to double bottom compartments may be through a cargo pump room, pump room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

Safe access to cofferdams, ballast tanks, cargo tanks and other compartments in the cargo area is to be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom compartments or to forward ballast tanks may be from a pump-room, deep cofferdam, pipe tunnel, double hull compartment or similar compartment not intended for the carriage of oil or hazardous cargoes.

Note 1: Access manholes to forward gas dangerous spaces are permitted from an enclosed gas-safe space provided that:

- their closing means are gastight and
- a warning plate is provided in their vicinity to indicate that the opening of the manholes is only permitted after checking that there is no flammable gas inside the compartment in question.

Note 2: Unless other additional arrangements provided to facilitate their access are considered satisfactory by the Society, the double bottom tanks are to be provided with at least two separate means of access complying with a) above.

b) For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the compartment. The minimum clear opening is to be not less than 600 mm x 600 mm.

c) For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the compartment, the minimum opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.

d) For oil tankers of less than 5000 t deadweight smaller dimensions may be approved by the Society in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

For oil tankers of less than 5,000 tonnes deadweight, the Society may approve, in special circumstances, smaller dimensions for the openings referred to in paragraphs a) and b), if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

e) Access ladders of cargo tanks are to be fitted with handrails and to be securely attached to the tank structure. They are not to be fitted vertically, unless justified by the size of the tanks. Rest platforms are to be provided at suitable intervals of not more than 10 m.

2.2.4 Access to the pipe tunnels

a) The pipe tunnels in the double bottom are to comply with the following requirements:

1) they are not to communicate with the engine room,

2) provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.

b) Where there is permanent access from a pipe tunnel to the main pump room, a watertight door is to be fitted complying with the requirements of Pt B, Ch 2, Sec 1, [6] and in addition with the following:

1) in addition to the bridge operation, the watertight door is to be capable of being manually closed from outside the main pump room entrance,

2) the watertight door is to be kept closed during normal operations of the ship except when access to the pipe tunnel is required.

Note 1: A notice is to be affixed to the door to the effect that it may not be left open.

2.2.5 Access to the forecastle spaces

Access to the forecastle spaces containing sources of ignition may be permitted through doors facing cargo area provided the doors are located outside hazardous areas as defined in Ch 7, Sec 5.

2.2.6 Safe access to the bow

Every tanker is to be provided with the means to enable the crew to gain safe access to the bow even in severe weather conditions. Such means of access are to be approved by the Society.

The access is to be by means of either a walkway on the deck or a permanently constructed gangway of substantial strength at or above the level of the superstructure deck or the first tier of a deckhouse which is to:

a) Be not less than 1 m in width, situated on or as near as practicable to the centreline of the ship and located so as not to hinder easy access across working areas of the deck.

b) Be fitted at each side throughout its length with a footstop and guard rails supported by stanchions. Such rails are to consist of no less than 3 courses, the lowest being not more than 230 mm and the uppermost being at least 1 m above the gangway or walkway, and no intermediate opening is to be more than 380 mm in height. Stanchions are to be at intervals of not more than 1,5 m.

c) Be constructed of fire resistant and non-slip material. If Fibre Reinforced Plastic (FRP) gratings are used in lieu of steel gratings, they are to be of a type approved by the Society and have the following characteristics:

- low-flame spread characteristics (see Pt C, Ch 4, Sec 1, [2.28])
- not capable of producing excessive quantities of smoke and toxic products, in accordance with the Fire Test Procedures Code
- L1 or L2 structural fire integrity levels, in accordance with ASTM F3059-2018.

d) Have openings, with ladders where appropriate, to and from the deck. Openings are not to be more than 40 m apart.

e) If the length of exposed deck to be traversed exceeds 70 m, have shelters of substantial construction set in way of the gangways or walkways at intervals not exceeding 45 m. Every such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides, and

f) If obstructed by pipes or other fittings of a permanent nature, be provided with means of passage over such obstruction.

2.2.7 Case of ships assigned the service notations oil tanker, flash point > 60°C, oil tanker, asphalt carrier or FLS tanker, flash point > 60°C

On ships assigned one of the following service notations:

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker, flash point > 60°C,

the access and openings are not required to comply with the provisions of [2.2.2]. However, the access doors, air inlets and openings to accommodation spaces, service spaces and control stations are not to face the cargo area.

2.3 Ventilation

2.3.1 Application

a) The requirements of [2.3.2] to [2.3.5] apply only to ships assigned the service notations **oil tanker** or **FLS tanker**.

b) Ships having one of the following service notations:

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker, flash point > 60°C,

are to comply with the provisions of [2.3.6].

2.3.2 General

a) Enclosed spaces within the cargo area are to be provided with efficient means of ventilation. Unless otherwise specified, portable means are permitted for that purpose. Ventilation fans are to be of non sparking construction according to Pt C, Ch 4, Sec 1, [2.33].

b) Ventilation inlets and outlets, especially for machinery spaces, are to be situated as far aft as practicable. Due consideration in this regard is to be given when the ship is equipped to load or discharge at the stern. Sources of ignition such as electrical equipment are to be so arranged as to avoid an explosion hazard.

2.3.3 Ventilation of cargo pump rooms

a) Ventilation exhaust ducts are to discharge upwards in locations at least 3 m measured horizontally from any ignition source and from any ventilation intake and opening to non-hazardous spaces.

b) Ventilation intakes are to be so arranged as to minimize the possibility of recycling hazardous vapours from ventilation discharge openings.

c) The ventilation ducts are not to be led through gas safe spaces, cargo tanks or slop tanks.

d) See also Ch 7, Sec 4, [3.5.1].

2.3.4 Ventilation of other pump rooms

a) Ventilation of pump rooms containing:

- ballast pumps serving spaces adjacent to cargo or slop tanks
- oil fuel pumps,

is to comply with paragraphs a) to c) of [2.3.3] and a) of Ch 7, Sec 4, [3.5.1].

b) The ventilation intakes of the pump rooms referred to in a) are to be located at a distance of not less than 3 m from the ventilation outlets of cargo pump rooms.

2.3.5 Ventilation of double hull and double bottom spaces

Double hull and double bottom spaces are to be fitted with suitable connections for the supply of air.

2.3.6 Case of ships having the service notations oil tanker, flash point > 60°C, oil tanker, asphalt carrier or FLS tanker, flash point > 60°C

On ships having one of the following service notations:

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

FLS tanker, flash point > 60°C,

the ventilation is not required to comply with requirements [2.3.2] to [2.3.5]. However, the following provisions apply:

- spaces located within the cargo area are to be efficiently ventilated. Portable means of ventilation are permitted
- ventilation of the cargo pump room is to comply with [2.3.3].

3 General arrangement of the ship with regard to pollution prevention

3.1 Application

3.1.1 Service notations

The requirements of the present Article apply only to ships having one of the following notations:

oil tanker

oil tanker, flash point > 60°C

oil tanker, asphalt carrier.

3.1.2 Tonnage

Unless otherwise specified, the requirements of the present Article apply only to ships of 150 gross tonnage and above.

3.2 Protection of the cargo tank length in the event of grounding or collision

3.2.1 Application

The requirements of the present sub-article apply to ships of 600 tons deadweight and above.

3.2.2 General

a) The design and construction of oil tankers is to pay due regard to the general safety aspects including the need for maintenance and inspections of wing and double bottom tanks or spaces.

b) Oil is not to be carried in any space extending forward of a collision bulkhead located in accordance with Pt B, Ch 2, Sec 1, [3]. An oil tanker that is not required to have a collision bulkhead in accordance with that regulation is not to carry oil in any space extending forward of the transverse plane perpendicular to the centreline that is located as if it were a collision bulkhead located in accordance with that regulation.

3.2.3 Case of ships of 5000 tons deadweight and above

On oil tankers of 5000 tons deadweight and above, the entire cargo tank length is to be protected by ballast tanks or spaces other than cargo and fuel oil tanks as follows:

a) Wing tanks or spaces

Wing tanks or spaces are to extend either for the full depth of the ship's side or from the top of the double bottom to the uppermost deck, disregarding a rounded gunwale where fitted. They are to be arranged such that the cargo tanks are located inboard of the moulded line of the side shell plating, nowhere less than the distance w which, as shown in Fig 1 is measured at any cross-section at right angles to the side shell, as specified below:

$$w = 0,5 + \frac{DW}{20000}(m)$$

or w = 2,0 m, whichever is the lesser.

The minimum value of w = 1,0 m.

b) Double bottom tanks or spaces

At any cross-section, the depth of each double bottom tank or compartment is to be such that the distance h between the bottom of the cargo tanks and the moulded line of the bottom shell plating measured at right angles to the bottom shell plating, as shown in Fig 1 is not less than specified below:

- *B/15 (m), or*
- *2,0 m, whichever is the lesser.*

The minimum value of h = 1,0 m.

c) Turn of the bilge area or at locations without a clearly defined turn of the bilge

Where the distance h and w are different, the distance w is to have preference at levels exceeding 1,5h above baseline as shown in Fig 1.

d) Aggregate capacity of the ballast tanks

On crude oil tankers of 20000 t deadweight and above and product carriers of 30000 t deadweight and above, the aggregate capacity of wing tanks, double bottom tanks, forepeak tanks and afterpeak tanks is to be not less than the capacity of segregated ballast tanks necessary to meet the requirements of [3.3.2]. Wing tanks or compartments and double bottom tanks used to meet the requirements of [3.3.2] are to be located as uniformly as practicable along the cargo tank length. Additional segregated ballast capacity provided for reducing longitudinal hull girder bending stress, trim, etc., may be located anywhere within the ship.

In calculating the aggregate capacity, the following is to be taken into account:

- *the capacity of engine-room ballast tanks is to be excluded from the aggregate capacity of ballast tanks*
- *the capacity of ballast tanks located inboard of double hull is to be excluded from the aggregate capacity of ballast tanks*
- *spaces such as void spaces located in the double hull within the cargo tank length should be included in the aggregate capacity of ballast tanks*

Any ballast carried in localised inboard extensions, indentation or recesses of the double hull, such as bulkhead stools, should be considered as excess ballast above the minimum requirement for segregated ballast capacity according to [3.3.2].

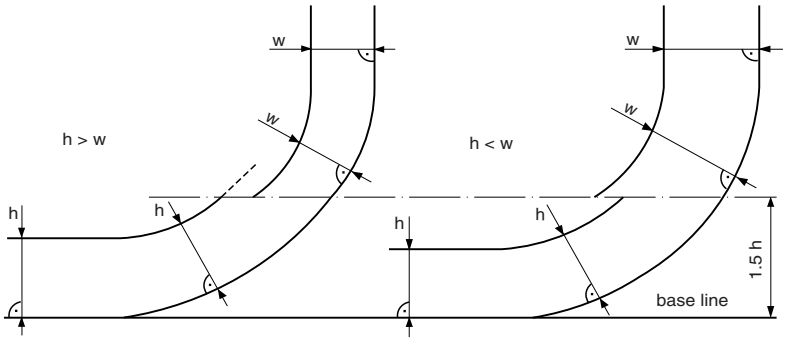
e) Suction wells in cargo tanks may protube into the double bottom below the boundary line defined by the distance h provided that such wells are as small as practicable and the distance between the well bottom and bottom shell plating is not less than 0,5 h.

f) Ballast and cargo piping is to comply with the provisions of Ch 7, Sec 4, [2.3.7] and Ch 7, Sec 4, [3.4.1].

Note 1: Other methods of design and construction of oil tankers may also be accepted as alternatives to the requirements prescribed in items a) to f), provided that such methods ensure at least the same level of protection against oil pollution in the event of collision or stranding and are approved in principle by the Society.

The Society will accept the methods of design and construction described in IMO Resolution *MEPC.110(49)*.

Figure 1 : Cargo tank boundary lines



Note 2: Double bottom tanks or spaces as required by the above paragraph may be dispensed with, provided that the design of the tanker is such that the cargo and vapour pressure exerted on the bottom shell plating forming a single boundary between the cargo and the sea does not exceed the external hydrostatic water pressure, as expressed by the following formula:

$$f \times h_c \times \rho_c \times g + 100\Delta_p \leq d_n \times \rho_s \times g$$

where:

h_c : *Height of cargo in contact with the bottom shell plating, in metres*

ρ_c : *Maximum cargo density, in t/m³*

d_n : *Minimum operating draught under any expected loading conditions, in metres*

ρ_s : *Density of seawater, in t/m³*

Δ_p : *Maximum set pressure of pressure/vacuum valve provided for the cargo tanks, in bars*

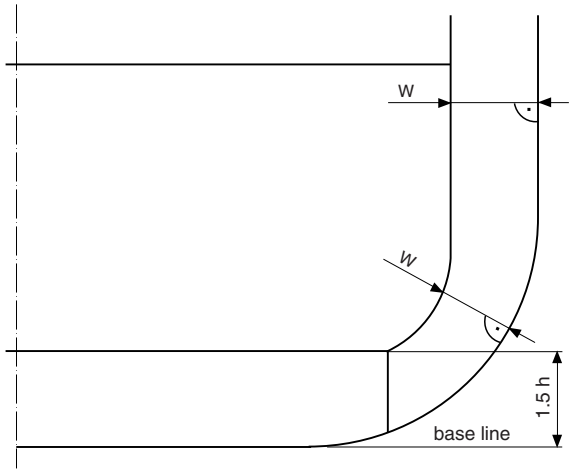
f : *Safety factor = 1,1*

g : *Standard acceleration of gravity (9,81 m/s²).*

Any horizontal partition necessary to fulfil the above requirements are to be located at a height of not less than B/6 or 6 m, whichever is the lesser, but not more than 0,6D, above the baseline where D is the moulded depth amidships.

The location of wing tanks or spaces is to be as defined in paragraph a) above except that, below a level 1,5h above the baseline where h is as defined above, the cargo tank boundary line may be vertical down to the bottom plating, as shown in Fig 2.

Figure 2 : Cargo tank boundary lines



3.2.4 Case of ships of less than 5000 tons deadweight

Oil tankers of less than 5000 tons deadweight are to:

a) At least be fitted with double bottom tanks or spaces having such a depth that the distance h specified in [3.2.3] b) complies with the following:

h = B/15 (m)

with a minimum value of h = 0,76 m;

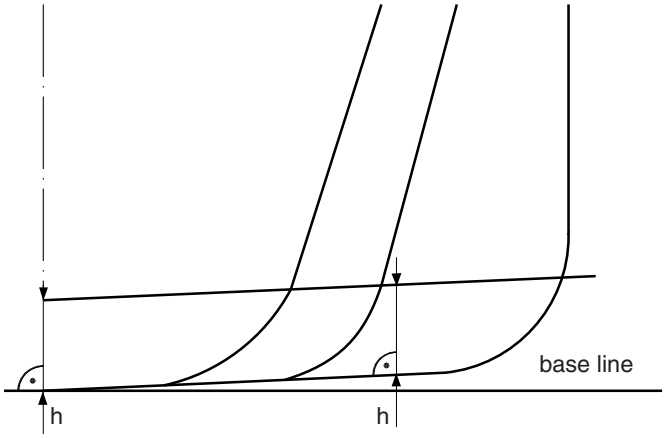
in the turn of the bilge area and at locations without a clearly defined turn of bilge, the cargo tank boundary line is to run parallel to the line of the midship flat bottom as shown in Fig 3; and

b) Be provided with cargo tanks so arranged that the capacity of each cargo tank does not exceed 700 m³ unless wing tanks or spaces are arranged in accordance with [3.2.3] a) complying with the following:

$$w = 0,4 + \frac{2,4DW}{20000}(m)$$

with a minimum value of w = 0,76 m.

Figure 3 : Cargo tank boundary lines



3.3 Segregation of oil and water ballast

3.3.1 General

a) In oil tankers of 150 gross tonnage and above, no ballast water is to be carried in any oil fuel tank.

b) Every crude oil tanker of 20000 tons deadweight and above and every product carrier of 30000 tons deadweight and above are to be provided with segregated ballast tanks and are to comply with requirements [3.3.2] and [3.3.3].

3.3.2 Capacity of the segregated ballast tanks

The capacity of the segregated ballast tanks is to be so determined that the ship may operate safely on ballast voyages without recourse to the use of cargo tanks for water ballast. In all cases, however, the capacity of segregated ballast tanks is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballast only, the ship's draughts and trim can meet each of the following requirements:

a) The moulded draught amidships, d_m in metres (without taking into account any ship's deformation) is to be not less than:

$d_m = 2,0 + 0,02\ L_{LL}$

b) The draughts at the forward and after perpendicular are to correspond to those determined by the draught amidships d_m as specified above, in association with the trim by the stern of not greater than $0,015L_{LL}$, and

c) In any case the draught at the after perpendicular is to be not less than that which is necessary to obtain full immersion of the propeller(s).

Refer also to paragraph d) of [3.2.3].

Note 1: In case of oil tankers less than 150 metres in length, the above formulae may be replaced by those set out in Appendix I to the Unified Interpretations of Annex I of MARPOL 73/78.

3.3.3 Carriage of ballast water in cargo tanks

a) In no case is ballast water to be carried in cargo tanks, except:

1) on those rare voyages when weather conditions are so severe that, in the opinion of the Master, it is necessary to carry additional ballast water in cargo tanks for the safety of the ship, and

2) in exceptional cases where the particular character of the operation of an oil tanker renders it necessary to carry ballast water in excess of the quantity required under [3.3.3], provided that such operation of the oil tanker falls under the category of exceptional cases.

Note 1: Exceptional cases are defined in the Unified Interpretations of Annex I of MARPOL 73/78

Such additional ballast water is to be processed and discharged in compliance with regulation 34 of Annex I of MARPOL 73/78 and an entry is to be made in the Oil Record Book Part II referred to in regulation 36 of that Annex.

b) In the case of crude oil tankers, the additional ballast permitted in paragraph a) above is to be carried in cargo tanks only if such tanks have been crude oil washed in accordance with [3.5] before departure from an oil unloading port or terminal.

3.4 Accidental oil outflow performance

3.4.1 Oil tankers are to comply with the requirements of the Regulation 23 of Annex I to Marpol Convention, as amended.

3.5 Cleaning of cargo tanks

3.5.1 General

a) Adequate means are to be provided for cleaning the cargo tanks.

Note 1: This provision does not apply to ships of less than 150 gross tonnage provided the conditions stated in [3.6.1] are fulfilled.

b) Every crude oil tanker of 20000 tons deadweight and above is to be fitted with a cargo tank cleaning system using crude oil washing complying with the following requirements. Unless such oil tanker carries crude oil which is not suitable for crude oil washing, the oil tanker is to operate the system in accordance with those requirements.

The crude oil washing installation and associated equipment and arrangements are to comply with the requirements of Ch 7, App 2.

3.5.2 Ballasting of cargo tanks

With respect to the ballasting of cargo tanks, sufficient cargo tanks are to be crude oil washed prior to each ballast voyage in order that, taking into account the tanker's trading pattern and expected weather conditions, ballast water is put only into cargo tanks which have been crude oil washed.

3.5.3 Operations and Equipment Manual

Every oil tanker operating with crude oil washing systems is to be provided with an Operations and Equipment Manual detailing the system and equipment and specifying operational procedures. Such a Manual is to be to the satisfaction of the Society and is to contain all the information set out in Ch 7, App 2. If an alteration affecting the crude oil washing system is made, the Operating and Equipment Manual is to be revised accordingly.

3.6 Retention of oil on board - Slop tanks

3.6.1 Application

a) The provisions of requirements [3.6.2] to [3.6.4] do not apply to ships of less than 150 gross tonnage for which the control of discharge of oil under Ch 7, Sec 4, [5.2.1] is to be effected by the retention of oil on board with subsequent discharge of all contaminated washings to reception facilities, unless adequate arrangements are made to ensure that any effluent which is allowed to be discharged into the sea is effectively monitored to ensure that the provisions of Ch 7, Sec 4, [5.2.1] are complied with.

Note 1: The provisions of requirements [3.6.2] to [3.6.4] may be waived for any oil tanker which engages exclusively on both voyages of 72 hours or less in duration and within 50 miles from the nearest land, provided that the oil tanker is engaged exclusively in trades between ports or terminals within a State Party to MARPOL 73/78 Convention. Any such waiver is to be subject to the requirements that the oil tanker is to retain on board all oily mixtures for subsequent discharge to reception facilities and to the determination by the Administration that facilities available to receive such oily mixtures are adequate.

b) The provisions of Ch 7, Sec 4, [5] are also to be complied with.

3.6.2 General

a) Adequate means are to be provided for transferring the dirty ballast residue and tank washings from the cargo tanks into a slop tank approved by the Society.

b) Arrangements are to be provided to transfer the oily waste into a slop tank or combination of slop tanks in such a way that any effluent discharged into the sea comply with the provisions of Ch 7, Sec 4, [5.2].

3.6.3 Capacity of slop tanks

The arrangement of the slop tank or combination of slop tanks is to have a capacity necessary to retain the slop generated by tank washings, oil residues and dirty ballast residues. The total capacity of the slop tank or tanks is not to be less than 3% of the oil carrying capacity of the ship, except that the Society may accept:

a) 2% for oil tankers where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without the introduction of additional water into the system

b) 2% where segregated ballast tanks are provided in accordance with [3.3], or where a cargo tank cleaning system using crude oil washing is fitted in accordance with [3.5]. This capacity may be further reduced to 1,5% for oil tankers where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without introduction of additional water into the system.

Oil tankers of 70 000 tons deadweight and above are to be fitted with at least two slop tanks.

3.6.4 Design of slop tanks

Slop tanks are to be so designed particularly in respect of the position of inlets, outlets, baffles or weirs where fitted, so as to avoid excessive turbulence and entrainment of oil or emulsion with the water.

3.7 Deck spills

3.7.1 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by providing a permanent continuous coaming of a suitable height extending from side to side.

Where gutter bars are installed on the weather decks of oil tankers in way of cargo manifolds and are extended aft as far as the aft bulkhead of superstructures for the purpose of containing cargo spills on deck during loading and discharge operations, the free surface effects caused by containment of a cargo spill during liquid transfer operations or of boarding seas while underway are to be considered with respect to the vessel's available margin of positive initial stability (GMo).

Where the gutter bars installed are higher than 300 mm, they are to be treated as bulwarks with freeing ports arranged in accordance with Pt B, Ch 11, Sec 12, [6] and provided with effective closures for use during loading and discharge operations. Attached closures are to be arranged in such a way that jamming is prevented while at sea, enabling the freeing ports to remain effective.

An assessment of the initial stability (GM_o) for compliance with the relevant intact stability requirements taking into account the free surface effect caused by liquids contained by the gutter bars is to be undertaken on:

- tankers having cargo tanks exceeding 60% of the vessel's maximum beam at midships regardless of gutter bar height
- ships without deck camber
- ships where the height of the installed gutter bars exceeds the camber.

3.8 Pump-room bottom protection

3.8.1 *This Article is applicable to oil tankers of 5000 tons deadweight and above.*

3.8.2 *The pump-room is to be provided with a double bottom such that at any cross-section the depth of each double bottom tank or space is to be such that the distance h between the bottom of the pump-room and the ship's base line measured at right angles to the ship's base line is to be not less than the lesser of:*

- *h= B/15 m*
- *h = 2 m*

without being taken less than 1 m.

3.8.3 *In case of pump rooms whose bottom plate is located above the base line by at least the minimum height required in [3.8.2] (e.g. gondola stern designs), there is no need for a double bottom construction in way of the pump-room.*

3.8.4 *Ballast pumps are to be provided with suitable arrangements to ensure efficient suction from double bottom tanks.*

3.8.5 *Notwithstanding the provisions of [3.8.2] and [3.8.3], where the flooding of the pump-room would not render the ballast or cargo pumping system inoperative, a double bottom need not be fitted.*

4 Structural arrangement of asphalt carrier independent tanks and supports

4.1 Supports

4.1.1 General

Supports of independent tanks are to be designed to allow, when expected, free thermal expansion in the three directions (longitudinal, transverse and vertical) to avoid thermal stress in the tank structures and transmission of loads from the tanks to the supports.

Generally, the supports should be also designed so as to limit the transmission of loads relative to hull deflection (global and local) from the ship structure to the tanks.

The supporting of the tanks is usually achieved by means of:

- vertical supports
- antirolling keys
- antipitching keys
- antiflotation keys
- anticollision keys.

The reaction forces in way of tank supports are to be transmitted as directly as possible to the hull primary supporting members, in order to minimize stress concentration.

Where the reaction forces are not in the plane of the primary supporting members, web plates and brackets are to be provided in order to transmit these loads by means of shear stresses.

4.1.2 Information to be submitted

For every support and key, the following information is to be submitted:

- general arrangement on the ship (positioning, total surface)
- detailed fabrication and integration in the ship hull structure
- mechanical characteristics of the support pads, including compressive and shear strengths, frictional coefficients and elasticity.

4.1.3 Type approval

All the support pads (wooden, synthetic) are to be of a type approved material.

4.1.4 Openings

Openings in the structures in way of tank supports are to be reduced as much as possible and local strengthening is to be provided, as necessary.

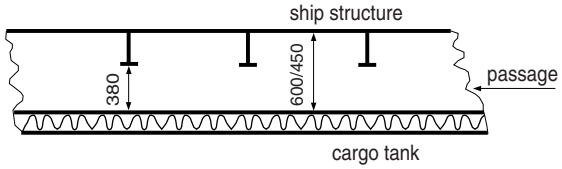
4.2 Inspectability of the cargo area

4.2.1 Passage through cargo tanks

a) Where the Surveyor needs to pass between the flat or curved surface to be inspected and structural elements such as deck beams, stiffeners, frames, girders etc., the distance between that surface and the free edge of the structural elements is to be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, is to be at least (see Fig 4):

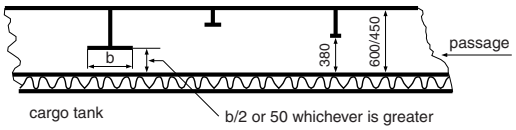
- 450 mm in the case of a curved tank surface, or
- 600 mm in the case of a flat tank surface.

Figure 4 : Minimum passage over cargo tanks



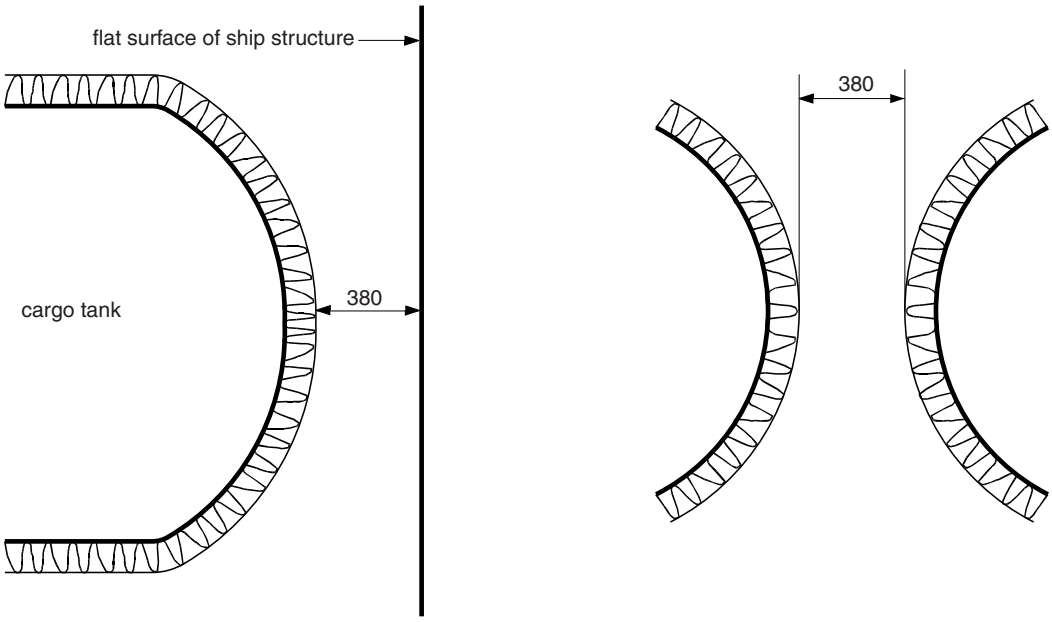
b) Where the Surveyor does not need to pass between the surface to be inspected and any part of the structure, the distance between the free edge of that structural element and the surface to be inspected is, for visibility reasons, to be at least 50 mm, or half the breadth of the structure face plate, whichever is the greater (see Fig 5).

Figure 5 : Minimum distance of structures from cargo tank to allow visual inspection



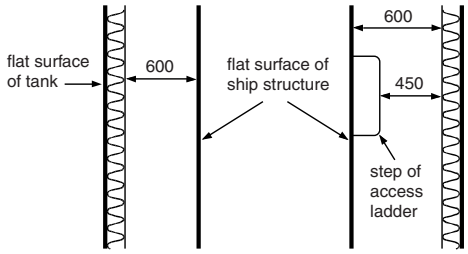
c) Where, for inspection of a curved surface, the Surveyor needs to pass between that surface and another flat or curved surface, to which no structural elements are fitted, the distance between both surfaces is to be at least 380 mm (see Fig 6). Where the Surveyor does not need to pass between a curved surface and another surface, a distance smaller than 380 mm may be accepted, taking into account the shape of the curved surface.

Figure 6 : Minimum passage between curved surfaces



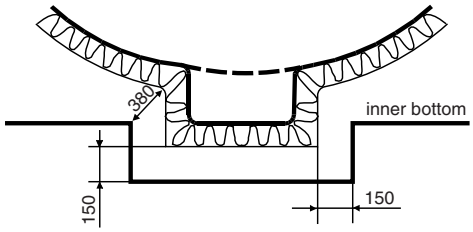
d) Where, for inspection of an approximately flat surface, the Surveyor needs to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces is to be at least 600 mm. A clearance of at least 450 mm is to be provided where fixed access ladders are fitted (see Fig 7).

Figure 7 : Minimum passage between flat surfaces



e) The minimum distances between a cargo tank sump and the adjacent double bottom structure in way of a suction well may not be less than that defined in Fig 8. If there is no suction well, the distance between the cargo tank sump and the inner bottom may not be less than 50 mm.

Figure 8 : Minimum distance of cargo tank sump and inner bottom

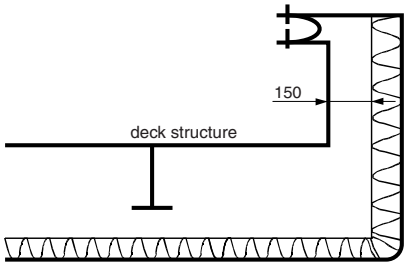


f) The distance between a cargo tank dome and deck structures may not be less than 150 mm (see Fig 9).

g) Where necessary for inspection, fixed or portable staging is to be installed. This staging may not impair the above specified distances.

h) Where fixed or portable ventilation ducting is to be fitted, it may not impair the above specified distances.

Figure 9 : Minimum distance between cargo dome and deck structures



4.2.2 Passage through hatches and manholes

a) The minimum clear opening of horizontal hatches may not be less than 600 x 600 mm, with a corner radius not exceeding 100 mm, as specified in Fig 10.

b) The minimum clear opening of manholes may not be less than 600 x 800 mm, as specified in Fig 11.

c) Circular access openings in cargo tanks are to have a diameter not less than 600 mm.

4.2.3 Cofferdams

Where fitted, cofferdams are to have sufficient size for easy access to all their parts. The width of the cofferdams may not be less than 600 mm.

4.2.4 Pipe tunnels

Pipe tunnels are to have enough space to permit inspection of pipes. The pipes in pipe tunnels are to be installed as high as possible from the ship's bottom.

Figure 10 : Minimum size of horizontal hatches

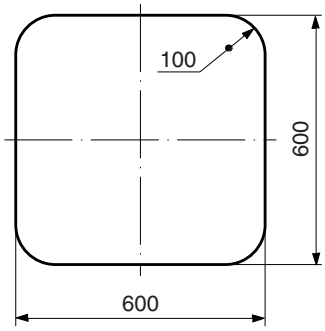
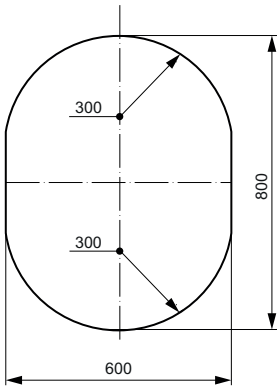


Figure 11 : Minimum size of manholes



Section 3 Hull and Stability

Symbols

L_{LL} : Load line length, in m, defined in Pt B, Ch 1, Sec 3, [2.1.2]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified

k : Material factor for steel, defined in Pt B, Ch 4, Sec 1, [4.2]

E : Young's modulus, in N/mm^2, to be taken equal to:

- E = 2,06·10^5 N/mm^2 for steels in general
- E = 1,95·10^5 N/mm^2 for stainless steels

C_{BM-LC} : Coefficient taken as the percentage of permissible SWBM

C_{SF-LC} : Coefficient taken as the percentage of permissible SWSF.

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the following documents are to be submitted for ships assigned with the service notation **oil tanker ESP** or **FLS tanker**:

- Arrangement of pressure/vacuum valves in cargo tanks,
- Cargo temperatures.

2 Stability

2.1 Application

2.1.1 The requirements in [2.2.2] and [2.3] apply only to ships with the service notation **oil tanker ESP**.

2.2 Intact stability

2.2.1 General

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.6] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2. In addition, the requirements in [2.2.2] are to be complied with.

2.2.2 Liquid transfer operations

Ships with certain internal subdivision may be subjected to lolling during liquid transfer operations such as loading, unloading or ballasting. In order to prevent the effect of lolling, the design of oil tankers of 5000 t deadweight and above is to be such that the following criteria are complied with*:*

a) The intact stability criteria reported in b) is to be complied with for the worst possible condition of loading and ballasting as defined in c*), consistent with good operational practice, including the intermediate stages of liquid transfer operations. Under all conditions the ballast tanks are to be assumed slack.*

b) The initial metacentric height GMo, in m, corrected for free surface measured at 0° heel, is to be not less than 0,15. For the purpose of calculating GMo, liquid surface corrections are to be based on the appropriate upright free surface inertia moment.

c) The vessel is to be loaded with:

- *all cargo tanks filled to a level corresponding to the maximum combined total of vertical moment of volume plus free surface inertia moment at 0° heel, for each individual tank*
- *cargo density corresponding to the available cargo deadweight at the displacement at which transverse KM reaches a minimum value*
- *full departure consumable*
- *1% of the total water ballast capacity.The maximum free surface moment is to be assumed in all ballast tanks.*

2.3 Damage stability for ships where the additional class notation SDS is required

2.3.1 General

Every oil tanker is to comply with the subdivision and damage stability criteria as specified in [2.3.8], after the assumed side or bottom damage as specified in [2.3.2], for the standard of damage described in [2.3.3], and for any operating draught reflecting actual partial or full load conditions consistent with trim and strength of the ship as well as specific gravities of the cargo.

The actual partial or full load conditions to be considered are those specified in Pt B, Ch 3, App 2, [1.2.6], *but ballast conditions where the oil tanker is not carrying oil in cargo tanks, excluding any oil residues, are not to be considered.*

2.3.2 Damage dimensions

The assumed extent of damage is to be as defined in Tab 1.

The transverse extent of damage is measured inboard the ship side at right angles to the centreline at the level of the summer load line.

For the purpose of determining the extent of assumed damage, suction wells may be neglected, provided such wells are not excessive in areas and extend below the tank for a minimum distance and in no case more than half the height of the double bottom.

The vertical extent of damage is measured from the moulded line of the bottom shell plating at centreline.

If any damage of a lesser extent than the maximum extent of damage specified in Tab 1 would result in a more severe condition, such damage is to be considered.

Table 1 : Extent of damage

Damage		Longitudinal extent	Transverse extent	Vertical extent
Side		l_C = 1/3 $L_{LL}^{2/3}$ or 14,5 m **(1)**	t_C = B/5 or 11,5 m **(1)**	v_C = without limit
Bottom	For 0,3 L_{LL} from the forward perpendicular	l_S = 1/3 $L_{LL}^{2/3}$ or 14,5 m **(1)**	t_S = B/6 or 10 m **(1)**	v_S = B/15 or 6 m **(1)**
	any other part	l_S = 1/3 $L_{LL}^{2/3}$ or 5 m **(1)**	t_S = B/6 or 5 m **(1)**	v_S = B/15 or 6 m **(1)**
(1) Whichever is the lesser				

2.3.3 Standard of damage

The damage in [2.3.2] is to be applied to all conceivable locations along the length of the ship, according to Tab 2.

Table 2 : Standard of damage

Ship's length, in m	Damage anywhere in ship's length	Damage between transverse bulkheads	Machinery space flooded
$L_{LL} \leq 100$	No	Yes **(1)** **(2)**	No
$100 < L_{LL} \leq 150$	No	Yes **(1)**	No
$150 < L_{LL} \leq 225$	Yes	No	Yes, alone
$L_{LL} > 225$	Yes	No	Yes
(1) Machinery space not flooded. **(2)** Exemptions from the requirements of [2.3.8] may be accepted by the Society on a case-by-case basis.			

2.3.4 Calculation method

The metacentric heights (GM), the stability levers (GZ) and the centre of gravity positions (KG) for judging the final survival conditions are to be calculated by the constant displacement method (lost buoyancy).

2.3.5 Flooding assumptions

The requirements of [2.3.8] are to be confirmed by calculations which take into consideration the design characteristics of the ship, the arrangements, configuration and contents of the damaged compartments and the distribution, specific gravities and free surface effect of liquids.

Where the damage involving transverse bulkheads is envisaged as specified in [2.3.3], transverse watertight bulkheads are to be spaced at least at a distance equal to the longitudinal extent of assumed damage specified in [2.3.2] in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage is to be assumed as non-existent for the purpose of determining flooded compartments.

Where the damage between adjacent transverse watertight bulkheads is envisaged as specified in [2.3.3], no main transverse bulkhead or a transverse bulkhead bounding side tanks or double bottom tanks is to be assumed damaged, unless:

- *the spacing of the adjacent bulkheads is less than the longitudinal extent of assumed damage specified in [2.3.2] or,*
- *there is a step or a recess in a transverse bulkhead of more than 3,05 metres in length, located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and after peak tank top is not to be regarded as a step.*

2.3.6 Progressive flooding

If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in [2.3.2], arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.

2.3.7 Permeabilities

The specific gravity of cargoes carried, as well as any outflow of liquid from damaged compartments, are to be taken into account for any empty or partially filled tank.

The permeability of compartments assumed to be damaged are to be as indicated in Tab 3.

Table 3 : Permeability

Compartments	Permeability
Appropriate for stores	0,60
Occupied by accommodation	0,95
Occupied by machinery	0,85
Void compartments	0,95
Intended for consumable liquids	0 to 0,95 **(1)**
Intended for other liquids	0 to 0,95 **(1)**
(1) The permeability of partially filled compartments is to be consistent with the amount of liquid carried in the compartment.	

2.3.8 Survival requirements

Oil tankers are to be regarded as complying with the damage stability criteria if the requirements of [2.3.9] and [2.3.10] are met.

2.3.9 Final stage of flooding

a) *The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place.* The progressive flooding is to be considered in accordance with Pt B, Ch 3, Sec 3, [3.3].

b) *The angle of heel due to unsymmetrical flooding may not exceed 25°, except that this angle may be increased up to 30° if no deck edge immersion occurs.*

c) *The stability is to be investigated and may be regarded as sufficient if the righting lever curve has at least a range of 20° beyond the position of equilibrium in association with a maximum residual righting lever, in m, of at least 0,1 within the 20° range; the area, in m·rad, under the curve within this range is to be not less than 0,0175.*

2.3.10 Intermediate stage of flooding

The Society is to be satisfied that the stability is sufficient during the intermediate stages of flooding. To this end the Society applies the same criteria relevant to the final stage of flooding also during the intermediate stages of flooding.

2.3.11 Bottom raking damage

This requirement applies to oil tankers of 20000 t deadweight and above.

The damage assumptions relative to the bottom damage prescribed in [2.3.2] are to be supplemented by the assumed bottom raking damage of Tab 4.

The requirements of [2.3.8] are to be complied with for the assumed bottom raking damage.

Table 4 : Bottom damage extent

Deadweight	Longitudinal extent	Transverse extent	Vertical extent
< 75000 t	0,4 L_{LL} **(1)**	B/3	**(2)**
≥ 75000 t	0,6 L_{LL} **(1)**	B/3	**(2)**
(1) Measured from the forward perpendicular. **(2)** Breach of the outer hull.			

2.3.12 Equalisation arrangements

Equalisation arrangements requiring mechanical aids such as valves or cross levelling pipes, if fitted, may not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of [2.3.9] and sufficient residual stability is to be maintained during all stages where equalisation is used. Compartments which are linked by ducts of a large cross-sectional area may be considered to be common.

2.3.13 Information to the Master

The Master of every oil tanker is to be supplied in an approved form with:

- *information relative to loading and distribution of cargo necessary to ensure compliance with the requirements relative to stability, and*
- *data on the ability of the ship to comply with damage stability criteria as determined in [2.3.8] including the effect of relaxation that may have been allowed as specified in Tab 2.*

3 Structure design principles

3.1 Framing arrangement

3.1.1 In general, within the cargo tank region of ships of more than 90 m in length, the bottom, the inner bottom and the deck are to be longitudinally framed.

Different framing arrangements are to be considered by the Society on a case-by-case basis, provided that they are supported by direct calculations.

3.2 Bulkhead structural arrangement

3.2.1 General

Transverse bulkheads may be either plane or corrugated.

3.2.2 Corrugated bulkheads

For ships of less than 120 m in length, vertically corrugated transverse or longitudinal bulkheads may be connected to the double bottom and deck plating.

For ships equal to or greater than 120 m in length, lower and upper stools are to be fitted.

4 Design loads

4.1 Loading conditions for longitudinal strength assessment

4.1.1 Seagoing conditions

In addition to the loading conditions specified in Pt B, Ch 5, Sec 8, the following seagoing loading conditions are to be included, as a minimum, in the loading manual:

a) Heavy ballast condition where the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in item b of Pt B, Ch 5, Sec 8, [3.1.1] are to be complied with. The fore peak water ballast tank is to be full, if fitted. If upper and lower fore peak tanks are fitted, the lower is required to be full and the upper tank may be full, partially full or empty. All the cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea. The draught at the forward perpendicular is not to be less than that for the normal ballast condition. The propeller is to be fully immersed. The trim is to be by the stern and is not to exceed 0,015 L_{LL}

b) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions

c) Any specified non-uniform distribution of loading

d) Conditions with high density cargo including the maximum design cargo density, when applicable

e) Design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks. This design condition is for assessment of hull strength and is not intended for ship operation.

4.1.2 Additional loading conditions

In addition to the loading conditions specified in Pt B, Ch 5, Sec 8, the following additional loading conditions are to be included in the loading manual if the ship is specifically approved and intended to be operated in such conditions:

a) Seagoing ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL Reg. 18

b) Seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of 0,9 T_{SC}

c) Seagoing loading conditions with cargo tanks less than 25% full with the combination of mean ship's draught greater than 0,9 T_{SC}

d) Seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1,025 t/m^3 or greater and a mean ship's draught of 0,6 T_{SC}

e) For ships arranged with cross ties in the centre cargo tank, seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between corresponding port and starboard wing cargo tanks exceeds 25% of the filling height in the wing cargo tank.

4.2 Local loads

4.2.1 Bottom impact pressure

For oil tankers of 20000 t deadweight and above and product carriers of 30000 t deadweight and above, the draught T_{LC} corresponding to loading conditions using the segregated ballast tanks only are to be considered in the calculation of the bottom impact pressure according to Pt B, Ch 5, Sec 5, [4.2.1] in addition to other loading conditions.

4.2.2 Cargo mass density

In the absence of more precise values, a cargo mass density of 0,9 t/m^3 is to be considered for calculating the internal pressures and forces in cargo tanks according to Pt B, Ch 5, Sec 6.

4.2.3 Partial filling

The carriage of cargoes with a mass density above the one considered for the design of the cargo tanks may be allowed with partly filled tanks under the conditions stated in Pt B, Ch 5, Sec 6, [2]. The classification certificate or a memorandum provided for in Pt A, Ch 1, Sec 2, [4.4] is to mention these conditions of carriage.

4.2.4 Overpressure due to cargo filling operations

For ships assigned the additional service feature **asphalt carrier**, the overproduce which may occurred under loading/unloading operations are to be considered, if any. In such a case, the diagram of the pressures in loading/unloading conditions is to be given by the Designer.

4.3 Load combinations for direct strength analysis

4.3.1 The loading conditions to be considered for the direct strength analysis are defined in [4.3.1] to [4.3.5].

4.3.2 Ships with structure symmetrical about centreline

For ships with structure symmetrical about the centreline, the loading patterns mirrored about centreline of another pattern may be omitted provided the results (yield and buckling) are mirrored.

4.3.3 Tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks

Any loading patterns with unequal filling levels in transversely paired wing cargo tanks that would result in a more onerous stress response are to be examined. The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the FE analysis. Where the GM and k_r are not given in the ship's loading manual, they are to be determined in accordance with Pt B, Ch 5, Sec 3.

If such loading pattern is considered, an operational restriction describing that the difference in filling level between corresponding port and starboard wing cargo tanks is not to exceed 25% of the filling height in the wing cargo tank, is to be added in the loading manual.

4.3.4 Tankers with two oil-tight longitudinal bulkheads

- Seagoing loading pattern with all cargo tanks abreast empty are to be analysed with a ship draught of 0,65 T_{SC} and 0,7 T_{SC} respectively. If conditions in the ship loading manual specify greater draughts, then the maximum specified draught in the ship's loading manual for the loading pattern is to be used.
- Seagoing and harbour loading patterns with all cargo tanks abreast fully loaded are to be analysed with a ship draught of 0,65 T_{SC} and 0,6 T_{SC} respectively. If conditions in the ship loading manual specify lesser draughts, then the minimum specified draught in the ship's loading manual for the loading pattern is to be used.

4.3.5 For loading patterns with cargo tank(s) empty, a minimum ship draught of 0,9 T_{SC} is to be used in the analysis. If conditions in the ship loading manual specify greater draughts, then the maximum specified draught for the actual condition is to be used.

4.3.6 Ballast conditions

Any ballast condition specified in the ship loading manual with ballast water filled in one or more cargo tanks is to be examined.

The actual loading pattern, draught, GM and k_r from the loading manual are to be used in the direct strength analysis. Where the GM and k_r are not given in the ship's loading manual, they are to be determined in accordance with Pt B, Ch 5, Sec 3.

5 Hull scantlings

5.1 Strength check with respect to stresses due to the temperature gradient

5.1.1 General

Direct calculations of stresses induced in the hull structures by the temperature gradient are to be performed:

- for ships intended to carry cargoes at temperatures exceeding 90°C
- and when part of the hull structures temperature exceeds 90°C

In these calculations, the water temperature is to be assumed equal to 0°C.

The calculations are to be submitted to the Society for review.

5.1.2 Material

For steels used at a temperature θ between 90°C and 300°C, and unless other information is specified, their minimum yield stress R_{eH} and Young's modulus E are to be taken as specified in Pt B, Ch 4, Sec 1, [2.1.1].

The material factor is to be adjusted accordingly.

5.1.3 Thermal stress for integral tanks

The stresses induced in the hull structures by the temperature gradient are to comply with the checking criteria in Pt B, Ch 8, App 1, [5.2.3].

5.1.4 Thermal stress for independent tanks

Where a thermal elongation is made possible due to the design of the tank supports, the thermal stress may be neglected provided the cargo temperature distribution is rather uniform.

In addition, precautions are to be taken, upon loading of any hot cargo, by pre-heating the tanks in order to minimize the temperature gradients within the cargo hold.

5.2 Hull girder stress for independent tanks structures

5.2.1 In general, the hull girder stresses may be taken equal to zero.

Where the length of the tank under consideration exceeds both 0,15L and 3,5 times its breadth, the stresses in the tank due to the hull girder loads are to be taken into account. These stresses are, in general, to be obtained by means of direct calculations based on a finite element model of the hull and the tank with its supporting and keying system.

6 Scantlings of independent tanks structures

6.1 Plating

6.1.1 In general, the net plating thickness of independent tanks is to be not less than the values obtained from the applicable formulae given in Pt B, Ch 7, Sec 4, where the lateral pressures are to be calculated according to Part B, Chapter 5.

6.2 Ordinary stiffeners

6.2.1 In general, the net scantlings of the ordinary stiffeners of independent tanks are to be not less than the values obtained from the applicable formulae given in Pt B, Ch 7, Sec 5, where the lateral pressures are to be calculated according to Part B, Chapter 5.

6.3 Primary supporting members

6.3.1 The net scantlings of the primary supporting members are to be obtained by means of direct calculations according to [8].

7 Supports of independent tanks

7.1 General

7.1.1 The reaction forces in way of tank supports are to be obtained from the structural analysis of the tank, taking into account the relative hull bottom stiffness and considering the loads and accelerations specified in Part B, Chapter 5, in addition to the static steel weight of the tank.

If the supports are not able to react in tension, the final distribution of the reaction forces at the supports is not to show any tensile forces.

7.2 Vertical supports

7.2.1 General

When used together with hot cargoes, the material of a vertical support is to present the following qualities:

- very low thermal conductivity
- good mechanical performances at the highest temperatures:
  - compressive strength, to reduce the supporting area
  - elasticity, to avoid cracks (no brittleness) and to spread the load
  - shear strength, to support horizontal forces due to thermal extension of the tank
  - average frictional coefficient, to reduce loads on keys while avoiding excessive shear stresses in the support.

7.2.2 Scantling

The tank structure and the ship structure are to be reinforced in way of the supports so as to withstand the combined reactions defined in [7.1] (compression induced by the vertical acceleration and shear induced by the longitudinal or transverse acceleration) and corresponding moments.

For the purpose of this assessment, the frictional coefficient of the vertical supports is to be taken equal to 0,3, unless duly justified.

7.3 Antirolling keys

7.3.1 General

Antirolling keys fitted at top of the tank are generally necessary for narrow and high tanks which may capsize at rolling, as well as for filling levels lower than 90%. Otherwise, bottom keys may be sufficient.

A risk of capsizing of the tank is to be considered when:

$a_Y \, y_G \geq (g - a_Z) \, z_G$

where:

g : Gravity acceleration, in m/s^2

a_Y, a_Z : Transverse and vertical accelerations for the BR dynamic load cases, as defined in Pt B, Ch 5, Sec 3, [3.2]

y_G, z_G : Transverse and vertical distances between the vertical support a side and the centre of gravity of the tank.

The frictional load taken by the vertical supports may be deduced from the lateral load, provided the minimum value of the frictional coefficients between tank and vertical supports are duly justified by the Designer. In general, for the purpose of this assessment, the frictional coefficient of the vertical supports is to be taken equal to 0,1.

7.3.2 Load cases

Antirolling keys are to be checked under transverse and vertical accelerations for the inclined ship condition, considering the maximum full tank weight.

7.4 Antipitching keys

7.4.1 Antipitching keys are fitted to prevent the tank from moving longitudinally.

They may also be used for anticollision purpose (see [7.5]).

7.4.2 Load cases

Antipitching keys are to be checked under longitudinal and vertical accelerations for the upright ship condition, considering the maximum full tank weight.

7.5 Anticollision keys

7.5.1 General

Anticollision keys may be combined with antipitching keys (see [7.4]).

7.5.2 Load cases

Anticollision keys are to withstand a collision force acting on the tank corresponding to half the tank and cargo weight in the forward direction and one quarter of the tank and cargo weight in the aftward direction, considering the maximum full tank weight.

7.6 Antiflotation keys

7.6.1 General

When antiflotation keys are fitted at the top of the tanks, they are positioned on both sides, in order to minimize the bending moment induced on deck transverses.

7.6.2 Load cases

Antiflotation keys are to withstand an upward force caused by an empty tank floating in a hold flooded up to the deepest equilibrium waterline after damage for the loading conditions among which the tank under consideration is empty.

7.7 Yielding criteria

7.7.1 It is to be checked that the Von Mises stress σ_{vm} in the supports and keys, in N/mm^2, is in compliance with the requirements in Pt B, Ch 8, App 1, [5.2.3] and Pt B, Ch 8, App 2, [4.1.3].

8 Independent tanks direct strength analysis

8.1 General

8.1.1 Yielding and buckling check of primary supporting members is to be performed within the cargo area by means of FE analysis.

8.2 Three cargo holds model

8.2.1 Model extension

As a rule, the cargo tank to be assessed is to be modelled with its two adjacent holds and tanks (fore and aft). The model is to include the hold, the cargo tank and the supports.

The assessment of a tank may be waived when the tank is similar enough to an already checked cargo tank.

8.2.2 Hold modelling

The following items of the hold are to be modelled:

- outer shell, inner shell, deck, bottom, inner bottom and transverse bulkheads plating
- double bottom longitudinal girders
- double side horizontal girders
- deck longitudinal girders
- transverse web frames
- primary supporting members of transverse bulkheads.

8.2.3 Cargo tank modelling

The following items of the cargo tank are to be modelled:

- shell plating
- bulkheads plating, including wash bulkheads, if any
- bottom plating
- top plating
- transverse web frames
- horizontal stringers
- girders.

In addition, the static steel weight of the tank is to be considered.

8.2.4 Supports and keys modelling

The cargo tanks are linked to the hold by the following supports and keys, acting in one direction:

- vertical supports (Z direction)
- antipitching keys (X direction), used also as anticollision keys
- antirolling keys (Y direction)
- antiflotation keys (Z direction).

They can be modelled by either linear elements (bar, flexible mounts, springs), or non-linear elements (gap elements).

When linear elements are used to model keys and supports not allowing tension loads, they are to be deleted when in tension.

Stiffness of these linear and/or non-linear elements is to be representative of the actual stiffness of the supports and keys.

The stiffness of the pad located between the lower and upper parts of the support may be calculated as follows: $K = E\ S / h$

where:

K : Stiffness of the pad, in N/mm

E : Young modulus of the pad, in MPa

S : Sectional area of the pad, in mm^2

h : Height of the pad, in mm.

The stiffness of the gap or spring element is to be taken as: $K_{element} = K / N_{elements}$

with:

$N_{elements}$: Number of elements used in the pad modelling.

8.2.5 Size of the elements

The mesh size are to be equal to the spacing of the longitudinal ordinary stiffeners. Each of these longitudinal stiffeners is to be modelled. The aspect ratio of the elements is to be as close to 1,0 as possible.

8.2.6 Boundary conditions

The requirements of Pt B, Ch 8, App 1, [2.5] are to be applied.

8.2.7 Yielding criteria

It is to be checked that the Von Mises stress σ_{vm} in the elements listed in [8.2.2] to [8.2.4], in N/mm^2, is in compliance with the criteria given in Pt B, Ch 8, App 1, [5.2.3].

9 Other structures

9.1 Machinery space

9.1.1 Extension of the hull structures within the machinery space

Longitudinal bulkheads carried through cofferdams are to continue within the machinery space and are to be used preferably as longitudinal bulkheads for liquid cargo tanks. In any case, such extension is to be compatible with the shape of the structures of the double bottom, deck and platforms of the machinery space.

9.2 Opening arrangement

9.2.1 Tanks covers

Covers fitted on all cargo tank openings are to be of sturdy construction, and to ensure tightness for hydrocarbon and water.

Aluminium is not permitted for the construction of tank covers. The use of reinforced fibreglass covers is to be specially examined by the Society.

For the protection of cargo tanks carrying crude oil and petroleum products having a flash point not exceeding 60°C, materials readily rendered ineffective by heat are not to be used for tank opening covers so as to prevent the spread of fire to the cargo.

10 Hull outfitting

10.1 Equipment

10.1.1 Emergency towing arrangements

The specific requirements in Pt B, Ch 12, Sec 4, [3] for ships with the service notation **oil tanker ESP** or **FLS tanker** and of 20000 t deadweight and above are to be complied with.

11 Protection of hull metallic structures

11.1 Protection by aluminium coatings

11.1.1 The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in the cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate.

11.2 Material and coatings of tanks

11.2.1 The resistance of materials and coatings and their compatibility with intended cargoes are the responsibility of the builder or owner. All supporting documents are, however, to be given to the Society to allow the issue of the list of cargoes annexed to the classification certificate.

Copy of the charts of coating and/or material resistance issued by the manufacturers is to be kept on board. These documents are to indicate the possible restrictions relative to their use.

12 Cathodic protection of tanks

12.1 General

12.1.1 Internal structures in spaces intended to carry liquids may be provided with cathodic protection.

Cathodic protection may be fitted in addition to the required corrosion protective coating, if any.

12.1.2 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to the Society for approval.

12.2 Anodes

12.2.1 Magnesium or magnesium alloy anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks.

12.2.2 Aluminium anodes are only permitted in cargo tanks and tanks adjacent to cargo tanks in locations where the potential energy does not exceed 28 kg m. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts.

However, where aluminium anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface.

Aluminium anodes are not to be located under tank hatches or washing holes, unless protected by the adjacent structure.

12.2.3 There is no restriction on the positioning of zinc anodes.

12.2.4 Anodes are to have steel cores and are to be declared by the Manufacturer as being sufficiently rigid to avoid resonance in the anode support and designed so that they retain the anode even when it is wasted.

12.2.5 The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

12.2.6 The supports at each end of an anode may not be attached to separate items which are likely to move independently.

12.2.7 Where anode inserts or supports are welded to the structure, they are to be arranged by the Shipyard so that the welds are clear of stress peaks.

12.2.8 As a general rule, the requirements [12.2.1] to [12.2.7] apply also to spaces or compartments adjacent to cargo or slop tanks.

12.3 Impressed current systems

12.3.1 Impressed current cathodic protections are not accepted in cargo or slop tanks, unless specially authorized by the Society.

13 Construction and testing

13.1 Welding and weld connections

13.1.1 It is recommended to use continuous fillet welding to connect primary supporting member web to its associated shell plating. The leg length of such a welding is not to be less than the value specified in Pt B, Ch 13, Sec 3, Tab 4.

Discontinuous welds are not allowed for primary members perpendicular to ordinary stiffeners.

For longitudinals, intermittent scallop welding can be accepted as for primary members parallel to longitudinals, especially in small ships.

Intermittent scallop welding can be accepted for some members.

Where scallop fillet is used, the scallops are to be avoided:

- in way of the connecting brackets and at least more than 200 mm beyond the beginning of the bracket
- more than 200 mm about on either side of the connection of the ordinary stiffeners to the primary stiffeners
- on bottom transverses, shell stringers and longitudinal bulkhead stringers
- on the lower half of side shell and longitudinal bulkhead transverses, and on the web frames of transverse bulkheads.

13.1.2 The weld factors for some hull structural connections are specified in Tab 5. These weld factors are to be used, in lieu of the corresponding factors specified in Pt B, Ch 13, Sec 3, Tab 2, to calculate the leg length of fillet weld T connections according to Pt B, Ch 13, Sec 3, [3.2.6]. For the connections of Tab 5, continuous fillet welding is to be adopted.

Table 5 : Weld factor w_F

Hull area	Connection		Weld factor w_F
	of	to	
Double bottom in way of cargo tanks	girders	bottom and inner bottom plating	0,48
		floors (interrupted girders)	
	floors	bottom and inner bottom plating	
		girders (interrupted floors)	
Bulkheads **(1)**	ordinary stiffeners	bulkhead plating	
(1) Not required to be applied to ships with the additional service feature **flash point > 60°C**.			

13.1.3 For ships of more than 250 m in length, leg lengths of fillet welds for transverse web frames and horizontal stringers on transverse bulkheads are to be reinforced as shown in Fig 1 and Fig 2.

The length, in m, of reinforcement is not to be less than the greater of the following values:

- $\ell = 2s$
- $\ell = 1,2$

where s is the spacing, in m, of the ordinary stiffeners.

13.2 Special structural details

13.2.1 The specific requirements in Pt B, Ch 13, Sec 5, [2.3] for ships with the service notation **oil tanker ESP**, **FLS tanker** or **asphalt carrier** are to be complied with.

Figure 1 : Reinforcement of throat thickness for ships greater than 250 m

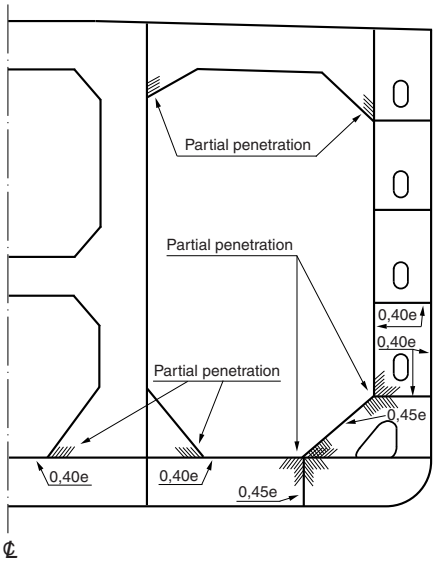
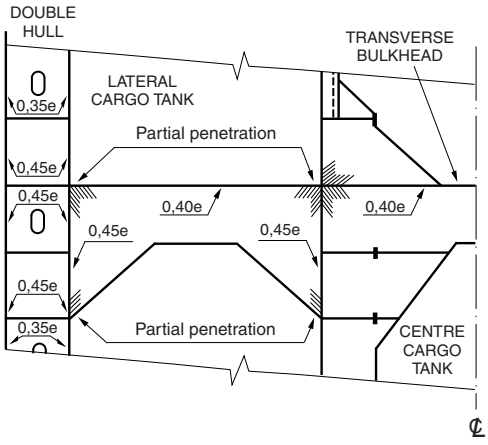


Figure 2 : Reinforcement of throat thickness for ships greater than 250 m



Section 4 Machinery and Cargo Systems

1 General

1.1 Application

1.1.1 Relaxations applying to certain service notations

Articles [2] to [7] provide requirements that apply to ships having the service notation **oil tanker** and, where indicated in the relevant notes, the relaxations which may be accepted for ships of less than 500 gross tonnage and for ships having the following service notations:

- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker**
- **FLS tanker, flash point > 60°C**.

Such relaxations are summarised in Tab 1.

1.1.2 Additional requirements

Additional requirements are provided in:

- [8] for ships having the service notation **oil tanker, asphalt carrier**
- [9] for ships intended to carry substances of pollution category Z.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 2 are to be submitted for approval.

1.3 Abbreviations

1.3.1 The following abbreviations are used in this Section.

FP : Flash point, in °C.

Table 1 : Possible relaxations according to service notation

Subject	Reference to the Rules	Service notation or other feature of the ship to which relaxations apply	Relaxations
Driven pumps for bilge, ballast, etc.	[2.1.4]	< 500 GT	equivalent arrangements accepted
Drainage of cofferdams	[2.2.5]	< 500 GT	hand pumps permitted
Ballast pumps	[2.3.2]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	Shaft misalignment compensation, gastightness of the shaft gland and temperature sensors are not required
Air and sounding pipes of spaces other than cargo tanks	[2.4]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	NA **(1)**
Cargo pumps	[3.2.3] [3.2.4] [3.2.5]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	Shaft misalignment compensation, gas-tightness of the shaft gland and temperature sensors are not required
Generation of static electricity	[3.4.4]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	NA **(1)**
Bow or stern cargo loading and unloading arrangement	[3.4.5]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	NA **(1)**

(1) NA means that the requirements referred to in the second column of the table are not applicable.

Subject	Reference to the Rules	Service notation or other feature of the ship to which relaxations apply	Relaxations
Cargo tank venting	[4.2]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	See Tab 5
Cargo tank purging/gas-freeing	[4.3]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	NA **(1)**
Tank level gauging	[4.4]	• **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker, flash point > 60°C**	See Tab 5
Tank washing	[4.6]	• **FLS tanker,** • **FLS tanker, flash point > 60°C**	NA **(1)**
Retention of oil on board	[5.2]	• **oil tanker, asphalt carrier** • **FLS tanker,** • **FLS tanker, flash point > 60°C**	NA **(1)**
Oil discharge monitoring and control system	[5.3]	• **oil tanker,** less than 150 gross tonnage • **oil tanker, flash point > 60°C**, and less than 150 gross tonnage • **oil tanker, asphalt carrier** • **FLS tanker** • **FLS tanker, flash point > 60°C**	NA **(1)**
Oil contaminated water discharge arrangements	[5.4]	• **FLS tanker** • **FLS tanker, flash point > 60°C**	NA **(1)**
Survey of pollution prevention equipment	[6.3.2]	• **FLS tanker** • **FLS tanker, flash point > 60°C**	NA **(1)**
(1) NA means that the requirements referred to in the second column of the table are not applicable.			

Table 2 : Documents to be submitted

No.	Description of the document **(1)**
1	General layout of cargo pump room with details of: • bulkhead penetrations • gas detection system • other alarms and safety arrangements
2	Diagram of cargo piping system
3	Diagram of the cargo tank venting system with: • indication of the outlet position • details of the pressure/vacuum valves and flame arrestors • details of the draining arrangements, if any
4	Diagram of the cargo tank level gauging system with overfill safety arrangements
5	Diagram of the cargo tank cleaning system
6	Diagram of the bilge and ballast systems serving the spaces located in the cargo area
7	Diagram of the cargo heating systems
8	Diagram of inert gas system with details of the inert gas plant
9	Diagram of gas measurement system for double hull and double bottom spaces
(1) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems	

2 Piping systems other than cargo piping system

2.1 General

2.1.1 Materials

a) Materials are to comply with the provisions of Pt C, Ch 1, Sec 10.

b) Spheroidal graphite cast iron may be accepted for bilge and ballast piping within double bottom or cargo tanks.

c) Grey cast iron may be accepted for ballast lines within cargo tanks, except for ballast lines to forward tanks through cargo tanks.

2.1.2 Independence of piping systems

a) Unless otherwise specified in this Chapter, bilge, ballast and scupper systems serving spaces located within the cargo area:

- are to be independent from any piping system serving spaces located outside the cargo area
- are not to lead outside the cargo area.

b) Fuel oil systems are to:

- be independent from the cargo piping system
- have no connections with pipelines serving cargo or slop tanks.

2.1.3 Passage through cargo tanks and slop tanks

a) Unless otherwise specified, bilge, ballast and fuel oil systems serving spaces located outside the cargo area are not to pass through cargo tanks or slop tanks. They may pass through ballast tanks or void spaces located within the cargo area.

b) Where expressly permitted, ballast pipes passing through cargo tanks are to fulfil the following provisions:

- they are to have welded or heavy flanged joints the number of which is kept to a minimum
- they are to be of extra-reinforced wall thickness as per Tab 3
- they are to be adequately supported and protected against mechanical damage.

c) Where required by Ch 7, Sec 2, [3.4.1], lines of piping which run through cargo tanks are to be fitted with closing devices.

2.1.4 Pumps forward of cargo tank area

One or more driven pumps are to be fitted, in a suitable space forward of cargo tanks, for bilge, ballast and, where relevant, fuel oil services.

Note 1: On ships of less than 500 gross tonnage, such pumps may be omitted provided that the above services are ensured by means of equivalent arrangements, subject to the approval of the Society.

Table 3 : Minimum wall thickness for carbon steel pipes

Nominal diameter (mm)	Minimum wall thickness (mm)
50	6,3
100	8,6
125	9,5
150	11,0
200 and above	12,5

2.2 Bilge system

2.2.1 Bilge pumps

a) At least one bilge pump is to be provided for draining the spaces located within the cargo area. Cargo pumps or stripping pumps may be used for this purpose.

b) Bilge pumps serving spaces located within the cargo area are to be located in the cargo pump room or in another suitable space within the cargo area.

2.2.2 Draining of spaces located outside the cargo area

For bilge draining of spaces located outside the cargo area, refer to Pt C, Ch 1, Sec 10, [6].

Note 1: Where the bilge pumps are designed to pump from the machinery space only, the internal diameter d, in mm, of the bilge main may be less than that required in Pt C, Ch 1, Sec 10, [6.8.1] but it is not to be less than that obtained from the following formula:

$$d = 35 + 3\sqrt{L_0(B + D)}$$

where:

L_0 : Length of the engine room, in m

B : Breadth of the ship, in m

D : Moulded depth of the ship to the bulkhead deck, in m.

In any case, the internal section of the bilge main is not to be less than twice that of the bilge suction pipes determined from Pt C, Ch 1, Sec 10, [6.8.3].

Attention is drawn to the requirements stated in Part C, Chapter 4 as regards the diameter to be adopted for the determination of fire pump capacity.

2.2.3 Draining of pump rooms

a) Arrangements are to be provided to drain the pump rooms by means of power pumps or bilge ejectors.

Note 1: On tankers of less than 500 gross tonnage, the pump rooms may be drained by means of hand pumps with a suction diameter of not less than 50 mm.

b) Cargo pumps or stripping pumps may be used for draining cargo pump rooms provided that:

- a screw-down non-return valve is fitted on the bilge suctions, and
- a remote control valve is fitted between the pump suction and the bilge distribution box.

c) Bilge pipe diameter is not to be less than 50 mm.

d) The bilge system of cargo pump rooms is to be capable of being controlled from outside.

e) A high level alarm is to be provided. Refer to item d) of [3.5.2].

2.2.4 Draining of tunnels and pump rooms other than cargo pump rooms

Arrangements are to be provided to drain tunnels and pump rooms other than cargo pump rooms. Cargo pumps may be used for this service under the provisions of [2.2.3], item b).

2.2.5 Draining of cofferdams located at the fore and aft ends of the cargo spaces

a) When they are not intended to be filled with water ballast, cofferdams located at the fore and aft ends of the cargo spaces are to be fitted with drainage arrangements.

b) Aft cofferdams adjacent to the cargo pump room may be drained by a cargo pump in accordance with the provisions of [2.2.3], items b) and c), or by bilge ejectors.

c) Cofferdams located at the fore end of the cargo spaces may be drained by the bilge or ballast pumps required in [2.1.4], or by bilge ejectors.

d) Drainage of the after cofferdam from the engine room bilge system is not permitted.

Note 1: On tankers of less than 500 gross tonnage, cofferdams may be drained by means of hand pumps with a suction diameter of not less than 50 mm.

2.2.6 Drainage of other cofferdams and void spaces located within the cargo area

Other cofferdams and void spaces located within the cargo area and not intended to be filled with water ballast are to be fitted with suitable means of drainage.

2.3 Ballast system

2.3.1 General

a) Every crude oil tanker of 20 000 tons deadweight and above and every product carrier of 30 000 tons deadweight and above is to be provided with segregated ballast tanks.

b) Except where expressly permitted, ballast systems serving segregated ballast tanks are to be completely separated from the cargo oil and fuel oil systems.

c) In oil tankers of 150 gross tonnage and above, no ballast water is normally to be carried in any fuel oil tank; see Pt C, Ch 1, Sec 10, [7.1.3].

d) In:

- crude oil tankers of 20 000 tons deadweight and above
- product carriers of 30 000 tons deadweight and above,

no ballast water is to be carried in cargo tanks, except in exceptional cases.

2.3.2 Ballast pumps

a) Ballast pumps are to be located in the cargo pump room, or a similar space within the cargo area not containing any source of ignition.

b) Where installed in the cargo pump room, ballast pumps are to comply with the applicable provisions of [3.2.3].

Note 1: The above provisions do not apply to tankers having one of the following service notations:

- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker, flash point > 60°C**.

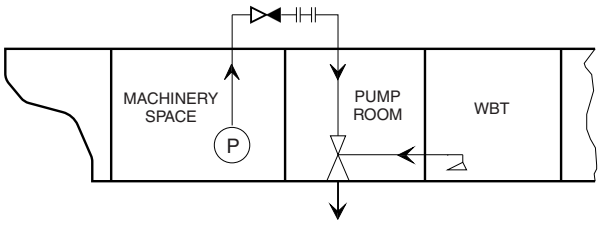
2.3.3 Pumping arrangements for ballast tanks within the cargo area

a) Segregated ballast tanks located within the cargo area are to be served by two different means. At least one of these means is to be a pump or an eductor used exclusively for dealing with ballast.

b) Pumps, ballast lines, vent lines and other similar equipment serving permanent ballast tanks shall be independent of similar equipment serving cargo tanks and of cargo tanks themselves. Discharge arrangements for permanent ballast tanks sited immediately adjacent to cargo tanks shall be outside machinery spaces and accommodation spaces. Filling arrangements may be in the machinery spaces provided that such arrangements ensure filling from tank deck level and a non-return valve and removable spool piece are fitted in the supply line outside the machinery space.

c) An eductor situated in the cargo area using water power from pumps in the machinery spaces may be accepted as a means to discharge permanent ballast from tanks and/or double bottoms adjacent to cargo tanks, provided the supply line is above deck level and a non-return valve and removable spool piece are fitted in the supply line outside the machinery space (See Fig 1).

Figure 1 : Discharge arrangement



2.3.4 Pumping arrangement for cofferdams located at the fore and aft ends of the cargo spaces

Where they are intended to be filled with water ballast, the cofferdams located at the fore and aft ends of the cargo spaces may be emptied by a ballast pump located inside the machinery compartment or the forward space mentioned in [2.1.4], whichever is the case, provided that:

- the suction is directly connected to the pump and not to a piping system serving machinery spaces
- the delivery is directly connected to the ship side.

2.3.5 Emergency discharge of segregated ballast

Provisions may be made for emergency discharge of the segregated ballast by means of a connection to a cargo pump through a detachable spool piece provided that:

- non-return valves are fitted on the segregated ballast connections to prevent the passage of oil to the ballast tank, and
- shut-off valves are fitted to shut off the cargo and ballast lines before the spool piece is removed.

The detachable spool piece is to be placed in a conspicuous position in the pump room and a permanent warning notice restricting its use is to be permanently displayed adjacent to it.

2.3.6 Carriage of ballast water in cargo tanks

a) Provisions are to be made for filling cargo tanks with sea water, where permitted. Such ballast water is to be processed and discharged using the equipment referred to in [5].

b) The sea water inlets and overboard discharges serving cargo tanks for the purpose of a) are not to have any connection with the ballast system of segregated ballast tanks.

c) Cargo pumps may be used for pumping ballast water to or from the cargo tanks, provided two shut-off valves are fitted to isolate the cargo piping system from the sea inlets and overboard discharges.

d) Ballast pumps serving segregated ballast tanks may be used for filling the cargo tanks with sea water provided that the connection is made on the top of the tanks and consists of a detachable spool piece and a screw-down non-return valve to avoid siphon effects.

2.3.7 Ballast pipes passing through tanks

a) In oil tankers of 600 tons deadweight and above, ballast piping is not to pass through cargo tanks except in the case of short lengths of piping complying with [2.1.3], item b).

b) Sliding type couplings are not to be used for expansion purposes where ballast lines pass through cargo tanks. Expansion bends only are permitted.

2.3.8 Fore peak ballast system

The fore peak tank may be ballasted with the system serving other ballast tanks within the cargo area, provided:

- the fore peak tank is considered as a hazardous area, and the hazardous area classification is defined in accordance with Ch 7, Sec 5
- the vent pipe openings are located on open deck at an appropriate distance from sources of ignition. In this respect, the hazardous zones distances are to be defined in accordance with Ch 7, Sec 5
- means are provided, on the open deck, to allow measurement of flammable gas concentrations within the tank by a suitable portable instrument
- the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:
  - In case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is provided at the manhole stating that the fore peak tank may only be opened after:
    - it has been proven to be gas free; or
    - any electrical equipment which is not certified safe in the enclosed space is isolated.
  - In case the enclosed space has a common boundary with the cargo tanks and is therefore a hazardous area, the enclosed space can be well ventilated.

2.4 Air and sounding pipes of spaces other than cargo tanks

2.4.1 Application

The provisions of [2.4] do not apply to ships having one of the following service notations:

- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker, flash point > 60°C**.

2.4.2 General

The air and sounding pipes fitted to the following spaces:

- cofferdams located at the fore and aft ends of the cargo spaces
- tanks and cofferdams located within the cargo area and not intended for cargo

are to be led to the open.

2.4.3 Air pipes

The air pipes referred to in [2.4.2] are to be arranged as per Pt C, Ch 1, Sec 10, [9] and are to be fitted with easily removable flame screens at their outlets.

2.4.4 Passage through cargo tanks

In oil tankers of 600 tons deadweight and above, the air and sounding pipes referred to in [2.4.2] are not to pass through cargo tanks except in the following cases:

- short lengths of piping serving ballast tanks
- lines serving double bottom tanks located within the cargo area, except in the case of oil tankers of 5 000 tons deadweight and above

where the provisions of [2.1.3], item b) are complied with.

2.5 Scupper pipes

2.5.1 Scupper pipes are not to pass through cargo tanks except, where this is impracticable, in the case of short lengths of piping complying with the following provisions:

- they are of steel
- they have only welded or heavy flanged joints the number of which is kept to a minimum
- they are of substantial wall thickness as per Pt C, Ch 1, Sec 10, Tab 25, column 1.

2.6 Heating systems intended for cargo

2.6.1 General

a) Heating systems intended for cargo are to comply with the relevant requirements of Pt C, Ch 1, Sec 10.

b) No part of the heating system is normally to exceed 220°C.

c) Blind flanges or similar devices are to be provided on the heating circuits fitted to tanks carrying cargoes which are not to be heated.

d) Heating systems are to be so designed that the pressure maintained in the heating circuits is higher than that exerted by the cargo oil. This need not be applied to heating circuits which are not in service provided they are drained and blanked-off.

e) Isolating valves are to be provided at the inlet and outlet connections of the tank heating circuits. Arrangements are to be made to allow manual adjustment of the flow.

f) Heating pipes and coils inside tanks are to be built of a material suitable for the heated fluid and of reinforced thickness as per Pt C, Ch 1, Sec 10, Tab 6. They are to have welded connections only.

2.6.2 Steam heating

To reduce the risk of liquid or gaseous cargo returns inside the engine or boiler rooms, steam heating systems of cargo tanks are to satisfy either of the following provisions:

- they are to be independent of other ship services, except cargo heating or cooling systems, and are not to enter machinery spaces, or
- they are to be provided with an observation tank on the water return system located within the cargo area. However, this tank may be placed inside the engine room in a well-ventilated position remote from boilers and other sources of ignition. Its air pipe is to be led to the open and fitted with a flame arrester.

2.6.3 Hot water heating

Hot water systems serving cargo tanks are to be independent of other systems. They are not to enter machinery spaces unless the expansion tank is fitted with:

- means for detection of flammable vapours
- a vent pipe led to the open and provided with a flame arrester.

2.6.4 Thermal oil heating

Thermal oil heating systems serving cargo tanks are to be arranged by means of a separate secondary system, located completely within the cargo area. However, a single circuit system may be accepted provided that:

- the system is so arranged as to ensure a positive pressure in the coil of at least 3 m water column above the static head of the cargo when the circulating pump is not in operation
- the thermal oil system expansion tank is to be fitted with high and low level alarms
- means are provided in the expansion tank for detection of flammable cargo vapours. Portable equipment may be accepted
- valves for the individual heating coils are provided with a locking arrangement to ensure that the coils are under static pressure at all times.

2.7 Use of crude oil as fuel

2.7.1 Where crude oil is intended to be used as fuel for main or auxiliary boilers or for engines, the crude oil installation is to comply with:

- the requirements of NR445, Pt D, Ch 1, Sec 19 [4], when the flashpoint is not less than that permitted under Pt C, Ch 1, Sec 1, [2.12.1]
- IMO IGF code, including the application of SOLAS II-1/55, when the flashpoint is lower than that permitted under Pt C, Ch 1, Sec 1, [2.12.1].

3 Cargo pumping and piping systems

3.1 General

3.1.1 A complete system of pumps and piping is to be fitted for handling the cargo oil. Except where expressly permitted, and namely for the bow and stern cargo loading and unloading stations, this system is not to extend outside the cargo area and is to be independent of any other piping system on board.

3.2 Cargo pumping system

3.2.1 Number and location of cargo pumps

a) Each cargo tank is to be served by at least two separate fixed means of discharging and stripping. However, for tanks fitted with an individual submerged pump, the second means may be portable.

b) Cargo pumps are to be located:

- in a dedicated pump room, or
- on deck, or
- when designed for this purpose, within the cargo tanks.

3.2.2 Use of cargo pumps

a) Except where expressly permitted in [2.2] and [2.3], cargo pumps are to be used exclusively for handling the liquid cargo and are not to have any connections to compartments other than cargo tanks.

b) Subject to their performance, cargo pumps may be used for tank stripping.

c) Cargo pumps may be used, where necessary, for the washing of cargo tanks.

3.2.3 Cargo pumps drive

a) Prime movers of cargo pumps are not to be located in the cargo area, except in the following cases:

- steam driven machine supplied with steam having a temperature not exceeding 220°C
- hydraulic motors
- electric motors in accordance with Ch 7, Sec 5, [2].

b) Pumps with a submerged electric motor are not permitted in cargo tanks.

c) Where cargo pumps are driven by a machine which is located outside the cargo pump room, the provisions of item a) of [3.5.2] are to be complied with.

3.2.4 Design of cargo pumps

a) Materials of cargo pumps are to be suitable for the products carried.

b) The delivery side of cargo pumps is to be fitted with relief valves discharging back to the suction side of the pumps (bypass) in closed circuit. Such relief valves may be omitted in the case of centrifugal pumps with a maximum delivery pressure not exceeding the design pressure of the piping, with the delivery valve closed.

c) Pump casings are to be fitted with temperature sensing devices; see Tab 4.

Note 1: The provisions of item c) above do not apply to ships having one of the following service notations:

- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker, flash point > 60°C**.

3.2.5 Monitoring of cargo pumps

Cargo pumps are to be monitored as required in Tab 4.

3.2.6 Control of cargo pumps

Cargo pumps are to be capable of being stopped from:

- a position outside the pump room, and
- a position next to the pumps.

Table 4 : Monitoring of cargo pumps

Equipment, parameter	Alarm	Indication	Comments
pump, discharge pressure	L	Local	• on the pump **(1)**, or • next to the unloading control station
pump casing, temperature **(2)**	H **(2)**		visual and audible, in cargo control room or pump control station
bearings, temperature **(2)**	H **(2)**		visual and audible, in cargo control room or pump control station
bulkhead shaft gland, temperature **(2)**	H **(2)**		visual and audible, in cargo control room or pump control station

(1) and next to the driving machine if located in a separate compartment

(2) not required for tankers having one of the following service notations:

- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker, flash point > 60°C**.

3.3 Cargo piping design

3.3.1 General

a) Unless otherwise specified, cargo piping is to be designed and constructed according to the requirements of Pt C, Ch 1, Sec 10 applicable to piping systems of:

- class III, in the case of ships having the service notation **oil tanker**
- class II, in the case of ships having the service notation **FLS tanker**, with the exception of cargo pipes and accessories having an open end or situated inside cargo tanks, for which class III may be accepted.

b) For tests, refer to [6].

3.3.2 Materials

a) For the protection of cargo tanks carrying crude oil and petroleum products having a flash point not exceeding 60°C, materials readily rendered ineffective by heat are not to be used for valves, fittings, cargo vent piping and cargo piping so as to prevent the spread of fire to the cargo.

b) Cargo piping is, in general, to be made of steel or cast iron.

c) Valves, couplings and other end fittings of cargo pipe lines for connection to hoses are to be of steel or other suitable ductile material.

d) Spheroidal graphite cast iron may be used for cargo oil piping within the double bottom or cargo tanks.

e) Grey cast iron may be accepted for cargo oil lines:

- within cargo tanks, and
- on the weather deck for pressure up to 1,6 Mpa.

It is not to be used for manifolds and their valves of fittings connected to cargo handling hoses.

f) Plastic pipes may be used in the conditions specified in Pt C, Ch 1, App 3. Arrangements are to be made to avoid the generation of static electricity.

3.3.3 Connection of cargo pipe lengths

Cargo pipe lengths may be connected either by means of welded joints or, unless otherwise specified, by means of flange connections.

3.3.4 Expansion joints

a) Where necessary, cargo piping is to be fitted with expansion joints or bends.

b) Expansion joints including bellows are to be of a type approved by the Society.

c) Expansion joints made of non-metallic material may be accepted only inside tanks and provided they are:

- of an approved type
- designed to withstand the maximum internal and external pressure
- electrically conductive.

d) In ships having the service notation **oil tanker**, sliding type couplings are not to be used for expansion purposes where lines for cargo oil pass through tanks for segregated ballast.

e) In ships having the service notation **FLS tanker**, slip joints are not to be used for cargo piping systems with the exception of pipe sections inside cargo tanks served by such sections.

3.3.5 Valves with remote control

a) Valves with remote control are to comply with Pt C, Ch 1, Sec 10, [2.7.3].

b) Submerged valves are to be remote controlled. In the case of a hydraulic remote control system, control boxes are to be provided outside the tank, in order to permit the emergency control of valves.

c) Valve actuators located inside cargo tanks are not to be operated by means of compressed air.

3.3.6 Cargo hoses

a) Cargo hoses are to be of a type approved by the Society for the intended conditions of use.

b) Hoses subject to tank pressure or pump discharge pressure are to be designed for a bursting pressure not less than 5 times the maximum pressure under cargo transfer conditions.

c) Unless bonding arrangements complying with Section 6 are provided, the ohmic electrical resistance of cargo hoses is not to exceed 10^6 Ω.

3.4 Cargo piping arrangement and installation

3.4.1 Cargo pipes passing through tanks or compartments

a) Cargo piping is not to pass through tanks or compartments located outside the cargo area.

b) Cargo piping and similar piping to cargo tanks is not to pass through ballast tanks except in the case of short lengths of piping complying with [2.1.3], item b).

c) Cargo piping may pass through vertical fuel oil tanks adjacent to cargo tanks on condition that the provisions of [2.1.3], item b) are complied with.

d) Cargo piping passing through cargo tanks is to comply with the provisions of Ch 7, Sec 2, [3.4.1].

3.4.2 Cargo piping passing through bulkheads

Cargo piping passing through bulkheads is to be so arranged as to preclude excessive stresses at the bulkhead. Bolted flanges are not to be used in the bulkhead.

3.4.3 Valves

a) Stop valves are to be provided to isolate each tank.

b) A stop valve is to be fitted at each end of the cargo manifold.

c) When a cargo pump in the cargo pump room serves more than one cargo tank, a stop valve is to be fitted in the cargo pump room on the line leading to each tank.

d) Main cargo oil valves located in the cargo pump room below the floor gratings are to be remote controlled from a position above the floor.

e) Valves are also to be provided where required by Ch 7, Sec 2, [3.4.1].

3.4.4 Prevention of the generation of static electricity

a) In order to avoid the generation of static electricity, the loading pipes are to be led as low as practicable in the tank.

b) Cargo pipe sections and their accessories are to be electrically bonded together and to the ship's hull.

Note 1: The provisions of [3.4.4] do not apply to ships having one of the following service notations:

- **oil tanker / flash point > 60°C**
- **oil tanker / asphalt carrier**
- **FLS tanker, flash point > 60°C**.

3.4.5 Bow or stern cargo loading and unloading arrangements

Where the ship is arranged for loading and unloading outside the cargo area, the following provisions are to be complied with:

a) The piping outside the cargo area is to be fitted with a shut-off valve at its connection with the piping system within the cargo area and separating means such as blank flanges or removable spool pieces are to be provided when the piping is not in use, irrespective of the number and type of valves in the line

b) The shore connection is to be fitted with a shut-off valve and a blank flange

c) Pipe connections outside the cargo area are to be of welded type only

d) Arrangements are made to allow the piping outside the cargo area to be efficiently drained and purged.

Note 1: The provisions of [3.4.5] do not apply to ships having one of the following service notations:

- **oil tanker / flash point > 60°C**
- **oil tanker / asphalt carrier**
- **FLS tanker, flash point > 60°C**.

3.4.6 Draining of cargo pumps and oil lines

Every oil tanker required to be provided with segregated ballast tanks or fitted with a crude oil washing system is to comply with the following requirements:

a) It is to be equipped with oil piping so designed and installed that oil retention in the lines is minimised, and

b) Means are to be provided to drain all cargo pumps and all oil lines at the completion of cargo discharge, where necessary by connection to a stripping device. The line and pump drainings are to be capable of being discharged both ashore and to a cargo tank or slop tank. For discharge ashore, a special small diameter line having a cross-sectional area not exceeding 10% of the main cargo discharge line is to be provided and is to be connected on the downstream side of the tanker's deck manifold valves, both port and starboard, when the cargo is being discharged; see Fig 2.

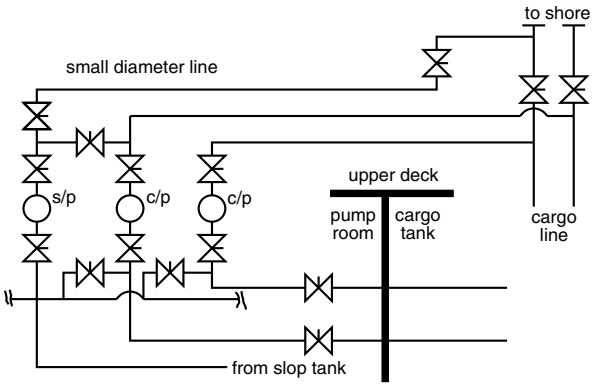
For oil tankers fitted with a crude oil washing system, refer also to Ch 7, App 2, [2.4.5].

3.4.7 Cleaning and gas-freeing

a) The cargo piping system is to be so designed and arranged as to permit its efficient cleaning and gas-freeing.

b) Requirements for inert gas systems are given in Ch 7, Sec 6, [5].

Figure 2 : Connection of small diameter line to the manifold valve



3.5 Arrangement of cargo pump rooms

3.5.1 Pump room ventilation

In addition to the provisions of Ch 7, Sec 2, [2.3.3], the ventilation of the cargo pump room is to comply with the following provisions:

a) *Cargo pump rooms are to be mechanically ventilated and discharges from exhaust fans are to be led to a safe place on the open deck. The ventilation of these rooms is to have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of changes of air is to be at least 20 per hour, based upon the gross volume of the space. The air ducts are to be arranged so that all of the space is effectively ventilated. The ventilation is to be of the suction type using fans of the non-sparking type.*

b) The ventilation ducts are to be so arranged that their suction is just above the transverse floor plates or bottom longitudinals in the vicinity of bilges.

c) An emergency intake located about 2 m above the pump room lower grating is to be provided. It is to be fitted with a damper capable of being opened or closed from the exposed main deck and lower grating level.

Ventilation through the emergency intake is to be effective when the lower intakes are sealed off due to flooding in the bilges.

d) The foregoing exhaust system is in association with open grating floor plates to allow the free flow of air.

e) Arrangements involving a specific ratio of areas of upper emergency and lower main ventilator openings, which can be shown to result in at least the required 20 air changes per hour through the lower inlets, can be adopted without the use of dampers. When the lower access inlets are closed then at least 15 air changes per hour should be obtained through the upper inlets.

3.5.2 Measures to prevent explosions

The provisions of [3.5.2] do not apply to ships having one of the following service notations:

- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker, flash point > 60°C**,

except where the cargo is carried at a temperature within 15°C of its flash point.

a) Where cargo pumps, ballast pumps and stripping pumps are driven by a machine which is located outside the cargo pump room, the following arrangements are to be made:

1) drive shafts are to be fitted with flexible couplings or other means suitable to compensate for any misalignment

2) the shaft bulkhead or deck penetration is to be fitted with a gas-tight gland of a type approved by the Society. The gland is to be efficiently lubricated from outside the pump room and so designed as to prevent overheating. The seal parts of the gland are to be of a material that cannot initiate sparks. The glands are to be constructed and fitted in accordance with the relative rules for fittings attached to watertight bulkheads, and if a bellows piece is incorporated in the design, it should be pressure tested before fitting.

3) *Temperature sensing devices are to be fitted for bulkhead shaft glands, bearings and pump casings. A continuous audible and visual alarm signal shall be automatically effected in the cargo control room or the pump control station.*

b) To discourage personnel from entering the cargo pump room when the ventilation is not in operation, the *lighting in the cargo pump room is to be interlocked with ventilation such that ventilation is to be in operation to energise the lighting.*

Failure of the ventilation system is not to cause the lighting to go out.

Where the lighting in cargo pump rooms can be commonly used as the emergency lighting, this lighting should be interlocked with the ventilation systems. However, this interlock should not prevent operation of the emergency lighting in case of loss of the main source of electrical power.

c) A system for continuously monitoring the concentration of hydrocarbon gases is to be fitted. Sampling points or detector heads are to be located in suitable positions in order that potentially dangerous leakages are readily detected. Sequential sampling is acceptable as long as it is dedicated for the pump room only, including exhaust ducts, and the sampling time is reasonably short. Detection positions are the zones where air circulation is reduced (e.g. recessed corners). *When the hydrocarbon gas concentration reaches a pre-set level, which shall not be higher than 10 per cent of the lower flammable limit (LFL), a continuous audible and visual alarm signal shall be automatically effected in the pump room, engine control room, cargo control room and navigation bridge to alert personnel to the potential hazard.*

d) All pump rooms are to be provided with bilge level monitoring devices together with appropriately located alarms or bilge high level alarms.

High liquid level in the bilges is to activate an audible and visual alarm in the cargo control room and on the navigation bridge.

3.6 Design of integrated cargo and ballast systems on tankers

3.6.1 Application

The following requirements are applicable to integrated cargo and ballast systems installed on tankers (i.e. cargo ships constructed or adapted for the carriage of liquid cargoes in bulk), irrespective of the size or type of the tanker.

Within the scope of these requirements, integrated cargo and ballast system means any integrated hydraulic and/or electric system used to drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).

3.6.2 Functional requirements

The operation of cargo and/or ballast systems may be necessary, under certain emergency circumstances or during the course of navigation, to enhance the safety of tankers.

As such, measures are to be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system, including its control and safety systems.

3.6.3 Design features

The following design features are, inter alia, to be fitted:

a) The emergency stop circuits of the cargo and ballast systems are to be independent from the circuits for the control systems. A single failure in the control system circuits or the emergency stop circuits are not to render the integrated cargo and ballast system inoperative.

b) Manual emergency stops of the cargo pumps are to be arranged in a way that they are not to cause the stop of the power pack making ballast pumps inoperable.

c) The control systems are to be provided with backup power supply, which may be satisfied by a duplicate power supply from the main switch board. The failure of any power supply is to provide audible and visible alarm activation at each location where the control panel is fitted.

d) In the event of failure of the automatic or remote control systems, a secondary means of control is to be made available for the operation of the integrated cargo and ballast system.This is to be achieved by manual overriding and/or redundant arrangements within the control systems.

4 Cargo tanks and fittings

4.1 Application

4.1.1

a) The provisions of Article [4] apply to cargo tanks and slop tanks.

b) The provisions of Article [4] apply for the various service notations in accordance with Tab 5.

Table 5 : Requirements applicable to cargo tanks according to the service notations

Reference of item	Subject	Service notations to which the item applies	Substitutive requirements for service notations to which the item does not apply
[4.2]	tank venting	• **oil tanker** • **FLS tanker**	• The relevant provisions of Pt C, Ch 1, Sec 10, [9] and Pt C, Ch 1, Sec 10, [11]are to be complied with. • Tank venting systems are to open to the atmosphere at a height of at least 760 mm above the weather deck **(1)**. • Tanks may be fitted with venting systems of the open type provided with a flame screen.
[4.3]	tank purging/ gas-freeing	• **oil tanker** • **FLS tanker**	No requirement
[4.4]	tank level gauging	• **oil tanker** • **FLS tanker**	• The relevant provisions of Pt C, Ch 1, Sec 10, [9] and Pt C, Ch 1, Sec 10, [11] are to be complied with. • Tanks may be fitted with gauging systems of the open type, such as a hand sounding pipe or other portable gauging devices.
[4.5]	protection against tank overload	• **oil tanker** • **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier** • **FLS tanker** • **FLS tanker, flash point > 60°C**	
[4.6]	tank washing	• **oil tanker** • **oil tanker, flash point > 60°C** • **oil tanker, asphalt carrier**	
(1) For ships having the notation **oil tanker, flash point > 60°C** and carrying bulk cargoes at a temperature exceeding flash point-15°C, this height is to be increased to 2,4 m.			

4.2 Cargo tank venting

4.2.1 Principle

Cargo tanks are to be provided with venting systems *entirely distinct from the air pipes of the other compartments of the ship. The arrangements and position of openings in the cargo tank deck from which emission of flammable vapours can occur are to be such as to minimise the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard.*

4.2.2 Design of venting arrangements

The venting arrangements are to be so designed and operated as to ensure that neither pressure nor vacuum in cargo tanks exceeds design parameters and be such as to provide for:

a) The flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves, and

b) The passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging,

c) A secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or under pressure in the event of failure of the arrangements in b). In addition, the secondary means shall be capable of preventing over-pressure or under-pressure in the event of damage to, or inadvertent closing of, the means of isolation required in [4.2.3] item b). Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required in b), with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of overpressure or under pressure conditions within a tank.

Note 1: Note 1: For ships that apply pressure sensors in each tank as an alternative secondary means of venting as allowed above, the setting of the over-pressure alarm shall be above the pressure setting of the P/V valve and the setting of the under-pressure alarm shall be below the vacuum setting of the P/V valve. The alarm settings are to be within the design pressures of the cargo tanks. The settings are to be fixed and not arranged for blocking or adjustment in operation. However, for ships that carry different types of cargo and use P/V valves with different settings (one setting for each type of cargo), the settings may be adjusted to account for the different types of cargo.

4.2.3 Combination of venting arrangements

a) The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

b) Where the arrangements are combined with other cargo tanks, either stop valves or other acceptable means are to be provided to isolate each cargo tank. Where stop valves are fitted, they are to be provided with locking arrangements which are to be under the control of the responsible ship's officer. There is to be a clear visual indication of the operational status of the valves or other acceptable means. Where tanks have been isolated, it is to be ensured that relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced. Any isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with [4.2.2].

Any isolation shall also continue to permit the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging in accordance with [4.2.2].

c) If cargo loading and ballasting or discharging of a cargo tank or cargo tank group is intended, which is isolated from a common venting system, that cargo tank or cargo tank group is to be fitted with a means for overpressure or under pressure protection as required in [4.2.2].

4.2.4 Arrangement of vent lines

The venting arrangements are to be connected to the top of each cargo tank and are to be self-draining to the cargo tanks under all normal conditions of trim and list of the ship. Where it may not be possible to provide self-draining lines, permanent arrangements are to be provided to drain the vent lines to a cargo tank.

Plugs or equivalent means are to be provided on the lines after the safety relief valves.

4.2.5 Pressure/vacuum valves

a) Pressure/vacuum valves are to be set at a positive pressure not exceeding 0,021 N/mm^2 and at a negative pressure not exceeding 0,007 N/mm^2.

Note 1: Higher setting values not exceeding 0,07 *N/mm^2* may be accepted in positive pressure if the scantlings of the tanks are appropriate.

b) Pressure/vacuum valves required by [4.2.2] may be provided with a bypass when they are located in a vent main or masthead riser. Where such an arrangement is provided, there are to be suitable indicators to show whether the bypass is open or closed.

c) Pressure/vacuum valves are to be of a type approved by the Society in accordance with Ch 7, App 1.

d) Pressure/vacuum valves are to be readily accessible.

e) Pressure/vacuum valves are to be provided with a manual opening device so that valves can be locked on open position. Locking means on closed position are not permitted.

4.2.6 Vent outlets

Openings for pressure release required by [4.2.2] item a) and *vent outlets for cargo loading, discharging and ballasting required by [4.2.2] item b) are to:*

a) Permit:

- *the free flow of vapour mixtures, or*
- *the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/s,*

b) Be so arranged that the vapour mixture is discharged vertically upwards,

c) Where the method is by free flow of vapour mixtures, be such that the outlet is not less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard,

d) Where the method is by high velocity discharge, be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard. These outlets are to be provided with high velocity devices of a type approved by the Society,

e) Be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1,25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The Master is to be provided with information regarding the maximum permissible loading rate for each cargo tank and in the case of combined venting systems, for each group of cargo tanks.

4.2.7 High velocity valves

a) High velocity valves are to be readily accessible.

b) High velocity valves not required to be fitted with flame arresters (see [4.2.8]) are not to be capable of being locked on open position.

4.2.8 Prevention of the passage of flame into the tanks

a) The venting system is to be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices are to comply with Ch 7, App 1.

b) A flame arresting device integral to the venting system may be accepted.

c) Flame screens and flame arresters are to be designed for easy overhauling and cleaning.

d) Ullage openings shall not be used for pressure equalization. They shall be provided with self-closing and tightly sealing covers. Flame arresters and screens are not permitted in these openings.

4.2.9 Prevention of liquid rising in the venting system

a) Provisions are to be made to prevent liquid rising in the venting system; refer to [4.5].

b) Cargo tanks gas venting systems are not to be used for overflow purposes.

c) Spill valves are not considered equivalent to an overflow system.

4.2.10 Additional provisions for ships fitted with an inert gas system

a) On ships fitted with an inert gas system, *one or more pressure/vacuum-breaking devices are to be provided to prevent the cargo tanks from being subject to:*

1) a positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum rated capacity and all other outlets are left shut, and

2) a negative pressure in excess of 700 mm water gauge if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices are to be installed on the inert gas main unless they are installed in the venting system required by [4.2.1] or on individual cargo tanks.

b) The location and design of the devices referred to in paragraph a) above are to be in accordance with requirements [4.2.1] to [4.2.9].

4.3 Cargo tank inerting, purging and/or gas-freeing

4.3.1 General

a) Arrangements are to be made for purging and/or gas-freeing of cargo tanks. The arrangements *are to be such as to minimise the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in a cargo tank. Accordingly, the provisions of [4.3.2] and [4.3.3], as applicable, are to be complied with.*

b) The arrangements for inerting, purging or gas-freeing of empty tanks as required in Pt C, Ch 4, Sec 15, [13.3.1], item b), are to be to the satisfaction of the Society and are to be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimized.

c) Ventilation/gas-freeing lines between fans and cargo tanks are to be fitted with means, such as detachable spool pieces, to prevent any back-flow of hydrocarbon gases through the fans when they are not used.

d) Discharge outlets are to be located at least 10 m measured horizontally from the nearest air intake and openings to enclosed spaces with a source of ignition and from deck machinery equipment which may constitute an ignition hazard.

4.3.2 Ships provided with an inert gas system

The following provisions apply to ships provided with an inert gas system:

a) On individual cargo tanks the gas outlet pipe, if fitted, is to be positioned as far as practicable from the inert gas / air inlet and in accordance with [4.2]. The inlet of such outlet pipes may be located either at the deck level or at not more than 1 m above the bottom of the tank.

b) The cross-sectional area of such gas outlet pipe referred to in a) above is to be such that an exit velocity of at least 20 m/s can be maintained when any three tanks are being simultaneously supplied with inert gas. Their outlets are to extend not less than 2 m above deck level.

c) Each gas outlet referred to in b) above is to be fitted with suitable blanking arrangements.

d) The arrangement of inert gas and cargo piping systems is to comply with the provisions of Pt C, Ch 4, Sec 15, [13.3.3], item b) 7).

e) The cargo tanks are first to be purged in accordance with the provisions of a) to d) above until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than 2% by volume. Thereafter, gas-freeing may take place at the cargo tank deck level.

4.3.3 Ships not provided with an inert gas system

When the ship is not provided with an inert gas system, the operation is to be such that the flammable vapour is discharged initially:

a) Through the vent outlets as specified in [4.2.6], or

b) Through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas-freeing operation, or

c) Through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/s and which are protected by suitable devices to prevent the passage of flame.

When the flammable vapour concentration at the outlet has been reduced to 30% of the lower flammable limit, gas-freeing may thereafter be continued at cargo tank deck level.

4.4 Cargo tank level gauging systems

4.4.1 General

a) Each cargo or slop tank is to be fitted with a level gauging system indicating the liquid level along the entire height of the tank. Unless otherwise specified, the gauge may be portable or fixed with local reading.

b) Gauging devices and their remote reading systems are to be type approved.

c) Ullage openings and other gauging devices likely to release cargo vapour to the atmosphere are not to be arranged in enclosed spaces.

4.4.2 Definitions

a) A “restricted gauging device” means a device which penetrates the tank and which, when in use, permits a small quantity of vapour or liquid to be exposed to the atmosphere. When not in use, the device is completely closed. Examples are sounding pipes.

b) A “closed gauging device” means a device which is separated from the tank atmosphere and keeps tank contents from being released. It may:

- penetrate the tank, such as float-type systems, electric probe, magnetic probe or protected sight glass,
- not penetrate the tank, such as ultrasonic or radar devices.

c) An “indirect gauging device” means a device which determines the level of liquid, for instance by means of weighing or pipe flow meter.

4.4.3 Tankers fitted with an inert gas system

a) In tankers fitted with an inert gas system, the gauging devices are to be of the closed type.

b) Use of indirect gauging devices will be given special consideration.

4.4.4 Tankers not fitted with an inert gas system

a) In tankers not fitted with an inert gas system, the gauging devices are to be of the closed or restricted types. Ullage openings may be used only as a reserve sounding means and are to be fitted with a watertight closing appliance.

b) Where restricted gauging devices are used, provisions are to be made to:

- avoid dangerous escape of liquid or vapour under pressure when using the device
- relieve the pressure in the tank before the device is operated.

c) Where used, sounding pipes are to be fitted with a a self-closing blanking device.

4.5 Protection against tank overfilling

4.5.1 General

a) Provisions are to be made to guard against liquid rising in the venting system of cargo or slop tanks to a height which would exceed the design head of the tanks. This is to be accomplished by high level alarms or overflow control systems or other equivalent means, together with gauging devices and cargo tank filling procedures.

Note 1: For ships having the service notation **FLS tanker**, only high level alarms are permitted.

b) Sufficient ullage is to be left at the end of tank filling to permit free expansion of liquid during carriage.

c) High level alarms, overflow control systems and other means referred to in a) are to be independent of the gauging systems referred to in [4.4].

4.5.2 High level alarms

a) High level alarms are to be type approved.

b) High level alarms are to give an audible and visual signal at the control station, where provided.

4.5.3 Other protection systems

a) Where the tank level gauging systems, cargo and ballast pump control systems and valve control systems are centralised in a single location, the provisions of [4.5.1] may be complied with by the fitting of a level gauge for the indication of the end of loading, in addition to that required for each tank under [4.4]. The readings of both gauges for each tank are to be as near as possible to each other and so arranged that any discrepancy between them can be easily detected.

b) Where a tank can be filled only from other tanks, the provisions of [4.5.1] are considered as complied with.

4.6 Tank washing systems

4.6.1 General

a) Adequate means are to be provided for cleaning the cargo tanks.

b) Every crude oil tanker of 20 000 tons deadweight and above is to be fitted with a cargo tank cleaning system using crude oil washing and complying with Ch 7, App 2.

c) Crude oil washing systems fitted on oil tankers other than crude oil tankers of 20 000 tons deadweight or above are to comply with the provisions of Ch 7, App 2 related to safety.

4.6.2 Washing machines

a) Tank washing machines are to be of a type approved by the Society.

b) Washing machines are to be made of steel or other electricity conducting materials with a limited propensity to produce sparks on contact.

4.6.3 Washing pipes

a) Washing pipes are to be built, fitted, inspected and tested in accordance with the applicable requirements of Pt C, Ch 1, Sec 10, depending on the kind of washing fluid, water or crude oil.

b) Crude oil washing pipes are also to satisfy the requirements of Article [3.3].

4.6.4 Use of crude oil washing machines for water washing operations

Crude oil washing machines may be connected to water washing pipes, provided that isolating arrangements, such as a valve and a detachable pipe section, are fitted to isolate water pipes.

4.6.5 Installation of washing systems

a) Tank cleaning openings are not to be arranged in enclosed spaces.

b) The complete installation is to be permanently earthed to the hull.

5 Prevention of pollution by cargo oil

5.1 General

5.1.1 Application

a) Unless otherwise specified, the provisions of [5.3] apply only to ships having the service notations **oil tanker** or **oil tanker, flash point > 60°C** and of 150 gross tonnage and above.

b) The provisions of Ch 7, Sec 2, [3.6]are to be complied with.

5.1.2 Provisions for oil tankers of less than 150 gross tonnage

The control of discharge for ships having the service notations **oil tanker** or **oil tanker, flash point > 60°C** and of less than 150 gross tonnage is to be effected by the retention of oil on board with subsequent discharge of all contaminated washings to reception facilities unless adequate arrangements are made to ensure that the discharge of any effluent which is allowed to be discharged into the sea is effectively monitored to ensure that the total quantity of oil discharged into the sea does not exceed 1/30 000 of the total quantity of the particular cargo of which the residue formed a part.

5.1.3 Exemptions

a) The provisions of [5.3] may be waived in the following cases:

- oil tankers which engage exclusively on both voyages of 72 hours or less in duration and within 50 miles from the nearest land, provided that the oil tanker is engaged exclusively in trades between ports or terminals within a State Party to MARPOL 73/78 Convention. Any such waiver is to be subject to the requirements that the oil tanker is to retain on board all oily mixtures for subsequent discharge to reception facilities and to the determination by the Administration that facilities available to receive such oily mixtures are adequate,
- oil tankers carrying products which through their physical properties inhibit effective product/water separation and monitoring, for which the control of discharge is to be effected by the retention of residues on board with discharge of all contaminated washings to reception facilities.

b) Where, in the view of the Society, the equipment referred to in [5.3.1] and [5.3.2] is not obtainable for the monitoring of discharge of oil refined products (white oils), compliance with such requirements may be waived provided that discharge is performed only in compliance with the applicable procedures.

5.2 Discharge into the sea of cargo oil or oily mixtures

5.2.1 *Any discharge into the sea of cargo oil or oily mixtures is to be prohibited except when all the following conditions are satisfied:*

a) the tanker is not within a special area,

Note 1: Special areas are defined in MARPOL Annex I, regulation (9).

b) The tanker is more than 50 nautical miles from the nearest land.

c) The tanker is proceeding on route.

d) The instantaneous rate of discharge of oil content does not exceed 30 litres per nautical mile.

e) The total quantity of oil discharged into the sea does not exceed 1/30000 of the total quantity of the particular cargo of which the residue formed a part.

f) The tanker has in operation an oil discharge and monitoring system complying with the provisions of [5.3] and a slop tank arrangement as required by Ch 7, Sec 2, [3.6].

5.2.2 *The provisions of [5.2.1] are not to apply to the discharge of segregated ballast.*

5.2.3 *The cargo oil residues which cannot be discharged into the sea in compliance with [5.2.1] above are to be retained on board or discharged to reception facilities.*

5.3 Oil discharge monitoring and control system

5.3.1 General

a) An oil discharge monitoring and control system is to be fitted.

b) A manually operated alternative method is to be provided.

5.3.2 Design of the discharge monitoring and control system

a) The discharge monitoring and control system is to be of a type approved in compliance with the provisions of IMO Resolution MEPC 108(49), as amended.

b) The discharge monitoring and control system is to be fitted with a recording device to provide a continuous record of the discharge in litres per nautical mile and total quantity discharged, or the oil content and rate of discharge. This record is to be identifiable as regards time and date.

c) The oil discharge monitoring and control system is to come into operation when there is any discharge of effluent into the sea and is to be such as will ensure that any discharge of oily mixture is automatically stopped when the instantaneous rate of discharge of oil content exceeds 30 litres per nautical mile.

d) Any failure of the monitoring and control system is to stop the discharge.

5.3.3 Oil/water interface detectors

Effective oil/water interface detectors approved by the Society are to be provided for a rapid and accurate determination of the oil/water interface in slop tanks and are to be available for use in other tanks where the separation of oil and water is effected and from which it is intended to discharge effluent directly to the sea.

5.4 Pumping, piping and discharge arrangements

5.4.1 Discharge manifold

In every oil tanker, a discharge manifold for connection to reception facilities for the discharge of dirty ballast water or oil contaminated water is to be located on the open deck on both sides of the ship.

5.4.2 Discharge pipelines

In every oil tanker, pipelines for the discharge of ballast water or oil contaminated water from cargo tank areas to the sea, where permitted, are to be led to the open deck or to the ship side above the waterline in the deepest ballast condition, except that:

a) Segregated ballast and clean ballast may be discharged below the waterline:

- in ports or at offshore terminals, or
- at sea by gravity,

provided that the surface of the ballast water has been examined immediately before the discharge to ensure that no contamination with oil has taken place.

b) On every oil tanker at sea, dirty ballast water or oil contaminated water from tanks in the cargo area, other than slop tanks, may be discharged by gravity below the waterline, provided that sufficient time has elapsed in order to allow oil/water separation to have taken place and the water ballast has been examined immediately before the discharge with an oil/water interface detector referred to in [5.3.3], in order to ensure that the height of the interface is such that the discharge does not involve any increased risk of harm to the marine environment.

5.4.3 Discharge stopping

Means are to be provided for stopping the discharge into the sea of ballast water or oil contaminated water from cargo tank areas, other than those discharges below the waterline permitted under [5.4.2], from a position on the upper deck or above located so that the manifold in use referred to in [5.4.1] and the discharge to the sea from the pipelines referred to in [5.4.2] may be visually observed. Means for stopping the discharge need not be provided at the observation position if a positive communication system such as a telephone or radio system is provided between the observation position and the discharge control position.

6 Certification, inspection and testing

6.1 Application

6.1.1 The provisions of this Article are related to cargo piping and other equipment fitted in the cargo area. They supplement those given in Pt C, Ch 1, Sec 10, [20] for piping systems.

6.2 Workshop tests

6.2.1 Tests for materials

Where required in Tab 6, materials used for pipes, valves and fittings are to be subjected to the tests specified in Pt C, Ch 1, Sec 10, [20.4.2].

6.2.2 Inspection of welded joints

Where required in Tab 6, welded joints are to be subjected to the examinations specified in Pt C, Ch 1, Sec 10, [3.6] for class II pipes.

6.2.3 Hydrostatic testing

a) Where required in Tab 6, cargo pipes, valves, fittings and pump casings are to be submitted to hydrostatic tests in accordance with the relevant provisions of Pt C, Ch 1, Sec 10, [20.5].

b) Expansion joints and cargo hoses are to be submitted to hydrostatic tests in accordance with the relevant provisions of Pt C, Ch 1, Sec 10, [20.5].

c) Where fitted, bellow pieces of gas-tight penetration glands are to be pressure tested.

6.2.4 Tightness tests

Tightness of the following devices is to be checked:

- gas-tight penetration glands
- cargo tank P/V and high velocity valves.

Note 1: These tests may be carried out in the workshops or on board.

6.2.5 Check of the safety valves setting

The setting pressure of the pressure/vacuum valves is to be checked in particular with regard to [4.2.5].

6.2.6 Summarising table

Inspections and tests required for cargo piping and other equipment fitted in the cargo area are summarised in Tab 6.

6.3 Shipboard tests

6.3.1 Pressure test

a) After installation on board, the cargo piping system is to be checked for leakage under operational conditions.

b) The piping system used in crude oil washing systems is to be submitted to hydrostatic tests in accordance with Ch 7, App 2, [3.2.1].

6.3.2 Survey of pollution prevention equipment

Every ship having the service notations **oil tanker** or **oil tanker, flash point > 60°C** and of 150 gross tonnage and above is to be subjected to an initial survey before the ship is put in service, to ensure that the equipment, systems, fittings, arrangements and materials fully comply with the relevant provisions of [4.6] and [5].

Table 6 : Inspection and testing at works

No.	Item	Tests for materials		Inspections and tests for the products			References to the Rules
		Y/N **(1)**	Type of material certificate **(2)**	during manufacturing **(1)**	after completion **(1) (3)**	Type of product certificate **(2)**	
1	pipes, valves and fittings of class II (see [3.3.1])	Y	• C where ND > 100mm • W where ND ≤ 100mm	Y **(4)**	Y	C	[6.2.1] [6.2.1] [6.2.2] [6.2.3]
2	expansion joints and cargo hoses	Y **(5)**	W	N	Y	C	[6.2.1] [6.2.3]
3	cargo pumps	Y	• C for cast body • W for welded construction	Y **(6)**	Y	C	see note **(6)** [6.2.3]
4	gas-tight penetration glands	N		N	Y	C	[6.2.3], [6.2.4]
5	cargo tank P/V and high velocity valves	Y	W	Y	Y	C	[6.2.1] [6.2.2] [6.2.3], [6.2.4]
6	flame arresters	N		N	Y	C	see note **(3)**
7	Oil discharge monitoring and control system	N			Y **(7)**	C	see note **(3)**
8	Oil/water interface detector	N			Y **(7)**	C	see note **(3)**

(1) Y = required, N = not required.
(2) C = class certificate, W = works' certificate.
(3) includes the checking of the rule characteristics according to the approved drawings.
(4) only in the case of welded construction.
(5) if metallic.
(6) inspection during manufacturing is to be carried out according to a program approved by the Society.
(7) may also be carried out on board.

7 Steering gear

7.1 General

7.1.1 In addition to the provisions of Pt C, Ch 1, Sec 14, the steering gear of ships having the service notation **oil tanker** or **FLS tanker** and of 10000 gross tonnage and above is to comply with the requirements of [7].

7.2 Design of the steering gear

7.2.1 *In every tanker of 10 000 gross tonnage and upwards, the main steering gear shall comprise two or more identical power units complying with the provisions of Pt C, Ch 1, Sec 14, [2.4.2].*

7.2.2 *Every tanker of 10 000 gross tonnage and upwards is, subject to the provisions of [7.3], to comply with the following:*

a) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in not more than 45 s after the loss of one power actuating system.

b) The main steering gear is to comprise either:

1) two independent and separate power actuating systems, each capable of meeting the requirements of Pt C, Ch 1, Sec 14, [2.2.1]; The two independent power actuating systems are to be so arranged that a mechanical or electrical failure in one of them will not render the other one inoperative, and be in accordance with Pt C, Ch 1, Sec 14, [2.3.3]; or

2) at least two identical power actuating systems which, acting simultaneously in normal operation, are to be capable of meeting the requirements of Pt C, Ch 1, Sec 14, [2.2.1]. Where necessary to comply with this requirement, interconnection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems remain(s) fully operational

c) Steering gear other than that of the hydraulic type is to achieve equivalent standards.

7.3 Alternative design for ships of less than 100 000 tonnes deadweight

7.3.1 General

For tankers of 10 000 gross tonnage and upwards, but of less than 100 000 tons deadweight, solutions other than those set out in [7.2], which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety standard is achieved and that:

a) Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 s; and

b) Where the steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, to the material used, to the installation of sealing arrangements and to testing and inspection and to the provision of effective maintenance.

7.3.2 Materials

Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder stock are to be made of duly tested ductile materials complying with recognised standards. Materials for pressure retaining components are to be in accordance with recognised pressure vessel standards. These materials are not to have an elongation of less than 12% or a tensile strength in excess of 650 N/mm^2.

7.3.3 Design

a) Design pressure

The design pressure is assumed to be at least equal to the greater of the following:

1) 1,25 times the maximum working pressure to be expected under the operating conditions required in Pt C, Ch 1, Sec 14, [2.2.1]

2) the relief valve setting.

b) Analysis

1) The manufacturers of rudder actuators are to submit detailed calculations showing the suitability of the design for the intended service

2) A detailed stress analysis of the pressure retaining parts of the actuator is to be carried out to determine the stress at the design pressure

3) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with the analyses, all foreseen dynamic loads are to be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending on the complexity of the design.

c) *Allowable stresses*

For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses are not to exceed:

- $\sigma_m \leq f$
- $\sigma_l \leq 1,5\ f$
- $\sigma_b \leq 1,5\ f$
- $\sigma_l + \sigma_b \leq 1,5\ f$
- $\sigma_m + \sigma_b \leq 1,5\ f$

where:

σ_m : *Equivalent primary general membrane stress*

σ_l : *Equivalent primary local membrane stress*

σ_b : *Equivalent primary bending stress*

f : *The lesser of σ_B/A or σ_y/B*

σ_B : *Specified minimum tensile strength of material at ambient temperature*

σ_y : *Specified minimum yield stress or 0,2% proof stress of material at ambient temperature*

A : *Equal to:*

- *4,0 for steel*
- *4,6 for cast steel*
- *5,8 for nodular cast iron*

B : *Equal to:*

- *2,0 for steel*
- *2,3 for cast steel*
- *3,5 for nodular cast iron*

d) *Burst test*

1) *Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test at the discretion of the Society and the detailed stress analysis required by [7.3.3], item b), need not be provided.*

2) *The minimum bursting pressure is to be calculated as follows:*

$$P_b = P \cdot A \cdot \frac{\sigma_{Ba}}{\sigma_B}$$

where:

P_b : *Minimum bursting pressure*

P : *Design pressure as defined in [7.3.3], item a)*

A : *As from [7.3.3], item c)*

σ_{Ba} : *Actual tensile strength*

σ_B : *Tensile strength as defined in [7.3.3], item c).*

7.3.4 Construction details

a) *General*

The construction is to be such as to minimise the local concentration of stress.

b) *Welds*

1) *The welding details and welding procedures are to be approved.*

2) *All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.*

c) *Oil seals*

1) *Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.*

2) *Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted at the discretion of the Society.*

d) *Isolating valves*

Isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly mounted on the actuator.

e) Relief valves

Relief valves for protecting the rudder actuator against overpressure as required in Pt C, Ch 1, Sec 14, [2.6.5] are to comply with the following:

1) The setting pressure is not to be less than 1,25 times the maximum working pressure expected under operating conditions required in Pt C, Ch 1, Sec 14, [2.2.1], item b)

2) The minimum discharge capacity of the relief valves is not to be less than the total capacity of all pumps which provide power for the actuator, increased by 10 per cent. Under such conditions, the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

7.3.5 Inspection and testing

a) Non-destructive testing

The rudder actuator is to be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing is to be in accordance with requirements of recognised standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

b) Other testing

1) Tests, including hydrostatic tests, of all pressure parts at 1,5 times the design pressure are to. be carried out.

2) When installed on board the ship, the rudder actuator is to be subjected to a hydrostatic test and a running test.

8 Additional requirements for ships assigned the additional service feature asphalt carrier

8.1 Application

8.1.1 The provisions of this Article apply, in addition to those contained in Articles [1] to [7] above, to oil tankers assigned the additional service feature **asphalt carrier**.

8.2 Additional requirements

8.2.1 Heating systems

a) Cargo tanks intended for the carriage of asphalt solutions are to be equipped with a heating system capable of preserving the asphalt solutions in their liquid state. Valves are to be fitted on the heating system inlet and outlet.

b) Cargo piping and associated fittings outside tanks are to be provided with suitable heating devices. For heating of piping and fittings, refer to [2.6].

8.2.2 Thermometers

Each tank is to be equipped with at least two thermometers in order to ascertain the temperature of the asphalt solution.

8.2.3 Insulation

Cargo piping and associated fittings outside tanks are to be suitably insulated, where necessary.

9 Specific requirements for ships having the notations “FLS tanker” or “FLS tanker, flash point > 60°C”

9.1 Application

9.1.1 The provisions of this Article, derived from Appendix II of the MARPOL 73/78 Convention, are related to the prevention of pollution by noxious liquid substances. They apply as follows:

a) Where the ship is granted only the service notation **FLS tanker** or **FLS tanker, flash point > 60°C**, these provisions replace those of [5] related to the prevention of pollution by cargo oil.

b) Where the ship is granted both service notations **oil tanker-FLS tanker**, or **oil tanker-FLS tanker, flash point > 60°C**, these provisions are additional to those of [5].

9.2 Design requirements

9.2.1 General

The requirements of [9.2] apply to ships carrying category Z substances (see Ch 7, App 3, Tab 2).

9.2.2 Underwater discharge

The underwater discharge outlet arrangement is to be such that the residue/water mixture discharged into the sea will not pass through the ship's boundary layer. To this end, when the discharge is made normal to the ship's shell plating, the minimum diameter of the discharge outlet is governed by the following equation:

$$D = \frac{Q_D}{5L}$$

where:

D : Minimum diameter of the discharge outlet, in m

L : Distance from the forward perpendicular to the discharge outlet, in m

Q_D : The maximum rate selected at which the ship may discharge a residue/water mixture through the outlet, in m^3/h.

When the discharge is directed at an angle to the ship's shell plating, the above relationship is to be modified by substituting for Q_D the component of Q_D which is normal to the ship's shell plating.

9.2.3 Ventilation equipment

a) If residues from cargo tanks are removed by means of ventilation, ventilation equipment meeting the following provisions is to be provided.

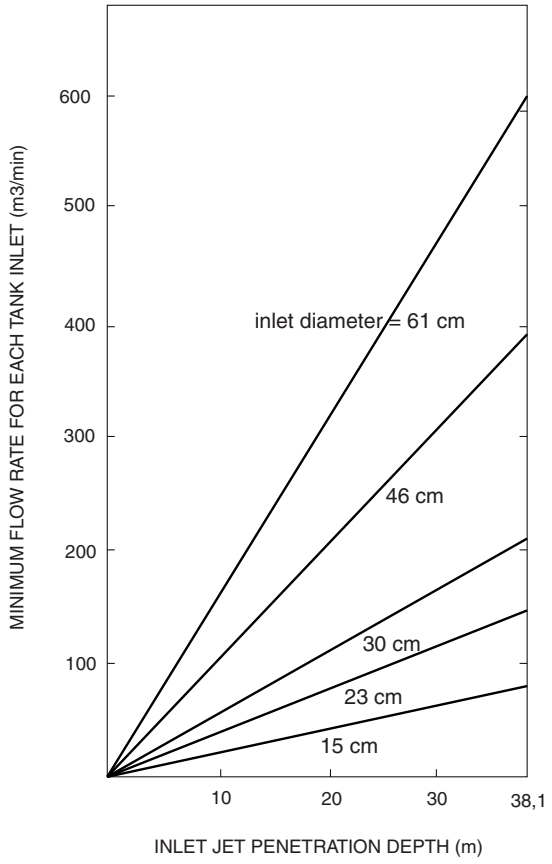
Note 1: Ventilation procedures may be applied only to those substances having a vapour pressure greater than 5.10^3 Pa at 20°C.

b) The ventilation equipment is to be capable of producing an air jet which can reach the tank bottom. Fig 3 may be used to evaluate the adequacy of ventilation equipment used for ventilating a tank of given depth.

c) The ventilation equipment is to be placed in the tank opening closest to the tank sump or suction point.

d) When practicable, the ventilation equipment is to be positioned so that the air jet is directed at the tank sump or suction point and impingement of the air jet on tank structural members is to be avoided as far as possible.

Figure 3 : Minimum flow rate as a function of jet penetration depth



Jet penetration depth is to be compared against tank height.

Section 5 Electrical Installations

1 General

1.1 Application

1.1.1 The requirements in this Section apply, in addition to those contained in Part C, Chapter 2 to ships with the service notation **oil tanker** or **FLS tanker**.

1.1.2 The design is to be in accordance with IEC publication 60092-502.

However, where the prescriptive requirements in the present Rules and IEC 60092-502 are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, Tab 1, the following are to be submitted for approval:

a) plan of hazardous areas

b) document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas

c) diagrams of tank level indicator systems, high level alarm systems and overflow control systems where requested.

1.3 System of supply

1.3.1 The following systems of generation and distribution of electrical energy are acceptable:

a) direct current:
- two-wire insulated

b) alternating current:
- single-phase, two-wire insulated
- three-phase, three-wire insulated.

1.3.2 Earthed systems with hull return are not permitted, with the following exceptions to the satisfaction of the Society:

a) impressed current cathodic protective systems

b) limited and locally earthed systems, such as starting and ignition systems of internal combustion engines, provided that any possible resulting current does not flow directly through any hazardous area

c) insulation level monitoring devices, provided that the circulation current of the device does not exceed 30 mA under the most unfavourable conditions.

1.3.3 Earthed systems without hull return are not permitted, with the following exceptions:

a) earthed intrinsically safe circuits and the following other systems to the satisfaction of the Society

b) power supplies, control circuits and instrumentation circuits in non-hazardous areas where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions, or

c) limited and locally earthed systems, such as power distribution systems in galleys and laundries to be fed through isolating transformers with the secondary windings earthed, provided that any possible resulting hull current does not flow directly through any hazardous area, or

d) alternating current power networks of 1,000 V root mean square (line to line) and over, provided that any possible resulting current does not flow directly through any hazardous area; to this end, if the distribution system is extended to areas remote from the machinery space, isolating transformers or other adequate means are to be provided.

1.3.4 In insulated distribution systems, no current carrying part is to be earthed, other than:

a) through an insulation level monitoring device

b) through components used for the suppression of interference in radio circuits.

1.4 Earth detection

1.4.1 The devices intended to continuously monitor the insulation level of all distribution systems are also to monitor all circuits, other than intrinsically safe circuits, connected to apparatus in hazardous areas or passing through such areas. An audible and visual alarm is to be given, at a manned position, in the event of an abnormally low level of insulation.

1.5 Mechanical ventilation of hazardous spaces

1.5.1 Electric motors driving fans of the ventilating systems of hazardous spaces are to be located outside the ventilation ducting.

1.5.2 Motors driving ventilating fans may be located within the ducting provided that they are of a certified safe type.

1.5.3 The materials used for the fans and their housing are to be in compliance with Pt C, Ch 4, Sec 1, [2.33].

1.5.4 Cargo pump-rooms and other enclosed spaces which contain cargo-handling equipment and similar spaces in which work is performed on the cargo should be fitted with mechanical ventilation systems, capable of being controlled from outside such spaces.

1.5.5 Provisions are to be made to ventilate the spaces defined in [1.5.4] prior to entering the compartment and operating the equipment.

1.6 Electrical installation precautions

1.6.1 Precautions against inlet of gases or vapours

Suitable arrangements are to be provided, to the satisfaction of the Society, so as to prevent the possibility of gases or vapours passing from a gas-dangerous space to another space through runs of cables or their conduits.

2 Hazardous locations and types of equipment

2.1 Special requirements for oil tankers carrying flammable liquids having a flash point not exceeding 60°C and for oil tankers carrying flammable liquids having a flash point exceeding 60°C heated to a temperature within 15°C of their flash point or above their flash point

2.1.1 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zone 0, 1 and 2 according to Pt C, Ch 2, Sec 1, [3.13.3]. The different spaces are to be classified according to Tab 1.

The types of electrical equipment admitted, depending on the zone where they are installed, are specified in Pt C, Ch 2, Sec 3, [10].

2.1.2 The explosion group and temperature class of electrical equipment of a certified safe type are to be at least IIA and T3 in the case of ships arranged for the carriage of crude oil or other petroleum products.

Other characteristics may be required for dangerous products other than those above.

2.1.3 A space separated by a gastight boundaries from a hazardous area may be classified as zone 0, 1, 2 or considered as non hazardous, taking into account the sources of release inside that space and its conditions of ventilation.

2.1.4 Access door and other openings are not to be provided between an area intended to be considered as non-hazardous and a hazardous area or between a space intended to be considered as zone 2 and a zone 1, except where required for operational reasons.

2.1.5 In enclosed or semi-enclosed spaces having a direct opening into any hazardous space or area, electrical installations are to comply with the requirements for the space or area to which the opening leads.

2.1.6 Where a space has an opening into an adjacent, more hazardous space or area, it may be made into a less hazardous space or non-hazardous space, taking into account the type of separation and the ventilation system.

2.1.7 A differential pressure monitoring device or a flow monitoring device, or both, are to be provided for monitoring the satisfactory functioning of pressurisation of spaces having an opening into a more hazardous zone.

In the event of loss of the protection by the over-pressure or loss of ventilation in spaces classified as zone 1 or zone 2, protective measures are to be taken.

2.2 Special requirements for oil tankers carrying flammable liquids having a flash point exceeding 60°C unheated or heated to a temperature below and not within 15°C of their flash point

2.2.1 For systems of supply and earth detection, the requirements under [1.3] and [1.4] apply.

2.2.2 Cargo tanks, slop tanks, any pipe work of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo are to be classified as zone 2.

2.3 Special requirements for FLS tankers

2.3.1 The requirements under Ch 8, Sec 10 apply.

Table 1 : Space descriptions and hazardous area zones for oil tankers carrying flammable liquids having a flash point not exceeding 60°C and for oil tankers carrying flammable liquids heated to a temperature within 15°C of their flash point or above their flash point

No.	Description of spaces	Hazardous area
1	The interior of cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or developing flammable gases and vapours	Zone 0
2	Void space adjacent to, above or below integral cargo tanks	Zone 1
3	Hold spaces	Zone 1
4	Cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks	Zone 1
5	Cargo pump rooms	Zone 1
6	Enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tank bulkheads, unless protected by a diagonal plate acceptable to the Society	Zone 1
7	Spaces, other than cofferdam, adjacent to and below the top of a cargo tank (for example, trunks, passageways and hold)	Zone 1
8	Areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo manifold valve, cargo valve, cargo pipe flange and cargo pump-room ventilation outlets.	Zone 1
9	Areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging or of small volumes of gas or vapour mixtures caused by thermal variation, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet	Zone 1
10	Areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of cargo pump entrances, cargo pump room ventilation inlet, openings into cofferdams, or other zone 1 spaces	Zone 1
11	Areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2,4 m above the deck	Zone 1
12	Areas on open deck over the cargo area where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck	Zone 1
13	Compartments for cargo hoses	Zone 1
14	Enclosed or semi-enclosed spaces in which pipes containing cargoes are located	Zone 1
15	Areas of 1,5 m surrounding a space of zone 1	Zone 2
16	Spaces 4 m beyond the cylinder and 4 m beyond the sphere defined in item 9	Zone 2
17	Fore peak ballast tank not adjacent to cargo tanks, when ballasted with the system serving ballast tanks in the cargo area according to Ch 7, Sec 4, [2.3.8]	Zone 2
18	Areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service area and 3 m beyond these up to a height of 2,4 m above the deck	Zone 2
19	Areas on open deck over the cargo area where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck surrounding open or semi-enclosed spaces of zone 1	Zone 2
20	Spaces forward of the open deck areas to which reference is made in 12 and 18, below the level of the main deck, and having an opening on to the main deck or at a level less than 0,5 m above the main deck, unless: • the doors and all openings are in non-hazardous area; and • the spaces are mechanically ventilated	Zone 2

Section 6 Fire Protection

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships having one of the following service notations:

- **oil tanker**
- **oil tanker, flash point > 60°C**
- **oil tanker, asphalt carrier**
- **FLS tanker**
- **FLS tanker, flash point > 60°C**.

1.2 Documents to be submitted

1.2.1 The documents listed in Ch 7, Sec 2, Tab 1 are to be submitted for approval in addition to chose listed in Tab 1.

Table 1 : Documents to be submitted

No.	Description of the document **(1)**
1	General arrangement drawing
2	Specification of the fire integrity of bulkheads and decks
3	Specification of the instruments for measuring oxygen and flammable vapour concentrations
4	Diagram of the pressure water system within the cargo area
5	For the foam extinguishing system within the cargo area: • diagrammatic arrangement drawing • calculation note • foam agent specification • characteristics of foam monitors and hoses
6	For the fire-extinguishing system in cargo pump rooms: • general arrangement drawing • calculation note
7	For the inert gas installation: • single-wire diagram of the installation together with the main characteristics: capacity, pressure, temperature, oxygen content, water content, • list of the components with their characteristics: pipes, scrubber, blowers, non-return devices, valves, pumps, protective devices for over-pressure and vacuum, • drawing of arrangement of installation on board, • diagram of instrumentation, alarm and safeguard systems, • specification of oxygen analyser, recorder and portable instrumentation, • operational manual containing instructions relative to the operation of the inert gas system and to safety.
(1) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.	

2 General requirements

2.1 Sources of ignition

2.1.1 Dangerous zones or spaces are not to contain:

- internal combustion engines
- steam turbines and steam piping with a steam temperature in excess of 220°C
- other piping systems and heat exchangers with a fluid temperature in excess of 220°C
- any other source of ignition.

Note 1: Dangerous zones and spaces correspond to hazardous areas defined in Pt C, Ch 2, Sec 1, [3.13].

2.2 Electrical equipment

2.2.1 For the installation of electrical equipment, refer to Ch 7, Sec 5.

2.3 Pipe trunk

2.3.1 Where an enclosed pipe trunk is situated within the cargo tanks deck area, the pipe trunk:

a) Is to be protected by a fixed fire-extinguishing system in accordance with [4.2.2] and the extinguishing system is to be operated from a readily accessible position outside the pipe trunk

b) Is not considered part of the cargo tanks deck area

c) The area of the pipe trunk is not to be included in the calculation of the foam solution rate of supply for the deck foam system required by Article [3]

d) Is to be adequately ventilated and protected in accordance with Ch 7, Sec 4, [3.5.2], item b) and item c), and is to contain no flammable gas sources other than pipes and flanges. If the pipe trunk contains any other source of flammable gas, i.e. valves and pumps, it is to be regarded as a cargo pump-room.

3 Fixed deck foam system

3.1 Application

3.1.1 Service notation oil tanker

Ships having the service notation **oil tanker** are to be provided with a fixed deck foam system complying with the provisions of [3.2] and [3.3] or with an equivalent fixed installation.

Note 1: To be considered equivalent, the system proposed in lieu of the deck foam system is to:

- *be capable of extinguishing spill fires and also preclude ignition of spilled oil not yet ignited, and*
- *be capable of combating fires in ruptured tanks.*

3.1.2 Service notation FLS tanker

Ships having the service notation **FLS tanker** are to be provided with a fixed deck foam system complying with [11.3] of the IBC Code. The type of foam to be used is specified in Ch 7, App 4, Tab 1. Where ordinary foam is considered suitable, foam fire-extinguishing systems complying with the provisions of [3.2] and [3.3] are acceptable.

3.1.3 Service notations oil tanker, flash point > 60°C or oil tanker, asphalt carrier

Ships having the service notations **oil tanker, flash point > 60°C** or **oil tanker, asphalt carrier** are to be provided with a fixed deck foam system complying with complying with the provisions of [3.2] and [3.3] or with an equivalent fixed installation. However, such a system is not required in the case of ships of less than 2000 gross tonnage.

Note 1: For the definition of "equivalent installation", refer to [3.1.1].

3.2 System design

3.2.1 Principles

a) The arrangements for providing foam are to be capable of delivering foam to the entire cargo tank deck area as well as into any cargo tank the deck of which has been ruptured.

b) The deck foam system is to be capable of simple and rapid operation.

c) Operation of a deck foam system at its required output shall permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main. Where the deck foam system is supplied by a common line from the fire main, additional foam concentrate shall be provided for operation of two nozzles for the same period of time required for the foam system.

The simultaneous use of the minimum required jets of water shall be possible on deck over the full length of the ship, in the accommodation spaces, service spaces, control stations and machinery spaces.

d) Foam from the fixed foam system is to be supplied by means of monitors and foam applicators.

Note 1: On tankers of less than 4000 tonnes deadweight, the Society may not require installation of monitors but only applicators.

e) Applicators are to be provided to ensure flexibility of action during fire-fighting operations and to cover areas screened from the monitors.

3.2.2 Foam solution - Foam concentrate

a) *The rate of supply of foam solution is not to be less than the greatest of the following:*

1) *0,6 l/min per square metre of cargo tanks deck area, where cargo tanks deck area means the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces,*

2) *6 l/min per square metre of the horizontal sectional area of the single tank having the largest such area, or*

3) *3 l/min per square metre of the area protected by the largest monitor, such area being entirely forward of the monitor, but in no case should the output of any monitor be less than 1,250 l/min.*

b) *Sufficient foam concentrate shall be supplied to ensure at least 20 minutes of foam generation in tankers fitted with an inert gas installation or 30 minutes of foam generation in tankers not fitted with an inert gas installation or not required to use an inert gas system.*

c) *The foam concentrate supplied on board shall be approved* by the Society based on IMO Circular MSC.1/Circ.1312 *for the cargoes intended to be carried. Type B foam concentrates shall be supplied for the protection of crude oil, petroleum products and non-polar solvent cargoes. Type A foam concentrates shall be supplied for polar solvent cargoes, as listed in the table of chapter 17 of the IBC Code. Only one type of foam concentrate shall be supplied, and it shall be effective for the maximum possible number of cargoes intended to be carried. For cargoes for which foam is not effective or is incompatible, additional arrangements to the satisfaction of the Society shall be provided.*

d) *Liquid cargoes with a flashpoint not exceeding 60°C for which a regular foam fire-fighting system is not effective shall comply with* the following provisions*:*

1) *The foam shall be of alcohol-resistant type;*

2) *The type of foam concentrates for use in chemical tankers shall be* approved by the Society based on IMO Circular MSC.1/Circ.1312*; and*

3) *The capacity and application rates of the foam extinguishing system shall comply with chapter 11 of the IBC Code, except that lower application rates may be accepted based on performance tests. For tankers fitted with inert gas systems, a quantity of foam concentrate sufficient for 20 min of foam generation may be accepted.*

3.2.3 Monitors and foam applicators

a) *Prototype tests of the monitors and foam applicators shall be performed to ensure the foam expansion and drainage time of the foam produced does not differ more than 10 per cent of that determined in [3.2.2], item c). When medium expansion ratio foam (between 21 to 1 and 200 to 1 expansion ratio) is employed, the application rate of the foam and the capacity of a monitor installation shall be to the satisfaction of the Society. At least 50 per cent of the foam solution supply rate required shall be delivered from each monitor.*

b) *The capacity of any applicator is to be not less than 400 l/min and the applicator throw in still air conditions is to be not less than 15 m.*

Note 1: Where, in pursuance of [3.2.1], the installation of monitors is not required on tankers of less 4000 tonnes deadweight, *the capacity of each applicator is to be at least 25% of the foam solution supply rate required in [3.2.2], items a) 1) and a) 2).*

3.3 Arrangement and installation

3.3.1 Monitors

a) *The number and position of monitors are to be such as to comply with item a) of [3.2.1].*

b) *The distance from the monitor to the farthest extremity of the protected area forward of that monitor is not to be more than 75 per cent of the monitor throw in still air conditions.*

c) *A monitor and hose connection for a foam applicator shall be situated both port and starboard at the front of the poop or accommodation spaces facing the cargo tank deck. The monitors and hose connections shall be aft of any cargo tanks, but may be located in the cargo area above pump-rooms, cofferdams, ballast tanks,* oil bunker tanks, *and void spaces adjacent to cargo tanks if capable of protecting the deck below and aft of each other.*

Note 1: On tankers of less than 4000 tonnes deadweight a hose connection for a foam applicator is to be situated both port and starboard at the front of the poop or accommodation spaces facing the cargo tank deck.

3.3.2 Applicators

a) *At least four foam applicators shall be provided on all tankers. The number and disposition of foam main outlets shall be such that foam from at least two applicators can be directed on to any part of the cargo tank deck area.*

b) Where the ship is provided with a stern or aft cargo loading or unloading arrangement, the deck foam system is to be so arranged as to permit the protection of the shore connection by at least two foam applicators.

3.3.3 Isolation valves

Valves are to be provided in the foam main, and in the fire main when this is an integral part of the deck foam system, immediately forward of any monitor position to isolate damaged sections of those mains.

3.3.4 Main control station

The main control station for the system is to be suitably located outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

4 Fire-extinguishing systems except deck foam system

4.1 Pressure water fire-extinguishing systems

4.1.1 The pressure water fire-fighting systems provided on ships having the service notations **oil tanker**, **oil tanker, flash point>60°C**, **oil tanker, asphalt carrier**, **FLS tanker** or **FLS tanker, flash point > 60°C** are subject to the provisions of Pt C, Ch 4, Sec 6, [1], except that:

a) The capacity of the fire pumps is to be calculated without taking into account the reduction permitted in Ch 7, Sec 4, [2.2.2].

b) Isolation valves are to be fitted in the fire main at poop front in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in the event of fire or explosion.

4.1.2 Attention is drawn to the provisions of item c) of [3.2.1].

4.2 Fire-extinguishing systems for cargo pump rooms

4.2.1 Application

a) Cargo pump rooms of ships having the service notations **oil tanker** or **FLS tanker** are to be provided with a fixed fire-extinguishing system complying with [4.2.2].

b) Cargo pump rooms of ships having the service notations **oil tanker, flash point > 60°C** or **oil tanker, asphalt carrier** are to be provided with a fixed fire-extinguishing system complying with [4.2.2], except where the cargo is carried at a temperature below and not within 15°C of the flash point.

4.2.2 Design and arrangement of the fire-extinguishing system

a) Where required by [4.2.1], *each cargo pump-room is to be provided with one of the following fixed fire-extinguishing systems operated from a readily accessible position outside the pump-room. Cargo pump-rooms are to be provided with a system suitable for machinery spaces of category A.*

1) Carbon dioxide fire-extinguishing system complying with the provisions of Pt C, Ch 4, Sec 15, [4] and with the following:

- *the alarms giving audible warning of the release of fire-extinguishing medium are to be safe for use in a flammable cargo vapour/air mixture,*
- *a notice is to be exhibited at the controls stating that due to the electrostatic ignition hazard, the system is to be used only for fire extinguishing and not for inerting purposes.*

2) A high-expansion foam system complying with the provisions of Pt C, Ch 4, Sec 15, [5.2], provided that the foam concentrate supply is suitable for extinguishing fires involving the cargoes carried.

3) A fixed pressure water-spraying system complying with the provisions of Pt C, Ch 4, Sec 15, [6].

b) Where the extinguishing medium used in the cargo pump-room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate need not be more than the maximum required for the largest compartment.

5 Inert gas systems

5.1 Application

5.1.1 Ships where an inert gas system is required

*a) Ships having the service notation **oil tanker** or **FLS tanker** and of 8 000 tonnes deadweight and upwards are to be fitted with and inert gas system complying with the provisions of this Article, or with equivalent systems or arrangements in accordance with [5.1.2].*

b) All tankers operating with a cargo tank cleaning procedure using crude oil washing are to be fitted with an inert gas system complying with the requirements of this Article.

c) Such system is to be provided in every cargo tank and slop tank.

d) Tankers required to be fitted with inert gas systems shall comply with the following provisions:

- *double hull spaces shall be fitted with suitable connections for the supply of inert gas*. This includes all ballast tanks and void spaces of double hull and double bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks, except cargo pump-rooms and ballast pump-rooms
- *where hull spaces are connected to a permanently fitted inert gas distribution system, means shall be provided to prevent hydrocarbon gases from the cargo tanks entering the double hull spaces through the system; and*
- *where such spaces are not permanently connected to an inert gas distribution system, appropriate means shall be provided to allow connection to the inert gas main.*

5.1.2 Requirements for equivalent systems

*a) For ships having the service notations **oil tanker** or **FLS tanker** and of 8 000 tonnes deadweight and upwards but less than 20 000 tonnes deadweight, the Society may accept other equivalent arrangements in accordance with item a) of [5.1.1] and following item b)*

b) Equivalent systems or arrangements shall:

- *be capable of preventing dangerous accumulation of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations, and*
- *be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.*

5.1.3 Ships where an inert gas system is fitted but not required

Inert gas systems provided on ships where such systems are not required by [5.1.1] are to comply with the provisions of [5.4].

5.2 General requirements

5.2.1 The inert gas system is to comply with the applicable requirements of Pt C, Ch 4, Sec 15, [13].

5.2.2 Plans in diagrammatic form are to be submitted for appraisal and are to include the following:

- details and arrangement of inert gas generating plant including all control monitoring devices
- arrangement of piping system for distribution of the inert gas.

5.2.3 An automatic control capable of producing suitable inert gas under all service conditions is to be fitted.

5.3 Additional requirements for nitrogen generator systems

5.3.1 The following requirements apply where a nitrogen generator system is fitted on board as required by [5.1.1]. For the purpose, the inert gas is to be produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials.

5.3.2 In addition to the applicable requirements of Pt C, Ch 4, Sec 15, [13], the nitrogen generator system is to comply with Ch 7, Sec 4, [4.3.2] and Ch 7, Sec 4, [4.2.10].

5.3.3 A nitrogen generator is to consist of a feed air treatment system and any number of membrane or adsorber modules in parallel necessary to meet the requirements of Pt C, Ch 4, Sec 15, [13.3.1], item b) 4).

5.3.4 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with Pt C, Ch 4, Sec 15, [13.3.1], item b) 5). In addition to Pt C, Ch 4, Sec 15, [13.3.2], item d), the system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

5.3.5 The system is to be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas required by Pt C, Ch 4, Sec 15, [13.3.1], item b). Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

5.3.6 The feed air treatment system fitted to remove free water, particles and traces of oil from the compressed air as required by Pt C, Ch 4, Sec 15, [13.5.2], item b), is also to preserve the specification temperature.

5.3.7 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck.

Note 1: "safe location" needs to address the two types of discharges separately:

- oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
  - outside of hazardous area;
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets

- nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

5.3.8 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

5.4 Nitrogen/inert gas systems fitted for purposes other than inerting required by [5.1.1]

5.4.1 Nitrogen/inert gas systems fitted on oil tankers of less than 8 000 tonnes deadweight and for which an inert gas system is not required by [5.1.1] are to comply with the following requirements.

5.4.2 Requirements of:

- Pt C, Ch 4, Sec 15, [13.3.2], item b)
- Pt C, Ch 4, Sec 15, [13.3.2], item d)
- Pt C, Ch 4, Sec 15, [13.3.4], item b)
- Pt C, Ch 4, Sec 15, [13.3.4], item c)
- Pt C, Ch 4, Sec 15, [13.3.4], item e) 1) regarding oxygen content and power supply to the indicating devices
- Pt C, Ch 4, Sec 15, [13.3.4], item e) 4)
- Pt C, Ch 4, Sec 15, [13.5.2] and
- Pt C, Ch 4, Sec 15, [13.5.3],

apply to the systems.

5.4.3 The requirements of [5.3] apply except requirements [5.3.1] to [5.3.3] and [5.3.5]

5.4.4 The two non-return devices as required by Pt C, Ch 4, Sec 15, [13.3.3], item a) 1) are to be fitted in the inert gas main. The non-return devices are to comply with Pt C, Ch 4, Sec 15, [13.3.3], item a) 2) and Pt C, Ch 4, Sec 15, [13.3.3], item a) 3); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by Pt C, Ch 4, Sec 15, [13.3.3], item a) 1) may be substituted by two non-return valves.

6 Fixed hydrocarbon gas detection systems

6.1 Engineering specifications

6.1.1 General

a) The fixed hydrocarbon gas detection system is to be designed, constructed and tested to the satisfaction of the Society based on IMO Circular MSC.1/Circ.1370.

b) The system is to be comprised of a central unit for gas measurement and analysis and gas sampling pipes in all ballast tanks and void spaces of double-hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks.

c) The system may be integrated with the cargo pump-room gas detection system, provided that the spaces referred to in item b) above are sampled at the rate required in [6.1.2], item c) 1). Continuous sampling from other locations may also be considered provided the sampling rate is complied with.

6.1.2 Component requirements

a) Gas sampling lines

1) Common sampling lines to the detection equipment shall not be fitted, except the lines serving each pair of sampling points as required in item 3) below.

2) The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where non-metallic materials are used, they shall be electrically conductive. The gas sampling lines shall not be made of aluminium.

3) The configuration of gas sampling lines is to be adapted to the design and size of each space. Except as provided in items 4) and 5) below, the sampling system shall allow for a minimum of two hydrocarbon gas sampling points, one located on the lower and one on the upper part where sampling is required. When required, the upper gas sampling point shall not be located lower than 1 m from the tank top. The position of the lower located gas sampling point shall be above the

height of the girder of bottom shell plating but at least 0,5 m from the bottom of the tank and it shall be provided with means to be closed when clogged. In positioning the fixed sampling points, due regard should also be given to the density of vapours of the oil products intended to be transported and the dilution from space purging or ventilation.

4) For ships with deadweight of less than 50000 tonnes, the Society may allow the installation of one sampling location for each tank for practical and/or operational reasons.

5) For ballast tanks in the double-bottom, ballast tanks not intended to be partially filled and void spaces, the upper gas sampling point is not required.

6) Means are to be provided to prevent gas sampling lines from clogging when tanks are ballasted by using compressed air flushing to clean the line after switching from ballast to cargo loaded mode. The system shall have an alarm to indicate if the gas sampling lines are clogged.

b) Gas analysis unit

The gas analysis unit shall be located in a safe space and may be located in areas outside the ship's cargo area; for example, in the cargo control room and/or navigation bridge in addition to the hydraulic room when mounted on the forward bulkhead, provided the following requirements are observed:

1) Sampling lines shall not run through gas safe spaces, except where permitted under item 5) below;

2) The hydrocarbon gas sampling pipes shall be equipped with flame arresters. Sample hydrocarbon gas is to be led to the atmosphere with outlets arranged in a safe location, not close to a source of ignitions and not close to the accommodation area air intakes;

3) A manual isolating valve, which shall be easily accessible for operation and maintenance, shall be fitted in each of the sampling lines at the bulkhead on the gas safe side;

4) The hydrocarbon gas detection equipment including sample piping, sample pumps, solenoids, analysing units etc., shall be located in a reasonably gas-tight cabinet (e.g., fully enclosed steel cabinet with a door with gaskets) which is to be monitored by its own sampling point. At a gas concentration above 30% of the lower flammable limit inside the steel enclosure the entire gas analysing unit is to be automatically shut down; and

5) Where the enclosure cannot be arranged directly on the bulkhead, sample pipes shall be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing unit, and are to be routed on their shortest ways.

c) Gas detection equipment

1) The gas detection equipment is to be designed to sample and analyse from each sampling line of each protected space, sequentially at intervals not exceeding 30 min.

2) Means are to be provided to enable measurements with portable instruments, in case the fixed system is out of order or for system calibration. In case the system is out of order, procedures shall be in place to continue to monitor the atmosphere with portable instruments and to record the measurement results.

3) Audible and visual alarms are to be initiated in the cargo control room, navigation bridge and at the analysing unit when the vapour concentration in a given space reaches a pre-set value, which shall not be higher than the equivalent of 30% of the lower flammable limit.

4) The gas detection equipment shall be so designed that it may readily be tested and calibrated.

7 Gas measurement and detection

7.1 Provisions applicable to all ships

7.1.1 All ships are to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air (%LEL) and at least two portable oxygen analysers. Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

Note 1: The number of portable detection instruments required above is considered equivalent to one portable instrument for measuring flammable vapour concentration, one portable instrument for measuring oxygen and sufficient spares.

7.1.2 The gas detectors required in [7.1.1] are to be type approved by the Society.

7.2 Additional provisions for ships having the service notation oil tanker or FLS tanker

7.2.1 Gas measurement

Ships having the service notation **oil tanker** or **FLS tanker** are to comply with the following provisions:

a) Suitable means are to be provided for the calibration of portable *instruments* for measuring oxygen and/or flammable vapour concentrations.

b) Suitable portable instruments for measuring oxygen and flammable vapour concentrations in double hull spaces and double-bottom spaces are to be provided. In selecting these instruments, due attention is to be given to their use in combination with the fixed gas sampling line systems referred to in item c).

c) Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of gas sampling lines is to be adapted to the design of such spaces.

d) The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastic materials are used, they are to be electrically conductive.

7.2.2 Fixed hydrocarbon gas detection systems

Ships having the service notation **oil tanker** or **FLS tanker** are to comply with the following provisions:

*a) In addition to the requirements in [7.2.1], ships having the service notation **oil tanker** or **FLS tanker** of 20000 tonnes deadweight and above, are to be provided with a fixed hydrocarbon gas detection system complying with [6] for measuring hydrocarbon gas concentrations in all ballast tanks and void spaces of double-hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks.*

Note 1: The term "cargo tanks" in the phrase "spaces adjacent to the cargo tanks" includes slop tanks except those arranged for the storage of oily water only.

The term "spaces" in the phrase "spaces under the bulkhead deck adjacent to cargo tanks" includes dry compartments such as ballast pump-rooms and bow thruster rooms and any tanks such as freshwater tanks, but excludes fuel oil tanks.

The term "adjacent" in the phrase "adjacent to the cargo tanks" includes ballast tanks, void spaces, other tanks or compartments located below the bulkhead deck located adjacent to cargo tanks and includes any spaces or tanks located below the bulkhead deck which form a cruciform (corner to corner) contact with the cargo tanks.

*b) Ships having the service notation **oil tanker** or **FLS tanker** provided with constant operative inerting systems for such spaces need not be equipped with fixed hydrocarbon gas detection equipment.*

c) Notwithstanding the above, cargo pump-rooms subject to the provisions of Ch 7, Sec 4, [3.5] need not comply with the present requirement.

7.3 Additional provisions for ships fitted with an inert gas system

7.3.1 In addition to the provisions of [7.1], for ships fitted with inert gas systems, at least two portable gas detectors are to be capable of measuring concentrations of flammable vapours in inerted atmosphere.

Gas detectors are to be capable of measuring any gas content from 0 to 100% in volume.

7.4 Provisions for installation of gas analysing units

7.4.1 The following provisions apply to gas analysing units of the sampling type located outside gas dangerous zones.

7.4.2 Gas analysing units with non-explosion proof measuring equipment may be located in areas outside cargo areas, e.g. in cargo control room, navigation bridge or engine room when mounted on the forward bulkhead provided the following requirements are observed:

a) Sampling lines are not to run through gas safe spaces, except where permitted under e).

b) The gas sampling pipes are to be equipped with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location.

c) Bulkhead penetrations of sample pipes between safe and dangerous areas are to be of approved type and have same fire integrity as the division penetrated. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead on the gas safe side.

d) The gas detection equipment including sample piping, sample pumps, solenoids, analysing units etc. is to be located in a reasonably gas tight (e.g. a fully enclosed steel cabinet with a gasketed door) which is to be monitored by its own sampling point. At gas concentrations above 30% LFL inside the steel cabinet the entire gas analysing unit is to be automatically shut down.

e) Where the cabinet cannot be arranged directly on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units, and are to be routed on their shortest ways.

Appendix 1 Devices to Prevent the Passage of Flame into the Cargo Tanks

1 General

1.1 Application

1.1.1 This Appendix reproduces the text of MSC Circ. 677. It is intended to cover the design, testing, location and maintenance of "devices to prevent the passage of flame into cargo tanks" (hereafter called "devices") of ships having the service notations **oil tanker** or **combination carrier** carrying crude oil, petroleum products having a flash point of 60°C (closed cup test) or less and a Reid vapour pressure below atmospheric pressure, and other liquids with similar fire hazard. It also applies to ships having the service notation **FLS tanker** carrying flammable products having such a flash point.

1.1.2 Ships having the service notations **oil tanker**, **combination carrier** or **FLS tanker** and fitted with an inert gas system in accordance with Ch 7, Sec 6, [5] are to be fitted with devices which comply with this Appendix, except that the tests specified in [4.2.3] and [4.3.3] are not required. Such devices are only to be fitted at openings unless they are tested in accordance with [4.4].

1.1.3 This Appendix is intended for devices protecting cargo tanks containing crude oil, petroleum products and flammable chemicals. In the case of the carriage of chemicals, the test media referred to in [4] can be used. However, devices for chemical tankers dedicated to the carriage of products with MESG less than 0,9 mm are to be tested with appropriate media.

Note 1: For MESG (Maximum Experimental Safe Gap) reference should be made to IEC 60079-1.

1.1.4 Devices are to be tested and located in accordance with this Appendix.

1.1.5 Devices are installed to protect:

a) Openings designed to relieve pressure or vacuum caused by thermal variations (see Ch 7, Sec 4, [4.2.2], item a));

b) Openings designed to relieve pressure or vacuum during cargo loading, ballasting or discharging (see Ch 7, Sec 4, [4.2.2], item b));

c) Outlets designed for gas-freeing (see Ch 7, Sec 4, [4.3.3]).

1.1.6 Devices are not to be capable of being bypassed or blocked open unless they are tested in the bypassed or blocked open position in accordance with [4].

1.1.7 This Appendix does not include consideration of sources of ignition such as lightning discharges, since insufficient information is available to formulate equipment recommendations. All cargo handling, tank cleaning and ballasting operations are to be suspended on the approach of an electrical storm.

1.1.8 This Appendix is not intended to deal with the possibility of the passage of flame from one cargo tank to another on tankers with common venting systems.

1.1.9 When outlet openings of gas-freeing systems on tankers not fitted with inert gas systems are required to be protected with devices, they are to comply with this Appendix except that the tests specified in [4.2.3] and [4.3.3] are not required.

1.1.10 Certain of the tests prescribed in [4] of this Appendix are potentially hazardous, but no attempt is made in this Appendix to specify safety requirements for these tests.

1.2 Definitions

1.2.1 Premise

For the purpose of this Appendix, the definitions given in the following paragraphs are applicable.

1.2.2 Flame arrester

A flame arrester is a device to prevent the passage of flame in accordance with a specified performance standard. Its flame arresting element is based on the principle of quenching.

1.2.3 Flame screen

A flame screen is a device utilising wire mesh to prevent the passage of unconfined flames in accordance with a specified performance standard.

1.2.4 Flame speed

The flame speed is the speed at which a flame propagates along a pipe or other system.

1.2.5 Flashback

Flashback is the transmission of a flame through a device.

1.2.6 High velocity vent

A high velocity vent is a device to prevent the passage of flame consisting of a mechanical valve which adjusts the opening available for flow in accordance with the pressure at the inlet of the valve in such a way that the efflux velocity cannot be less than 30 m/s.

1.2.7 Pressure/vacuum valve

A pressure/vacuum valve is a device designed to maintain pressure and vacuum in a closed container within preset limits.

Note 1: Pressure/vacuum valves are devices to prevent the passage of flame when designed and tested in accordance with this Appendix.

1.3 Instruction manual

1.3.1 The manufacturer is to supply a copy of the instruction manual, which is to be kept on board the tanker and which is to include:

a) Installation instructions

b) Operating instructions

c) Maintenance requirements, including cleaning (see [2.3.3])

d) A copy of the laboratory report referred to in [4.6]

e) Flow test data, including flow rates under both positive and negative pressures, operating sensitivity, flow resistance and velocity.

2 Design of the devices

2.1 Principles

2.1.1 Depending on their service and location, devices are required to protect against the propagation of:

a) moving flames, and/or

b) stationary flames from pre-mixed gases after ignition of gases resulting from any cause.

2.1.2 When flammable gases from outlets ignite, the following four situations may occur:

a) At low gas velocities the flame may:

1) flashback, or

2) stabilise itself as if the outlet were a burner.

b) At high gas velocities, the flame may:

1) burn at a distance above the outlet, or

2) be blown out.

2.1.3 In order to prevent the passage of flame into a cargo tank, devices are to be capable of performing one or more of the following functions:

a) Permitting the gas to pass through passages without flashback and without ignition of the gases on the protected side when the device is subjected to heating for a specified period

b) Maintaining an efflux velocity in excess of the flame speed for the gas irrespective of the geometric configuration of the device and without the ignition of gases on the protected side, when the device is subjected to heating for a specified period; and

c) Preventing an influx of flame when conditions of vacuum occur within the cargo tanks.

2.2 Mechanical design

2.2.1 The casing or housing of devices is to meet similar standards of strength, heat resistance and corrosion resistance as the pipe to which it is attached.

2.2.2 The design of devices is to allow for ease of inspection and removal of internal elements for replacement, cleaning or repair.

2.2.3 All flat joints of the housing are to be machined true and are to provide an adequate metal-to-metal contact.

2.2.4 Flame arrester elements are to fit in the housing in such a way that flame cannot pass between the element and the housing.

2.2.5 Resilient seals may be installed only if their design is such that if the seals are partially or completely damaged or burned, the device is still capable of effectively preventing the passage of flame.

2.2.6 Devices are to allow for efficient drainage of moisture without impairing their efficiency to prevent the passage of flame.

2.2.7 The casing, flame arrester element and gasket materials are to be capable of withstanding the highest pressure and temperature to which the device may be exposed under both normal and specified fire test conditions.

2.2.8 End-of-line devices are to be so constructed as to direct the efflux vertically upwards.

2.2.9 Fastenings essential to the operation of the device, i.e. screws, etc., are to be protected against loosening.

2.2.10 Means are to be provided to check that any valve lifts easily without remaining in the open position.

2.2.11 Devices in which the flame arresting effect is achieved by the valve function and which are not equipped with flame arrester elements (e.g. high velocity valves) are to have a width of the contact area of the valve seat of at least 5 mm.

2.2.12 Devices are to be resistant to corrosion in accordance with [4.5.1].

2.2.13 Elements, gaskets and seals are to be of material resistant to both seawater and the cargoes carried.

2.2.14 The casing of the housing is to be capable of passing a hydrostatic pressure test, as required in [4.5.2].

2.2.15 In-line devices are to be able to withstand without damage or permanent deformation the internal pressure resulting from detonation when tested in accordance with [4.4].

2.2.16 A flame arrester element is to be designed to ensure quality control of manufacture to meet the characteristics of the prototype tested, in accordance with this Appendix.

2.3 Performance

2.3.1 Devices are to be tested in accordance with [4.5] and thereafter shown to meet the test requirements of [4.2] to [4.4], as appropriate.

Note 1: End-of-line devices which are intended for exclusive use at openings of inerted cargo tanks need not be tested against endurance burning as specified in [4.2.3].

Note 2: Where end-of-line devices are fitted with cowls, weather hoods and deflectors, etc., these attachments are to be fitted for the tests described in [4.2].

Note 3: When venting to atmosphere is not performed through an end-of-line device according to Note 2, or a detonation flame arrester according to [3.2.2], the in-line device is to be specifically tested with the inclusion of all pipes, tees, bends, cowls, weather hoods, etc., which may be fitted between the device and atmosphere. The testing is to consist of the flashback test in [4.2.2] and, if for the given installation it is possible for a stationary flame to rest on the device, the testing is also to include the endurance burning test in [4.2.3].

2.3.2 Performance characteristics such as the flow rates under both positive and negative pressure, operating sensitivity, flow resistance and velocity are to be demonstrated by appropriate tests.

2.3.3 Devices are to be designed and constructed to minimise the effect of fouling under normal operating conditions. Instructions on how to determine when cleaning is required and the method of cleaning are to be provided for each device in the manufacturer's instruction manual.

2.3.4 Devices are to be capable of operating in freezing conditions and if any device is provided with heating arrangements so that its surface temperature exceeds 85°C, then it is to be tested at the highest operating temperature.

2.3.5 Devices based upon maintaining a minimum velocity are to be capable of opening in such a way that a velocity of 30 m/s is immediately initiated, maintaining an efflux velocity of at least 30 m/s at all flow rates and, when the gas flow is interrupted, closing in such a way that this minimum velocity is maintained until the valve is fully closed.

2.3.6 In the case of high velocity vents, the possibility of inadvertent detrimental hammering leading to damage and/or failure is to be considered, with a view to eliminating it.

Note 1: Hammering is intended to mean a rapid full stroke opening/ closing, not foreseen by the manufacturer during normal operations.

2.4 Flame screens

2.4.1 Flame screens are to be:

a) Designed in such a manner that they cannot be inserted improperly in the opening

b) Securely fitted in openings so that flames cannot circumvent the screen

c) Able to meet the requirements of this Appendix. For flame screens fitted at vacuum inlets through which vapours cannot be vented, the test specified in [4.2.3] need not be complied with

d) Protected against mechanical damage.

2.5 Marking of devices

2.5.1 Each device is to be permanently marked, or have a permanently fixed tag made of stainless steel or other corrosion-resistant material, to indicate:

a) The manufacturer's name or trade mark

b) The style, type, model or other manufacturer's designation for the device

c) The size of the outlet for which the device is approved

d) The approved location for installation, including maximum or minimum length of pipe, if any, between the device and the atmosphere

e) The direction of flow through the device

f) The test laboratory and report number, and

g) Compliance with the requirements of this Appendix.

3 Sizing, location and installation of devices

3.1 Sizing of devices

3.1.1 To determine the size of devices to avoid inadmissible pressure or vacuum in cargo tanks during loading or discharging, calculations of pressure losses are to be carried out.

The following parameters are to be taken into account:

a) Loading/discharge rates

b) Gas evolution

c) pressure loss through devices, taking into account the resistance coefficient

d) Pressure loss in the vent piping system

e) Pressure at which the vent opens if a high velocity valve is used

f) Density of the saturated vapour/air mixture

g) Possible fouling of a flame arrester; 70% of its rated performance is to be used in the pressure drop calculation of the installation.

3.2 Location and installation of devices

3.2.1 General

a) Devices are to be located at the vent outlets to atmosphere unless tested and approved for in-line installation.

b) Devices for in-line installation may not be fitted at the outlets to atmosphere unless they have also been tested and approved for that position.

3.2.2 Detonation flame arresters

Where detonation flame arresters are installed as in-line devices venting to atmosphere, they are be located at a sufficient distance from the open end of the pipeline so as to preclude the possibility of a stationary flame resting on the arrester.

3.2.3 Access to the devices

Means are to be provided to enable personnel to reach devices situated more than 2 m above deck to facilitate maintenance, repair and inspection.

4 Type test procedures

4.1 Principles

4.1.1 Tests are to be conducted by a laboratory acceptable to the Society.

4.1.2 Each size of each model is to be submitted for type testing. However, for flame arresters, testing may be limited to the smallest and the largest sizes and one additional size in between to be chosen by the Society. Devices are to have the same dimensions and most unfavourable clearances expected in the production model. If a test device is modified during the test program, the testing is to be restarted.

4.1.3 Tests described in this Article using gasoline vapours (a non-leaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds with a boiling range approximating 65°C ± 75°C), technical hexane vapours or technical propane, as appropriate, are suitable for all devices protecting tanks containing a flammable atmosphere of the cargoes referred to in Ch 7, Sec 1, [1.1.3]. This does not preclude the use of gasoline vapours or technical hexane vapours for all tests referred to in this Article.

4.1.4 After the relevant tests, the device is not to show mechanical damage that affects its original performance.

4.1.5 Before the tests the following equipment, as appropriate, is to be properly calibrated:

a) Gas concentration meters

b) Thermometers

c) Flow meters

d) Pressure meters, and

e) Time recording devices.

4.1.6 The following characteristics are to be recorded, as appropriate, throughout the tests:

a) Concentration of fuel in the gas mixture

b) Temperature of the test gas mixture at inflow of the device, and

c) Flow rates of the test gas mixtures when applicable.

4.1.7 Flame passage is to be observed by recording, e.g. temperature, pressure, or light emission, by suitable sensors on the protected side of the device; alternatively, flame passage may be recorded on video tape.

4.2 Test procedure for flame arresters located at openings to the atmosphere

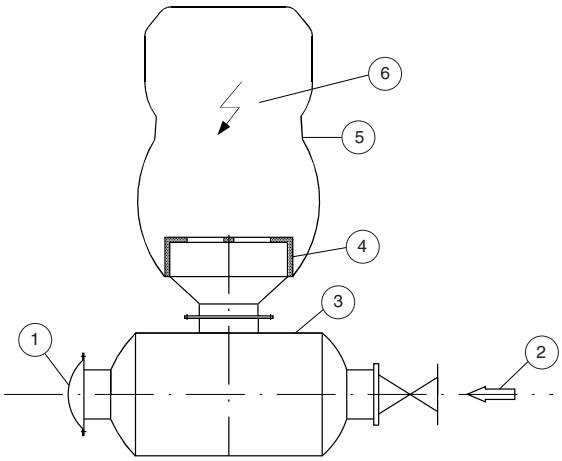
4.2.1 Test rig

The test rig is to consist of an apparatus producing an explosive mixture, a small tank with a diaphragm, a flanged prototype of the flame arrester, a plastic bag and a firing source in three positions (see Fig 1). Other test rigs may be used, provided the tests referred to in this Article are carried out to the satisfaction of the Society.

Note 1: The dimensions of the plastic bag are dependent on those of the flame arrester, but for flame arresters normally used on tankers the plastic bag may have a circumference of 2 m, a length of 2,5 m and a wall thickness of 0,05 mm.

Note 2: In order to avoid remnants of the plastic bag from falling back on to the device being tested after ignition of the fuel/air mixture, it may be useful to mount a coarse wire frame across the device within the plastic bag. The frame is to be so constructed as not to interfere with the test result.

Figure 1 : Test rig for flashback test



(1): Plastic bursting diaphragm

(2): Explosive mixture inlet

(3): Tank

(4): Flame arresting device

(5): Plastic bag

(6): Ignition source

4.2.2 Flashback test

A flashback test is to be carried out as follows:

a) The tank, flame arrester assembly and the plastic bag (see [4.2.1]) enveloping the prototype flame arrester are to be filled so that this volume contains the most easily ignitable propane/air mixture (see IEC 60079-1). The concentration of the mixture is to be verified by appropriate testing of the gas composition in the plastic bag. Where devices referred to in [2.3.1], Note 3 are tested, the plastic bag is to be fitted at the outlet to atmosphere. Three ignition sources are to be installed along the axis of the bag, one close to the flame arrester, another as far away as possible therefrom, and the third at the mid-point between these two. These three sources are to be fired in succession, twice in each of the three positions. The temperature of the test gas is to be within the range of 15°C to 40°C.

b) If a flashback occurs, the tank diaphragm will burst and this will be audible and visible to the operator by the emission of a flame. Flame, heat and pressure sensors may be used as an alternative to a bursting diaphragm.

4.2.3 Endurance burning test

An endurance burning test is to be carried out, in addition to the flashback test, for flame arresters at outlets where flows of explosive vapour are foreseeable:

a) The test rig as referred to in [4.2.1] may be used, without the plastic bag. The flame arrester is to be so installed that the mixture emission is vertical. In this position the mixture is to be ignited. Where devices referred to in [2.3.1] Note 3, are tested, the flame arrester is to be so installed as to reflect its final orientation.

b) Endurance burning is to be achieved by using the most easily ignitable gasoline vapour/air mixture or the most easily ignitable technical hexane vapour/air mixture with the aid of a continuously operated pilot flame or a continuously operated spark igniter at the outlet. The test gas is be introduced upstream of the tank shown in Fig 1. Maintaining the concentration of the mixture as specified above, by varying the flow rate, the flame arrester is to be heated until the highest obtainable temperature on the cargo tank side of the arrester is reached. Temperatures are to be measured, for example, at the protected side of the flame quenching matrix of the arrester (or at the seat of the valve in the case of testing high velocity vents according to [4.3]). The highest obtainable temperature may be considered to have been reached when the rate of rise of temperature does not exceed 0,5°C per minute over a ten-minute period. This temperature is to be maintained for a period of ten minutes, after which the flow is to be stopped and the conditions observed. The temperature of the test gas is to be within the range of 15°C to 40°C.

   If no temperature rise occurs at all, the arrester is to be inspected for a more adequate position of the temperature sensor, taking account of the visually registered position of the stabilised flame during the first test sequence. Positions which require the drilling of small holes into fixed parts of the arrester are to be taken into account. If all this is not successful, the temperature sensor is to be affixed at the unprotected side of the arrester in a position near to the stabilised flame.

   If difficulties arise in establishing stationary temperature conditions (at elevated temperatures), the following criteria is to apply: using the flow rate which produced the maximum temperature during the foregoing test sequence, endurance burning is to be continued for a period of two hours from the time the above-mentioned flow rate has been established. After that period the flow is to be stopped and the conditions observed. Flashback is not to occur during this test.

4.2.4 Pressure/vacuum valve integrated to a flame arresting device

When a pressure/vacuum valve is integrated to a flame arresting device, the flashback test is to be performed with the pressure/vacuum valve blocked open. If there are no additional flame quenching elements integrated in a pressure valve, this valve is to be considered and tested as a high velocity vent valve according to [4.3].

4.3 Test procedures for high velocity vents

4.3.1 Test rig

The test rig is to be capable of producing the required volume flow rate. In Fig 2 and Fig 3 drawings of suitable test rigs are shown. Other test rigs may be used provided the tests are performed to the satisfaction of the Society.

4.3.2 Flow condition test

A flow condition test is to be carried out with high velocity vents using compressed air or gas at agreed flow rates. The following are to be recorded:

a) The flow rate; where air or a gas other than vapours of cargoes with which the vent is to be used is employed in the test, the flow rates achieved are to be corrected to reflect the vapour density of such cargoes

b) The pressure before the vent opens; the pressure in the test tank on which the device is located is not to rise at a rate greater than 0,01 $N/mm^2/min$

c) The pressure at which the vent opens

d) The pressure at which the vent closes

e) The efflux velocity at the outlet which is not to be less than 30 m/s at any time when the valve is open.

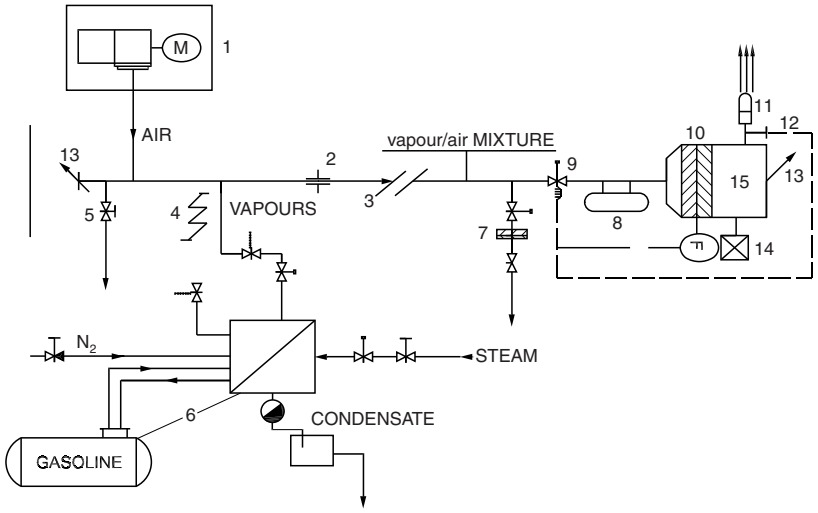
4.3.3 Fire safety tests

The following fire safety tests are to be conducted while adhering to [2.3.6] using a mixture of gasoline vapour and air or technical hexane vapour and air, which produces the most easily ignitable mixture at the point of ignition. This mixture is to be ignited with the aid of a permanent pilot flame or a spark igniter at the outlet.

a) Flashback tests in which propane may be used instead of gasoline or hexane are to be carried out with the vent in the upright position and then inclined at 10° from the vertical. For some vent designs further tests with the vent inclined in more than one direction may be necessary. In each of these tests the flow is to be reduced until the vent closes and the flame is extinguished, and each is to be carried out at least 50 times. The vacuum side of combined valves is to be tested in accordance with [4.2.2] with the vacuum valve maintained in the open position for the duration of this test, in order to verify the efficiency of the device which is to be fitted.

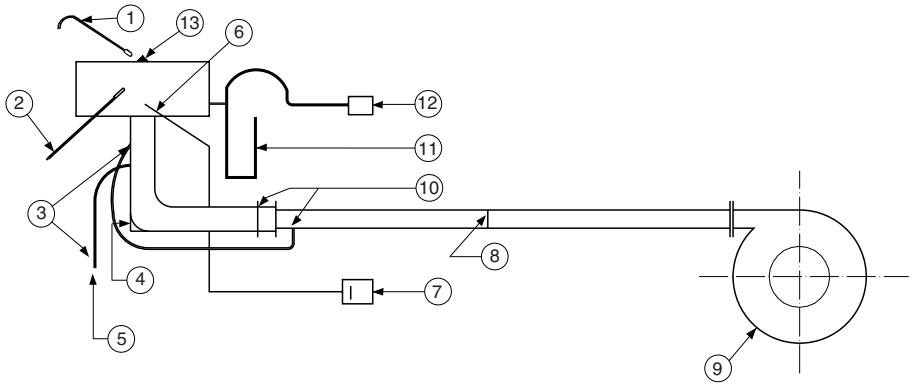
b) An endurance burning test, as described in [4.2.3], is to be carried out. Following this test, the main flame is to be extinguished and then, with the pilot flame burning or the spark igniter discharging, small quantities of the most easily ignitable mixture are to be allowed to escape for a period of ten minutes maintaining a pressure below the valve of 90% of the valve opening setting, during which time flashback is not to occur. For the purpose of this test the soft seals or seats are to be removed.

Figure 2 : Schematic plan of the test plant for high velocity valves (endurance burning test only)



(1): Fan with variable speed
(2): Volume rate indicator
(3): Pipe (diameter=500 mm, length=30 m)
(4): Heated vapour pipe
(5): Air bypass
(6): Evaporator and gasoline storage tank
(7): Vapour/air mixture bypass
(8): Extinguishing agents
(9): Automatic control and quick action stop valve
(10): Explosion arresting crimped ribbon with temperature sensors for the safety of the test rig
(11): High velocity valve to be tested
(12): Flame detector
(13): Bursting diaphragm
(14): Concentration indicator
(15): Tank

Figure 3 : Test rig for high velocity vents



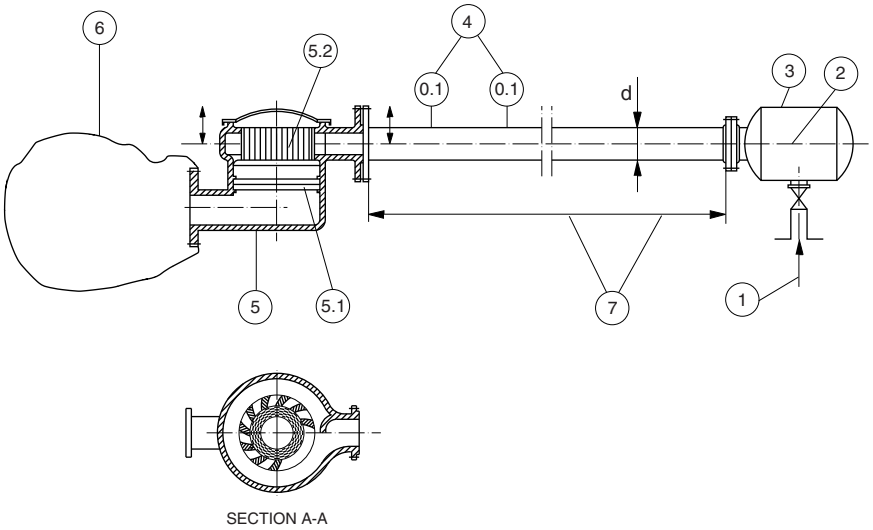
(1): Primary igniter
(2): Secondary igniter
(3): Cocks
(4): Explosion door
(5): Gas supply
(6): Flashback detector
(7): Chart recorder
(8): Flow meter
(9): Fan
(10): Spade blank and bypass line for low rates
(11): Pressure gauge
(12): Gas analyser
(13): High velocity vent to be tested

4.4 Test rig and test procedures for detonation flame arresters located in-line

4.4.1 A flame arrester is to be installed at one end of a pipe of suitable length and of the same diameter as the flange of the flame arrester. On the opposed flange a pipe of a length corresponding to 10 pipe diameters is to be affixed and closed by a plastic bag or diaphragm. The pipe is to be filled with the most easily ignitable mixture of propane and air, which is then to be ignited. The velocity of the flame near the flame arrester is to be measured and is to have the same value as that for stable detonations.

Note 1: The dimensions of the plastic bag are to be at least 4 m circumference, 4 m length and a material wall thickness of 0,05 mm.

Figure 4 : Test rig for arresters located in-line



(1): Explosive mixture inlet

(2): Ignition source; ignition within non-streaming mixture

(3): Tank

(4): Measuring system for flame speed of a stable detonation

(5): Flame arrester located in-line; (5.1): Flame arrester element; (5.2): Shock wave absorber

(6): Plastic bag

(7): l/d = 100

4.4.2 Three detonation tests are to be conducted, no flashback is to occur through the device and no part of the flame arrester is to be damaged or show permanent deformation.

4.4.3 Other test rigs may be used provided the tests are carried out to the satisfaction of the Society. A drawing of the test rig is shown in Fig 4.

4.5 Operational test procedure

4.5.1 Corrosion test

A corrosion test is to be carried out. In this test a complete device, including a section of the pipe to which it is fitted, is to be exposed to a 5% sodium chloride solution spray at a temperature of 25°C for a period of 240 hours, and allowed to dry for 48 hours. An equivalent test may be conducted to the satisfaction of the Society. Following this test, all movable parts are to operate properly and there are to be no corrosion deposits which cannot be washed off.

4.5.2 Hydraulic pressure test

A hydraulic pressure test is to be carried out in the casing or housing of a sample device, in accordance with [2.2.15].

4.6 Laboratory report

4.6.1 The laboratory report is to include:

a) Detailed drawings of the device

b) Types of tests conducted; where in-line devices are tested, this information is to include the maximum pressures and velocities observed in the test

c) Specific advice on approved attachments

d) Types of cargo for which the device is approved

e) Drawings of the test rig

f) In the case of high velocity vents, the pressures at which the device opens and closes and the efflux velocity, and

g) All the information marked on the device in [2.5].

Appendix 2 Design of Crude Oil Washing Systems

1 General

1.1 Application

1.1.1 This Appendix reproduces the text of IMO Resolution A.446. It applies to ships having the notation **oil tanker** in the conditions stated in Ch 7, Sec 4, [4.6.1].

1.2 Definitions

1.2.1 Arrival ballast

For the purpose of this Appendix, "arrival ballast" means clean ballast as defined in Ch 7, Sec 1, [1.3.5].

1.2.2 Departure ballast

For the purpose of this Appendix, "departure ballast" means ballast other than arrival ballast.

1.3 Operations and Equipment Manual

1.3.1 The Operations and Equipment Manual of the crude oil washing system is to be submitted to the Society for information. It is to contain at least the following information:

a) Line drawing of the crude oil washing system showing the respective position of pumps, lines and washing machines which relate to the crude oil washing system

b) A description of the system and a listing of procedures for checking that equipment is working properly during crude oil washing operations. This is to include a listing of the system and equipment parameters to be monitored, such as line pressure, oxygen level, machine revolutions, duration of cycles, etc. The established values for these parameters are to be included. The results of the tests carried out in accordance with [3.3] and the values of all parameters monitored during such tests are also to be included.

c) Other information referred to in [2.1.8], [2.2.2], [2.3.2], [2.3.5], [2.4.3] and [3.3.1].

2 Design and installation

2.1 Piping

2.1.1 The crude oil washing pipes and all valves incorporated in the supply piping system are to be of steel or other equivalent material, of adequate strength having regard to the pressure to which they may be subjected, and properly jointed and supported.

Note 1: Grey cast iron may be permitted in the supply system for crude oil washing systems when complying with nationally approved standards.

2.1.2 The crude oil washing system is to consist of permanent pipework and is to be independent of the fire mains and of any system other than for tank washing except that sections of the ship's cargo system may be incorporated into the crude oil washing system provided that they meet the requirements applicable to crude oil pipework. Notwithstanding the above requirements, in combination carriers the following arrangements may be allowed:

a) The removal of the equipment, if necessary, when carrying cargoes other than crude oil, provided that, when reinstated, the system is as originally fitted and tested for oil-tightness

b) The use of flexible hose pipes to connect the crude oil washing system to tank washing machines if it is necessary to locate these machines in a cargo tank hatch cover. Such flexible hose pipes are to be provided with flanged connections, manufactured and tested in accordance with standards acceptable to the Society, and consistent with the duties the hoses are required to perform. The length of these hoses is not to be greater than necessary to connect the tank washing machines to an adjacent point just outside the hatch coaming. The hoses are to be removed to a suitably prepared and protected stowage location when not in use.

2.1.3 Provisions are to be made to prevent overpressure in the tank washing supply piping. Any relief device fitted to prevent overpressure is to discharge into the suction side of the supply pump. Alternative methods to the satisfaction of the Society may be accepted provided an equivalent degree of safety and environmental protection is provided.

Note 1: Where the system is served only by centrifugal pumps so designed that the pressure derived cannot exceed that for which the piping is designed, a temperature sensing device located in the pump casing is required to stop the pump in the case of overheating.

2.1.4 Where hydrant valves are fitted for water washing purposes on tank washing lines, all such valves are to be of adequate strength and provisions are to be made for such connections to be blanked off by blank flanges when washing lines may contain crude oil. Alternatively, hydrant valves are to be isolated from the crude oil washing system by spade blanks.

2.1.5 All connections for pressure gauges or other instrumentation are to be provided with isolating valves adjacent to the lines unless the fitting is of the sealed type.

2.1.6 No part of the crude oil washing system is to enter machinery spaces. Where the tank washing system is fitted with a steam heater for use when water washing, the heater is to be located outside machinery spaces and effectively isolated during crude oil washing by double shut-off valves or by clearly identifiable blanks.

2.1.7 Where combined crude oil-water washing supply piping is provided, the piping is to be so designed that it can be drained so far as practicable of crude oil, before water washing is commenced, into designated spaces. These spaces may be the slop tank or other cargo spaces.

2.1.8 The piping system is to be of such diameter that the greatest number of tank cleaning machines required, as specified in the Operations and Equipment Manual, can be operated simultaneously at the designed pressure and throughput. The arrangement of the piping is to be such that the required number of tank cleaning machines for each cargo compartment as specified in the Operations and Equipment Manual can be operated simultaneously.

2.1.9 The crude oil washing supply piping is to be anchored (firmly attached) to the ship's structure at appropriate locations, and means are to be provided to permit freedom of movement elsewhere to accommodate thermal expansion and flexing of the ship. The anchoring is to be such that any hydraulic shock can be absorbed without undue movement of the supply piping. The anchors are normally to be situated at the ends furthest from the entry of the crude oil supply to the supply piping. If tank washing machines are used to anchor the ends of branch pipes then special arrangements are necessary to anchor these sections when the machines are removed for any reason.

2.2 Tank washing machines

2.2.1 Tank washing machines for crude oil washing are to be permanently mounted and of a design acceptable to the Society.

2.2.2 The performance characteristic of a tank washing machine is governed by nozzle diameter, working pressure and the movement pattern and timing. Each tank cleaning machine fitted is to have a characteristic such that the sections of the cargo tank covered by that machine will be effectively cleaned within the time specified in the Operations and Equipment Manual.

2.2.3 Tank washing machines are to be mounted in each cargo tank and the method of support is to be to the satisfaction of the Society. Where a machine is positioned well below the deck level to cater for protuberances in the tank, consideration may need to be given to additional support for the machine and its supply piping.

2.2.4 Each machine is to be capable of being isolated by means of stop valves in the supply line. If a deck mounted tank washing machine is removed for any reason, provision is to be made to blank off the oil supply line to the machine for the period the machine is removed. Similarly, provision is to be made to close the tank opening with a plate or equivalent means.

Note 1: Where more than one submerged machine is connected to the same supply line, a single isolating stop valve in the supply line may be acceptable provided the rotation of the submerged machine can be verified in accordance with [2.2.10]

2.2.5 The number and location of tank washing machines are to be to the satisfaction of the Society.

2.2.6 The location of the machines is dependent upon the characteristics detailed in [2.2.2] and upon the configuration of the internal structure of the tank.

2.2.7 The number and location of the machines in each cargo tank are to be such that all horizontal and vertical areas are washed by direct impingement or effectively by deflection or splashing of the impinging jet. In assessing an acceptable degree of jet deflection and splashing, particular attention is to be paid to the washing of upward facing horizontal areas and the following parameters are to be used:

a) For horizontal areas of a tank bottom and the upper surfaces of a tank's stringers and other large primary structural members, the total area shielded from direct impingement by deck or bottom transverses, main girders, stringers or similar large primary structural members is not to exceed 10 per cent of the horizontal area of the tank bottom, the upper surface of stringers, and other large primary structural members.

b) For vertical areas of the sides of a tank, the total area of the tank's sides shielded from direct impingement by deck or bottom transverses, main girders, stringers or similar large primary structural members is not to exceed 15 per cent of the total area of the tank's sides.

In some installations, it may be necessary to consider the fitting of more than one type of tank washing machine in order to effect adequate coverage.

Note 1: With regard to the application of this requirement, a slop tank is considered as a cargo tank.

2.2.8 At the design stage the following minimum procedures are to be used to determine the area of the tank surface covered by direct impingement:

a) Using suitable structural plans, lines are set out from the tips of each machine to those parts of the tank within the range of the jets.

b) Where the configuration of the tanks is considered by the Society to be complicated, a pinpoint of light simulating the tip of the tank washing machine in a scale model of the tank is to be used.

2.2.9 The design of the deck mounted tank washing machines is to be such that means are provided external to cargo tanks which, when crude oil washing is in progress, would indicate the rotation and arc of the movement of the machine. Where the deck mounted machine is of the non-programmable, dual nozzle type, alternative methods to the satisfaction of the Society may be accepted provided an equivalent degree of verification is attained.

2.2.10 Where submerged machines are required, they are to be non-programmable and, in order to comply with the requirements of [2.2.7], it is to be possible to verify their rotation by one of the following methods:

a) By indicators external to the tanks

b) By checking the characteristic sound pattern of the machine, in which case the operation of the machine is to be verified towards the end of each wash cycle. Where two or more submerged machines are installed on the same supply line, valves are to be provided and arranged so that the operation of each machine can be verified independently of other machines on the same supply line.

c) By gas freeing the tank and checking the operation of the machine with water during ballast voyages.

2.3 Pumps

2.3.1 Pumps supplying crude oil to tank cleaning machines are to be either the cargo pumps or pumps specifically provided for the purpose.

2.3.2 The capacity of the pumps is to be sufficient to provide the necessary throughput at the required pressure for the maximum number of tank cleaning machines required to be operated simultaneously as specified in the Operations and Equipment Manual. In addition to the above requirement, if an eductor system is fitted for tank stripping, the pumps are to be capable of supplying the eductor driving fluid to meet the provisions of [2.4.2].

2.3.3 The capacity of the pumps is to be such that the requirements of [2.3.2] can be met with any one pump inoperative. The pumping and piping arrangements are to be such that the crude oil washing system can be effectively operated with any one pump out of use.

2.3.4 The carriage of more than one grade of cargo is not to prevent crude oil washing of tanks.

2.3.5 To permit crude oil washing to be effectively carried out where the back pressure presented by the shore terminal is below the pressure required for crude oil washing, provision is to be made such that an adequate pressure to the washing machines can be maintained in accordance with [2.3.2]. This requirement is to be met with any one cargo pump out of action. The minimum supply pressure required for crude oil washing is to be specified in the Operations and Equipment Manual. Should this minimum supply pressure not be obtainable, crude oil washing operations are not to be carried out.

2.4 Stripping system

2.4.1 The design of the system for stripping crude oil from the bottom of every cargo tank is to be to the satisfaction of the Society.

2.4.2 The design and capacity of the tank stripping system are to be such that the bottom of the tank being cleaned is kept free of accumulations of oil and sediment towards completion of the tank washing process.

2.4.3 The stripping system is to be at least 1,25 times the total throughput of all the tank cleaning machines to be operated simultaneously when washing the bottom of the cargo tanks as described in the ship's Operations and Equipment Manual.

2.4.4 Means such as level gauges, hand dipping and stripping system performance gauges as referred to in [2.4.8] are to be provided for checking that the bottom of every cargo tank is dry after crude oil washing. Suitable arrangements for hand dipping are to be provided at the aftermost portion of a cargo tank and in three other suitable locations unless other approved means are fitted for efficiently ascertaining that the bottom of every cargo tank is dry. For the purpose of this paragraph, the cargo tank bottom is to be considered "dry" if there is no more than a small quantity of oil near the stripping suction with no accumulation of oil elsewhere in the tank.

2.4.5 Means are to be provided to drain all cargo pumps and lines at the completion of cargo discharge, where necessary, by connection to a stripping device. The line and pump draining is to be capable of being discharged both to a cargo tank and ashore. For discharge ashore, a special small diameter line is to be provided for this purpose and connected outboard of the ship's manifold valve. The cross-sectional area of this line is not to exceed 10 per cent of that of a main cargo discharge line.

Note 1: In crude oil tankers having individual cargo pumps in each tank, each pump having an individual piping system, dispensation from the required special small diameter line may be granted in cases where the combined amount of oil left in the tank after stripping and the volume

of oil in the piping system from the manifold to the tank is less than 0,00085 times the volume of the cargo tank. The above consideration is also to apply if a deepwell cargo pump system is provided with an evacuating system for retained oil.

2.4.6 The means for stripping oil from cargo tanks are to be a positive displacement pump, self-priming centrifugal pump or eductor or other methods to the satisfaction of the Society. Where a stripping line is connected to a number of tanks, means are to be provided for isolating each tank not being stripped at that particular time.

2.4.7 The carriage of more than one grade of cargo is not to prevent crude oil washing of tanks.

2.4.8 Equipment is to be provided for monitoring the efficiency of the stripping system. All such equipment is to have remote read out facilities in the cargo control room or in some other safe and convenient place easily accessible to the officer in charge of cargo and crude oil washing operations. Where a stripping pump is provided, the monitoring equipment is to include either a flow indicator, or a stroke counter or revolution counter as appropriate, and pressure gauges at the inlet and discharge connections of the pump or equivalent. Where eductors are provided, the monitoring equipment is to include pressure gauges at the driving fluid intake and at the discharge and a pressure/vacuum gauge at the suction intake.

2.4.9 The internal structure of the tank is to be such that drainage of oil to the tank suctions of the stripping system is adequate to meet the requirements of [2.4.2] and [2.4.4].

2.5 Ballast lines

2.5.1 Where a separate ballast water system for ballasting cargo tanks is not provided, the arrangement is to be such that the cargo pump, manifolds and pipes used for ballasting can be safely and effectively drained of oil before ballasting.

3 Inspection and testing

3.1 Initial survey

3.1.1 The initial survey required in Ch 7, Sec 4, [6.3.2] is to include a complete inspection of the crude oil washing equipment and arrangements and, except for the cases specified in [3.3.3], an examination of the tanks after they have been crude oil washed and the additional checks specified in [3.3.1] and [3.3.2] to ensure that the washing system efficiency is in accordance with this Appendix.

3.2 Piping

3.2.1 The piping system is to be tested to one and a half times the working pressure after it has been installed on the ship.

3.3 Tank washing machines

3.3.1 To confirm the cleanliness of the tank and to verify the design in respect of the number and location of the tank washing machines, a visual inspection is to be made by entry to the tanks after a crude oil wash but prior to any water rinse which may be specified in the Operations and Equipment Manual. The bottom of the tank to be inspected may, however, be flushed with water and stripped in order to remove any wedge of liquid crude oil remaining on the tank bottom before gas freeing for entry. This inspection is to ensure that the tank is essentially free of oil clingage and deposits. If the flushing procedure is adopted, a similar but unflushed tank is to be used for the test specified in [3.3.2].

3.3.2 To verify the effectiveness of the stripping and drainage arrangements, a measurement is to be made of the amount of oil floating on top of the departure ballast. The ratio of the volume of oil on top of the departure ballast water to the volume of tanks that contain this water is not to exceed 0,00085. This test is to be carried out after crude oil washing and stripping in a tank similar in all relevant respects to the tank examined in accordance with [3.3.1] above, which has not been subjected to a water rinse or to the intervening water flushing permissible in [3.3.1] above.

3.3.3 When the Society is satisfied that ships are similar in all relevant respects, the provisions of [3.3.1] and [3.3.2] need only be applied to one such ship. Furthermore, where a ship has a series of tanks that are similar in all relevant respects then, for that series of tanks, the requirements of [3.3.1] need only be applied to one tank of that series.

3.4 Stripping system

3.4.1 Care is to be taken that both longitudinal and transverse drainage are satisfactory. Drainage is to be verified during the inspection required by [3.3].

Appendix 3 Lists of Oils

1 Application

1.1 Scope of the lists of oils

1.1.1 The lists set out in this Appendix include the oils the carriage in bulk of which is covered by the service notations **oil tanker** or **oil tanker, flash point > 60°C** or **oil tanker, asphalt carrier**, under the provisions of Ch 7, Sec 1, [1.1.3].

2 Lists of products

2.1 List of oils

2.1.1 The list given in Tab 1 is reproduced from Appendix 1 of the MARPOL 73/78 Convention, except that naphtha solvent is, in the opinion of the Society, to be considered as a chemical to which Part D, Chapter 8 applies. This list is not necessarily comprehensive.

Table 1 : List of oils

Asphalt solutions • Blending stocks • Roofers flux • Straight run residue	Gasoline blending stock • Alkylates - fuel • Reformates • Polymer - fuel
Oils • Clarified • Crude oil • Mixtures containing crude oil • Diesel oil • Fuel oil n° 4 • Fuel oil n° 5 • Fuel oil n° 6 • Residual fuel oil • Road oil • Transformer oil • Aromatic oil (excluding vegetable oil) • Lubricating oils and blending stocks • Mineral oil • Spindle oil • Turbine oil	Gasolines • Casinghead (natural) • Automotive • Aviation • Straight run • Fuel oil n° 1 (kerosene) • Fuel oil n° 1-D • Fuel oil n° 2 • Fuel oil n° 2-D
Distillates • Straight run • Flashed feed stocks	Jet fuels • JP-1 (kerosene) • JP-3 • JP-4 • JP-5 (kerosene, heavy) • Turbo fuel • Kerosene • Mineral spirit
Gas oil • Cracked	Naphtha • Petroleum • Heartcut distillate oil

Appendix 4 List of Products for which Part D, Chapter 8 and IBC Code do not Apply

1 Application

1.1 Scope of the list

1.1.1 The list set out in this Appendix includes all products to which Part D, Chapter 8 and IBC Code do not apply. Such products are allowed to be carried by ships having the service notation **FLS tanker** or, where their flash point is above 60°C, also by ships having the service notation **FLS tanker flash point > 60 °C**.

Where indicated in the list, some products are also allowed to be carried by ships having the service notation **tanker**.

1.2 Safety and pollution hazards

1.2.1

a) *The following are products which have been reviewed for their safety and pollution hazards and determined not to present hazards to such an extent as to warrant application of the* IBC *Code* and Part D, Chapter 8.

b) *Although the products listed in this* Appendix *fall outside the scope of the* IBC *Code* and Part D, Chapter 8*, some safety precautions* are *needed for their safe transportation*. Relevant requirements are summarized in Tab 1.

c) *Some liquid substances are identified as falling into pollution category Z and, therefore, subject to certain requirements of MARPOL Annex II*.

d) *Liquid mixtures which are assessed or provisionally assessed under Regulation 6.3 of MARPOL Annex II as falling into pollution category Z or OS, and which do not present safety hazards, may be carried under the appropriate entry in this* Appendix *for "Noxious or Non-Noxious liquid substances, not otherwise specified (n.o.s.)"*.

e) The liquid substances identified as falling into pollution category OS are not subject to any requirements of MARPOL Annex II in particular in respect of:
- the discharge of bilge or ballast water or other residues or mixtures containing only such substances
- the discharge into the sea of clean ballast or segregated ballast.

2 List of products for which Part D, Chapter 8 and IBC Code do not apply

2.1

2.1.1 The list of products for which Part D, Chapter 8 and IBC Code do not apply is given in Tab 1. The relevant symbols and notations used in Tab 1 are given in Tab 2.

Table 1 : List of easy chemicals

Product name	Pollution category	Electrical equipment temperature class	Electrical equipment apparatus group	Flash-point (°C)	Fire protection	Service notation
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Acetone	Z	T1	IIA	–18	A	FLS
Alcoholic beverages, not otherwise specified	Z	–	–	20 to 60 **(1)**	A	FLS
Apple juice	OS	–	–	NF	–	T
n-Butyl alcohol	Z	T2	IIA	29	A	FLS
sec-Butyl alcohol	Z	T2	IIA	24	A	FLS
Calcium carbonate slurry	OS	–	–	NF	–	T
Clay slurry	OS	–	–	NF	–	T
Coal slurry	OS	–	–	NF	–	T
Ethyl alcohol	Z	T2	IIB	13	A	FLS
Glucose solution	OS	–	–	NF	–	T
Glycerol ethoxylated	OS	–	–	>60	–	FLS>60
Hydrogenated starch hydrolysate	OS	–	–	NF	–	T

Product name	Pollution category	Electrical equipment temperature class	Electrical equipment apparatus group	Flash-point (°C)	Fire protection	Service notation
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Isopropyl alcohol	Z	T2	IIA	22	A	FLS
Kaolin slurry	OS	–	–	NF	–	T
Lecithin	OS	–	–	NF	–	T
Maltitol solution	OS	–	–	NF	–	T
Microsilica slurry	OS	–	–	NF	–	T
Molasses	OS	–	–	>60	–	FLS>60
Noxious liquid, n.o.s. (trade name ..., contains ...) Cat. Z	Z	–	–	<60	A	FLS
Non noxious liquid, n.o.s. (trade name …, contains ...) Cat. OS	OS	–	–	<60	A	FLS
Orange juice (concentrated)	OS	–	–	NF	–	T
Orange juice (not concentrated)	OS	–	–	NF	–	T
Potassium chloride solution (less than 26%)	OS	–	–	NF	–	T
Propylene glycol	OS	T2	–	>60	–	FLS>60
Sodium acetate solutions	Z	–	–	NF	–	T
Sodium bicarbonate solutions (less than 10%)	OS	–	–	NF	–	T
Sorbitol solution	OS	–	–	>60	–	FLS>60
Sulphonated polyacrylate solution	Z	–	–	<60	A	FLS
Tetraethyl silicate monomer/oligomer (20% in ethanol)	Z	T2	IIB	<60	A	FLS
Triethylene glycol	OS	T2	–	>60	–	FLS>60
Vegetable protein solution (hydrolysed)	OS	–	–	NF	–	T
Water	OS	–	–	NF	–	T
(1) Composition dependent						

Table 2 : Symbols and notations used in the list of easy chemicals

Items	Column	Comments
Product name	(a)	Gives the alphabetical name of the products
Pollution category	(b)	The letter Z refers to the pollution category Z as defined in MARPOL Annex II. The symbol OS means that the product was evaluated and found to fall outside the pollution categories X, Y and Z defined in MARPOL Annex II
Electrical equipment temperature class	(c)	The symbols T1 to T6 refer to the electrical equipment temperature classes defined in IEC Publication 60079-20-1:2010
Electrical equipment apparatus group	(d)	The symbols IIA, IIB and IIC refer to the electrical equipment apparatus groups defined in IEC Publication 60079-20-1:2010
Flash point	(e)	NF: non-flammable product
Fire protection	(f)	The letters A, B, C and D refer to the following fire-extinguishing media determined to be effective for certain products: A : Alcohol-resistant foam (or multi-purpose foam) B : Regular foam, encompasses all foams that are not of an alcohol-resistant type, including fluoro-protein and aqueous-film-forming foam (AFFF) C : Water spray D : Dry chemical (powder)
Service notation	(g)	The symbols FLS, FLS>60 and T are defined as follows: FLS : Means that the product is allowed to be carried by a ship having the service notation **FLS tanker** FLS>60 : Means that the product is allowed to be carried by a ship having the service notation **FLS tanker**, **flash point > 60°C** T : Means that the product is allowed to be carried by a ship having the service notation **tanker**

Appendix 5 Accidental Oil Outflow Performance

Symbols

d_s : Load line draught, equal to the vertical distance, in m, from the moulded baseline at mid-length to the waterline corresponding to the summer freeboard to be assigned to the ship. Calculations pertaining to this regulation are to be based on draught d_S, notwithstanding assigned draughts that may exceed d_S, such as the tropical loadline

d_B : Vertical distance, in metres, from the moulded baseline at mid-length to the waterline corresponding to 30% of the depth D_S

B_S : Greatest moulded breadth of the ship, in metres, at or below the deepest load line d_S

B_B : Greatest moulded breadth of the ship, in metres, at or below the waterline d_B

D_S : Moulded depth, in metres, measured at mid-length to the upper deck at side

ρ_s : Density of sea water, to be taken as 1025 kg/m^3

ρ_n : Nominal density of cargo oil, in kg/m^3, to be taken equal to:

$\rho_n = 1000\ (DWT)/C$

C : Total volume of cargo oil, in m^3, at 98% tank filling.

1 General

1.1 Purpose

1.1.1 The purpose of the present Appendix is to provide a method for the calculation of the accidental oil outflow performance referred to in Ch 7, Sec 2, [3.4.1].

1.2 Application

1.2.1 The requirements of the present Appendix apply only to ships having one of the following notations:

oil tanker

oil tanker, flash point > 60°C

oil tanker, asphalt carrier

2 Accidental oil outflow performance

2.1 Mean oil outflow parameter

2.1.1 To provide adequate protection against oil pollution in the event of collision or stranding the following is to be complied with:

a) For oil tankers of 5000 tonnes deadweight (DWT) and above, the mean oil outflow parameter O_M is to be as follows:

- for C = 200000 m^3:

  $O_M = 0,015$
- for 200000 m^3 < C < 400000 m^3:

  $O_M = 0,012 + (0,003/200000)\ (400000 - C)$
- for C = 400000 m^3:

  $O_M = 0,012$

For combination carriers between 5000 tonnes deadweight (DWT) and 200000 m^3 capacity, the mean oil outflow parameter O_M may be applied, provided calculations are submitted to the satisfaction of the Society, demonstrating that after accounting for its increased structural strength, the combination carrier has at least equivalent oil outflow performance to a standard double hull tanker of the same size having a $O_M = 0,015$.

- for C = 100000 m^3:

  $O_M = 0,021$
- for 100000 m^3 < C < 200000 m^3:

  $O_M = 0,015 + (0,006/100000)\ (200000 - C)$

b) For oil tankers of less than 5000 tonnes deadweight (DWT):

The length of each cargo tank is not to exceed 10 m or one of the following values, whichever is the greater:

- where no longitudinal bulkhead is provided inside the cargo tanks:
  $(0,5\ b_i/B + 0,1)\ L$ without exceeding 0,2 L
- where centreline longitudinal bulkhead is provided inside the cargo tanks:
  $(0,25\ b_i/B + 0,15)\ L$
- where two or more longitudinal bulkheads are provided inside the cargo tanks:
  as defined in Tab 1.

Table 1 : Length of each cargo tank for oil tankers of less than 5000 tonnes deadweight (DWT)

Wing cargo tanks	Centre cargo tanks		
0,2 L	$b_i/B \geq 0,2$ L	$b_i/B < 0,2$ L	
	0,2 L	no centreline longitudinal bulkhead is provided	a centreline longitudinal bulkhead is provided
		$(0,5\ b_i/B + 0,1)$ L	$(0,25\ b_i/B + 0,15)$ L

Note 1:

b_i : Minimum distance from the ship's side to the outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centreline at the level corresponding to the assigned summer freeboard.

2.2 Calculation

2.2.1 Assumptions

The cargo block length extends between the forward and aft extremities of all tanks arranged for the carriage of cargo oil, including slop tanks.

Where this regulation refers to cargo tanks, it is to be understood to include all cargo tanks, slop tanks and fuel tanks located within the cargo block length.

The ship is to be assumed loaded to the load line draught d_S without trim or heel.

All cargo oil tanks is to be assumed loaded to 98% of their volumetric capacity.

For the purposes of these outflow calculations, the permeability of each space within the cargo block, including cargo tanks, ballast tanks and other non-oil spaces is to be taken as 0,99, unless proven otherwise.

Suction wells may be neglected in the determination of tank location provided that such wells are as small as practicable and the distance between the well bottom and bottom shell plating is not less than 0,5h, where h is equal to B/15 or 2,0 m, whichever is the lesser, without being taken less than 1,0 m.

2.2.2 Combination of oil outflow parameters

The mean oil outflow is to be calculated independently for side damage and for bottom damage and then combined into the non-dimensional oil outflow parameter O_M, as follows:

$$O_M = (0,4\ O_{MS} + 0,6\ O_{MB})/C$$

where:

O_{MS} : Outflow for side damage, in m^3

O_{MB} : Outflow for bottom damage, in m^3.

For bottom damage, independent calculations for mean outflow is to be done for 0 m and minus 2,5 m tide conditions, and then combined as follows:

$$O_{MB} = 0,7\ O_{MB(0)} + 0,3\ O_{MB(2,5)}$$

where:

$O_{MB(0)}$: Outflow for 0 m tide condition

$O_{MB(2,5)}$: Outflow for minus 2,5 m tide condition, in m^3.

2.2.3 Mean outflow

a) The mean outflow, in m^3, for side damage O_{MS} is to be calculated as follows:

$$O_{MS} = C_3\ \Sigma(P_{S(i)}\ O_{s(i)})$$

where:

i : Represents each cargo tank under consideration

n : Total number of cargo tanks

$P_{S(i)}$: Probability of penetrating cargo tank i from side damage, calculated in accordance with [2.2.4]

$O_{S(i)}$: Outflow, in m^3, from side damage to cargo tank i, which is assumed equal to the total volume in cargo tank i at 98% filling

C_3 : • for ships having two longitudinal bulkheads inside the cargo tanks, provided these bulkheads are continuous over the cargo block and $P_{S(i)}$ is developed in accordance with this regulation:

$C_3 = 0,77$

• for all other ships:

$C_3 = 1,00$

b) The mean outflow for bottom damage is to be calculated for each tidal condition as follows:

• $O_{MB(0)} = \Sigma(P_{B(i)}\ O_{B(i)}\ C_{DB(i)})$

where:

i : Represents each cargo tank under consideration

n : Total number of cargo tanks

$P_{B(i)}$: Probability of penetrating cargo tank i from bottom damage calculated in accordance with [2.2.5]

$O_{B(i)}$: Outflow from cargo tank i, in m^3 as defined in item c)

$C_{DB(i)}$: Factor to account for oil capture as defined in item d)

• $O_{MB(2,5)} = \Sigma(P_{B(i)}\ O_{B(i)}\ C_{DB(i)})$

where:

$O_{B(i)}$: Outflow from cargo tank i, in m^3, after tidal change.

c) The oil outflow $O_{B(i)}$ for each cargo oil tank is to be calculated based on pressure-balance principles, in accordance with the following assumptions:

• the ship is to be assumed stranded with zero trim and heel, with the stranded draught prior to tidal change equal to the load line draught d_s

• the cargo level after damage is to be calculated as follows:

$h_c = ((d_s + t_c - Z_l)\ \rho_s - (1000\ p) / g) / \rho_n$

where:

h_c : Height of the cargo oil above Z_l, in m

t_c : Tidal change, in m. Reductions in tide shall be expressed as negative values

Z_l : Height of the lowest point in the cargo tank above baseline, in m

p : If an inert gas system is fitted, the normal overpressure, in kPa, to be taken as not less than 5 kPa.

If an inert gas system is not fitted, the overpressure may be taken as 0

• for cargo tanks bounded by the bottom shell, unless proven otherwise, oil outflow $O_{B(i)}$ is to be taken not less than 1% of the total volume of cargo oil loaded in cargo tank i, to account for initial exchange losses and dynamic effects due to current and waves.

d) In the case of bottom damage, a portion from the outflow from a cargo tank may be captured by non-oil compartments. This effect is approximated by application of the factor $C_{DB(i)}$ for each tank, which is to be taken as follows:

• for cargo tanks bounded from below by non-oil compartments:

$C_{DB(i)} = 0,6$

• for cargo tanks bounded by the bottom shell:

$C_{DB(i)} = 1,0$

2.2.4 Probability of breaching a compartment from side damage

The probability P_S of breaching a compartment from side damage is to be calculated as follows:

$P_S = P_{SL}\ P_{SV}\ P_{ST}$

where:

P_{SL} : Probability the damage extends into the longitudinal zone bounded by X_a and X_f

$P_{SL} = 1 - P_{Sf} - P_{Sa}$

P_{SV} : Probability the damage extends into the vertical zone bounded by Z_l and Z_u

$P_{SV} = 1 - P_{Su} - P_{Sl}$

P_{ST} : Probability the damage extends transversely beyond the boundary defined by y

$P_{ST} = 1 - P_{Sy}$

P_{Sa}, P_{Sf}, P_{Sl} and P_{Su} are to be determined by linear interpolation from Tab 2 of probabilities for side damage provided in Tab 2 where:

P_{Sa} : Probability the damage lies entirely aft of location X_a / L

P_{Sf} : Probability the damage lies entirely forward of location X_f / L

P_{Sl} : Probability the damage lies entirely below the tank

P_{Su} : Probability the damage lies entirely above the tank.

P_{Sy}, the probability the damage lies entirely outboard of the tank, is to be determined as follows:

- for $y / B_S = 0,05$:

  $P_{Sy} = (24,96 – 199,6\ y / B_S)\ (y / B_S)$
- for $0,05 < y / B_S < 0,10$:

  $P_{Sy} = 0,749 + (5 – 44,4\ (y / B_S – 0,05))\ (y / B_S – 0,05)$
- for $y / B_S = 0,10$:

  $P_{Sy} = 0,888 + 0,56\ (y / B_S – 0,1)$

P_{Sy} is not to be taken greater than 1.

Compartment boundaries X_a, X_f, Z_l, Z_u and y are to be developed as follows:

X_a : Longitudinal distance from the aft terminal of L to the aftmost point on the compartment being considered, in m

X_f : Longitudinal distance from the aft terminal of L to the foremost point on the compartment being considered, in m

Z_l : Vertical distance from the moulded baseline to the lowest point on the compartment being considered, in m

Z_u : Vertical distance from the moulded baseline to the highest point on the compartment being considered, in m

Z_u is not to be taken greater than D_s

y : Minimum horizontal distance measured at right angles to the centreline between the compartment under consideration and the side shell, in m.

Note 1: For symmetrical tank arrangements, damages are considered for one side of the ship only, in which case all "y" dimensions are to be measured from that same side.

For asymmetrical arrangements refer to the Explanatory Notes on matters related to the accidental oil outflow performance, adopted by the IMO by resolution MEPC.122(52).

Table 2 : Probabilities for side damage

X_a/L	P_{Sa}	X_f/L	P_{Sf}	Z_l/D_S	P_{Sl}	Z_u/D_S	P_{Su}
0,00	0,000	0,00	0,967	0,00	0,000	0,00	0,968
0,05	0,023	0,05	0,917	0,05	0,000	0,05	0,952
0,10	0,068	0,10	0,867	0,10	0,001	0,10	0,931
0,15	0,117	0,15	0,817	0,15	0,003	0,15	0,905
0,20	0,167	0,20	0,767	0,20	0,007	0,20	0,873
0,25	0,217	0,25	0,717	0,25	0,013	0,25	0,836
0,30	0,267	0,30	0,667	0,30	0,021	0,30	0,789
0,35	0,317	0,35	0,617	0,35	0,034	0,35	0,733
0,40	0,367	0,40	0,567	0,40	0,055	0,40	0,670
0,45	0,417	0,45	0,517	0,45	0,085	0,45	0,599
0,50	0,467	0,50	0,467	0,50	0,123	0,50	0,525
0,55	0,517	0,55	0,417	0,55	0,172	0,55	0,452
0,60	0,567	0,60	0,367	0,60	0,226	0,60	0,383
0,65	0,617	0,65	0,317	0,65	0,285	0,65	0,317
0,70	0,667	0,70	0,267	0,70	0,347	0,70	0,255
0,75	0,717	0,75	0,217	0,75	0,413	0,75	0,197
0,80	0,767	0,80	0,167	0,80	0,482	0,80	0,143
0,85	0,817	0,85	0,117	0,85	0,553	0,85	0,092
0,90	0,867	0,90	0,068	0,90	0,626	0,90	0,046
0,95	0,917	0,95	0,023	0,95	0,700	0,95	0,013
1,00	0,967	1,00	0,000	1,00	0,775	1,00	0,000

2.2.5 Probability of breaching a compartment from bottom damage

The probability P_B of breaching a compartment from bottom damage is to be calculated as follows:

$P_B = P_{BL}\ P_{BT}\ P_{BV}$

where:

P_{BL} : Probability the damage extends into the longitudinal zone bounded by X_a and X_f

$P_{BL} = 1 – P_{Bf} – P_{Ba}$

P_{BT} : Probability the damage extends into the transverse zone bounded by Y_p and Y_s

$P_{BT} = 1 – P_{Bp} – P_{Bs}$

P_{BV} : Probability the damage extends vertically above the boundary defined by z

$P_{BV} = 1 – P_{Bz}$

P_{Ba}, P_{Bf}, P_{Bp} and P_{Bs} are to be determined by linear interpolation from Tab 3 of probabilities for bottom damage, where:

P_{Ba} : Probability the damage lies entirely aft of location X_a / L

P_{Bf} : Probability the damage lies entirely forward of location X_f / L

P_{Bp} : Probability the damage lies entirely to port of the tank

P_{Bs} : Probability the damage lies entirely to starboard of the tank.

P_{Bz}, the probability the damage lies entirely below the tank, is to be determined as follows:

- for $z / D_S \leq 0,1$:

  $P_{Bz} = (14,5 - 67\ z / D_S)\ (z / D_S)$

- for $z / D_S > 0,1$:

  $P_{Bz} = 0,78 + 1,1\ (z / D_S - 0,1)$

P_{Bz} is not to be taken greater than 1.

Compartment boundaries X_a, X_f, Y_p, Y_s, and z are to be developed as follows:

X_a and X_f: As defined in [2.2.4]

Y_p : Transverse distance from the port-most point on the compartment located at or below the waterline d_B, to a vertical plane located $B_B / 2$ to starboard of the ship's centreline, in m

Y_s : Transverse distance from the starboard-most point on the compartment located at or below the waterline d_B, to a vertical plane located $B_B / 2$ to starboard of the ship's centreline, in m

z : Minimum value of z over the length of the compartment, where, at any given longitudinal location, z is the vertical distance from the lower point of the bottom shell at that longitudinal location to the lower point of the compartment at that longitudinal location, in m.

Table 3 : Probabilities for bottom damage

X_a/L	P_{Ba}	X_f/L	P_{Bf}	Y_p/B_B	P_{Bp}	Y_s/B_B	P_{Bs}
0,00	0,000	0,00	0,969	0,00	0,844	0,00	0,000
0,05	0,002	0,05	0,953	0,05	0,794	0,05	0,009
0,10	0,008	0,10	0,936	0,10	0,744	0,10	0,032
0,15	0,017	0,15	0,916	0,15	0,694	0,15	0,063
0,20	0,029	0,20	0,894	0,20	0,644	0,20	0,097
0,25	0,042	0,25	0,870	0,25	0,594	0,25	0,133
0,30	0,058	0,30	0,842	0,30	0,544	0,30	0,171
0,35	0,076	0,35	0,810	0,35	0,494	0,35	0,211
0,40	0,096	0,40	0,775	0,40	0,444	0,40	0,253
0,45	0,119	0,45	0,734	0,45	0,394	0,45	0,297
0,50	0,143	0,50	0,687	0,50	0,344	0,50	0,344
0,55	0,171	0,55	0,630	0,55	0,297	0,55	0,394
0,60	0,203	0,60	0,563	0,60	0,253	0,60	0,444
0,65	0,242	0,65	0,489	0,65	0,211	0,65	0,494
0,70	0,289	0,70	0,413	0,70	0,171	0,70	0,544
0,75	0,344	0,75	0,333	0,75	0,133	0,75	0,594
0,80	0,409	0,80	0,252	0,80	0,097	0,80	0,644
0,85	0,482	0,85	0,170	0,85	0,063	0,85	0,694
0,90	0,565	0,90	0,089	0,90	0,032	0,90	0,744
0,95	0,658	0,95	0,026	0,95	0,009	0,95	0,794
1,00	0,761	1,00	0,000	1,00	0,000	1,00	0,844

3 Piping arrangements

3.1 Provision regarding piping arrangements

3.1.1 Lines of piping that run through cargo tanks in a position less than $0,30\ B_S$ from the ship's side or less than $0,30\ D_S$ from the ship's bottom is to be fitted with valves or similar closing devices at the point at which they open into any cargo tank. These valves is to be kept closed at sea at any time when the tanks contain cargo oil, except that they may be opened only for cargo transfer needed for essential cargo operations.

Credit for reducing oil outflow through the use of an emergency rapid cargo transfer system or other system arranged to mitigate oil outflow in the event of an accident may be taken into account only after the effectiveness and safety aspects of the system are approved by the Society.

CHAPTER 8
CHEMICAL TANKERS

Section 1 General
Section 2 Ship Survival Capability and Location of Cargo Tanks
Section 3 Ship Arrangement
Section 4 Cargo Containment
Section 5 Cargo Transfer
Section 6 Materials for Construction
Section 7 Cargo Temperature Control
Section 8 Cargo Tank Venting and Gas-Freeing Arrangements
Section 9 Environmental Control
Section 10 Electrical Installations
Section 11 Fire Protection and Fire Extinction
Section 12 Mechanical Ventilation in the Cargo Area
Section 13 Instrumentation
Section 14 Protection of Personnel
Section 15 Special Requirements
Section 16 Operational Requirements
Section 17 Summary of Minimum Requirements
Section 18 List of Chemicals to which this Chapter Does Not Apply
Section 19 Index of Products Carried In Bulk
Section 20 Transport of Liquid Chemical Wastes
Section 21 Criteria for Assigning Carriage Requirements for Products Subject to the IBC Code

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **chemical tanker**, in accordance with Pt A, Ch 1, Sec 2, [4.4.4].

1.1.2 Ships which are intended for the carriage of dangerous chemicals in bulk are to comply with the requirements of the latest version of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code), as amended.

1.1.3 These Rules and the IBC Code refer to ships carrying products which are listed in the table in Chapter 17 of the IBC Code or in the current MEPC.2/Circular, and in Ch 8, Sec 17.

1.1.4 In general, this Chapter applies to cargo containment and handling systems and to the interfaces between these systems and the remainder of the ship, which are to comply with the additional applicable requirements indicated in Tab 1.

Table 1 : Additional applicable requirements

Item		Reference
Ship arrangement	L ≥ 65 m	• Part B
	L < 65 m	• NR600
Hull	L ≥ 65 m	• Part B
	L < 65 m	• NR600
Stability		• Part B
Machinery and cargo system		• Part C
Electrical installations:		• Part C
Automation		• Part C
Fire protection, detection and extinction		• Part C
Note 1: NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.		

1.2 IBC Code requirements and the Society's rules

1.2.1 General

a) For ships having the service notation **chemical tanker**, the IBC Code requirements are to be considered as rule requirements, unless otherwise specified, and with the exception indicated in [1.2.2].

b) The rule requirements of this Chapter include:
   - additional requirements to the IBC Code
   - Society's interpretations of the IBC Code.

c) The requirements of this Chapter are cross referenced to the applicable Chapters, Sections or paragraphs of the IBC Code, as appropriate, under the wording "IBC CODE REFERENCE".

1.2.2 IBC Code requirements not within the scope of classification

The following requirements of the IBC Code are not within the scope of classification:

- Chapter 1, Section 1.4 - Equivalents
- Chapter 1, Section 1.5 - Surveys and certification
- Chapter 2, as far as survival requirements after flooding are concerned, when the additional class notation **SDS** is not assigned
- Chapter 16 - Operational requirements.

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.2.4]).

1.2.3 Equivalences

As far as the requirements for class are concerned, the following wording in the IBC Code is to be given the meanings indicated in Tab 2.

Table 2 : Equivalences

IBC Code wording	Meaning for classification only
Administration	Society
IBC Code or Chemical Code	Part D, Chapter 8 of the Rules
Recognised Standard	Rules
should be	is to be or are to be (as appropriate)

1.2.4 Certificate of Fitness

a) The responsibility for interpretation of the IBC Code requirements for the purpose of issuing an International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk lies with the Administration of the state whose flag the ship is entitled to fly.

b) Whenever the Society is authorised by an Administration to issue on its behalf the "Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk", or where the Society is authorised to carry out investigations and surveys on behalf of an Administration on the basis of which the "Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk" will be issued by the Administration, or where the Society is requested to certify compliance with the IBC Code, the full compliance with the requirements of the IBC Code, including the operational requirements mentioned in [1.2.2], is to be granted by the Society.

1.3 Definitions

1.3.1 Acids means dangerous chemicals to which special requirement 15.11 of the IBC Code applies.

1.3.2 Low-flashpoint products means oil or noxious liquid substances with a flashpoint not exceeding 60°C.

1.3.3 Toxic products means dangerous chemicals to which special requirement 15.12 of the IBC Code applies.

2 Additional requirements

2.1 Ships assigned the additional service feature IPxxx or IPxxx-capable

2.1.1 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** are to comply with the following requirements in addition to the applicable requirements of this Chapter:

- carriage of toxic products, low-flashpoint products or acids is not permitted when the total number of persons on board exceeds 60
- for the purpose of carrying industrial personnel, the areas and spaces where industrial personnel are not permitted to enter are to be clearly marked
- the arrangements for personnel transfer are to be located outside the cargo area
- the access to the arrangements for personnel transfer are to be, as far as practicable, located outside the cargo area.

2.2 Emergency towing arrangement

2.2.1 Emergency towing arrangements are to be fitted on chemical tankers of 20 000 dwt and above in accordance with Pt B, Ch 12, Sec 4, [3].

2.3 Steering gear

2.3.1 Additional requirements for steering gear of chemical tankers of 10 000 dwt and above are given in Ch 7, Sec 4, [7].

3 Documentation to be submitted

3.1

3.1.1 Tab 3 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules for the parts of the ship not affected by the cargo, as applicable.

Table 3 : Documentation to be submitted

No	A/I	Document
1	I	List of products to be carried, including maximum vapour pressure, maximum liquid cargo temperature, cargo mass density and other important design conditions
2	I	General arrangement plan, showing location of cargo tanks and fuel oil, ballast and other tanks
3	A	Gas-dangerous zones plan
4	A	Location of void spaces and accesses to dangerous zones
5	A	Ventilation duct arrangement in gas-dangerous spaces and adjacent zones
6	A	Details of hull structure in way of cargo tanks, including support arrangement for tanks, saddles, anti-floating and anti-lifting devices, deck sealing arrangements, independent cargo tanks, etc.
7	A	Hull stress analysis
8	A	Hull ship-motion analysis, where a direct analysis is preferred to the methods indicated in Section 4
9	A	Intact and damage stability calculations
10	A	Scantlings, material and arrangement of the cargo containment system
11	A	Details of steel cladding or lining
12	A	Plans, arrangement and calculations of pressure/vacuum valves
13	A	Details of cargo handling, including arrangements and details of piping and fittings and details of heating system, if any
14	A	Details of cargo pumps
15	A	Details of process pressure vessels and relative valving arrangement
16	A	Bilge and ballast system in cargo area
17	A	Gas freeing system in cargo tanks including inert gas system
18	A	Ventilation system in cargo area
19	A	Details of electrical equipment installed in cargo area, including the list of certified safe equipment and apparatus and electrical bonding of cargo tanks and piping
20	A	Schematic electrical wiring diagram
21	A	Gas detection system
22	A	Cargo tank instrumentation
23	A	Details of fire-extinguishing appliances and systems in cargo area
24	I	Loading and unloading operation description, including cargo tank filling limits, where applicable
25	I	Procedure and arrangement manual
Note 1: A = to be submitted for approval I = to be submitted for information.		

Section 2 Ship Survival Capability and Location of Cargo Tanks

1 Freeboard and intact stability

1.1 Intact stability

1.1.1 General

IBC CODE REFERENCE: Ch 2, 2.2.2

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.7] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2.

1.1.2 Free surface effect of liquids

IBC CODE REFERENCE: Ch 2, 2.2.3

The free surface effect is to be calculated in accordance with Pt B, Ch 3, Sec 2, [4].

1.1.3 Information to be supplied

IBC CODE REFERENCE: Ch 2, 2.2.5

The Master of the ship is to be supplied with a Loading Manual as specified in Pt B, Ch 1, Sec 5, [2] and a Trim and Stability booklet as specified in Pt B, Ch 3, App 2.

2 Conditions of loading

2.1 Additional loading conditions for ships where additional class notation SDS is requested

2.1.1

IBC CODE REFERENCE: Ch 2, 2.9.2.3

Loading conditions other than those in the Loading Manual and the Trim and Stability booklet are to be previously submitted to the Society. Alternatively, such cases may be examined by the Master or a delegated officer when a loading instrument approved in accordance with the requirements in Pt B, Ch 1, Sec 5, [3] is installed on board.

3 Location of cargo tanks

3.1 Minimum distance of cargo tanks from shell

3.1.1 Exceptions

IBC CODE REFERENCE: Ch 2, 2.6.1

Any cargo tank, irrespective of its location, may be used for collecting contaminated cargo pump room bilge water or tank washings, as an exception to the requirements in IBC Code 2.6.1.1.

3.2 Suction wells

3.2.1

IBC CODE REFERENCE: Ch 2, 2.6.2

In general, the area of suction wells is not to be greater than that required to accommodate cargo pumps, suction pipes, valves, heating coils etc., and to ensure efficient flow and the necessary access for cleaning and maintenance.

4 Flooding assumptions for ships where additional class notation SDS is requested

4.1 Tunnels, ducts and pipes in the damaged zone

4.1.1 Strength of internal structures

IBC CODE REFERENCE: Ch 2, 2.7.7

Tunnels, ducts, pipes, doors, bulkheads and decks which might form watertight boundaries of intact spaces in the case of assumed conventional damage are to have minimum strength adequate to withstand the pressure height corresponding to the deepest equilibrium waterline in damaged conditions.

4.1.2 Progressive flooding

IBC CODE REFERENCE: Ch 2, 2.7.7

Progressive flooding is to be considered in accordance with Pt B, Ch 3, Sec 3, [3.3].

5 Standard of damage for ships where additional class notation SDS is requested

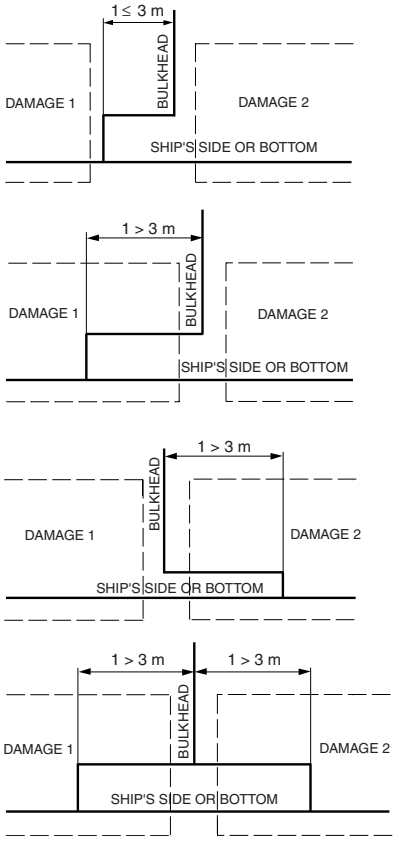
5.1 Damage to stepped machinery space forward bulkhead

5.1.1

IBC CODE REFERENCE: Ch 2, 2.8

The concept of a stepped machinery space forward bulkhead is already implicit in the requirements in IBC Code 3.2.1 and Regulation II-2/56 of SOLAS 74(83). For damage stability considerations, when the recess for a pump room or for a cargo pump room extends into the adjacent machinery space or cargo tank by more than 3 metres, damage is to be treated as defined in Fig 1.

Figure 1 : Damage to stepped machinery space forward bulkhead



5.2 Longitudinal extension of damage to superstructure

5.2.1

IBC CODE REFERENCE: Ch 2, 2.8

The longitudinal extent of damage to the superstructure in the case of side damage to a machinery space aft, with the standards of damage as per IBC Code 2.8.1, is generally to be the same as the longitudinal extent of the side damage to the machinery space (see Fig 2).

6 Survival requirements for ships where additional class notation SDS is requested

6.1 General

6.1.1

IBC CODE REFERENCE: Ch 2, 2.9

Ships are to be capable of surviving the assumed damage specified in IBC Code 2.5.1 and 2.5.2 to the standard provided in IBC Code 2.8.1 and for the loading conditions in Pt B, Ch 3, App 2, [1.2.7] in a condition of stable equilibrium and such as to satisfy the criteria in IBC Code 2.9.

6.2 Intermediate stages of flooding

6.2.1

IBC CODE REFERENCE: Ch 2, 2.9.2.3

The criteria applied to the residual stability during intermediate stages of flooding are to be those relevant to the final stage of flooding as specified in IBC Code 2.9.3. However, small deviation from these criteria may be accepted by the Society on a case by case basis.

6.3 Definition of range of positive stability

6.3.1

IBC CODE REFERENCE: Ch 2, 2.9

The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs) (see Fig 3).

6.4 Survival criterion

6.4.1 Unprotected openings

IBC CODE REFERENCE: Ch 2, 2.9.3.1

Other openings capable of being closed weathertight do not include ventilators (complying with ILLC 19(4)) that for operational reasons have to remain open to supply air to the engine room or emergency generator room (if the same is considered buoyant in the stability calculation or protecting openings leading below) for the effective operation of the ship.

6.5 Type 3 ships less than 125 m in length

6.5.1

IBC CODE REFERENCE: Ch 2, 2.8.1.6

The flooding of the machinery space, if located aft on a type 3 ship less than 125 m in length, is to comply as far as practicable with the criteria in IBC Code 2.9. Relaxation of parts of these requirements may be accepted on a case-by-case basis.

Figure 2 : Longitudinal extent of damage to superstructure

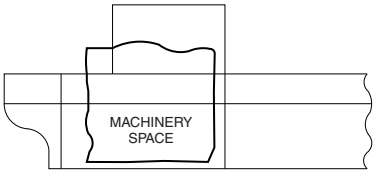
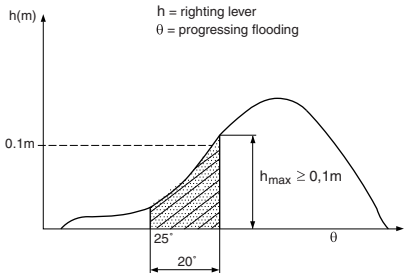


Figure 3 : Range of positive stability



Section 3 Ship Arrangement

1 Cargo segregation

1.1 Segregation of cargoes mutually reacting

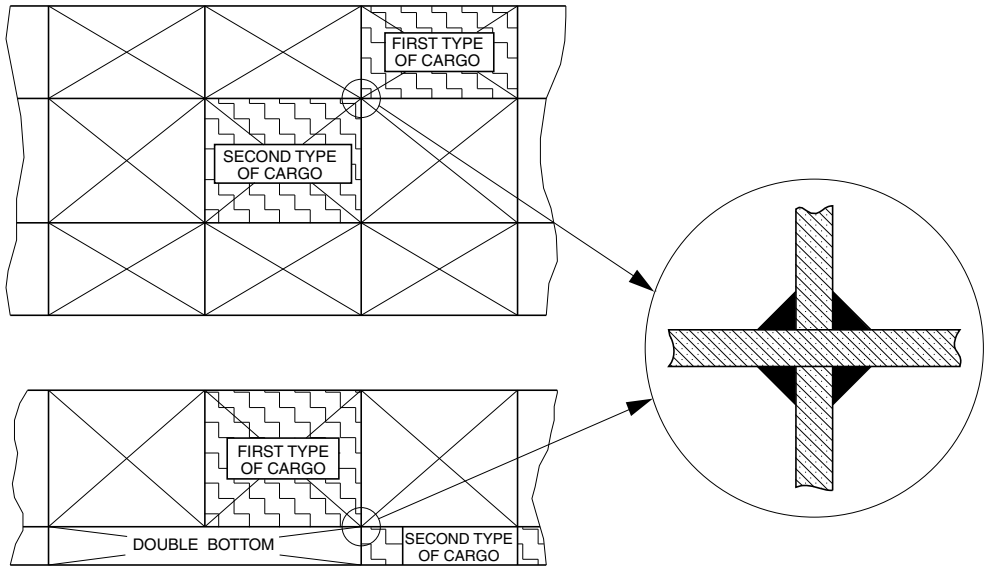
1.1.1 Common edges

IBC CODE REFERENCE: Ch 3, 3.1.2

The common edge in a cruciform joint, either vertically or horizontally, may be considered a “double barrier” for the purpose of segregation:

- between mutually reactive products (see Fig 1)
- between water reactive products and water (see Fig 1).

Figure 1 : Segregation of mutually hazardously reactive cargoes



1.1.2 Chain lockers

IBC CODE REFERENCE: Ch 3, 3.1.2

The chain locker is to be arranged outside the hazardous areas defined in Ch 8, Sec 10 and at least 10 m measured horizontally from any vent outlet of a controlled tank venting system.

1.1.3 Location of fuel tanks in cargo area

On ships having the service notation **chemical tanker** and carrying liquid cargoes having a flashpoint not exceeding 60°C and/or toxic liquid cargoes, fuel tanks located with a common boundary to cargo or slop tanks are not to be situated within, nor extend partly into, the cargo tank block as defined in Ch 7, Sec 1, [1.3.4]. Such tanks may, however, be situated aft and/or forward of the cargo tank block. They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, may be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements applicable to hazardous area classification must however be met.

Note 1: For the purpose of this requirement, toxic liquid cargoes include those for which toxic vapour detection is specified in column “k” of the table of chapter 17 of the IBC Code.

1.2 Cargo piping arrangement

1.2.1 Bow or stern loading arrangement

IBC CODE REFERENCE: Ch 3, 3.1.3

The requirement in IBC Code 3.1.3 is considered to be satisfied if the requirements in IBC Code 3.7, relevant to bow or stern loading and unloading arrangements, are complied with.

2 Accommodation, service and machinery spaces and control stations

2.1 Location of paint lockers

2.1.1

IBC CODE REFERENCE: Ch 3, 3.2.1

Paint lockers, regardless of their use, cannot be located above the cargo area.

2.2 Air intakes and other openings to accommodation spaces

2.2.1 IBC CODE REFERENCE: Ch 3, 3.2.2, Ch 3, 3.2.3, Ch 3, 3.7.4.

The requirements relevant to air intakes are also applicable to air outlets.

2.3 Windows, sidescuttles and doors to accommodation spaces

2.3.1 General requirements

IBC CODE REFERENCE: Ch 3, 3.2.3

a) Access facing the cargo area or other prohibited zones is to be restricted to stores for cargo-related and safety equipment, cargo control stations and emergency shower spaces.

b) Access to forecastle spaces containing sources of ignition may be permitted through doors facing cargo area provided the doors are located outside hazardous areas as defined in Pt C, Ch 2, Sec 1, [3.13.3] and Ch 8, Sec 10, Tab 1 or Ch 8, Sec 10, Tab 2.

However, for small ships alternative arrangements may be specially considered by the Society.

c) The bolt spacing for bolted plates mentioned in the paragraph in the reference is to be such as to guarantee a suitable gas-tightness.

2.3.2 Ships fitted with deckhouses originating from main deck

IBC CODE REFERENCE: Ch 3, 3.2.3

On all chemical tankers, regardless of the type of products to be carried, where a deckhouse is substituted for a superstructure and liquid products could flow along the sides of the house, the house front is to be continued to the sides of the ship in the form of a sill, or a permanent spillage barrier is to be arranged as described in Regulation II-2/56.6 of SOLAS 74(83).

2.4 Safe access to the bow

2.4.1 Ships assigned the service notation **chemical carrier** are *to be provided with the means to enable the crew to gain safe access to the bow even in severe weather conditions. Such means of access are to be approved by* the Society.

The access is to be by means of either a walkway on the deck or a permanently constructed gangway of substantial strength at or above the level of the superstructure deck or the first tier of a deckhouse which is to:

a) be not less than 1 m in width, situated on or as near as practicable to the centreline of the ship and located so as not to hinder easy access across working areas of the deck.

b) be fitted at each side throughout its length with a footstop and guard rails supported by stanchions. Such rails are to consist of no less than 3 courses, the lowest being not more than 230 mm and the uppermost being at least 1 m above the gangway or walkway, and no intermediate opening is to be more than 380 mm in height. Stanchions are to be at intervals of not more than 1,5 m.

c) be constructed of fire resistant and non-slip material. If Fibre Reinforced Plastic (FRP) gratings are used in lieu of steel gratings, they are to be of a type approved by the Society and have the following characteristics:

- low-flame spread characteristics (see Pt C, Ch 4, Sec 1, [2.28])
- not capable of producing excessive quantities of smoke and toxic products, in accordance with the Fire Test Procedures Code
- L1 or L2 structural fire integrity levels, in accordance with ASTM F3059-2018.

d) have openings, with ladders where appropriate, to and from the deck. Openings are not to be more than 40 m apart.

e) if the length of exposed deck to be traversed exceeds 70 m, have shelters of substantial construction set in way of the gangways or walkways at intervals not exceeding 45 m. Every such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides, and

f) if obstructed by pipes or other fittings of a permanent nature, be provided with means of passage over such obstruction.

3 Cargo pump rooms

3.1 General requirement

3.1.1 Means of escape

IBC CODE REFERENCE: Ch 3, 3.3.1

In general, a cargo pump room is to be provided with one set of access/escape ladders. Where it is envisaged that personnel are normally employed in a pump room or the pump room is unusually large, an additional means of escape may be required.

3.1.2 Segregation

IBC CODE REFERENCE: Ch 3, 3.3.1

Cargo pump rooms and pump rooms may not give direct access to other ship spaces and are to be separated from adjacent spaces by means of gas-tight bulkheads and/or decks.

3.2 Machinery driven by shafting passing through pump room bulkheads

3.2.1

IBC CODE REFERENCE: Ch 3, 3.3.7

a) Bulkhead or deck penetrations of cargo pump rooms, or of pump rooms intended for runs of shafts driving pumps and/or fans, are to be provided with gas-tight sealing devices to the satisfaction of the Society.

b) Lubrication or other means of ensuring permanence of gas-tightness of the above-mentioned sealing devices is to be arranged in such a way that it can be checked from outside the cargo pump room.

4 Access to spaces in the cargo area

4.1 General

4.1.1 Independent cargo tanks

Where independent tanks are installed in hold spaces, requirements in [4.2] and [4.3] are to be applied, as far as practicable, to ballast and void spaces adjacent to hold spaces.

When such requirements are found to be incompatible with the size and arrangement of the ship, smaller dimensions may be accepted by the Society, providing convenient access to any part of those spaces is maintained.

4.1.2 Access to fuel oil tanks

IBC CODE REFERENCE: Ch 3, 3.4.1

The requirements in IBC Code 3.4.1 apply to fuel oil tanks adjacent to cargo tanks even if such fuel oil tanks are not included in the cargo area.

4.1.3 Accesses and escapes from double bottom tanks and similar spaces

IBC CODE REFERENCE: Ch 3, 3.4.1

To cater for restrictions in the movement of personnel and to limit the time needed for a possible emergency escape, two separate means of access are generally to be fitted in double bottom tanks and similar spaces where obstructions impede movement. The two accesses are to be as widely separated as practicable. Only one access may be approved in special circumstances if, it being understood that the escapes have the required dimensions, the ability to readily traverse the space and to remove an injured person can be proved to the satisfaction of the Society.

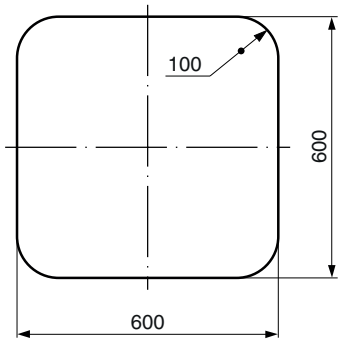
4.2 Horizontal openings

4.2.1

IBC CODE REFERENCE: Ch 3, 3.4.2

The shape of the minimum acceptable clear opening of 600 mm by 600 mm is indicated in Fig 2.

Figure 2 : Shape of minimum acceptable clear opening of 600 mm by 600 mm



4.3 Vertical openings

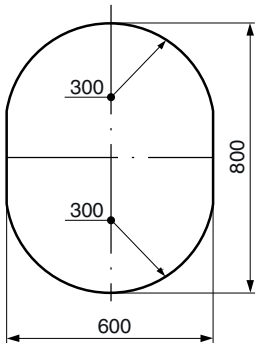
4.3.1

IBC CODE REFERENCE: Ch 3, 3.4.3

For pressure cargo tanks only, access openings may be circular openings having a diameter not less than 600 mm.

The minimum size of vertical oval openings is defined in Fig 3.

Figure 3 : Minimum size of vertical oval openings



5 Bilge and ballast arrangements

5.1 Ballast segregation

5.1.1 Filling arrangement

IBC CODE REFERENCE: Ch 3, 3.5.1

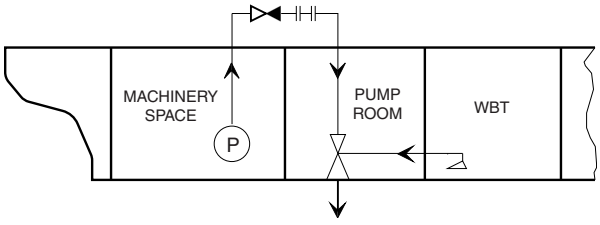
Where filling arrangements for ballast tanks located in the cargo area are provided in the machinery spaces, a non-return valve and removable spool piece are to be fitted in the supply line outside the machinery spaces.

5.1.2 Eductors

IBC CODE REFERENCE: Ch 3, 3.5.1

An eductor situated in the cargo area using water power from pumps in the machinery spaces may be accepted as a means to discharge permanent ballast from tanks and/or double bottoms adjacent to cargo tanks, provided the supply line is above deck level and a non-return valve and removable spool piece are fitted in the supply line outside the machinery space (see Fig 4).

Figure 4 : Discharge arrangement



5.1.3 Fore peak ballast system

IBC CODE REFERENCE: Ch 3, 3.5.1

The fore peak tank can be ballasted with the system serving other ballast tanks within the cargo area, provided:

- the fore peak tank is considered as a hazardous area, and the hazardous area classification is defined in accordance with Ch 8, Sec 10
- the vent pipe openings are located on open deck at an appropriate distance from sources of ignition. In this respect, the hazardous zones distances are to be defined in accordance with Ch 8, Sec 10
- means are provided, on the open deck, to allow measurement of flammable gas concentrations within the tank by a suitable portable instrument
- the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:
  - In case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is provided at the manhole stating that the fore peak tank may only be opened after:
    - it has been proven to be gas free; or
    - any electrical equipment which is not certified safe in the enclosed space is isolated.
  - In case the enclosed space has a common boundary with the cargo tanks and is therefore a hazardous area, the enclosed space can be well ventilated.

5.2 Ballast filling arrangement

5.2.1 Clarification

IBC CODE REFERENCE: Ch 3, 3.5.2

The filling of cargo tanks with ballast may be performed at deck level by means of pumps serving permanent ballast tanks, as specified in IBC Code 3.5.2, provided that a removable spool piece or flexible hose plus a shut-off valve are fitted on the inlet to the cargo tank. The shut-off valve is in addition to the required non-return valve. Consideration is to be given to the arrangement of the in-tank piping and the possible creation of static electricity (see Fig 4).

5.3 Bilge

5.3.1 Arrangement

IBC CODE REFERENCE: Ch 3, 3.5.3

The relaxation relevant to the bilge system for spaces which are separated from cargo tanks by a double bulkhead is to be understood as limited to spaces not enclosing piping which may contain cargo.

5.3.2 Use of cargo pumps as bilge pumps

IBC CODE REFERENCE: Ch 3, 3.5.3

a) Cargo pumps may also be used as bilge pumps provided they are connected to the bilge piping through a shut-off valve and a non-return valve arranged in series.

b) In the case of carriage of corrosive liquids, one of the cargo pumps may be used for bilge service provided it is connected to the bilge piping through two shut-off valves plus a non-return valve arranged in series.

c) In cargo pump rooms of ships carrying toxic or corrosive products, suitable means for conveying spills from cargo pumps and valves to collecting trays are to be fitted. Trays may also consist of part of the pump room bottom, suitably bounded and protected against the corrosive action of products. Spills may be disposed of by means of suitable pumps or eductors. In the case of carriage of mutually incompatible products, the above-mentioned means for collecting and disposing of spills are to be different and separated from each other.

6 Integrated cargo and ballast systems

6.1

6.1.1 Integrated cargo and ballast pumps are to comply with the provisions of Ch 7, Sec 4, [3.6].

7 Bow or stern loading and unloading arrangements

7.1 Coamings

7.1.1

IBC CODE REFERENCE: Ch 3, 3.7.7

In general, the height of the coaming is to be not less than 150 mm. In any case, it is to be not less than 50 mm above the upper edge of the sheerstrake.

Section 4 Cargo Containment

Symbols

k : Material factor for steel, defined in Pt B, Ch 4, Sec 1, [2.2].

1 General

1.1 Application

1.1.1 The requirements of this sections are to be applied in addition to the Chapter 4 of the IBC Code.

2 Structure design principles

2.1 Materials

2.1.1 Steels for hull structure

In addition to the requirements of Pt B, Ch 4, Sec 1, [2], materials of cargo tanks are to be considered by the Society on a case-by-case basis for all the products intended to be carried.

2.1.2 Rolled plates

IBC CODE REFERENCE: CHAPTER 4

Rolled plates of non-alloyed steel or stainless steel may be used for the construction of tanks. Mechanical characteristics, approval procedure and testing of these plates are to comply with the applicable requirements in NR216 Materials.

2.1.3 Young's modulus for stainless steels

IBC CODE REFERENCE: CHAPTER 4

For stainless steels, Young's modulus is to be taken equal to 193000 N/mm^2.

2.1.4 Rubber and synthetic material liner

IBC CODE REFERENCE: CHAPTER 4

The suitability of rubber or synthetic material lining is to be considered by the Society on a case-by-case basis.

2.2 Hull structure

2.2.1 Framing arrangement

IBC CODE REFERENCE: CHAPTER 4

In general, within the cargo tank region of chemical tankers of more than 90 m in length, the bottom, the inner bottom and the deck are to be longitudinally framed.

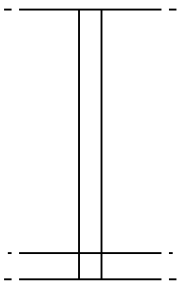
Different framing arrangements are considered by the Society on a case-by-case basis, provided that they are supported by direct calculations.

2.3 Bulkhead structure

2.3.1 Corrugated bulkhead connections

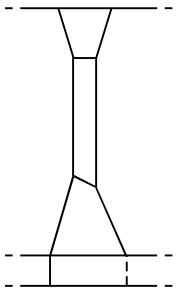
For ships with L < 120 m, vertically corrugated transverse or longitudinal bulkheads may be connected to the double bottom and deck plating (see Fig 1).

Figure 1 : Corrugated bulkhead connections without stool



For ships with L ≥ 120 m, a lower and an upper stool are generally to be fitted (see Fig 2). Different arrangements may be considered by the Society on a case-by-case basis, provided that they are supported by direct calculations carried out according to Pt B, Ch 8, App 1. These calculations are to investigate, in particular, the zones of connection of the bulkhead with bottom and deck plating and are to be submitted to the Society for review.

Figure 2 : Corrugated bulkhead connections with lower and upper stools



3 Hull girder loads

3.1 Still water loads

3.1.1 Loading conditions

In addition to the requirements in Pt B, Ch 5, Sec 4, [2.1], still water loads are to be calculated for the following loading conditions:

- homogeneous loading conditions (excluding tanks intended exclusively for segregated ballast tanks) at maximum draught
- partial loading conditions (see [3.1.2])
- high density cargo, heated cargo and segregated cargo loading conditions
- any specified non-homogeneous loading condition
- light and heavy ballast conditions
- mid-voyage conditions related to tank cleaning or other operations where these differ significantly from the ballast conditions.

3.1.2 Partial filling

Loading conditions with partial filling of the tanks by cargoes with a mass density above the cargo mass density used for the design may be allowed.

3.2 Load combinations for direct strength analysis

3.2.1 The loading conditions to be considered for the direct strength analysis are defined in Ch 7, Sec 3, [5.1].

4 Hull scantlings

4.1 Plating

4.1.1 Calculation of equivalent thickness for clad plates made of non-alloyed steel - stainless steel

The clad plate thickness is to be not less than that obtained from the following formula:

$$t_P = t + t_S\left(1 - \frac{E_I}{206000}\right)$$

where:

t : Thickness, in mm, of the clad plate, to be obtained from the applicable formulae in Pt B, Ch 7, Sec 4, as if it were made of homogeneous material with the following properties:

- elastic modulus, in N/mm^2, to be taken equal to:

  E = 206000
- material factor, to be obtained from the following formula:

  $$k_0 = k\frac{E_I}{206000}$$

k : Material factor of the rolled stainless steel plate, defined in Pt B, Ch 4, Sec 1, [2.2]

E_I : Elastic modulus, in N/mm^2, of the rolled stainless steel plate

t_S : Thickness, in mm, of the stainless steel cladding, to be taken not less than 2,0 mm

Stainless steel cladding thicknesses other than those above are to be considered by the Society on a case-by-case basis.

5 Scantlings of independent tank structures

5.1 General

5.1.1 Ships designed with independent cargo tanks are to comply with the applicable provisions of Part D, Chapter 7.

6 Supports of independent tanks

6.1 General

6.1.1 Ships designed with independent cargo tanks are to comply with the applicable provisions of Part D, Chapter 7.

7 Other structures

7.1 Machinery space

7.1.1 Extension of the hull structures within the machinery space

IBC CODE REFERENCE: CHAPTER 4

Longitudinal bulkheads carried through cofferdams are to continue within the machinery space and be used preferably as longitudinal bulkheads for liquid cargo tanks. This extension is to be compatible with the shape of the structures of the double bottom, of the deck and of platforms in the machinery space.

8 Protection of hull metallic structures

8.1 Aluminium coatings

8.1.1

IBC CODE REFERENCE: CHAPTER 4

The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in the cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate.

8.2 Passivation treatment

8.2.1

IBC CODE REFERENCE: CHAPTER 4

For a stainless steel structure, a passivation treatment is to be made carefully on the whole area of the tanks for a new ship, and on the whole repaired area in the case of repairs. This applies in particular to the passivation treatment of the welds.

9 Construction and testing

9.1 Welding and weld connections

9.1.1 General

The requirements in [9.1.2] to [9.1.5] are to be considered in addition to the applicable requirements in Pt B, Ch 13, Sec 2 and Pt B, Ch 13, Sec 3.

9.1.2 Welding of bulkheads of cargo integral tanks of type 1 chemical carriers

IBC CODE REFERENCE: CHAPTER 4

The boundaries of bulkheads of cargo integral tanks of type 1 chemical carriers are to be connected, for their whole length, to the hull structures by means of full penetration welding. As an alternative to full penetration weldings, the weld preparation is to be indicated on the drawings and non-destructive examinations are to be carried out on 100% of the welds.

9.1.3 Welding of bulkheads of cargo integral tanks of type 2 chemical carriers

IBC CODE REFERENCE: CHAPTER 4

The lower part (over 10% in height, as a minimum) of the boundaries of bulkheads of cargo integral tanks, i.e. the connection with the bottom (or double bottom, if any) and the connection with the lower part of the sloping plates, of type 2 chemical carriers are to be connected, for their whole length, to the hull structures by means of full penetration welding. As an alternative to full penetration weldings, the weld preparation is to be indicated on the drawings and non-destructive examinations are to be carried out on 100% of the welds.

The other part of the tank boundaries may be connected by means of fillet welding.

9.1.4 Welding of stiffeners made of non-alloyed steel to stainless steel plates

IBC CODE REFERENCE: CHAPTER 4

In general, stiffeners made of non-alloyed steel may not be directly welded to thin stainless steel plates.

However, where the welding of stiffeners and hull components made of normal strength steel to stainless steel plates is deemed acceptable by the Society, such welding is to be performed using austenitic-ferritic electrodes with high-grade nickel and chromium, such as the electrode type with 24% Cr, 14% Ni and 3% Mo.

9.1.5 Welding on clad plates

IBC CODE REFERENCE: CHAPTER 4

Welds carried out on clad plates are to be considered by the Society on a case-by-case basis.

In particular, when fillet welding is carried out directly on the rolled plate, the ultrasonic inspection of the plating bond is to be performed on a strip bond 100 mm wide, centred on the plate perpendicular to the plating. This ultrasonic inspection is to be carried out in accordance with NR216 Materials and Welding, Ch 3, Sec 11, [1.9].

9.2 Structural details

9.2.1 The specific requirements in Pt B, Ch 13, Sec 5, [2.3] for ships with the service notation **chemical tanker** are to be complied with.

Section 5 Cargo Transfer

1 Piping scantlings

1.1 General

1.1.1 Other requirements

IBC CODE REFERENCE: Ch 5, 5.1

Cargo pipes and accessories are to satisfy requirements of Pt C, Ch 1, Sec 10.

1.2 Pipe classes

1.2.1

IBC CODE REFERENCE: Ch 5, 5.1

According to Pt C, Ch 1, Sec 10, [1.5.2], cargo pipes and associated accessories are considered as:

a) Class I when the design pressure is above 1,5 MPa, or the pipe is intended for toxic substances requesting full compliance with Ch 17, 15.12 of the IBC Code

b) Class II when the design pressure is equal to or less than 1,5 MPa

c) Class III when they are open ended or placed inside cargo tanks.

1.3 Pipe wall thickness calculation

1.3.1 Piping subjected to green seas

IBC CODE REFERENCE: Ch 5, 5.1.1

For piping subjected to green seas, the design pressure P, in MPa, in the formula in 5.1.1 of the IBC Code is to be replaced by an equivalent pressure P′ given by the following formula:

$$P' = \frac{1}{2}\left(P + \sqrt{P^2 + 0{,}006\,R'K\frac{D_C}{D}}\right)$$

where:

D_C : External diameter of the pipe taking into account the insulation (in mm), whose thickness is to be taken at least equal to:

40 mm if D ≤ 50 mm

80 mm if D ≥ 150 mm

Intermediate values are to be determined by interpolation

R′ : Drag corresponding to the effect of green seas, in daN/mm², such as given in Tab 1 as a function of the location of the pipes and of their height H (in m) above the deepest loadline; intermediate values are to be determined by interpolation.

1.3.2 Corrosion allowance

IBC CODE REFERENCE: Ch 5, 5.1.1

The coefficient C (added corrosion thickness) for the formula in 5.1.1 of the IBC Code is normally to be equal to at least 3 mm. The Society may accept a lesser value for pipes made of austenitic or austenitic-ferritic stainless steel, pipes with internal lining or, if applicable, pipes with acceptable external protective lining or painting.

Table 1 :

External diameter of pipe **(1)**	Aft of the quarter of the ship's length			Forward of the quarter of the ship's length		
	H ≤ 8	H = 13	H ≥ 18	H ≤ 8	H = 13	H ≥ 18
≤25	1500	250	150	2200	350	150
50	1400	250	150	2000	350	150
75	1100	250	150	1600	350	150
100	700	250	150	700	350	150
≥ 150	500	250	150	700	350	150

(1) D_C if the pipe is insulated, D otherwise.

2 Piping fabrication and joining details

2.1 Pipes not required to be joined by welding

2.1.1

IBC CODE REFERENCE: Ch 5, 5.2.2

Cargo piping is to be welded except for necessary flanged connections to valves, expansion joints (as permitted in 5.2.2.1 of the IBC Code), spool pieces and similar fittings or where required for coating, lining, fabrication, inspection or maintenance.

2.2 Expansion joints

2.2.1

IBC CODE REFERENCE: Ch 5, 5.2.4

The use of bellows is not permitted for corrosive and polymerising products, except if provision is made to prevent stagnation of liquids.

2.3 Non-destructive testing of welded joints

2.3.1

IBC CODE REFERENCE: Ch 5, 5.2.5

a) Butt welded joints of pipes and accessories are to be submitted to radiographic examination. A minimum of 10% of the welded joints are to be selected at random in agreement with the Surveyor. The selected joints are to be tested over their full length. The Surveyor may require to extend the number of joints to be tested depending on the results of the inspection.

b) All butt welded joints of pipes and accessories are to be submitted to liquid penetrant examination or equivalent method over their full length

c) Relaxation of the above requirements may be considered by the Society on a case-by-case basis for pipes welded at workshops. However, this only applies to ships exclusively intended to carry cargoes with minor fire risk.

3 Piping arrangements

3.1 Arrangement of cargo piping

3.1.1 Arrangement of cargo piping under deck

IBC CODE REFERENCE: Ch 5, 5.5.2

The intent of the provisions in 5.5.2 of the IBC Code is to preclude the hazard of cargo leaking past a shut-off valve gland into the space where the valve is located.

3.1.2 Arrangement of cargo piping on deck

IBC CODE REFERENCE: Ch 5, 5.5.2

Cargo piping on cargo tanks is to be extended down to the bottom of each tank.

3.1.3 Arrangement of cargo piping inside cargo tanks

IBC CODE REFERENCE: Ch 5, 5.5.2

The ends of cargo tank filling pipes are to be located as near as possible to the tank bottom in order to reduce the risk of generating static electricity.

3.1.4 Pipe connections

IBC CODE REFERENCE: Ch 5, 5.3.2

Flanges are to be provided on connections to prevent the projection of liquids in case of leakage if pipes are intended to carry cargoes involving serious risks of skin toxicity.

3.1.5 Aluminised pipes

IBC CODE REFERENCE: Ch 5, 5.5

Aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

3.2 Removable piping systems

3.2.1

IBC CODE REFERENCE: Ch 5, 5.5

Pumps, piping and associated fittings are to constitute a permanently fitted system; in general, removable parts are not allowed, except for specific cases for which it can be proved, to the satisfaction of the Society, that no effective alternative solutions are available. In such circumstances, the safety measures deemed necessary will be considered by the Society on a case-by-case basis.

4 Cargo transfer control systems

4.1 General

4.1.1

IBC CODE REFERENCE: Ch 5, 5.6.1

a) One blank flange is to be provided in addition to the stop valve required in 5.6.1.2 of the IBC Code at each cargo hose connection.

b) The requirements of 5.6.1 of the IBC Code are not intended to be additional to those for piping below deck in 5.5.2 and 5.5.3 of the IBC Code.

4.2 Control, monitoring and alarm devices and cargo control room

4.2.1

IBC CODE REFERENCE: Ch 5, 5.6

a) The cargo pump control is to be fitted in a position which is readily accessible, even in the event that the cargo piping or hoses break. This position is to be clearly indicated.

b) Where a cargo control room is fitted, the following controls, monitoring and alarms are to be connected to this room:
- cargo pump control
- control of loading/unloading valves
- level gauges
- temperature indicators
- high level alarms
- very high level alarms
- high/low temperature alarms
- high/low pressure alarms
- fixed gas detecting system alarms.

c) In general, high/low temperature alarms are also to be transduced to the navigation bridge.

d) The cargo control room is to be located above the weather deck and may be considered as a dangerous space or a safe space, depending on its location and on the possible presence of a product or of its vapours. If it is considered a dangerous space, it is to be provided with a ventilation system capable of supplying at least 20 air changes per hour, it is not to be located in the accommodation area and only safe type electrical equipment is allowed.

e) A cargo control room without cargo pump and valve control is defined as a “cargo control station”.

5 Ship’s cargo hoses

5.1 Compatibility

5.1.1

IBC CODE REFERENCE: Ch 5, 5.7.1

The requirement of 5.7.1 of the IBC Code applies to cargo hoses carried on board the vessel and “compatibility with the cargo” means that:

a) The cargo hose does not lose its mechanical strength or deteriorate unduly when in contact with the cargo, and

b) The cargo hose material does not affect the cargo in a hazardous way.

Consideration is to be given to internal and external surfaces with respect to the above where hoses may be used as an integral part of, or connected to, emergency cargo pumps and submerged in the cargo tank.

6 Bonding

6.1 Static electricity

6.1.1 Acceptable resistance

IBC CODE REFERENCE: Ch 10, 10.3

To avoid the hazard of an incendive discharge due to the build-up of static electricity resulting from the flow of the liquid/gases/vapours, the resistance between any point on the surface of the cargo and slop tanks, piping systems and equipment, and the hull of the ship is not to be greater than 10^6 Ω.

6.1.2 Bonding straps

IBC CODE REFERENCE: Ch 10, 10.3

Bonding straps are required for cargo and slop tanks, piping systems and equipment which are not permanently connected to the hull of the ship, for example:

a) Independent cargo tanks

b) Cargo tank piping systems which are electrically separated from the hull of the ship

c) Pipe connections arranged for the removal of the spool pieces.

d) Wafer-style valves with non-conductive (e.g PTFE) gaskets or seals.

Where bonding straps are required, they are to be:

a) Clearly visible so that any shortcoming can be clearly detected

b) Designed and sited so that they are protected against mechanical damage and are not affected by high resistivity contamination, e.g. corrosive products or paint

c) Easy to install and replace.

7 Certification, inspection and testing

7.1 Application

7.1.1 The provisions of this Article are related to cargo piping and other equipment fitted in the cargo area. They supplement those given in Pt C, Ch 1, Sec 10, [20] for piping systems.

7.2 Inspection and testing

7.2.1 Testing of materials

Where required in Tab 2, materials used for pipes, valves and fittings are to be subjected to the tests specified in Pt C, Ch 1, Sec 10, [20.4.2].

7.2.2 Inspection of welded joints

Where required in Tab 2 Pt C, Ch 1, Sec 10, [3.6] the requirements of Pt C, Ch 1, Sec 10, [3.6.3] are not applicable for chemical carrier cargo piping and are to be replaced by those of [2.3.1].

7.2.3 Hydrostatic testing

IBC CODE REFERENCE: Ch 5, 5.4.2

a) Where required in Tab 2, cargo pipes, valves, fittings and pump casings are to be submitted to hydrostatic tests in accordance with the relevant provisions of Pt C, Ch 1, Sec 10, [20.5].

b) Expansion joints and cargo hoses are to be submitted to hydrostatic tests in accordance with the relevant provisions of Pt C, Ch 1, Sec 10, [20.5].

c) Where fitted, bellow pieces of gas-tight penetration glands are to be pressure tested.

7.2.4 Tightness tests

Tightness of the gas-tight penetration glands is to be checked.

Note 1: These tests may be carried out in the workshops or on board.

7.2.5 Certification

Inspection, tests and certification requirements for cargo piping and other equipment fitted in the cargo area are given in Tab 2.

7.3 Shipboard tests

7.3.1 Pressure test

IBC CODE REFERENCE: Ch 5, 5.4.3

After installation on board, the cargo piping system is to be checked for leakage under operational conditions.

Table 2 : Inspection and testing at works

No	Item	Tests for materials		Inspections and tests for the products			References to the Rules
		Y/N **(1)**	Type of material certificate **(2)**	during manufacturing **(1)**	after completion **(1) (3)**	Type of product certificate **(2)**	
1	seamless or stainless steel cargo pipes	Y	• C where ND>25mm • W where ND≤25mm	Y **(4)**	Y	C	[7.2.1] [7.2.1] [7.2.2] [7.2.3]
2	pipes of class II, cargo valves and fittings	Y	• C where ND>100mm • W where ND≤100mm	Y **(4)**	Y	C	[7.2.1] [7.2.1] [7.2.2] [7.2.3]
3	expansion joints and cargo hoses	Y **(5)**	W	N	Y	C	[7.2.1] [7.2.3]
4	cargo pumps	Y	• C for cast body • W for welded construction	Y **(6)**	Y	C	see note **(6)** [7.2.3]
5	gas-tight penetration glands	N		N	Y	C	[7.2.3], [7.2.4]
6	cargo tank P/V valves	Y	W	Y	Y	C	[7.2.1] [7.2.2] [7.2.3] Ch 8, Sec 8, [2.1.1]
7	flame arresters	N		N	Y	C	see note **(3)**

(1) Y = required, N = not required.
(2) C = class certificate, W = works' certificate.
(3) includes the checking of the rule characteristics according to the approved drawings.
(4) only in the case of welded construction.
(5) if metallic.
(6) inspection during manufacturing is to be carried out according to a program approved by the Society.

Section 6 Materials for Construction

1 General

1.1 Material and coating characteristics

1.1.1

IBC CODE REFERENCE: Ch 6

a) Materials and coating systems of structures and equipment which may come into contact with liquid cargo or vapour are to be selected in accordance with the list of cargoes intended to be carried.

b) The resistance of materials and coatings and their compatibility with intended cargoes are the responsibility of the Builder or Owner. All supporting documents are, however, to be given to the Society to permit the drafting of the list of cargoes annexed to the classification certificate.

Copy of the charts of coating and/or material resistance issued by the manufacturers is to be kept on board. These documents are to indicate the possible restrictions relative to their use.

c) As a general requirement, the provisions under NR216 Materials and Welding apply. Materials for tanks are, in any case, to have properties which are not lower than those of hull steels used according to NR216 Materials and Welding.

d) The above-mentioned materials are, in themselves, to be resistant to the action of the products to be carried. However, materials which are not, in themselves, resistant to such action may be used, provided they are protected by resistant materials after the positive outcome of prior checks and tests performed to the satisfaction of the Society. In this case, the Society may also require surveys to be carried out at shorter intervals than those between normal surveys.

e) In the construction of cargo tanks intended to carry cargo and sea water ballast alternately, the utmost care is to be given to the selection of structural material (in general austenitic stainless steel) with particular attention to its resistance to different types of isolated corrosion:

- pitting
- stress corrosion
- interstice corrosion.

In addition, these structures are to be constructed with the same type of material to avoid galvanic corrosion, which would arise if dissimilar materials were present. In addition to the structures, the above is also intended to apply to the materials of systems, devices and apparatuses fitted in the tanks.

f) Sea water ballast tank structures may be partly of stainless steel and partly of hull steel, provided suitable measures are taken against hull steel corrosion. The use of appropriate protective coatings is subject to the positive outcome of the previous checks and tests, to the satisfaction of the Society, which may also require surveys to be performed at shorter intervals than for normal surveys. In estimating the suitability of the protective system, the Society may also require that the cathodic area is drastically reduced (for example, by also suitably protecting stainless steel structures) for the purpose of avoiding extremely isolated corrosion in hull steel structures which could possibly turn out, for various reasons, not to be protected by coating.

g) The use of aluminium coatings is prohibited in the cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo gas may accumulate.

2 Special requirements for materials

2.1 Miscellaneous requirements

2.1.1 Non-metallic materials

IBC CODE REFERENCE: Ch. 6

Non-metallic materials used in cargo tanks and connected equipment are to be suitable for the liquids and vapours to which they are exposed.

2.1.2 Primers

IBC CODE REFERENCE: Ch. 6

Primers containing zinc may not be used for stainless steel. Where such type of primer is used for other items which are welded to stainless steel, provisions are to be made to avoid the contamination of the stainless steel by zinc.

Section 7 Cargo Temperature Control

1 General

1.1 Heated cargoes

1.1.1 Approval

The capacity of a ship to maintain specific cargoes under heated conditions is the responsibility of the Builder or the Owner.

However, all relevant supporting documents are to be given to the Society in order to establish the list of cargoes possibly attached to the classification certificate as per Pt A, Ch 1, Sec 2, [4.4.4].

1.1.2 Application

Except for ships intended for restricted voyages, any cargo with a melting point equal to 20°C, or above, is to be capable of being maintained under heated conditions.

Attention is drawn to the fact that, for safety reasons, certain cargoes are not to be heated above a specific temperature.

1.1.3 Temperature indication

When a ship is fitted with a heating system capable of maintaining the liquid temperature above 90°C, the ship's structure and materials are to be checked for this temperature and the maximum permissible temperature is to be stated on the classification certificate or on a memorandum.

1.2 Cargo heating and cooling systems

1.2.1 Cargo temperature control systems

IBC CODE REFERENCE: Ch 7, 7.1.1

Wherever a particular temperature (higher or lower than the ambient temperature) is required to be maintained for the preservation of the cargo, one of the following systems is to be adopted:

a) Thermal insulated tanks capable of maintaining the temperature of the cargo within acceptable limits for the time of the voyage.

b) A heating or cooling plant or refrigerating plant.

c) A combination of a) and b) above.

1.2.2 Additional requirements for heating and cooling plants

IBC CODE REFERENCE: Ch 7, 7.1.1

a) Manifolds for the delivery and backflow of heating media are to be fitted on the weather deck; connections to cargo tanks for inlet and outlet are to be in way of the cargo tank top.

b) Where the heat exchanger room is located in the accommodation area and considered as gas-safe, it is to be treated as a machinery space (not a category A machinery space) and provided with independent mechanical extraction ventilation as well as with scuppers discharging directly into the machinery space.

1.2.3 Reference temperature

IBC CODE REFERENCE: Ch 7, 7.1.1

Wherever the cargo temperature is maintained by a heating or refrigerating plant, unless otherwise indicated in the contract specification, the system is to be designed taking into account the reference temperatures indicated in Tab 1.

Table 1 :

Reference temperature (°C)		
	Heating system	Cooling system
Sea	0	32
Air	5	45

1.2.4 Redundancy

IBC CODE REFERENCE: Ch 7, 7.1.1

Wherever the heating or cooling system is essential for the preservation of the cargo, the following components are to be duplicated:

a) Coils and ducts in cargo tanks

b) Heating or cooling sources

c) Circulating pumps for cargo and heating cooling media; if suitable for the use, cargo pumps may be employed for the circulation of the heating or cooling media

d) Refrigeration plant.

1.2.5 Maximum surface temperature

Depending on the class temperature of the cargoes being carried, the maximum surface temperature of the heating system, within enclosed spaces inside the cargo area should not exceed the values of Tab 2.

Table 2 :

Class temperature	Maximum surface temperature of the heating system
T1	450°C
T2	300°C
T3	200°C
T4	135°C
T5	100°C
T6	85°C

1.3 Valves and other fittings

1.3.1 Means for purging

IBC CODE REFERENCE: Ch 7, 7.1.3

Cargo heating or cooling systems are to be fitted with the necessary connections to purge, by inert gas or compressed air, the heating or cooling circuit of each cargo tank and to perform the pressure testing of the system.

1.4 Cargo temperature measuring system

1.4.1 Alarm

IBC CODE REFERENCE: Ch 7, 7.1.5

a) An alarm system is required for those products which are carried in a heated condition (see 15.13.6 of the IBC Code) and for which, in column "o" of the tables in Chapter 17 of the IBC Code, reference is made to the requirements of 15.13 of the IBC Code.

b) An alarm system is required for those products for which a carrying temperature not greater than certain limits is required by Chapter 15 of the IBC Code, such as elementary phosphorus and molten sulphur.

c) An alarm connection to the navigation bridge and to the cargo control station, if fitted, is to be provided.

1.5 Requirements for special products

1.5.1 Products which may damage the cargo heating or cooling system

IBC CODE REFERENCE: Ch 7, 7.1.6

a) The provisions of 7.1.6 of the IBC Code also apply to products which may damage the cargo heating or cooling system.

b) If the sampling equipment mentioned in 7.1.6.3 of the IBC Code consists of an observation tank for drains, this tank is generally to comply with the following requirements:

- it is to be located in the cargo area and provided with an air pipe with the end fitted with a flame screen, as per the Rules, and arranged at not less than 3 m from openings of accommodation spaces and from sources of ignition
- it is to be fitted with a connection for discharge into the slop tanks with associated shut-off valves and sight glass and equipped with a sampling cock for backflowing medium analysis.

Section 8 Cargo Tank Venting and Gas-Freeing Arrangements

1 Cargo tank venting

1.1 Venting system drainage

1.1.1 Large amounts of drainage

IBC CODE REFERENCE: Ch 8, 8.2.3

When large amounts of drainage from vent lines of the cargo tanks are envisaged, a hose connection to the drain line of the slop tank is to be provided.

2 Types of tank venting system

2.1 Controlled tank venting system

2.1.1 Tests of pressure/vacuum valves

IBC CODE REFERENCE: Ch. 8, 8.3.2

The tightness and the setting pressure of the cargo tanks pressure/vacuum or pressure- and vacuum-relief valves are to be checked. Inspections and tests for these valves are given in Ch 8, Sec 5, Tab 2.

2.1.2 By-passing of P/V valves

IBC CODE REFERENCE: Ch 8, 8.3.2

By-passing of P/V valves is allowed during cargo operations for cargoes which do not require a vapor return system, provided that the vent-line outlet is fitted with flame arresters and is located at the required height above the deck level. However, by-passing of high-velocity valves is not permitted.

2.1.3 Position of vent outlets

IBC CODE REFERENCE: Ch 8, 8.3.4

The requirements relevant to air intakes in IBC Code 8.3.4 are also intended to be applicable to air outlets.

2.1.4 Flame arresters

IBC CODE REFERENCE: Ch. 8, 8.3.5

Inspections and tests for flame arresters are given in Ch 8, Sec 5, Tab 2.

2.2 Position of vent outlets

2.2.1 Outlets from tanks intended for flammable and toxic products

IBC CODE REFERENCE: Ch. 8, 8.3.3

Vent outlets of cargo tanks intended for the carriage of flammable or toxic products are to be arranged at a distance of not less than 3 m from exhaust ducts and as far as possible from inlet ducts to pump rooms and cargo pump rooms.

3 Cargo tank gas-freeing

3.1 Fans

3.1.1

IBC CODE REFERENCE: Ch 8, 8.6

The impellers and housing of either fixed or portable fans fitted in dangerous spaces are to be of non-sparking materials according to 12.1.8 of the IBC Code.

Section 9 Environmental Control

1 General

1.1 Control by padding

1.1.1 Padding medium

IBC CODE REFERENCE: Ch 9, 9.1.3

The padding medium is to be compatible from the point of view of safety with the products to be carried, it is not to react with them and with air and it is to have chemical and physical properties deemed suitable by the Society. The system is to comply with the requirements for inert gas systems, as applicable.

1.2 Control by drying

1.2.1 Simultaneous carriage of incompatible products

IBC CODE REFERENCE: Ch 9, 9.1.4

In the case of simultaneous carriage of mutually incompatible products, dry gas supply piping systems to each cargo space are to be separate from each other.

1.3 Control by inerting

1.3.1 Application

IBC CODE REFERENCE: Ch 9, 9.1

a) *Ships having the service notations **chemical tanker** and of 8 000 tonnes deadweight and upwards, carrying crude oil or petroleum products having a flashpoint not exceeding 60°C (closed cup test), as determined by an approved flashpoint apparatus, and a Reid vapour pressure which is below the atmospheric pressure, or other liquid products having a similar fire hazard, are to be equipped with an inert gas system complying with the requirements of Article [2], or with equivalent systems or arrangements in accordance with items b) and c).*

b) *For ships having the service notations **chemical tanker** and of 8 000 tonnes deadweight and upwards and of less than 20,000 tonnes deadweight, the Society may accept other equivalent arrangements in accordance with item a) and item c)*

c) *Equivalent systems or arrangements shall:*
   - *be capable of preventing dangerous accumulation of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations, and*
   - *be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.*

1.3.2 Simultaneous carriage of incompatible products

IBC CODE REFERENCE: Ch 9, 9.1

The inert gas is to comply with the requirements of 9.1.3 of the IBC Code, adapted, to the satisfaction of the Society, to the individual characteristics of the products to be carried. In the case of simultaneous carriage of mutually incompatible products, inert gas supply piping systems to each cargo space are to be separate from each other.

1.3.3 Ships with no fixed inert gas system

IBC CODE REFERENCE: Ch 9, 9.1

Where no fixed installation for inert gas and/or dry gas production is provided for on board, the minimum quantity to be kept on board is established by the Master, based on the duration of the voyage, the anticipated daily temperature variations, gas leakage through cargo tank seals and experience of previous similar cases.

1.3.4 Additional requirements

IBC CODE REFERENCE: Ch 9, 9.1

a) In addition to the provisions in 9.1.3 of the IBC Code, the inert gas system is to comply with the requirements of Article [2].

b) These requirements apply where an inert gas system based on Nitrogen or oil fired inert gas generators is fitted on board chemical tankers. Any proposal to use other sources of inert gas will be specially considered.

1.4 Control by ventilation

1.4.1

IBC CODE REFERENCE: Ch 9, 9.1

When a cargo space ventilation system other than the venting system mentioned under 8.2 of the IBC Code is required following these provisions, such system is to be specially examined by the Society.

2 Inert gas systems

2.1 General requirements

2.1.1 The inert gas system is to comply with the applicable requirements of Pt C, Ch 4, Sec 15, [13].

2.1.2 Plans in diagrammatic form are to be submitted for appraisal and are to include the following:

- details and arrangement of inert gas generating plant including all control monitoring devices
- arrangement of piping system for distribution of the inert gas

2.1.3 An automatic control capable of producing suitable inert gas under all service conditions is to be fitted

2.2 Additional requirements for nitrogen generator systems

2.2.1 The following requirements apply where a nitrogen generator system is fitted on board as required by [1.3.1]. For the purpose, the inert gas is to be produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials.

2.2.2 In addition to the applicable requirements of Pt C, Ch 4, Sec 15, [13], the nitrogen generator system is to comply with Ch 7, Sec 4, [4.3.2], and Ch 7, Sec 4, [4.2.10].

2.2.3 A nitrogen generator is to consist of a feed air treatment system and any number of membrane or adsorber modules in parallel necessary to meet the requirements of Pt C, Ch 4, Sec 15, [13.3.1], item b) 4).

2.2.4 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with Pt C, Ch 4, Sec 15, [13.3.1], item b) 5). In addition to Pt C, Ch 4, Sec 15, [13.3.2], item d), the system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

2.2.5 The system is to be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas required by Pt C, Ch 4, Sec 15, [13.3.1], item b). Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

2.2.6 The feed air treatment system fitted to remove free water, particles and traces of oil from the compressed air as required by Pt C, Ch 4, Sec 15, [13.5.2], item b), is also to preserve the specification temperature.

2.2.7 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck.

Note 1: "safe location" needs to address the two types of discharges separately:

- oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
  - outside of hazardous area;
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets
- nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

2.2.8 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

2.3 Nitrogen /Inert gas systems fitted for purposes other than inerting required by [1.3.1]

2.3.1 Nitrogen/inert gas systems fitted on chemical tankers of less than 8 000 tonnes deadweight and for which an inert gas system is not required by [1.3.1] are to comply with the following requirements.

2.3.2 Requirements of:

- Pt C, Ch 4, Sec 15, [13.3.2], item b)
- Pt C, Ch 4, Sec 15, [13.3.2], item d)
- Pt C, Ch 4, Sec 15, [13.3.4], item b)
- Pt C, Ch 4, Sec 15, [13.3.4], item c)
- Pt C, Ch 4, Sec 15, [13.3.4], item e) 1) regarding oxygen content and power supply to the indicating devices
- Pt C, Ch 4, Sec 15, [13.3.4], item e) 4)
- Pt C, Ch 4, Sec 15, [13.5.2] and
- Pt C, Ch 4, Sec 15, [13.5.3],

apply to the systems.

2.3.3 The requirements of [2.2] apply except requirements [2.2.1] to [2.2.3] and [2.2.5].

2.3.4 The two non-return devices as required by Pt C, Ch 4, Sec 15, [13.3.3], item a) 1) are to be fitted in the inert gas main. The non-return devices are to comply with Pt C, Ch 4, Sec 15, [13.3.3], item a) 2) and Pt C, Ch 4, Sec 15, [13.3.3], item a) 3); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by Pt C, Ch 4, Sec 15, [13.3.3], item a) 1) may be substituted by two non-return valves.

Section 10 Electrical Installations

1 General

1.1 Application

1.1.1 The requirements in this Section apply, in addition to those contained in Part C, Chapter 2, to chemical tankers.

1.1.2 The design is to be in accordance with IEC publication 60092-502.

However, where the prescriptive requirements in the present Rules and IEC 60092-502 are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, Tab 1, the following documents are to be submitted for approval:

a) Plan of hazardous areas

b) Document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas

c) Diagrams of tank level indicator systems, high level alarm systems and overflow control systems where requested.

1.3 System of supply

1.3.1 Acceptable systems of supply

The following systems of generation and distribution of electrical energy are acceptable:

a) Direct current:
- two-wire insulated

b) Alternating current:
- single-phase, two-wire insulated
- three-phase, three-wire insulated.

In insulated distribution systems, no current carrying part is to be earthed, other than:

a) through an insulation level monitoring device

b) through components used for the suppression of interference in radio circuits.

1.3.2 Earthed system with hull return

Earthed systems with hull return are not permitted, with the following exceptions to the satisfaction of the Society:

a) impressed current cathodic protective systems

b) limited and locally earthed systems, such as starting and ignition systems of internal combustion engines, provided that any possible resulting current does not flow directly through any hazardous area

c) insulation level monitoring devices, provided that the circulation current of the device does not exceed 30 mA under the most unfavourable conditions.

1.3.3 Earthed systems without hull return

Earthed systems without hull return are not permitted, with the following exceptions:

a) Earthed intrinsically safe circuits and the following other systems to the satisfaction of the Society

b) Power supplies, control circuits and instrumentation circuits in non-hazardous areas where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions, or

c) Limited and locally earthed systems, such as power distribution systems in galleys and laundries to be fed through isolating transformers with the secondary windings earthed, provided that any possible resulting hull current does not flow directly through any hazardous area, or

d) Alternating current power networks of 1,000 V root mean square (line to line) and over, provided that any possible resulting current does not flow directly through any hazardous area; to this end, if the distribution system is extended to areas remote from the machinery space, isolating transformers or other adequate means are to be provided.

1.4 Earth detection

1.4.1 Monitoring of circuits in hazardous areas

The devices intended to continuously monitor the insulation level of all distribution systems are also to monitor all circuits, other than intrinsically safe circuits, connected to apparatus in hazardous areas or passing through such areas. An audible and visual alarm is to be given, at a manned position, in the event of an abnormally low level of insulation.

1.5 Mechanical ventilation of hazardous spaces

1.5.1 Electric motors driving fans of the ventilating systems of hazardous spaces are to be located outside the ventilation ducting.

1.5.2 Motors driving ventilating fans may be located within the ducting provided that they are of a certified safe type.

1.5.3 The materials used for the fans and their housing are to be in compliance with Pt C, Ch 4, Sec 1, [2.33].

1.5.4 Cargo pump-rooms and other enclosed spaces which contain cargo-handling equipment and similar spaces in which work is performed on the cargo should be fitted with mechanical ventilation systems, capable of being controlled from outside such spaces.

1.5.5 Provisions are to be made to ventilate the spaces defined in [1.5.4] prior to entering the compartment and operating the equipment.

1.6 Electrical installation precautions

1.6.1 Precautions against corrosion

Where products are liable to damage the materials normally used in electrical apparatuses, special attention is to be paid to the selection of materials for conductors, insulation and metal parts to be installed in gas-dangerous spaces. Copper, aluminium and insulation materials are to be protected as far as possible in order to prevent contact with products and/or their corrosive vapours (e.g. by means of encasing). This provision applies to those products for which the symbol Z is listed in column “m” of the tables in Chapter 17 of the IBC Code.

1.6.2 Precautions against inlet of gases or vapours

Suitable arrangements are to be provided, to the satisfaction of the Society, so as to prevent the possibility of gases or vapours passing from a gas-dangerous space to another space through runs of cables or their conduits.

2 Hazardous locations and types of equipment

2.1 Electrical equipment permitted in hazardous areas for ships carrying dangerous chemicals in bulk having a flash-point not exceeding 60°C and ships carrying dangerous chemicals in bulk having a flash point exceeding 60°C heated to a temperature within 15°C of their flash point or above their flashpoint

2.1.1 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zone 0, 1 and 2 according to Pt C, Ch 2, Sec 1, [3.13.3]. The different spaces are to be classified according to Tab 1.

The types of electrical equipment admitted, depending on the zone where they are installed, are specified in Pt C, Ch 2, Sec 3, [10].

2.1.2 A space separated by a gastight boundaries from a hazardous area may be classified as zone 0, 1, 2 or considered as non hazardous, taking into account the sources of release inside that space and its conditions of ventilation.

2.1.3 Access door and other openings are not to be provided between an area intended to be considered as non-hazardous and a hazardous area or between a space intended to be considered as zone 2 and a zone 1, except where required for operational reasons.

2.1.4 In enclosed or semi-enclosed spaces having a direct opening into any hazardous space or area, electrical installations are to comply with the requirements for the space or area to which the opening leads.

2.1.5 Where a space has an opening into an adjacent, more hazardous space or area, it may be made into a less hazardous space or non-hazardous space, taking into account the type of separation and the ventilation system.

2.1.6 A differential pressure monitoring device or a flow monitoring device, or both, are to be provided for monitoring the satisfactory functioning of pressurisation of spaces having an opening into a more hazardous zone.

In the event of loss of the protection by the over-pressure or loss of ventilation in spaces classified as zone 1 or zone 2, protective measures are to be taken.

2.2 Electrical equipment permitted in hazardous areas for ships carrying dangerous chemicals in bulk having a flash-point exceeding 60°C unheated or heated to a temperature below and not within 15°C of their flashpoint

2.2.1 For systems of supply and earth detection, the requirements under Ch 7, Sec 5, [1.3] and Ch 7, Sec 5, [1.4] apply.

2.2.2 Cargo tanks, slop tanks, any pipe work of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo are to be classified as zone 2.

2.3 Electrical equipment permitted in tankers carrying cargoes (for example acids) reacting with other products/materials to evolve flammable gases

2.3.1 The different spaces are to be classified according to Tab 2.

Table 1 : Space descriptions and hazardous area zones for ships carrying dangerous chemicals in bulk having a flash point not exceeding 60°C and ships carrying dangerous chemicals in bulk having a flash point exceeding 60°C heated to a temperature within 15°C of their flash point or above their flash point

No.	Description of spaces	Hazardous area
1	The interior of cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or developing flammable gases and vapours	Zone 0
2	Void space adjacent to, above or below integral cargo tanks	Zone 1
3	Hold spaces	Zone 1
4	Cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks	Zone 1
5	Cargo pump rooms	Zone 1
6	Enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tank bulkheads, unless protected by a diagonal plate acceptable to the Society	Zone 1
7	Spaces, other than cofferdam, adjacent to and below the top of a cargo tank (for example, trunks, passageways and hold)	Zone 1
8	Areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation.	Zone 1
9	Areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet	Zone 1
10	Areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams, or other zone 1 spaces	Zone 1
11	Areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2,4 m above the deck	Zone 1
12	Areas on open deck over the cargo area where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck	Zone 1
13	Compartments for cargo hoses	Zone 1
14	Enclosed or semi-enclosed spaces in which pipes containing cargoes are located	Zone 1
15	Areas of 1,5 m surrounding a space of zone 1	Zone 2
16	Spaces 4 m beyond the cylinder and 4 m beyond the sphere defined in item 9	Zone 2
17	Fore peak ballast tank not adjacent to cargo tanks, when ballasted with the system serving ballast tanks in the cargo area according to Ch 8, Sec 3, [5.1.3]	Zone 2
18	Areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service area and 3 m beyond these up to a height of 2,4 m above the deck	Zone 2
19	Areas on open deck over the cargo area where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck surrounding open or semi-enclosed spaces of zone 1	Zone 2
20	Spaces forward of the open deck areas to which reference is made in 12 and 18, below the level of the main deck, and having an opening on to the main deck or at a level less than 0,5 m above the main deck, unless: • the doors and all openings are in non-hazardous area; and • the spaces are mechanically ventilated	Zone 2

Table 2 : Space descriptions and hazardous area zones in tankers carrying cargoes (for example acids) reacting with other products/materials to evolve flammable gases.

No.	Description of spaces	Hazardous area
1	The interior of cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or developing flammable gases and vapours.	Zone 1
2	Cargo pump rooms.	Zone 1
3	Compartments for cargo hoses.	Zone 1
4	Areas of 1,5 m surrounding the openings of zone 1 spaces specified above.	Zone 2
5	Void space adjacent to, above or below integral cargo tanks.	Zone 2
6	Hold spaces.	Zone 2
7	Cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks, fore peak ballast tank when ballasted with the system serving ballast tanks in the cargo area according to Ch 8, Sec 3, [5.1.3]	Zone 2
8	Enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tank bulkheads, unless protected by a diagonal plate acceptable to the society.	Zone 2
9	Spaces, other than cofferdam, adjacent to and below the top of a cargo tank (for example, trunks, passageways and hold).	Zone 2
10	Enclosed or semi-enclosed spaces in which pipes containing cargoes are located.	Zone 2
11	Areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of any cargo tank outlet, gas or vapour outlet, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets, and cargo tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation.	Zone 2
12	Areas on open deck within spillage coamings surrounding cargo manifold valves and 1,5 m beyond these, up to a height of 1,5 m above the deck.	Zone 2
13	Areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 3 m radius centred upon the centre of the outlet, and within a hemisphere of 3 m radius below the outlet.	Zone 2

Section 11 Fire Protection and Fire Extinction

1 General

1.1 Application

1.1.1 Fire-fighting

IBC CODE REFERENCE: Ch 11, 11.1.1.3 and

IBC CODE REFERENCE: Ch 11.1.1.4

Ships having the service notation **chemical tanker** are to comply with the requirements of:

- Pt C, Ch 4, Sec 6, [1]
- Pt C, Ch 4, Sec 6, [3] and
- Pt C, Ch 4, Sec 6, [4] except Pt C, Ch 4, Sec 6, [4.7]

regardless of the size of the ship.

- Pt C, Ch 4, Sec 6, [4.7] only for ships of 2000 gross tonnage and above.

2 Cargo pump rooms

2.1 Fixed fire-extinguishing systems

2.1.1 Halogenated hydrocarbon system

IBC CODE REFERENCE: Ch 11, 11.2.1.2

With reference to 11.2.1.2 of the IBC Code, it is to be noted that new installations of halogenated hydrocarbon systems have been prohibited on all (new and existing) ships since 1 October 1994.

3 Cargo area

3.1 Temperature of steam and heating media within the cargo area

3.1.1

IBC CODE REFERENCE: Ch 11, 11.3

The maximum temperature of the steam and heating media in the cargo area is to be adjusted to comply with maximum surface temperature in Ch 8, Sec 7, [1.2.5].

3.2 Monitors and foam applicators

3.2.1 Capacity for ships of less than 4000 tonnes deadweight

IBC CODE REFERENCE: Ch 11, 11.3.7

For ships of less than 4000 tonnes deadweight, the minimum required capacity for a monitor is to be not less than 1000 litres/min and the application rate that each monitor is to be capable of supplying is to be at least 10 litres/min per each square metre of the surface to be protected.

3.3 Simultaneous use of foam and water systems

3.3.1 Required number of jets of water

IBC CODE REFERENCE: Ch 11, 11.3.12

The simultaneous use of the minimum required number of jets of water is to be possible, in general, on deck over the full length of the ship, in the accommodation and service spaces, in control spaces and in machinery spaces.

3.4 Portable fire-extinguishing equipment

3.4.1 Capacity of portable fire-extinguishing equipment

IBC CODE REFERENCE: Ch 11, 11.3.14

The capacity of each item of portable fire-extinguishing equipment is to comply with the relevant provisions of the 1974 SOLAS Convention, as amended.

3.5 Ships carrying flammable products

3.5.1 Internal combustion engines

IBC CODE REFERENCE: Ch 11, 11.3.15

Internal combustion engines are not to be installed in cargo pump rooms, in pump rooms and in other spaces adjacent to or located above cargo tanks. However, reciprocating steam engines with a working temperature lower than the temperature stated in [3.1] may be installed in the above-mentioned rooms and spaces.

Section 12 Mechanical Ventilation in the Cargo Area

1 Spaces normally entered during cargo handling operations

1.1 Miscellaneous requirements

1.1.1 Ventilation system stopping

IBC CODE REFERENCE: Ch 12, 12.1

All required ventilation systems are to be capable of being stopped from a position located outside the served spaces and above the weather deck.

1.1.2 Warning notices

IBC CODE REFERENCE: Ch 12, 12.1

In the proximity of entrances to all spaces served by the required mechanical ventilation systems, a clearly visible warning is to be posted requiring such spaces to be adequately ventilated prior to entering and relevant ventilation systems to be kept in operation all the time persons are present in the spaces themselves.

1.1.3 Prevention of dangerous operation of electric motors

IBC CODE REFERENCE: Ch 12, 12.1

A suitable automatic device is to be fitted to prevent operation of electric motors driving cargo pumps and operation of other electrical equipment not of a certified safe type prior to ventilating the spaces where such motors or equipment are located, in order to render them gas-safe (to this end it is pointed out that IEC provisions require at least 10 changes of air based on the volume of the served space).

1.1.4 Prevention of dangerous operation of cargo pumps

IBC CODE REFERENCE: Ch 12, 12.1

An automatic device is to be fitted capable of stopping motors driving cargo pumps and de-energising any other electrical equipment not of a certified safe type in the case of stoppage of ventilation in spaces where such motors and equipment are fitted. This provisions does not apply to motors and other electrical equipment fitted in the engine room.

1.1.5 Alternative to extraction type ventilation systems

IBC CODE REFERENCE: Ch 12, 12.1

As an alternative to ventilation systems of the extraction type, required in [1.1.4], a ventilation system of the positive pressure type may be accepted:

- in the case of cargo pump rooms adjacent to cargo tanks or to other gas-dangerous spaces, or
- where, in adjacent gas-safe spaces, inclusive of spaces containing motors of cargo pumps, an adequate overpressure is kept in relation to the cargo pump rooms themselves.

1.1.6 Location of upper end of inlet ducts

IBC CODE REFERENCE: Ch 12, 12.1

With reference to the requirements of [1.1.5], the upper ends of inlet ducts are generally to be located at a distance not less than 3 m from ventilation ducts and air intakes serving the safe spaces mentioned therein.

1.1.7 Minimum distance between inlet and extraction ducts

IBC CODE REFERENCE: Ch 12, 12.1

With reference to [1.1.6], the upper ends of (inlet and extraction) ventilation ducts serving the same space are to be located at a distance from each other, measured horizontally, of not less than 3 m and, in general, at an adequate height above the weather deck, but in any case not less than 2,4 m. Greater heights are required in 15.17 of the IBC Code.

1.1.8 Upper ends of ventilation ducts in ships carrying materials producing flammable vapours

IBC CODE REFERENCE: Ch 12, 12.1

For flammable products, or for products which may react with the ship's materials producing flammable vapours (such as strong acids), the upper ends of ventilation ducts are to be located at a distance of not less than 3 m from any source of ignition, as per the provisions of Ch 8, Sec 8, [2.2].

1.1.9 Dampers

IBC CODE REFERENCE: Ch 12, 12.1

Ventilation ducts are to be provided with metallic dampers, fitted with the indication "open" and "closed". The dampers are to be located above the weather deck, in a readily accessible position.

1.1.10 Location of electric motors of fans

IBC CODE REFERENCE: Ch 12, 12.1

Electric motors driving fans are to be placed outside the served spaces and outside the ventilation ducts, in a suitable position with respect to the presence of flammable vapours.

1.1.11 Penetration of motor shafts through bulkheads

IBC CODE REFERENCE: Ch 12, 12.1

Runs of shafts of electric motors driving fans through bulkheads or decks of gas-dangerous spaces or through ventilation ducts are to be provided with gas-tight seals, with oil glands or equivalent means, deemed suitable by the Society.

They have to be fitted with temperature sensing devices for bulkhead shaft glands bearings and pump casings. Alarms are to be initiated in the cargo control room or the pump control station.

Means are to be provided to compensate for any misalignment.

Shaft bulkhead lubricating means is to be located outside the cargo pump room. If the shaft bulkhead penetration system includes a bellow, this bellow is to be hydraulically tested at a pressure of at least 3,5 bars before being fitted on board.

1.2 Additional requirements for non-sparking fans

1.2.1 Non-sparking fans

IBC CODE REFERENCE: Ch 12, 12.1

a) A fan is considered as non-sparking if in both normal and abnormal conditions it is unlikely to produce sparks.

b) The air gap between the impeller and the casing is to be not less than 0,1 of the shaft diameter in way of the impeller bearing and not less than 2 mm. It need not be more than 13 mm.

1.2.2 Materials for non-sparking fans

IBC CODE REFERENCE: Ch 12, 12.1

a) The impeller and the housing in way of the impeller are to be made of alloys which are recognised as being spark proof by appropriate tests.

b) Electrostatic charges in both the rotating body and the casing are to be prevented by the use of antistatic materials. Furthermore, the installation on board of the ventilation units is to be such as to ensure their safe bonding to the hull.

c) Tests may not be required for fans having the following combinations:
- impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity
- impellers and housings of non-ferrous materials
- impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller
- any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm design tip clearance.

d) The following impellers and housings are considered as sparking and are not permitted:
- impellers of an aluminium alloy or magnesium alloy and a ferrous housing, regardless of tip clearance
- housing made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance
- any combination of ferrous impeller and housing with less than 13 mm design tip clearance.

1.2.3 Type test for non-sparking fans

IBC CODE REFERENCE: Ch 12, 12.1

Type tests on the finished product are to be carried out in accordance with the requirements of the Society.

2 Pump rooms and other enclosed spaces normally entered

2.1 Clarification of general requirement

2.1.1

IBC CODE REFERENCE: Ch 12, 12.2

a) The provisions of 12.2 of the IBC Code apply to all pump rooms, whether or not the control for pumps and valves which are installed in such rooms is fitted externally.

b) The distance of the upper ends of extraction and inlet ducts from air intakes and other openings of spaces mentioned in 12.1.5 of the IBC Code is not to be less than 3 m measured horizontally. These systems are to be capable of being controlled from outside the spaces they serve and, in the proximity of the entrances to such spaces, the warning notice mentioned in [1.1.2] is to be posted.

3 Spaces not normally entered

3.1 Portable fans

3.1.1

IBC CODE REFERENCE: Ch 12, 12.3

The type of portable fans and their connections to spaces to be ventilated are to be deemed suitable by the Society. Portable fans driven by electric or internal combustion motors are not acceptable.

Section 13 Instrumentation

1 Gauging

1.1 Types of gauging devices

1.1.1 Arrangement

IBC CODE REFERENCE: Ch 13, 13.1.1

a) In almost all cases a cargo code which requires a high level alarm and overflow control also requires a closed gauging device. A cargo tank containing such a product therefore requires three sensors:
   1) one level gauging
   2) one high level alarm
   3) one overflow control.

b) The sensing elements for 1), 2) and 3) are to be separated, although sensors for 2) and 3) (reed switches, float chambers, electronic devices, etc.) may be contained in the same tube.

c) Electronic, pneumatic and hydraulic circuits required for sensors 1), 2) and 3) are to be independent of each other such that a fault on any one will not render either of the others inoperative.

d) Where processing units are used to give digital or visual indication, such as in a bridge space, the independence of circuitry is to be maintained at least beyond this point.

e) The power is to be supplied from distribution boards.

f) Where a control room or a bridge space containing a modular unit is envisaged, separate level indication and visual alarms are to be provided for each of the functions 1), 2) and 3). An audible alarm is also to be provided but since this is not directional it need not be separate.

g) An audible alarm is also to be arranged in the cargo area.

h) Where there is no control room, an audible and visual alarm is to be arranged at the cargo control station.

i) Testing of sensors is to be arranged from outside the tanks, although entry into product clean tanks is not precluded.

j) Simulation testing of electronic circuits or circuits which are self-monitored is acceptable.

1.1.2 Example of restricted gauging device

IBC CODE REFERENCE: Ch 13, 13.1.1

A restricted gauging device may consist of a sounding pipe with an inside diameter not greater than 200 mm, fitted with a gas-tight plug. The pipe is to have holes in order to make its internal pressure equal to that of the tank. Therefore the holes are to be located inside the cargo tank in the proximity of the top.

2 Vapour detection

2.1 Vapour detection instruments

2.1.1 Spaces to be monitored

IBC CODE REFERENCE: Ch 13, 13.2.1

Vapour detection instruments, either fixed or portable, are to be of a type recognised suitable by the Society for the products to be carried. The spaces to be monitored are:

- cargo pump rooms
- spaces containing motors driving cargo pumps, except for the machinery space
- enclosed spaces containing cargo piping, equipment connected with cargo handling, cofferdams, enclosed spaces and double bottoms adjacent to cargo tanks
- pipe tunnels
- other spaces, in the opinion of the Society, depending on the ship type.

Where a fixed system is installed, it is to serve the spaces among those listed above which are normally entered by the crew.

2.2 Provisions for installation of gas analysing units

2.2.1 Gas analysing units are to be in compliance with the requirements in Ch 7, Sec 6, [7.4].

Section 14 Protection of Personnel

1 Protective equipment

1.1 Location of protective equipment

1.1.1

IBC CODE REFERENCE: Ch 14, 14.1.2

a) Lockers for work clothes or protective equipment which are not new or have not undergone a thorough cleaning process are not to open directly into accommodation spaces.

b) When a locker for clothes which have not undergone a thorough cleaning process is arranged in the accommodation area, it is to be bounded by "A-0" bulkheads and decks and provided with independent exhaust mechanical ventilation. The access to accommodation spaces, if allowed, is to be arranged through two substantially gas-tight self-closing steel doors without any hold-back device.

2 Safety equipment

2.1 Additional equipment for ships carrying toxic products

2.1.1

IBC CODE REFERENCE: Ch 14, 14.2.4

With regard to 14.2.4 of the IBC Code, the equivalent quantity of spare bottled air in lieu of the low pressure air line is to be at least 4800 litres.

2.2 Medical first aid equipment

2.2.1

IBC CODE REFERENCE: Ch 14, 14.2.9

First aid equipment, whose preservation in good condition is the Master's responsibility, is to be kept in a special, clearly indicated locker.

Section 15 Special Requirements

1 Ammonium nitrate solution (93% or less)

1.1 Ammonia injection

1.1.1 Injection procedure

IBC CODE REFERENCE: Ch 15, 15.2.6

Gaseous ammonia may be injected into the cargo while the latter is circulated by the cargo pump.

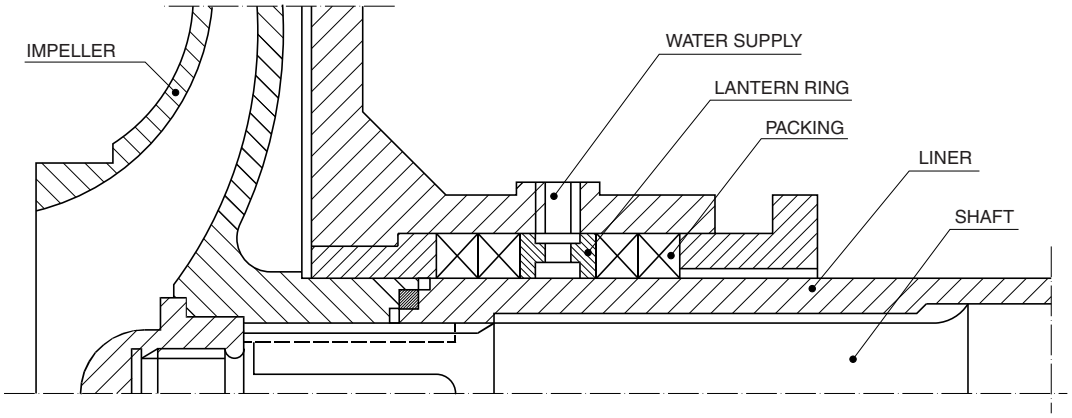
1.2 Cargo pumps

1.2.1 Seal

IBC CODE REFERENCE: Ch 15, 15.2.7

The seal for the centrifugal pump is to be a stuffing box provided with a lantern ring. Fresh water under pressure is to be injected into the stuffing box at the location of the lantern ring (see Fig 1).

Figure 1 : Seal



2 Hydrogen peroxide solutions

2.1 Hydrogen peroxide solutions over 60% but not over 70%

2.1.1 Water-spray system

IBC CODE REFERENCE: Ch 15, 15.5.10

It is specified that, for the purpose of evaluating the estimated size of the cargo spill in the case of failure, cargo piping/hose failure is to be assumed to be total.

3 Propylene oxide and mixtures of ethylene oxide/propylene oxide with an ethylene oxide content of not more than 30% by weight

3.1 Tank cleaning

3.1.1

IBC CODE REFERENCE: Ch 15, 15.8.3

Until an amendment in this respect is prepared at IMO, it is specified that the initial wording of the text of 15.8.3 of the IBC Code "Before carrying these products,....." is to be intended as follows: "Before initial loading of these products and before each loading of these products subsequent to loading of other products".

3.2 Joints in cargo lines

3.2.1

IBC CODE REFERENCE: Ch 15, 15.8.12

Screwed connections are only allowed for accessory and instrumental lines with an external diameter of 25 mm or less.

3.3 Oxygen content in tank vapour spaces

3.3.1 Analysing equipment

IBC CODE REFERENCE: Ch 15, 15.8.28

Analysing equipment to determine oxygen and propylene oxide contents is to be of a type recognised as suitable by the Society. When portable analysers are used, there are to be at least two. When a fixed system is installed, a portable analyser is also to be provided.

3.4 Valves at cargo hose connections

3.4.1 Shut-off valve closing time

IBC CODE REFERENCE: Ch 15, 15.8.30

The closing time of shut-off valves provided at each cargo hose connection is to take account of the loading/unloading rate and is to be such as to avoid dangerous overpressure in cargo piping and hoses mentioned in the paragraphs

4 Acids

4.1 Electrical arrangements

4.1.1

IBC CODE REFERENCE: Ch 15, 15.11.5

In enclosed spaces adjacent to cargo tanks, electrical materials and equipment complying with the provisions of 10.1.2.1 of the IBC Code are allowed.

4.2 Leak detection system

4.2.1 Electrical equipment

IBC CODE REFERENCE: Ch 15, 15.11.5

Hazardous areas are to be defined as per Ch 8, Sec 10, Tab 2. Electrical materials and equipment are to have minimum explosion group IIC or IIB+H2 and temperature class T1.

4.3 Lining for tanks and piping

4.3.1 Lining approved for use with acids

IBC CODE REFERENCE: Ch 15, 15.11.2

“Lining” is an acid-resistant material that is applied to the tank or piping system in a solid state i.e. not spray on.

The requirement for the elasticity of a lining to be not less than the supporting boundary plating is to prevent debonding at the interface between the lining and the lined surface.

5 Toxic products

5.1 Position of tank vent outlets

5.1.1 Distance to ventilation openings

IBC CODE REFERENCE: Ch 15, 15.12.1.3

The requirements relevant to air intakes in IBC Code 15.12.1.3 are also intended to be applicable to air outlets.

5.2 Return line to shore installation

5.2.1 Valving on connection to shore installation

IBC CODE REFERENCE: Ch 15, 15.12.2

The above-mentioned systems are to be fitted with a shut-off valve and a blank flange in way of the vapour return line to the shore installation.

6 Cargoes protected by additives

6.1 Prevention of blockage by polymerisation

6.1.1 Arrangements

IBC CODE REFERENCE: Ch 15, 13.6

In addition to being designed so as to avoid internal obstructions due to polymer formation, the above-mentioned systems are to be fitted with pressure/vacuum valves and devices to prevent the passage of flame which are accessible for inspection and maintenance.

7 Cargoes with a vapour pressure greater than 0,1013 MPa (1,013 bar) absolute at 37,8°C

7.1 General

7.1.1 System for maintaining cargo temperature below boiling point

IBC CODE REFERENCE: Ch 15, 15.14.1

a) Any system installed for the purpose of keeping the cargo temperature below its boiling point is to be constructed to the satisfaction of the Society.

b) Whenever cargo tanks are designed specifically for the carriage of products dealt with in 15.7 of the IBC Code, they are to be capable of withstanding the vapour pressure of such products corresponding to 45°C.

7.2 Return of expelled gases

7.2.1 Valving of shore connection

IBC CODE REFERENCE: Ch 15, 15.14.4

The above-mentioned systems are to be fitted with a shut-off valve and a blank flange in way of the vapour return line to the shore installation.

8 Special cargo pump room requirements

8.1 Clarification

8.1.1

IBC CODE REFERENCE: Ch 15, 15.18

As far as concerns the possibility of allowing the arrangement of cargo pump rooms below deck in specific cases, it is specified that, in practice, no circumstance can be foreseen where such an arrangement may be permitted.

9 Overflow control

9.1 Independence of systems

9.1.1 Gauging devices

IBC CODE REFERENCE: Ch 15, 15.19

In almost all cases where, for the carriage of a product, a cargo high level alarm or cargo overflow control is required, a closed gauging device is also required.

9.1.2 Separation of device sensing elements

IBC CODE REFERENCE: Ch 15, 15.19

A cargo tank intended to carry such a product therefore requires:

a) Level gauging

b) High level alarm

c) Overflow control.

The sensing elements for the devices under a), b) and c) are to be separated, although sensors for b) and c) (micro-switches, float chambers, electronic devices, etc.) may be contained in the same metal tube sections.

9.1.3 Electronic and hydraulic circuits for sensors

IBC CODE REFERENCE: Ch 15, 15.19

Electronic, pneumatic and hydraulic circuits required for sensors for a), b) and c) are to be independent of each other such that a fault on any one of them will not render either of the others inoperative. Where processing units are used to give digital or visual indication such as in a bridge space, the independence of circuitry is to be maintained at least up to such units. The power is to be supplied from distribution boards.

9.1.4 Alarms in cargo control room

IBC CODE REFERENCE: Ch 15, 15.19

Where a cargo control room or a bridge space containing a modular unit is envisaged, separate level indications and visual alarms are to be provided for each of the functions a), b) and c). An audible alarm is also to be provided; there need not be a separate alarm for each function since separate alarms could not be distinguished. An audible alarm is also to be arranged in the cargo area.

9.1.5 Alarms where cargo control room is not provided

IBC CODE REFERENCE: Ch 15, 15.19

a) Where no cargo control room is provided, an audible and visual alarm is to be arranged at the cargo control station, which generally coincides with the navigation bridge.

b) The audible and visual high level and cargo overflow alarms are to be located so as to be easily heard and noticed by the personnel in charge of loading/unloading operations. Attention is drawn to the fact that such alarms are generally grouped together into two independent signals; therefore it is not possible to single out directly the cargo tank from which the alarm signal is coming. In such cases, the Master is to arrange for a person to be present at the cargo control station, in order to be able to warn the personnel in charge of loading operations on deck.

9.1.6 Testing of sensors

IBC CODE REFERENCE: Ch 15, 15.19

Testing of sensors is to be arranged from outside the tanks, although entry into product clean tanks is not prohibited. Simulation testing of electronic circuits or circuits which are self-monitoring is acceptable.

Section 16 Operational Requirements

1 General

1.1

1.1.1 This Section is void, as the provisions of Chapter 16 of the IBC Code are operating requirements which are not mandatory for the class.

Section 17 Summary of Minimum Requirements

1 General

1.1

1.1.1 The list of products and the minimum requirements referred to elsewhere in this Section is the one of Chapter 17 of the IBC code.

Section 18 List of Chemicals to which this Chapter Does Not Apply

1 General

1.1

1.1.1 This Section is void, as there are no additional or alternative requirements to those indicated in Chapter 18 of the IBC Code.

Section 19 Index of Products Carried In Bulk

1 General

1.1

1.1.1 This Section is void, as there are no additional or alternative requirements to those indicated in Chapter 19 of the IBC Code.

Section 20 Transport of Liquid Chemical Wastes

1 General

1.1

1.1.1 This Section is void, as there are no additional or alternative requirements to those indicated in Chapter 20 of the IBC Code.

Section 21 Criteria for Assigning Carriage Requirements for Products Subject to the IBC Code

1 General

1.1

1.1.1 This Section is void, as there are no additional or alternative requirements to those indicated in Chapter 21 of the IBC Code.

CHAPTER 9
LIQUEFIED GAS CARRIERS

Section 1 General

Section 2 Ship Survival Capability and Location of Cargo Tanks

Section 3 Ship Arrangement

Section 4 Cargo Containment

Section 5 Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems

Section 6 Materials of Construction and Quality Control

Section 7 Cargo Pressure / Temperature Control

Section 8 Vent Systems for Cargo Containment

Section 9 Cargo Containment System Atmosphere Control

Section 10 Electrical Installations

Section 11 Fire Protection and Extinction

Section 12 Artificial Ventilation in the Cargo Area

Section 13 Instrumentation and Automation Systems

Section 14 Personnel Protection

Section 15 Filling Limits for Cargo Tanks

Section 16 Use of Cargo as Fuel

Section 17 Special Requirements

Section 18 Operating Requirements

Section 19 Summary of Minimum Requirements

Section 20 Hull Scantling

Section 21 Additional Requirements for Ship carrying Liquefied Hydrogen in Bulk

Appendix 1 Guidance for Calculation of Pressures and Accelerations

Appendix 2 Correspondances between Part D, Chapter 9 and the IGC Code

Appendix 3 Correspondances between Pt D, Chapter 9 and IMO Circular MSC.1/Circ.1679

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **liquefied gas carrier**, in accordance with Pt A, Ch 1, Sec 2, [4.4.5].

Note 1: The service notation is to be completed by the additional service features, as defined in Pt A, Ch 1, Sec 2, [4.4.5], indicating the cargo type, the IMO ship type, the cargo containment system type, the cargo tank design pressure P_{design} and minimum temperature T_{min}.

1.1.2 Ships which are intended for the carriage of liquefied gases are to comply with the requirements of the latest version of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), as amended.

1.1.3 This Chapter and the IGC Code refer to ships carrying products which are listed in the table in Chapter 19 of the IGC Code and in Ch 9, Sec 19.

1.1.4 This Chapter and the IGC Code include requirements for the carriage of cargo in containment systems incorporating integral, membrane or independent tank types as detailed in Chapter 4 of the IGC Code and in Ch 9, Sec 4.

1.1.5 In general, this Chapter applies to cargo containment and handling systems and to the interfaces between these systems and the remainder of the ship, which is to comply with the additional applicable requirements indicated in Tab 1.

Table 1 : Additional applicable requirements

Item	Reference
Ship arrangement	Part B
Hull	Part B
Stability	Part B
Machinery and cargo system	Part C
Electrical installations:	Part C
Automation	Part C
Fire protection, detection and extinction	Part C

1.1.6 Additional service features for ships using their cargo or other low-flashpoint gaseous fuels

The additional service features **LNGfuel** or **LPGfuel** or, as relevant, other additional service features defined in Pt A, Ch 1, Sec 2, [4.16], may be assigned to **liquefied gas carriers** designed and equipped to use:

- their cargoes as fuel and complying with the requirements of Ch 9, Sec 16 or
- other low-flashpoint gaseous fuels provided that the fuel storage and distribution systems design and arrangements for such gaseous fuels comply with the requirements of the present chapter for gas as a cargo.

The above additional service features are completed with **singlefuel** when the propulsion system uses only gas as fuel or **dualfuel** when the propulsion system uses both gas and fuel oil as fuel.

1.2 IGC Code requirements or other IMO Circulars and the Society's Rules

1.2.1 General

a) For ships assigned the service notation **liquefied gas carrier**, the IGC Code requirements are to be considered as Rule requirements, unless otherwise specified, and with the exception indicated in [1.2.2].

b) The rule requirements of this Chapter include:
   - requirements of the IGC Code and, in section 16, of IMO Circular MSC.1/Circ.1679 "Interim guidelines for use of liquefied petroleum gas (LPG) cargo as fuel", printed in italic type: in reproducing such text, applicable for the purpose of Classification, in this Chapter, the word "Administration", wherever mentioned, has been replaced by the word "Society"
   - additional requirements to the IGC Code
   - Society's interpretations of the IGC Code.

c) The correspondence between the references of the IGC Code and those of the present Chapter are given in Ch 9, App 3.

   The correspondence between the references of the IMO Circular MSC.1/Circ.1679 and those of the present Chapter are given in Ch 9, App 2.

1.2.2 IGC Code requirements not within the scope of classification

The following requirements of the IGC Code are not within the scope of classification:

- Chapter 1, Section 1.3 - Equivalents
- Chapter 1, Section 1.4 - Surveys and certification
- Chapter 18 - Operating requirements.

These requirements are applied by the Society when acting on behalf of the flag Administration, within the scope of delegation (see [1.2.5]).

1.2.3 Carriage of products not listed in the Code

The requirements of the IGC Code and the additional requirements of this Chapter are also applicable to new products, which may be considered to come within the scope of this Chapter, but are not at present listed in the table in Chapter 19 of the IGC Code.

Specific requirements for liquefied hydrogen product, including requirements of IMO Resolution MSC.565(108) "Revised Recommendations for Carriage of Liquefied Hydrogen in Bulk" are given in Ch 9, Sec 21.

1.2.4 Particularly hazardous products

For the carriage in bulk of products which are not listed in the table in Chapter 19 of the IGC Code, presenting more severe hazards than those covered by the IGC Code, the Society reserves the right to establish requirements and/or conditions additional to those contained in this Chapter.

1.2.5 Certificate of fitness

a) The responsibility for interpretation of the IGC Code requirements for the purpose of issuing an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk lies with the Administration of the state whose flag the ship is entitled to fly.

b) Whenever the Society is authorised by an Administration to issue on its behalf the "Certificate of Fitness for the Carriage of Liquefied Gases in Bulk", or where the Society is authorised to carry out investigations and surveys on behalf of an Administration on the basis of which the "Certificate of Fitness for the Carriage of Liquefied Gases in Bulk" will be issued by the Administration, or where the Society is requested to certify compliance with the IGC Code, the full compliance with the requirements of the IGC Code, including the operative requirements mentioned in [1.2.2], is to be granted by the Society.

2 Application and implementation

2.1

2.1.1 *When cargo tanks contain products for which the Code requires a type 1G ship, neither flammable liquids having a flashpoint of 60°C (closed cup test) or less, nor flammable products listed in Ch 9, Sec 19, shall be carried in tanks located within the protective zones described in Ch 9, Sec 2, [4.1.1], item a).*

2.1.2 *Similarly, when cargo tanks contain products for which the Code requires a type 2G/2PG ship, the flammable liquids as described in [2.1.1], shall not be carried in tanks located within the protective zones described in Ch 9, Sec 2, [4.1.1], item b).*

2.1.3 *In each case, for cargo tanks loaded with products for which the Code requires a type 1G or 2G/2PG ship, the restriction applies to the protective zones within the longitudinal extent of the hold spaces for those tanks.*

2.1.4 *The flammable liquids and products described in [2.1.1] may be carried within these protective zones when the quantity of products retained in the cargo tanks, for which the Code requires a type 1G or 2G/2PG ship is solely used for cooling, circulation or fuelling purposes.*

2.1.5 *Except as provided in [2.1.6], when it is intended to carry products covered by this Code and products covered by the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code), adopted by IMO resolution MSC.4(48), as amended, the ship shall comply with the requirements of both Codes appropriate to the products carried.*

2.1.6 *The requirements of this Code shall take precedence when a ship is designed and constructed for the carriage of the following products:*

a) Those listed exclusively in Ch 9, Sec 19, and

b) One or more of the products that are listed both in the Code and in the International Bulk Chemical Code. These products are marked with (1) in Ch 9, Sec 19, Tab 1, column "Product name".

2.1.7 *When a ship is intended to exclusively carry one or more of the products referred to in [2.1.6], item a) the requirements of the International Bulk Chemical Code, as amended, shall apply.*

2.1.8 *The ship's compliance with the requirements of the International Gas Carrier Code shall be shown by its International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk. Compliance with the amendments to the Code, as appropriate, shall also be indicated in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.*

2.1.9 *Where reference is made in the Code to a paragraph, all the provisions of the subparagraph of that designation shall apply.*

2.1.10 *When a ship is intended to operate for periods at a fixed location in a re-gasification and gas discharge mode or a gas receiving, processing, liquefaction and storage mode,* the Society *and port Administrations involved in the operation shall take appropriate steps to ensure implementation of the provisions of the Code as are applicable to the proposed arrangements. Furthermore, additional requirements shall be established based on the principles of the Code as well as recognized standards that address specific risks not envisaged by it. Such risks may include, but not be limited to:*

- *fire and explosion*
- *evacuation*
- *extension of hazardous areas*
- *pressurized gas discharge to shore*
- *high-pressure gas venting*
- *process upset conditions*
- *storage and handling of flammable refrigerants*
- *continuous presence of liquid and vapour cargo outside the cargo containment system*
- *tank over-pressure and under-pressure*
- *ship-to-ship transfer of liquid cargo, and*
- *collision risk during berthing manoeuvres.*

2.1.11 *Where a risk assessment or study of similar intent is utilized within the Code, the results shall also include, but not be limited to, the following as evidence of effectiveness:*

- *description of methodology and standards applied*
- *potential variation in scenario interpretation or sources of error in the study*
- *validation of the risk assessment process by an independent and suitable third party*
- *quality system under which the risk assessment was developed*
- *the source, suitability and validity of data used within the assessment*
- *the knowledge base of persons involved within the assessment*
- *system of distribution of results to relevant parties, and*
- *validation of results by an independent and suitable third party.*

2.1.12 *Although the Code is legally treated as a mandatory instrument under the SOLAS Convention, the provisions of Ch 9, App 1, [1] and* Appendices 1, 3 and 4 of IGC code *are recommendatory or informative.*

3 Additional requirements

3.1 Emergency towing arrangement

3.1.1 Emergency towing arrangements are to be fitted on liquefied gas carriers of 20 000 dwt and above in accordance with Pt B, Ch 12, Sec 4, [3].

3.2 Steering gear

3.2.1 Additional requirements for steering gear of liquefied gas carriers of 10 000 GT and above are given in Ch 7, Sec 4, [7].

3.3 Ships assigned the additional service feature IPxxx or IPxxx-capable

3.3.1 Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** are to comply with the following requirements in addition to the applicable requirements of this Chapter:

- carriage of toxic products or liquefied gases which require flammable vapour detection in accordance with Ch 9, Sec 19, Tab 1 is not permitted when the total number of persons on board exceeds 60
- for the purpose of carrying industrial personnel, the areas and spaces where industrial personnel are not permitted to enter are to be clearly marked
- the arrangements for personnel transfer are to be located outside the cargo area
- the access to the arrangements for personnel transfer are to be, as far as practicable, located outside the cargo area.

4 Definitions

4.1

4.1.1 *Except where expressly provided otherwise, the following definitions apply to the Code. Additional definitions are provided throughout the Code.*

4.1.2 *Accommodation spaces are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries without cooking appliances and similar spaces.*

4.1.3 *"A" class divisions are divisions as defined in regulation II-2/3.2 of the SOLAS Convention.*

4.1.4 *Administration means the Government of the State whose flag the ship is entitled to fly. For Administration (port), see port Administration.*

4.1.5 *Anniversary date means the day and the month of each year that will correspond to the date of expiry of the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.*

4.1.6 *Boiling point is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure.*

4.1.7 *Breadth (B) means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship with a metal shell, and to the outer surface of the hull in a ship with a shell of any other material. The breadth (B) shall be measured in metres.*

4.1.8 *Cargo area is that part of the ship which contains the cargo containment system and cargo pump and compressor rooms and includes the deck areas over the full length and breadth of the part of the ship over these spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the foremost hold space are excluded from the cargo area.*

4.1.9 *Cargo containment system is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure, if necessary, for the support of these elements. If the secondary barrier is part of the hull structure, it may be a boundary of the hold space.*

4.1.10 *Cargo control room is a space used in the control of cargo handling operations.*

4.1.11 *Cargo machinery spaces are the spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine-room.*

4.1.12 *Cargo pumps are pumps used for the transfer of liquid cargo including main pumps, booster pumps, spray pumps, etc.*

4.1.13 *Cargoes are products listed in Ch 9, Sec 19, that are carried in bulk by ships subject to the Code.*

4.1.14 *Cargo service spaces are spaces within the cargo area, used for workshops, lockers and store-rooms that are of more than 2 m^2 in area.*

4.1.15 *Cargo tank is the liquid-tight shell designed to be the primary container of the cargo and includes all such containment systems whether or not they are associated with the insulation or/and the secondary barriers.*

4.1.16 *Closed loop sampling is a cargo sampling system that minimizes the escape of cargo vapour to the atmosphere by returning product to the cargo tank during sampling.*

4.1.17 *Cofferdam is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.*

4.1.18 *Control stations are those spaces in which ship's radio, main navigating equipment or the emergency source of power is located or where the fire-recording or fire control equipment is centralized. This does not include special fire control equipment, which can be most practically located in the cargo area.*

4.1.19 *Flammable products are those identified by an "F" in Ch 9, Sec 19, Tab 1, column "Vapour detection".*

4.1.20 *Flammability limits are the conditions defining the state of fuel-oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.*

4.1.21 *Gas carrier is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in Ch 9, Sec 19, Tab 1.*

4.1.22 *Gas combustion unit (GCU) is a means of disposing excess cargo vapour by thermal oxidation.*

4.1.23 *Gas consumer is any unit within the ship using cargo vapour as a fuel.*

4.1.24 *Hazardous area is an area in which an explosive gas atmosphere is, or may be expected to be present, in quantities that require special precautions for the construction, installation and use of electrical equipment. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity, reactivity and low temperature. These hazards shall also be taken into account and additional precautions for the ventilation of spaces and protection of the crew will need to be considered. Examples of hazardous areas include, but are not limited to, the following:*

- *the interiors of cargo containment systems and any pipework of pressure-relief or other venting systems for cargo tanks, pipes and equipment containing the cargo*
- *interbarrier spaces*
- *hold spaces where the cargo containment system requires a secondary barrier*
- *hold spaces where the cargo containment system does not require a secondary barrier*
- *space separated from a hold space by a single gastight steel boundary where the cargo containment system requires a secondary barrier*
- *cargo machinery spaces*
- *areas on open deck, or semi-enclosed spaces on open deck, within 3 m of possible sources of gas release, such as cargo valve, cargo pipe flange, cargo machinery space ventilation outlet, etc.*
- *areas on open deck, or semi-enclosed spaces on open deck within 1,5 m of cargo machinery space entrances, cargo machinery space ventilation inlets*
- *areas on open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2,4 m above the weather deck*
- *an area within 2,4 m of the outer surface of a cargo containment system where such surface is exposed to the weather*
- *enclosed or semi-enclosed spaces in which pipes containing cargoes are located, except those where pipes containing cargo products for boil-off gas fuel burning systems are located*
- *an enclosed or semi-enclosed space having a direct opening into any hazardous area*
- *void spaces, cofferdams, trunks, passageways and enclosed or semi-enclosed spaces, adjacent to, or immediately above or below, the cargo containment system*
- *areas on open deck or semi-enclosed spaces on open deck above and in the vicinity of any vent riser outlet, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet and within a hemisphere of 6 m radius below the outlet, and*
- *areas on open deck within spillage containment surrounding cargo manifold valves and 3 m beyond these up to a height of 2,4 m above deck.*

Note 1: Refer to Ch 9, Sec 10 for a separate list of examples and classification of hazardous areas for the purpose of selection and design of electrical installations.

4.1.25 *Non-hazardous area is an area other than a hazardous area.*

4.1.26 *Hold space is the space enclosed by the ship's structure in which a cargo containment system is situated.*

4.1.27 *IBC Code means the International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk, adopted by the Maritime Safety Committee of the Organization by resolution MSC.4(48), as amended.*

4.1.28 *Independent means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems.*

4.1.29 *Insulation space is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation.*

4.1.30 *Interbarrier space is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material.*

4.1.31 *Length (L) is the length as defined in the International Convention on Load Lines in force.*

4.1.32 *Machinery spaces of category A are those spaces, and trunks to those spaces, which contain either:*

- *internal combustion machinery used for main propulsion, or*

  internal combustion machinery used for purposes other than main propulsion where such machinery has, in the aggregate, a total power output of not less than 375 kW, or
- *any oil-fired boiler or oil fuel unit or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.*

4.1.33 *Machinery spaces are machinery spaces of category A and other spaces containing propelling machinery, boilers, oil fuel units, steam and internal-combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces and the trunks to such spaces.*

4.1.34 *MARVS is the maximum allowable relief valve setting of a cargo tank (gauge pressure).*

4.1.35 *Nominated surveyor is a surveyor nominated/appointed by an Administration to enforce the provisions of the SOLAS Convention regulations with regard to inspections and surveys and the granting of exemptions therefrom.*

4.1.36 *Oil fuel unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 MPa gauge.*

4.1.37 *Organization is the International Maritime Organization (IMO).*

4.1.38 *Permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.*

4.1.39 *Port Administration means the appropriate authority of the country for the port where the ship is loading or unloading.*

4.1.40 *Primary barrier is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.*

4.1.41 *Products is the collective term used to cover the list of gases indicated in chapter 19 of this Code.*

4.1.42 *Public spaces are those portions of the accommodation that are used for halls, dining rooms, lounges and similar permanently enclosed spaces.*

4.1.43 *Relative density is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.*

4.1.44 *Secondary barrier is the liquid-resisting outer element of a cargo containment system, designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level. Types of secondary barrier are more fully defined in Ch 9, Sec 4.*

4.1.45 *Separate systems are those cargo piping and vent systems that are not permanently connected to each other.*

4.1.46 *Service spaces are those used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store-rooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.*

4.1.47 *SOLAS Convention means the International Convention for the Safety of Life at Sea, 1974, as amended.*

4.1.48 *Tank cover is the protective structure intended to either protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.*

4.1.49 *Tank dome is the upward extension of a portion of a cargo tank. In the case of below-deck cargo containment systems, the tank dome protrudes through the weather deck or through a tank cover*

4.1.50 *Thermal oxidation method means a system where the boil-off vapours are utilized as fuel for shipboard use or as a waste heat system subject to the provisions of chapter 16 or a system not using the gas as fuel complying with this Code.*

4.1.51 *Toxic products are those defined by a "T" in Ch 9, Sec 19, Tab 1 column "Vapour detection".*

4.1.52 *Turret compartments are those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high-pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves.*

4.1.53 *Vapour pressure is the equilibrium pressure of the saturated vapour above the liquid, expressed in Pascals (Pa) absolute at a specified temperature.*

4.1.54 *Void space is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, oil fuel tank, cargo pumps or compressor room, or any space in normal use by personnel.*

5 Documentation to be submitted

5.1

5.1.1 Tab 2 lists the plans, information, analysis, etc. which are to be submitted in addition to the information required in the other Parts of the Rules for the parts of the ship not affected by the cargo, as applicable. When cargo is used as fuel, additional documents are to be submitted as mentioned in Ch 9, Sec 16, [1].

Table 2 : Documents to be submitted

No.	A/I **(1)**	Documents
1	I	List of products to be carried, including maximum vapour pressure, maximum liquid temperature and other important design conditions
2	I	General arrangement plan, showing location of cargo tanks and fuel oil, ballast and other tanks
3	A	Hazardous area plan
4	A	Location of void spaces and accesses to hazardous areas
5	A	Air locks between safe and hazardous areas
6	A	Ventilation systems in the cargo area and in hazardous area spaces, including ventilation duct arrangement in adjacent zones
7	A	Details of hull structure in way of cargo tanks, including support arrangement for tanks, saddles, anti-floating and anti-lifting devices, deck sealing arrangements, etc.
8	A	Calculation of the hull temperature in all the design cargo conditions
9	A	Distribution of quality and steel grades in relation to the contemplated actual temperature obtained by the calculation in item 8
10	A	Hull stress analysis
11	A	Hull ship motion analysis, where a direct analysis is preferred to the methods indicated in Ch 9, Sec 4
12	A	Intact and damage stability calculations
13	A	Scantlings, material and arrangement of the cargo containment system, including the secondary barrier, if any
14	A	Stress analysis of the cargo tanks, including fatigue analysis and crack propagation analysis for type "B" tanks. This analysis may be integrated with that indicated in item 10
15	I	Calculation of the thermal insulation suitability, including boil-off rate and refrigeration plant capability, if any, cooling down and temperature gradients during loading and unloading operations
16	A	Details of insulation
17	A	Details of ladders, fittings, swash bulkheads and towers in tanks and relative stress analysis, if any
18	A	Details of tank domes and deck sealings
19	A	Plans, arrangement and calculations of safety relief valves
20	A	Details of cargo handling and vapour system, including arrangements and details of piping and fitting
21	A I	• Details of cargo pumps and cargo compressors • Documents and information related to the operation of cargo pumps and compressors under static and dynamic conditions and shipboard accelerations, see Ch 9, Sec 5, [13.2]
22	A	Details of process pressure vessels and relative valving arrangement
23	A	Piping stress analysis when T<-110°C
24	A	Cargo tank pressure control philosophy (description)
25	A	Bilge and ballast system in cargo area
26	A	Gas freeing system in cargo tanks including inert gas system
27	A	Interbarrier space drainage, inerting and pressurisation systems
28	A	Hull structure heating system, if any
29	A	Refrigeration and reliquefaction plant system diagram, if any
30	A	Details of electrical equipment installed in cargo area and hazardous areas, including the list of certified safe equipment and apparatus and electrical bonding of cargo tanks and piping
31	A	Schematic electrical wiring diagram in cargo area
32	A	Gas detection system
33	A	Cargo tank instrumentation, including cargo and hull temperature monitoring system
34	A	Emergency shutdown system
35	A	Jettison system, if any
36	A	Details of fire-extinguishing appliances and systems in cargo area
37	A	Loading and unloading operation description, including cargo tank filling limits
38	A	Cargo operating manual
39	A	Cargo tank testing and inspection procedures for in-service inspection as defined in Ch 9, Sec 4, [2.1.6]
40	A	Programme of gas trials
41	I	When applicable, P & A manual
42	**(2)**	Additional documentation for machinery using gas as fuel

(1) A : to be submitted for approval ; I : to be submitted for information

(2) See Ch 9, Sec 16, Tab 1 and, as applicable, Ch 9, Sec 16, Tab 4.

6 Cargo equipment trials

6.1 Scope

6.1.1 Trials in working conditions

All the equipment to which this Chapter is applicable is to be tested in actual working conditions.

6.1.2 Trials to be carried out when the ship is loaded

Those trials which may only be carried out when the ship is loaded are to be held at the first loading of the ship.

For LNG carriers, the extent of the examinations that are to be conducted before and after the first loaded voyage is given in [6.2.4].

6.2 Extent of the tests

6.2.1 Cargo equipment testing procedure

The cargo equipment testing procedure is to be submitted to the Society for review.

6.2.2 Ships with mechanical refrigeration units

Ships fitted with a mechanical refrigeration unit are to be subjected to an initial testing procedure in order to check the suitability of the plant in respect of the applicable requirements. The recording of the data of the reliquefaction system, such as working duration and ambient conditions, may be carried out during the first loaded voyage.

6.2.3 Use of cargo as fuel

The arrangements for using cargo as fuel are to be subjected to a special testing procedure.

6.2.4 Verifications before and after the first loaded voyage:

a) Surveyor attendance is required at the first cargo loading and first cargo unloading.

b) Surveyor attendance during new building gas trials can be considered to comply with the applicable verifications and examinations survey requirements given in item c) and item d), with the exceptions of the survey requirements marked (*)

c) The following examinations are to be conducted at gas trials or first full cargo loading, as applicable to cargo containment system:

Note 1: When attending at first full cargo loading, priority is to be given to latter stages of loading.

- verify the satisfactory functionality of the emergency shutdown system during testing
- satisfactory operation of gas detection system
- satisfactory operation of cargo tank pressure monitoring system
- satisfactory operation of interbarrier space(s) and insulation space(s) pressure monitoring system, as applicable
- satisfactory operation of cargo tank temperature monitoring system
- satisfactory operation of cargo tank level indicating system
- satisfactory operation of interbarrier space(s) and inner hull temperature monitoring system, as applicable
- inert gas generator, if operating
- nitrogen generating plant, if operating
- nitrogen pressure control system for insulation, interbarrier, and annular spaces, as applicable
- reliquefaction plant, if fitted
- equipment fitted for the burning of cargo vapours such as boilers, engines, gas combustion units, etc., if operating
- examination of on-deck cargo piping systems including expansion and supporting arrangements
- verification and examination of all piping systems, including valves, fittings and associated equipment for handling cargo or vapours
- advise Master to carry out cold spot examination of the hull and external insulation during transit voyage to unloading port and record in ship's logbook; and
- advise Master to test high-level alarm(s) with liquid cargo during voyage and record in ship's logbook, when loading condition permits.

d) The following examinations are to be conducted at gas trials or first full cargo unloading, as applicable to cargo containment system:

Note 2: When attending at first full cargo unloading, priority is to be given to the commencement of unloading.

- examination of on-deck cargo piping systems including expansion and supporting arrangements
- review logbook entry of emergency shutdown system testing prior to commencement of unloading
- (*) review cargo logs and alarm reports for cargo tank pressure, temperature, and level indicating systems
- satisfactory operation of cargo compressors
- satisfactory operation of cargo pumps
- inert gas generator, if operating
- nitrogen generating plant, if operating
- nitrogen pressure control system for insulation, interbarrier, and annular spaces, as applicable
- (*) review of records for satisfactory operation of the reliquefaction plant, if fitted
- review of records for equipment fitted for the burning of cargo vapours such as boilers, engines, gas combustion units, etc.
- (*) on ships fitted with membrane tanks, review records of the cofferdam and inner hull temperature sensors to verify the readings are not below the allowable temperature for the selected grade of steel
- (*) cofferdam heating system, if in operation
- (*) review logbook entries for cold spot examination; and
- (*) review logbook entry for testing of high-level alarm(s) with liquid cargo. If cargo conditions did not permit testing, the Surveyor is to require testing at the first occasion where cargo conditions allow for testing. Master to be advised to record testing in ship's logbook which is to be verified no later than the first annual survey.

e) To demonstrate satisfactory functionality of the verifications, ship's Master is to be required to arrange and provide to the Surveyor print outs or screen shots showing:

- trends of cargo tanks pressure and temperature
- trends of pressure and temperature distribution of interbarrier space(s) and insulation space(s), and temperature distribution of inner hull, as applicable
- trends record of performance of cofferdam heating system, when fitted
- trends record of consumption of nitrogen gas, and whether any abnormality has been observed.
- list of any gas alarms, if occurred:
  - Cargo Tanks Containment System Cold Spot Inspection Statement; and
  - activation of Cargo Tanks High-Level Alarm and Overfill Protection tests.

7 Additional service features BOG-reliquefaction and subcooling

7.1 General

7.1.1 Application

The service notation **Liquefied gas carrier** is to be completed by the following additional service features indicating which systems are installed on board the ship to control the cargo tank pressure without losing cargo volume during navigation:

a) The additional service feature **BOG-reliquefaction** is assigned, in accordance with Pt A, Ch 1, Sec 2, [4.4.5], to liquefied gas carriers equipped with a reliquefaction installation complying with the requirements of Ch 9, Sec 7, [3]

b) The additional service feature **subcooling** is assigned, in accordance with Pt A, Ch 1, Sec 2, [4.4.5], to liquefied gas carriers equipped with a cooling installation aiming at reducing the cargo temperature and complying with the requirements of Ch 9, Sec 7, [6].

8 Additional service feature STL-SPM

8.1 General

8.1.1 Application

a) The additional service feature **STL-SPM** is assigned, in accordance with Pt A, Ch 1, Sec 2, [4.4.5], to liquefied gas carriers used as regaseification terminal, fitted forward with equipment for not permanent mooring, or for connection to single buoy, and complying with the requirements of the present Article.

b) The buoy and the mooring system may be not included within classification. In case the buoy and the mooring are covered by class, the Rules for the Classification of Offshore Loading and Off loading Buoys (NR494) are applicable to the buoy and the **POSA** additional class notation may be assigned to the mooring system.

8.1.2 Scope

The following items are covered by the additional service feature **STL-SPM**:

- ship structure, in way of the mooring or the single buoy
- hatch cover
- cylinders
- swivel
- piping and risers
- stoppers
- winch
- interface between equipment and ship structure
- ventilation
- handling equipment (HPU and control system)
- drainage of compartment
- fire and gas detection system
- fire extinction system
- emergency escape.

8.1.3 Applicable rules

a) The items listed in [8.1.2] are to comply with the applicable requirements of IGC code.

b) Components of the equipment used for mooring at single point are to comply with the applicable requirements of Pt B, Ch 12, Sec 4 for **ETA** (Emergency Towing Arrangement) and Pt F, Ch 11, Sec 3, for **SPM** (Single Point Mooring).

c) The swivel is to be classed according to Section 8 of the NR494 Rules for the Classification of Offshore Loading and Off loading Buoys.

d) The lifting appliances are to meet the applicable requirements of NR526 Rules for Lifting Appliances.

e) The risers are to be specially considered.

8.2 Documentation to be submitted

8.2.1 Plans and documents to be submitted for approval

In addition to the documents listed in Pt B, Ch 1, Sec 4, the following plans and documents are to be submitted to the Society for approval:

- ship structure drawings, in way of the mooring or the single buoy
- local reinforcements of ship structure below equipment
- ventilation plan
- emergency escape
- drawings of equipment
- fire and gas detection, wiring and arrangement diagram
- cable list
- STL, auxiliary and bridge system
- lighting installation, wiring and arrangement diagram
- electrical starter circuit diagram
- architecture diagram of control and safety system
- control and wiring diagram of:
  - hydraulic system for buoy locking devices
  - winches
- fire extinction
- drainage system.

8.2.2 Plans and documents to be submitted for information

The following documents are to be submitted to the Society for information:

- DLOC (design load operating conditions)
- structural calculation
- fatigue calculation
- model test results
- explosion calculation
- CCTV diagram
- operation procedure of system.

8.3 Structural design

8.3.1 Design loads

a) Model tests in mooring conditions are generally to be carried out to determine the loads.

b) For the ship structure, calculations based on test results or mooring and hydrodynamic calculations are to be submitted and subject to special examination by the Society.

8.3.2 Scantlings

The deck structure supporting accessories is to be reinforced on basis of loads given by the designer.

8.4 Mechanical installation

8.4.1 When hydraulic installation is used, it is to be in compliance with the applicable requirements of Pt C, Ch 1, Sec 10, [14].

8.4.2 The hydraulic cylinders are considered as pressure vessels; the scantlings of the shells and the ends are to be in compliance with the applicable requirements of Pt C, Ch 1, Sec 3.

8.4.3 Securing devices are to be simple to operate and easily accessible.

8.4.4 Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or to be of the gravity type. Where hydraulic securing devices are applied, they have to remain locked in the event of loss of the hydraulic fluid.

8.4.5 The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

8.4.6 The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

8.5 Electrical and automation installation

8.5.1 Unless otherwise specified, the requirements in Part C, Chapter 2 and Part C, Chapter 3 are applicable to the system fitted in STL.

8.5.2 The STL room is to be considered as hazardous area. Electrical equipment are to be avoided in this area. When electrical equipment are fitted, they are to be of a safe type IIA T3 and considered as Zone 1.

8.5.3 The STL system is to be considered as a primary essential service.

8.5.4 The electrical equipment located in flooded space are to be IP 68 for the appropriate depth.

8.5.5 The electrical equipment located in non flooded space are to be IP 67.

8.5.6 Local control of systems is always to be available.

Section 2 Ship Survival Capability and Location of Cargo Tanks

1 General

1.1

1.1.1 *Ships subject to the Code shall survive the hydrostatic effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship and the environment, the cargo tanks shall be protected from penetration in the case of minor damage to the ship resulting, for example, from contact with a jetty or tug, and also given a measure of protection from damage in the case of collision or grounding, by locating them at specified minimum distances inboard from the ship's shell plating. Both the damage to be assumed and the proximity of the tanks to the ship's shell shall be dependent upon the degree of hazard presented by the product to be carried. In addition, the proximity of the cargo tanks to the ship's shell shall be dependent upon the volume of the cargo tank.*

1.1.2 *Ships subject to the Code shall be designed to one of the following standards:*

a) *A type 1G ship is a gas carrier intended to transport the products indicated in Ch 9, Sec 19 that require maximum preventive measures to preclude their escape*

b) *A type 2G ship is a gas carrier intended to transport the products indicated in Ch 9, Sec 19, that require significant preventive measures to preclude their escape*

c) *A type 2PG ship is a gas carrier of 150 m in length or less intended to transport the products indicated in Ch 9, Sec 19 that require significant preventive measures to preclude their escape, and where the products are carried in type C independent tanks designed (see Ch 9, Sec 4, [10]) for a MARVS of at least 0,7 MPa gauge and a cargo containment system design temperature of –55°C or above. A ship of this description that is over 150 m in length is to be considered a type 2G ship*

d) *A type 3G ship is a gas carrier intended to carry the products indicated in Ch 9, Sec 19 that require moderate preventive measures to preclude their escape.*

Therefore, a type 1G ship is a gas carrier intended for the transportation of products considered to present the greatest overall hazard and types 2G/2PG and type 3G for products of progressively lesser hazards. Accordingly, a type 1G ship shall survive the most severe standard of damage and its cargo tanks shall be located at the maximum prescribed distance inboard from the shell plating.

1.1.3 *The ship type required for individual products is indicated in Ch 9, Sec 19, Tab 1.*

1.1.4 *If a ship is intended to carry more than one of the products listed in Ch 9, Sec 19, the standard of damage shall correspond to the product having the most stringent ship type requirements. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.*

1.1.5 *For the purpose of this Code, the position of the moulded line for different containment systems is shown in Fig 5 to Fig 9.*

2 Freeboard and stability

2.1 General

2.1.1 *Ships subject to the Code may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment shall not be greater than the maximum draught otherwise permitted by this Code.*

2.1.2 *The stability of the ship, in all seagoing conditions and during loading and unloading cargo, shall comply with the requirements of the International Code on Intact Stability. This includes partial filling and loading and unloading at sea, when applicable. Stability during ballast water operations shall fulfil stability criteria.*

Note 1: Refer to the International Code on Intact Stability, 2008 (2008 IS Code), adopted by the Maritime Safety Committee of the Organization by resolution MSC.267(85).

2.1.3 The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.8] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2.

2.1.4 *When calculating the effect of free surfaces of consumable liquids for loading conditions, it shall be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface. The tank or combination of tanks to be taken into account shall be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments shall be calculated by a method according to the International Code on Intact Stability.*

2.1.5 The free surface effect is to be calculated in accordance with Pt B, Ch 3, Sec 2, [4].

2.1.6 *Solid ballast shall not normally be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, its disposition shall be governed by the need to enable access for inspection and to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.*

2.1.7 *The Master of the ship shall be supplied with a loading and stability information booklet. This booklet shall contain details of typical service conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the ship's survival capabilities. The booklet shall also contain sufficient information to enable the Master to load and operate the ship in a safe and seaworthy manner.*

2.1.8 The Master of the ship is to be supplied with a Loading Manual as specified in Pt B, Ch 1, Sec 5, [2] and a Trim and Stability booklet as specified in Pt B, Ch 3, App 2.

2.1.9 *All ships, subject to the Code shall be fitted with a stability instrument, capable of verifying compliance with intact and damage stability requirements, approved by* the Society *having regard to the performance standards recommended by the Organization.*

Note 1: Refer to part B, chapter 4, of the International Code on Intact Stability, 2008 (2008 IS Code), as amended; the Guidelines for the Approval of Stability Instruments (MSC.1/Circ.1229), annex, section 4, as amended; and the technical standards defined in part 1 of the Guidelines for verification of damage stability requirements for tankers (MSC.1/Circ.1461).

a) Ships constructed before 1 July 2016 shall comply with the requirements of [2.1.9] at the first scheduled renewal survey of the ship after 1 July 2016 but not later than 1 July 2021

b) Notwithstanding the requirements of item a), a stability instrument installed on a ship constructed before 1 July 2016 need not be replaced provided it is capable of verifying compliance with intact and damage stability, to the satisfaction of the Society*, and*

c) For the purposes of control under SOLAS regulation XI-1/4, the Society *shall issue a document of approval for the stability instrument.*

2.1.10 The Society *may waive the requirements of [2.1.9] for the following ships, provided the procedures employed for intact and damage stability verification maintain the same degree of safety, as being loaded in accordance with the approved conditions.*

Note 1: Refer to operational guidance provided in part 2 of the Guidelines for verification of damage stability requirements for tankers (MSC.1/Circ.1461).

Any such waiver shall be duly noted on the International Certificate of Fitness:

a) Ships which are on a dedicated service, with a limited number of permutations of loading such that all anticipated conditions have been approved in the stability information provided to the Master in accordance with the requirements of [2.1.7]

b) Ships where stability verification is made remotely by a means approved by the Society

c) Ships which are loaded within an approved range of loading conditions, or

d) Ships constructed before 1 July 2016 provided with approved limiting KG/GM curves covering all applicable intact and damage stability requirements.

2.1.11 Conditions of loading

Damage survival capability shall be investigated on the basis of loading information submitted to the Society *for all anticipated conditions of loading and variations in draught and trim. This shall include ballast and, where applicable, cargo heel.*

Loading conditions other than those in the Loading Manual and the Trim and Stability booklet are to be previously submitted to the Society. Alternatively, such cases may be examined by the Master or a delegated officer when a loading instrument approved in accordance with the requirements in Pt B, Ch 1, Sec 5, [3] is installed on board.

3 Damage assumptions

3.1 General

3.1.1 *The assumed maximum extent of damage shall be as per Tab 1.*

3.2 Other damage

3.2.1 *If any damage of a lesser extent than the maximum damage specified in [3.1.1] would result in a more severe condition, such damage shall be assumed*

3.2.2 *Local damage anywhere in the cargo area extending inboard distance "d" as defined in [4.1.1], measured normal to the moulded line of the outer shell shall be considered. Bulkheads shall be assumed damaged when the relevant list items of [6.1.2] apply. If a damage of a lesser extent than "d" would result in a more severe condition, such damage shall be assumed.*

Table 1 : Assumed maximum extent of damage

Side damage	Longitudinal extent:	1/3 $L^{2/3}$ or 14,5 m, whichever is less
	Transverse extent: measured inboard from the moulded line of the outer shell at right angles to the centreline at the level of the summer waterline	B/5 or 11,5 m, whichever is less
	Vertical extent: from the moulded line of the outer shell	Upwards, without limit

		For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Bottom damage	Longitudinal extent:	$1/3L^{2/3}$ or 14,5 m, whichever is less	$1/3L^{2/3}$ or14,5 m, whichever is less
	Transverse extent:	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
	Vertical extent:	B/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline (see [4.1.4])	B/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline (see [4.1.4])

4 Location of cargo tanks

4.1 General

4.1.1 *Cargo tanks shall be located at the following distances inboard:*

a) Type 1G ships:

from the moulded line of the outer shell, not less than the transverse extent of side damage specified in Tab 1 and, from the moulded line of the bottom shell at centreline, not less than the vertical extent of bottom damage specified in Tab 1, and nowhere less than the distance d, in m, defined as follows:

- *for V_c below or equal to 1000 m^3: $d = 0,8$*
- *for 1000 $m^3 < V_c < 5000\ m^3$: $d = 0,75 + V_c \cdot 0,2/4000$*
- *for 5000 $m^3 \leq V_c < 30000\ m^3$: $d = 0,8 + V_c / 25000$*
- *for $Vc \geq 30000\ m^3$: $d = 2,0$*

where

V_c : *100% of the gross design volume of the individual cargo tank at 20°C, including domes and appendages (see Fig 1 and Fig 2). For the purpose of cargo tank protective distances, the cargo tank volume is the aggregate volume of all the parts of tank that have a common bulkhead(s), and*

d : *Distance, in m, measured at any cross-section at a right angle from the moulded line of outer shell.*

Tank size limitations may apply to type 1G ship cargoes in accordance with Ch 9, Sec 17.

b) Types 2G/2PG:

from the moulded line of the bottom shell at centreline not less than the vertical extent of bottom damage specified in Tab 1 and nowhere less than the distance d as indicated in [4.1.1], item a) (see Fig 1 and Fig 2).

c) Type 3G ships:

from the moulded line of the bottom shell at centreline not less than the vertical extent of bottom damage specified in Tab 1 and nowhere less than the distance d, where d = 0,8 m from the moulded line of outer shell (see Fig 1 and Fig 4).

4.1.2 Deck cargo tanks are to be located not less than 800 mm inboard from the side shell.

4.1.3 *For the purpose of tank location, the vertical extent of bottom damage shall be measured to the inner bottom when membrane or semi-membrane tanks are used, otherwise to the bottom of the cargo tanks. The transverse extent of side damage shall be measured to the longitudinal bulkhead when membrane or semi-membrane tanks are used, otherwise to the side of the cargo tanks. The distances indicated in [3] and [4] shall be applied as in Fig 5 to Fig 9. These distances shall be measured plate to plate, from the moulded line to the moulded line, excluding insulation.*

4.1.4 *Except for type 1G ships, suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in Tab 1 provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25% of the depth of the double bottom or 350 mm, whichever is less. Where there is no double bottom, the protrusion below the upper limit of bottom damage shall not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored when determining the compartments affected by damage.*

4.1.5 *Cargo tanks shall not be located forward of the collision bulkhead*

Figure 1 : Cargo tank location requirements - Centreline profile - Type 1G, 2G, 2GP and 3G ships

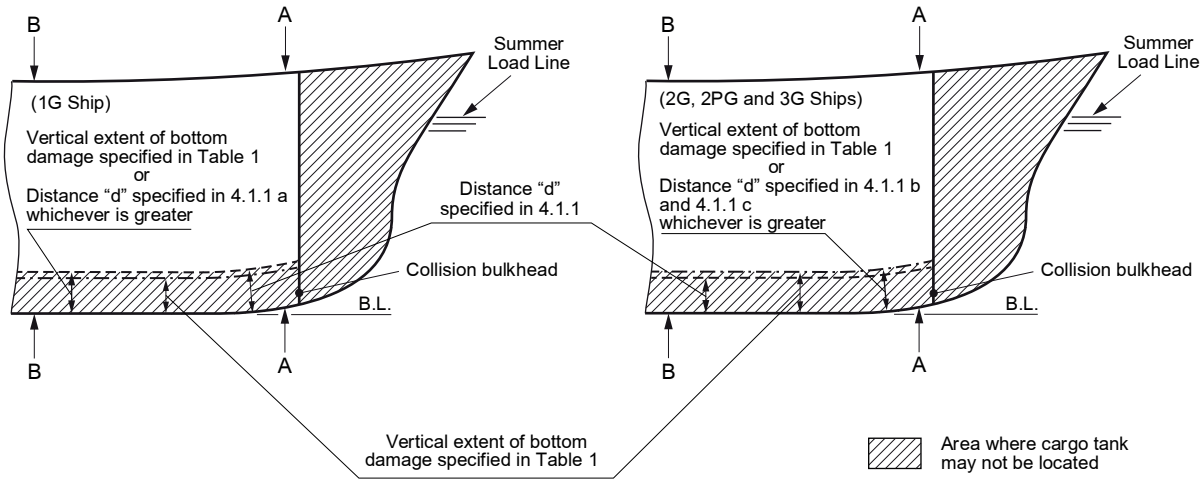


Figure 2 : Cargo tank location requirements - Transverse sections - Type 1G ships

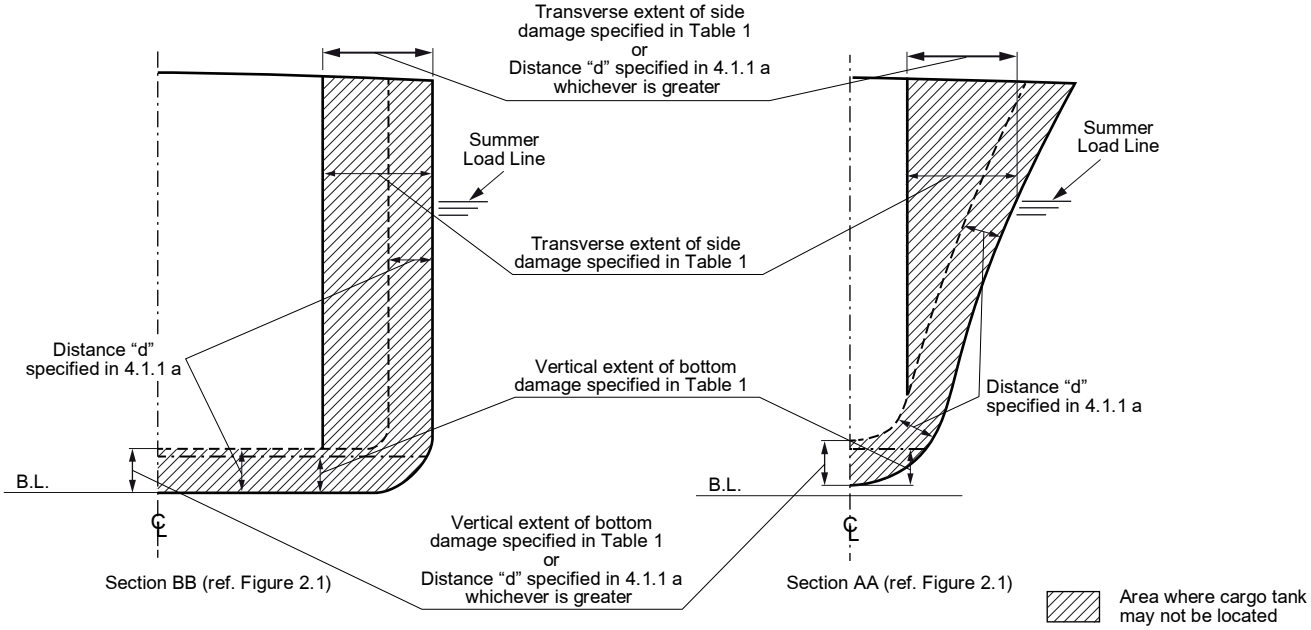


Figure 3 : Cargo tank location requirements - Transverse sections - Type 2G and 2PG ships

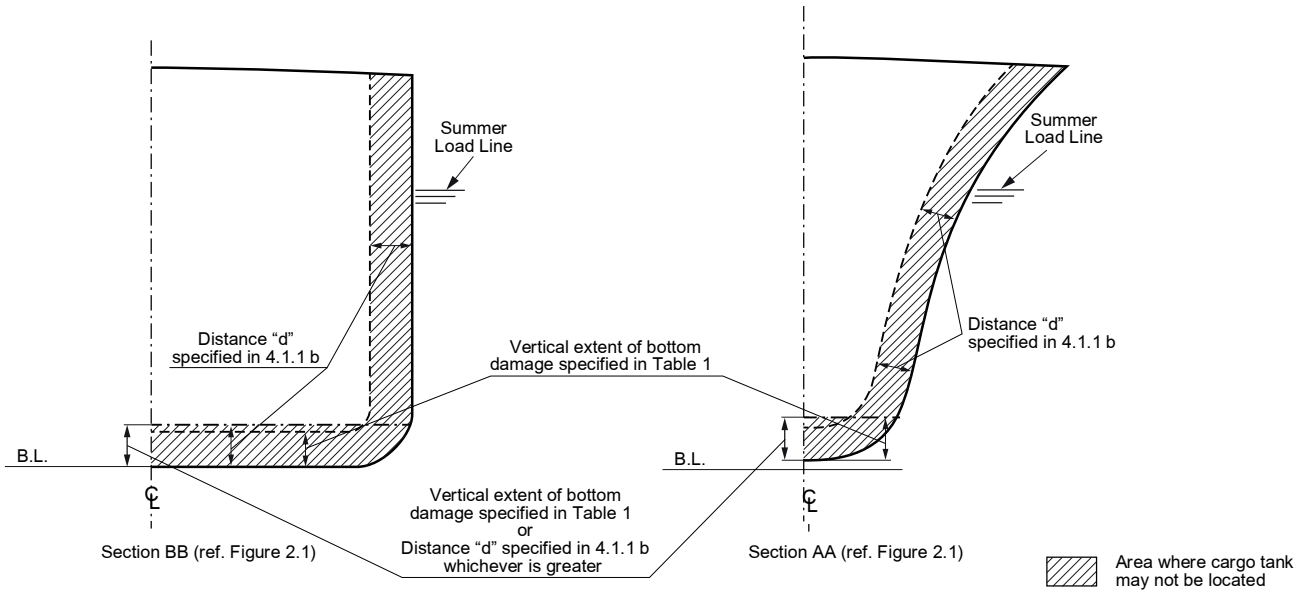


Figure 4 : Cargo tank location requirements - Transverse sections - Type 3G ships

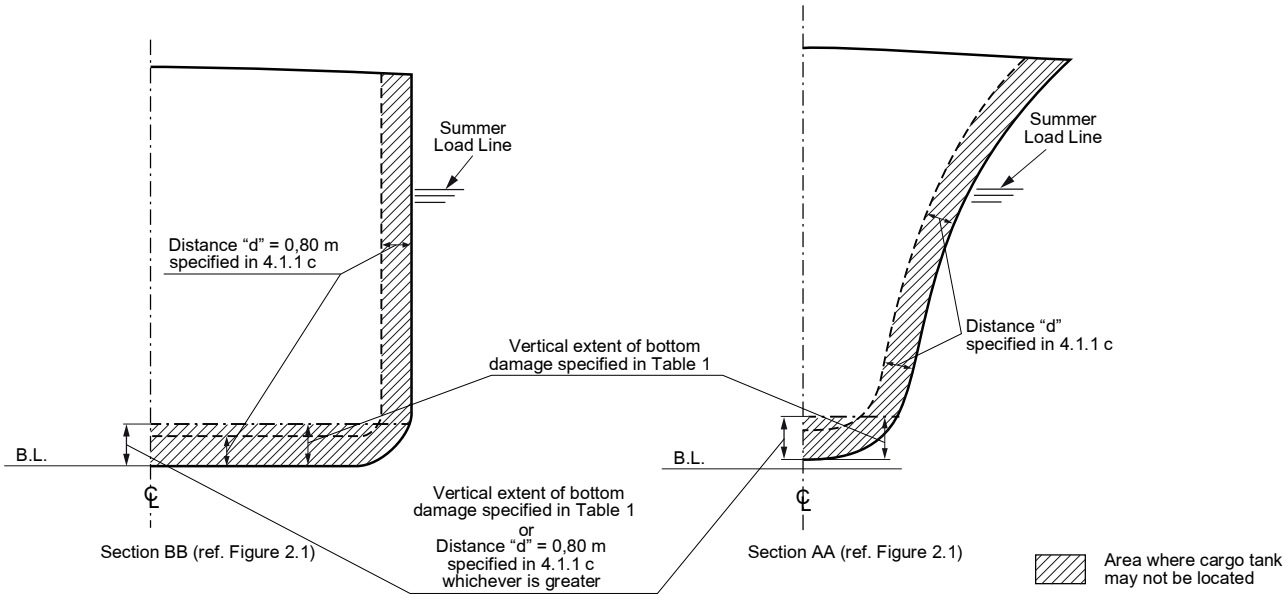


Figure 5 : Protective distance - Independent primary tank

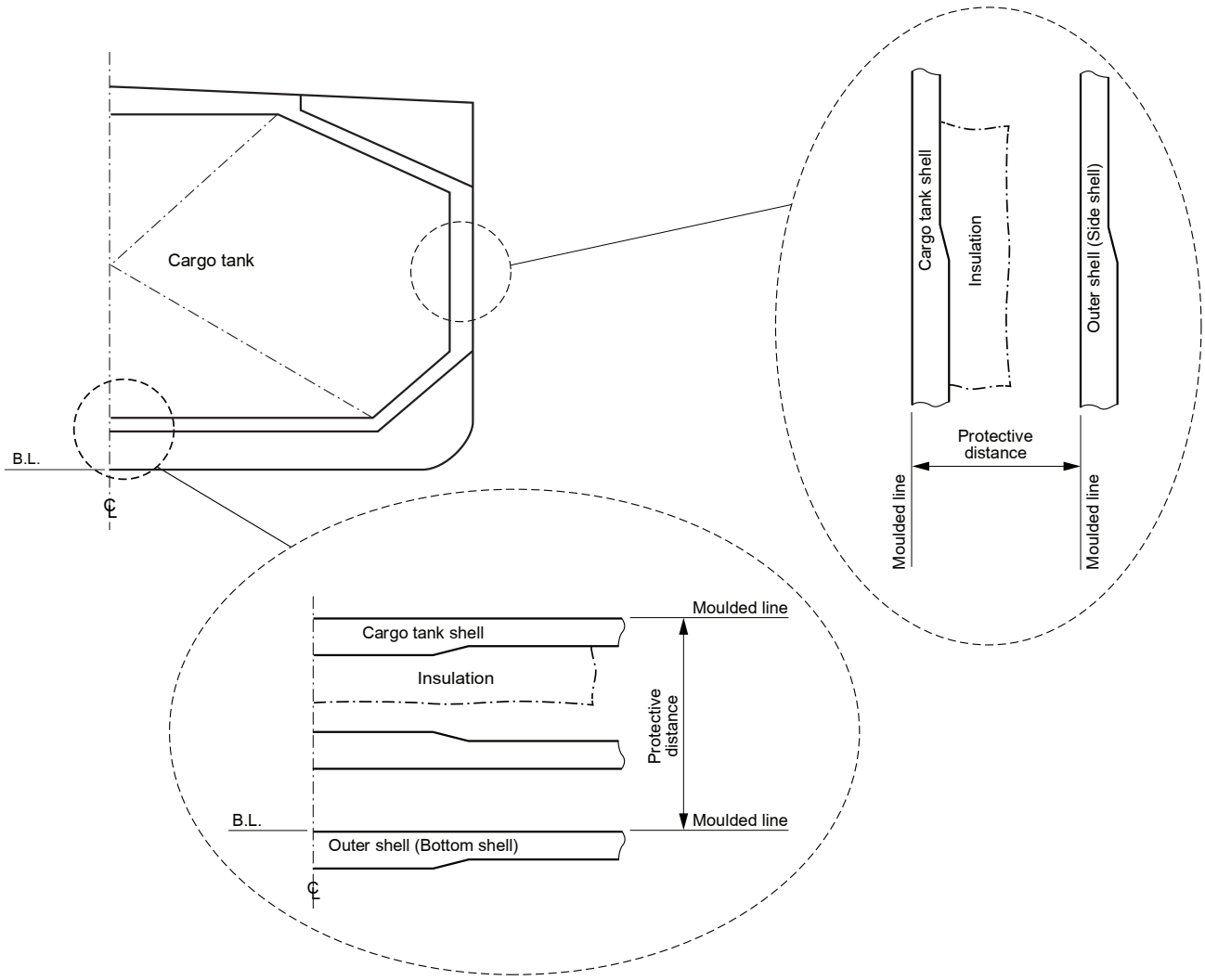


Figure 6 : Protective distance - Semi-membrane tank

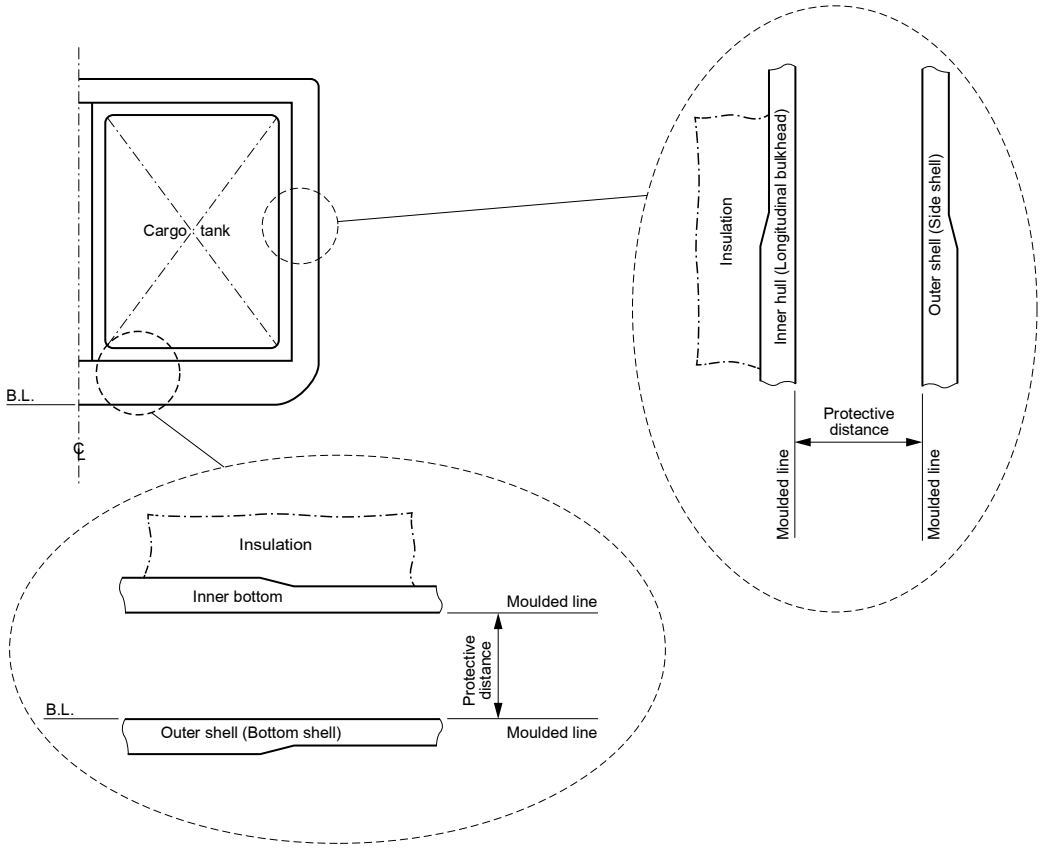


Figure 7 : Protective distance - Membrane tank

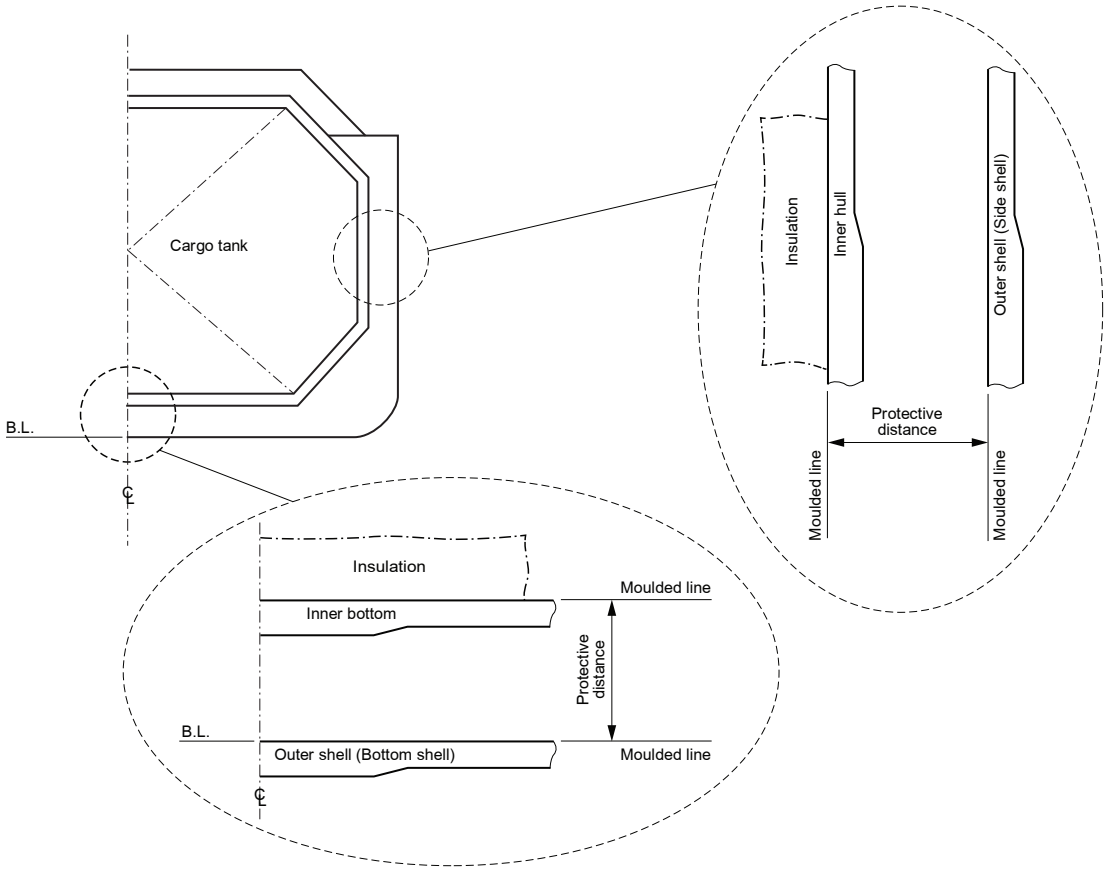


Figure 8 : Protective distance - Spherical tank

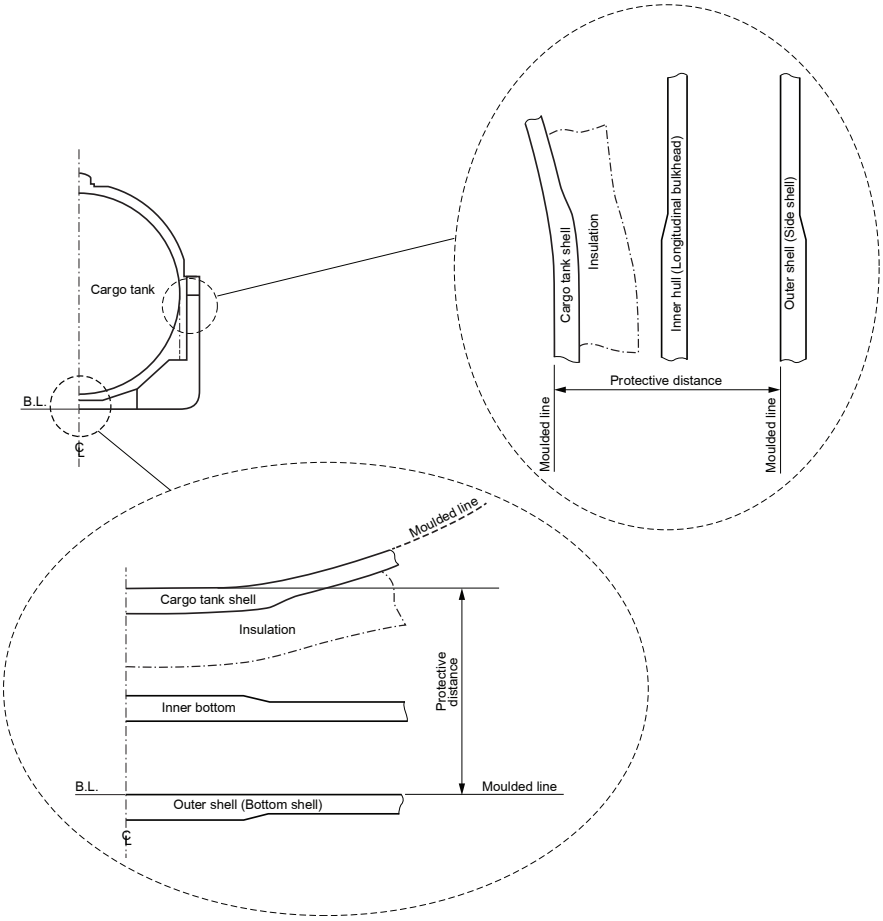
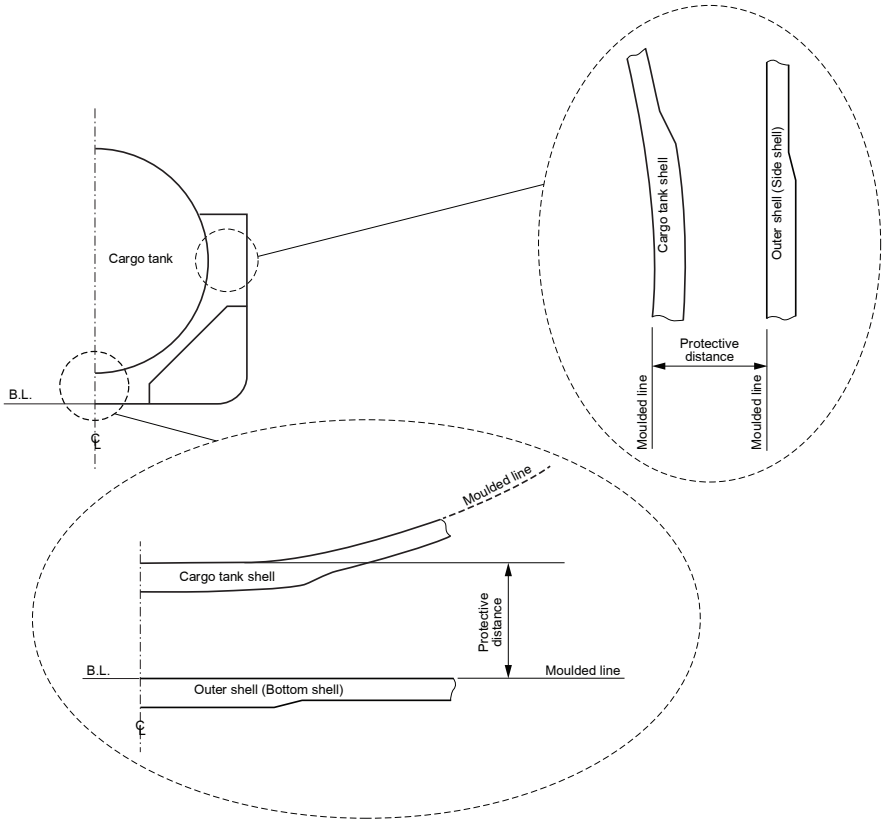


Figure 9 : Protective distance - Pressure type tank



5 Flood assumptions

5.1 General

5.1.1 *The requirements of [7] shall be confirmed by calculations that take into consideration the design characteristics of the ship, the arrangements, configuration and contents of the damaged compartments, the distribution, relative densities and the free surface effects of liquids and the draught and trim for all conditions of loading.*

5.1.2 *The permeabilities of spaces assumed to be damaged shall be as per Tab 2.*

5.1.3 *Wherever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.*

5.1.4 *Where the damage between transverse watertight bulkheads is envisaged, as specified in [6.1.2], item d), item e) and item f), transverse bulkheads shall be spaced at least at a distance equal to the longitudinal extent of damage specified in Tab 1 (see Side damage / longitudinal extent) in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage shall be assumed as non-existent for the purpose of determining flooded compartments. Further, any portion of a transverse bulkhead bounding side compartments or double bottom compartments shall be assumed damaged if the watertight bulkhead boundaries are within the extent of vertical or horizontal penetration required by [3]. Also, any transverse bulkhead shall be assumed damaged if it contains a step or recess of more than 3 m in length located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and the after peak tank top shall not be regarded as a step for the purpose of this paragraph.*

5.1.5 *The ship shall be designed to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.*

5.1.6 *Equalization arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, shall not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of [7.1.3], and sufficient residual stability shall be maintained during all stages where equalization is used. Spaces linked by ducts of large cross-sectional area may be considered to be common.*

5.1.7 *If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in [3], arrangements shall be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.*

5.1.8 Tunnels, ducts, pipes, doors, bulkheads and decks which might form watertight boundaries of intact spaces in the case of assumed conventional damage are to have mini- mum strength adequate to withstand the pressure height corresponding to the deepest equilibrium waterline in dam- aged conditions.

5.1.9 *The buoyancy of any superstructure directly above the side damage shall be disregarded. However, the unflooded parts of superstructures beyond the extent of damage may be taken into consideration, provided that:*

- *they are separated from the damaged space by watertight divisions and the requirements of [7.1.3], item a) in respect of these intact spaces are complied with; and*
- *openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in [7.1.3], item a). However, the immersion of any other openings capable of being closed weathertight may be permitted.*

Table 2 : Permeabilities of spaces assumed to be damaged

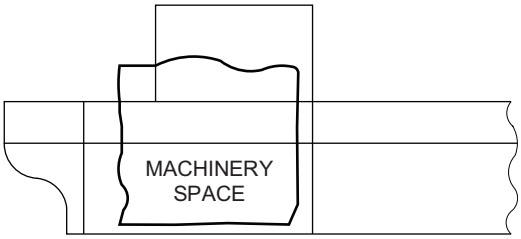
Spaces	Permeabilities
Stores	0,60
Accommodation	0,95
Machinery	0,85
Voids	0,95
Hold spaces	0,951
Consumable liquids	0 to 0,952
Other liquids	0 to 0,952
Note 1: Other values of permeability can be considered based on the detailed calculations. Interpretations of regulation of part B-1 of SOLAS chapter II-1 (MSC/Circ.651) are referred. **Note 2:** The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment.	

6 Standard of damage

6.1 General

6.1.1 The longitudinal extent of damage to the superstructure (see also [5.1.9]) in the case of side damage to a machinery space aft, as per [6.1.2], is to be the same as the longitudinal extent of the side damage to the machinery space (see Fig 10).

Figure 10 : Longitudinal extension of superstructure damage



6.1.2 *Ships shall be capable of surviving the damage indicated in [3] with the flood assumptions in [5], to the extent determined by the ship's type, according to the following standards:*

a) A type 1G ship shall be assumed to sustain damage anywhere in its length

b) A type 2G ship of more than 150 m in length shall be assumed to sustain damage anywhere in its length

c) A type 2G ship of 150 m in length or less shall be assumed to sustain damage anywhere in its length, except involving either of the bulkheads bounding a machinery space located aft

d) A type 2PG ship shall be assumed to sustain damage anywhere in its length except involving transverse bulkheads spaced further apart than the longitudinal extent of side damage as specified in Tab 1

e) A type 3G ship of 80 m in length or more shall be assumed to sustain damage anywhere in its length, except involving transverse bulkheads spaced further apart than the longitudinal extent of side damage specified in Tab 1, and

f) A type 3G ship less than 80 m in length shall be assumed to sustain damage anywhere in its length, except involving transverse bulkheads spaced further apart than the longitudinal extent of side damage specified in Tab 1 and except damage involving the machinery space when located after.

The flooding of the machinery space, if located aft on a type 3G ship less than 80 m in length, is to comply as far as practicable with the criteria in [7]. Relaxation of parts of these requirements may be accepted on a case-by-case basis.

6.1.3 *In the case of small type 2G/2PG and 3G ships that do not comply in all respects with the appropriate requirements of [6.1.2], item c), item e) and item f), special dispensations may only be considered by* the Society *provided that alternative measures can be taken which maintain the same degree of safety. The nature of the alternative measures shall be approved and clearly stated and be available to the port Administration. Any such dispensation shall be duly noted on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.*

7 Survival requirements

7.1 General

7.1.1 *Ships subject to the Code shall be capable of surviving the assumed damage specified in [3], to the standard provided in [6], in a condition of stable equilibrium and shall satisfy the following criteria.*

7.1.2 Ships are to be capable of surviving the assumed damage specified in [3.1.1] and [3.2] to the standard provided in [6.1.2] and for the loading conditions in Pt B, Ch 3, App 2, [1.2.8] in a condition of stable equilibrium and such as to satisfy the criteria in [7].

7.1.3 *In any stage of flooding:*

a) The waterline, taking into account sinkage, heel and trim, shall be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings shall include air pipes and openings that are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers that maintain the high integrity of the deck, remotely operated sliding watertight doors, hinged watertight access doors with open/closed indication locally and at the navigation bridge, of the quick-acting or single-action type that are normally closed at sea, hinged watertight doors that are permanently closed at sea, and sidescuttles of the non-opening type;

b) The maximum angle of heel due to unsymmetrical flooding shall not exceed 30°, and

c) The residual stability during intermediate stages of flooding shall not be less than that required by item a).

The criteria applied to the residual stability during intermediate stages of flooding are to be those relevant to the final stage of flooding as specified in [7.1.4]. However, small deviations from these criteria may be accepted by the Society on a case-by-case basis.

7.1.4 *At final equilibrium after flooding:*

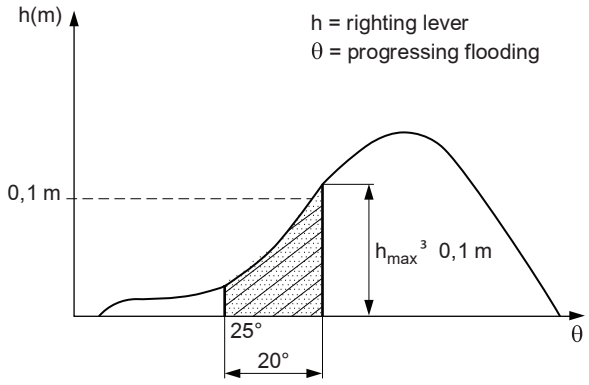
a) The righting lever curve shall have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0,1 m within the 20° range; the area under the curve within this range shall not be less than 0,0175 m-radians. The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs). Unprotected openings shall not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in [7.1.3] and other openings capable of being closed weathertight may be permitted.

Note 1: "other openings capable of being closed weathertight" do not include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship.

See also Fig 11.

b) The emergency source of power shall be capable of operating.

Figure 11 : Range of positive stability



Section 3 Ship Arrangement

1 General

1.1 Segregation of the cargo area

1.1.1 *Hold spaces shall be segregated from machinery and boiler spaces, accommodation spaces, service spaces, control stations, chain lockers, domestic water tanks and from stores. Hold spaces shall be located forward of machinery spaces of category A. Alternative arrangements, including locating machinery spaces of category A forward, may be accepted, based on SOLAS regulation II-2/17, after further consideration of involved risks, including that of cargo release and the means of mitigation.*

1.1.2 Bow thrusters are allowed to be fitted forward of the hold spaces.

1.1.3 *Where cargo is carried in a cargo containment system not requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in [1.1.1] or spaces either below or outboard of the hold spaces may be effected by cofferdams, oil fuel tanks or a single gastight bulkhead of all-welded construction forming an "A-60" class division. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.*

1.1.4 *Where cargo is carried in a cargo containment system requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in [1.1.1], or spaces either below or outboard of the hold spaces that contain a source of ignition or fire hazard, shall be effected by cofferdams or oil fuel tanks. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.*

1.1.5 Hold spaces may be separated from each other by single bulkheads. Where cofferdams are used instead of single bulkheads, they may be used as ballast tanks subject to special approval by the Society.

1.1.6 *Turret compartments segregation from spaces referred to in [1.1.1], or spaces either below or outboard of the turret compartment that contain a source of ignition or fire hazard, shall be effected by cofferdams or an A-60 class division. A gastight "A-0"class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.*

1.1.7 *In addition, the risk of fire propagation from turret compartments to adjacent spaces shall be evaluated by a risk analysis (see Ch 9, Sec 1, [2.1.11]) and further preventive measures, such as the arrangement of a cofferdam around the turret compartment, shall be provided if needed.*

1.1.8 *When cargo is carried in a cargo containment system requiring a complete or partial secondary barrier:*

- *at temperatures below –10°C, hold spaces shall be segregated from the sea by a double bottom, and*
- *at temperatures below – 55°C, the ship shall also have a longitudinal bulkhead forming side tanks.*

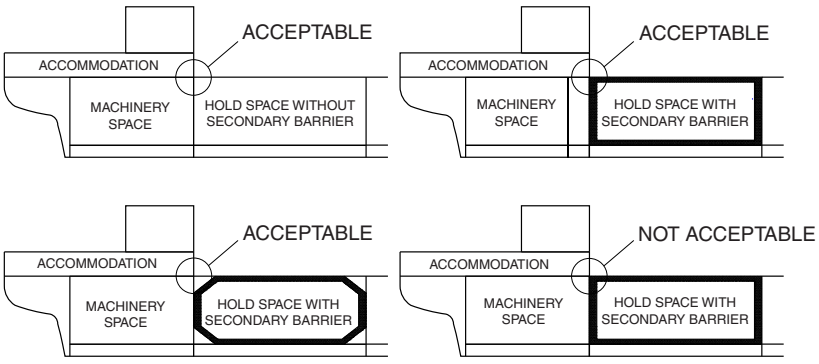
1.1.9 *Arrangements shall be made for sealing the weather decks in way of openings for cargo containment systems.*

1.2 Accommodation, service and machinery spaces and control stations

1.2.1 *No accommodation space, service space or control station shall be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations that face the cargo area shall be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship having a containment system requiring a secondary barrier.*

1.2.2 Some acceptable and unacceptable arrangements of accommodation spaces, with respect to cargo tanks, are shown in Fig 1.

Figure 1 : Acceptability of common corners between hold spaces and other spaces



1.2.3 *To guard against the danger of hazardous vapours, due consideration shall be given to the location of air intakes/outlets and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements.*

Compliance with the relevant requirements, in particular with [1.2.5], [1.8], Ch 9, Sec 8, [2.1.14] and Ch 9, Sec 12, [1.2.5], as applicable, also ensures compliance with this requirement, relevant to precautions against hazardous vapours.

1.2.4 *Access through doors, gastight or otherwise, shall not be permitted from a non-hazardous area to a hazardous area except for access to service spaces forward of the cargo area through airlocks, as permitted by [1.6.1], when accommodation spaces are aft.*

1.2.5 *Entrances, air inlets,* air outlets *and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo area. They shall be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4% of the length (L) of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m.*

1.2.6 Doors facing the cargo area or located in prohibited zones in the sides are to be restricted to stores for cargo-related and safety equipment, cargo control stations as well as decontamination showers and eye wash.

Where such doors are permitted, the space may not give access to other spaces covered in [1.2.5], [1.2.8] or [1.2.10], and the common boundaries with these spaces are to be insulated with A60 class bulkheads.

The space define above is to be in accordance with Ch 9, Sec 12, [1.2].

1.2.7 Bolted plates of A60 class for removal of machinery may be accepted on bulkheads facing cargo areas, provided signboards are fitted to warn that these plates may only be opened when the ship is in gas-free condition.

1.2.8 *Windows and sidescuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned in [1.2.5] shall be of the fixed (non-opening) type. Wheelhouse windows may be non-fixed and wheelhouse doors may be located within the limits defined in [1.2.5] so long as they are designed in a manner that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured.*

1.2.9 *For ships dedicated to the carriage of cargoes that have neither flammable nor toxic hazards,* the Society *may approve relaxations from the above requirements.*

1.2.10 Accesses to forecastle spaces containing sources of ignition may be permitted through a single door facing the cargo area, provided the doors are located outside hazardous areas as defined in Ch 9, Sec 10.

1.2.11 *Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in [1.2.5], except wheelhouse windows, shall be constructed to "A-60" class. Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse shall be of fixed (non-opening) type.*

1.2.12 *All air intakes, outlets and other openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices. When carrying toxic products, they shall be capable of being operated from inside the space. The requirement for fitting air intakes and openings with closing devices operated from inside the space for toxic products need not apply to spaces not normally manned, such as deck stores, forecastle stores, workshops. In addition, the requirement does not apply to cargo control rooms located within the cargo area.*

Note 1: The requirement for fitting air intakes and openings with closing devices operable from inside the space in ships intended to carry toxic products should apply to spaces which are used for the ships' radio and main navigating equipment, cabins, mess rooms, toilets, hospitals, galleys, etc., Engine room casings, cargo machinery spaces, electric motor rooms and steering gear compartments are generally considered as spaces not covered by this paragraph and therefore the requirement for closing devices need not be applied to these spaces.

When internal closing is required, this is to include both ventilation intakes and outlets.

The closing devices are to give a reasonable degree of gas- tightness. Ordinary steel fire-flaps without gaskets/seals are normally not considered satisfactory.

1.2.13 *Control rooms and machinery spaces of turret systems may be located in the cargo area forward or aft of cargo tanks in ships with such installations. Access to such spaces containing sources of ignition may be permitted through doors facing the cargo area, provided the doors are located outside hazardous areas or access is through airlocks.*

1.2.14 Safe access to the bow

Ships assigned the service notation **liquefied gas carrier** are *to be provided with the means to enable the crew to gain safe access to the bow even in severe weather conditions. Such means of access are to be approved by* the Society.

The access is to be by means of either a walkway on the deck or a permanently constructed gangway of substantial strength at or above the level of the superstructure deck or the first tier of a deckhouse which is to:

a) Be not less than 1 m in width, situated on or as near as practicable to the centreline of the ship and located so as not to hinder easy access across working areas of the deck.

b) Be fitted at each side throughout its length with a footstop and guard rails supported by stanchions. Such rails are to consist of no less than 3 courses, the lowest being not more than 230 mm and the uppermost being at least 1 m above the gangway or walkway, and no intermediate opening is to be more than 380 mm in height. Stanchions are to be at intervals of not more than 1,5 m.

c) *Be constructed of fire resistant and non-slip material.* If Fibre Reinforced Plastic (FRP) gratings are used in lieu of steel gratings, they are to be of a type approved by the Society and have the following characteristics:
   - low-flame spread characteristics (see Pt C, Ch 4, Sec 1, [2.28])
   - not capable of producing excessive quantities of smoke and toxic products, in accordance with the Fire Test Procedures Code
   - L1 or L2 structural fire integrity levels, in accordance with ASTM F3059-2018.

d) *Have openings, with ladders where appropriate, to and from the deck. Openings are not to be more than 40 m apart*

e) *If the length of exposed deck to be traversed exceeds 70 m, have shelters of substantial construction set in way of the gangways or walkways at intervals not exceeding 45 m. Every such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides, and*

f) *If obstructed by pipes or other fittings of a permanent nature, be provided with means of passage over such obstruction.*

1.3 Cargo machinery spaces and turret compartments

1.3.1 Cargo pump rooms and/or cargo compressor rooms of ships carrying flammable gases may not contain electrical equipment, except as provided for in Ch 9, Sec 10, or other ignition sources such as internal combustion engines or steam engines with operating temperature which could cause ignition or explosion of mixtures of such gases, if any, with air.

1.3.2 *Cargo machinery spaces shall be situated above the weather deck and located within the cargo area. Cargo machinery spaces and turret compartments shall be treated as cargo pump-rooms for the purpose of fire protection according to SOLAS regulation II-2/9.2.4, and for the purpose of prevention of potential explosion according to SOLAS regulation II-2/4.5.10.*

1.3.3 *When cargo machinery spaces are located at the after end of the aftermost hold space or at the forward end of the foremost hold space, the limits of the cargo area, as defined in Ch 9, Sec 1, [4.1.8], shall be extended to include the cargo machinery spaces for the full breadth and depth of the ship and the deck areas above those spaces.*

1.3.4 *Where the limits of the cargo area are extended by [1.3.3], the bulkhead that separates the cargo machinery spaces from accommodation and service spaces, control stations and machinery spaces of category A shall be located so as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.*

1.3.5 *Cargo compressors and cargo pumps may be driven by electric motors in an adjacent non-hazardous space separated by a bulkhead or deck, if the seal around the bulkhead penetration ensures effective gastight segregation of the two spaces. Alternatively, such equipment may be driven by certified safe electric motors adjacent to them if the electrical installation complies with the requirements of Ch 9, Sec 10.*

1.3.6 *Arrangements of cargo machinery spaces and turret compartments shall ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in cargo machinery spaces, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.*

An emergency escape hatch with one vertical ladder may be accepted as an escape route if the vertical ladder does not interfere with the opening and closing of hatches and if hatches can be operated by one person, from either side, in both light and dark conditions. Moreover, hatch and vertical ladder are to ensure safe access for personnel wearing protective clothing and breathing apparatus.

1.3.7 *All valves necessary for cargo handling shall be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.*

1.3.8 *Turret compartments shall be designed to retain their structural integrity in case of explosion or uncontrolled high-pressure gas release (overpressure and/or brittle fracture), the characteristics of which shall be substantiated on the basis of a risk analysis with due consideration of the capabilities of the pressure relieving devices.*

1.4 Cargo control rooms

1.4.1 *Any cargo control room shall be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation spaces, service spaces or control stations, provided the following conditions are complied with:*

- *the cargo control room is a non-hazardous area*
- *if the entrance complies with [1.2.5], the control room may have access to the spaces described above, and*
- *if the entrance does not comply with [1.2.5], the cargo control room shall have no access to the spaces described above and the boundaries for such spaces shall be insulated to "A-60" class.*

1.4.2 *If the cargo control room is designed to be a non-hazardous area, instrumentation shall, as far as possible, be by indirect reading systems and shall, in any case, be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detection system within the cargo control room will not cause the room to be classified as a hazardous area, if installed in accordance with Ch 9, Sec 13, [6.1.11].*

1.4.3 *If the cargo control room for ships carrying flammable cargoes is classified as a hazardous area, sources of ignition shall be excluded and any electrical equipment shall be installed in accordance with Ch 9, Sec 10.*

1.5 Access to spaces in the cargo area

1.5.1 Designated passageways below and above cargo tanks are to have at least the cross-sections as specified in [1.5.6], item a).

1.5.2 Where fitted, cofferdams are to have sufficient size for easy access to all their parts. The width of the cofferdams may not be less than 600 mm.

1.5.3 Pipe tunnels are to have enough space to permit inspection of pipes. The pipes in pipe tunnels are to be installed as high as possible from the ship's bottom.

1.5.4 *Visual inspection of at least one side of the inner hull structure shall be possible without the removal of any fixed structure or fitting. If such a visual inspection, whether combined with those inspections required in [1.5.5], Ch 9, Sec 4, [2.4.3] or Ch 9, Sec 4, [7.4.8] or not, is only possible at the outer face of the inner hull, the inner hull shall not be a fuel-oil tank boundary wall.*

1.5.5 *Inspection of one side of any insulation in hold spaces shall be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.*

1.5.6 *Arrangements for hold spaces, void spaces, cargo tanks and other spaces classified as hazardous areas, shall be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and shall also allow for the evacuation of injured and/or unconscious personnel. Such arrangements shall comply with the following:*

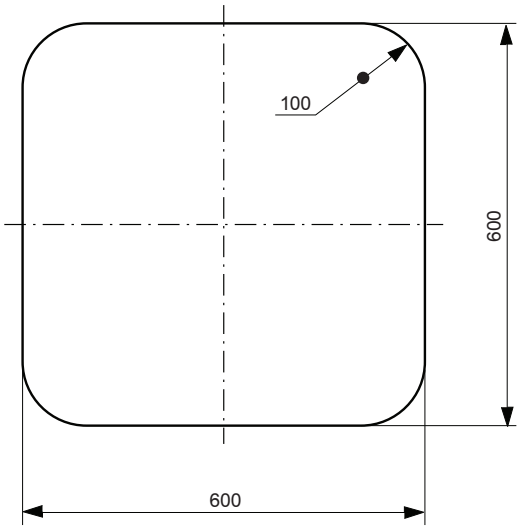
a) Access shall be provided as follows:

1) Access to all cargo tanks. Access shall be direct from the weather deck

2) Access through horizontal openings hatches or manholes. The dimensions shall be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall be not less than 600 mm x 600 mm.

The term "minimum clear opening of not less than 600 x 600 mm" means that such openings may have corner radii up to a maximum of 100 mm (see Fig 2). *In such a case where as a consequence of structural analysis of a given design the stress is to be reduced around the opening, it is considered appropriate to take measures to reduce the stress such as making the opening larger with increased radii, e.g. 600 x 800 with 300 mm radii, in which a clear opening of 600 mm x 600 mm with corner radii up to 100 mm maximum fits.*

Figure 2 : Minimum horizontal hatch size



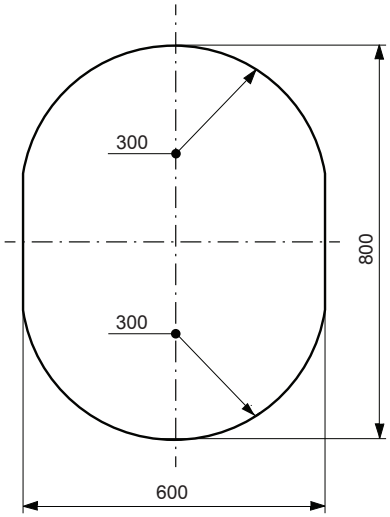
3) Access through vertical openings or manholes providing passage through the length and breadth of the space. The minimum clear opening shall be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided.

The term "minimum clear opening of not less than 600 x 800 mm" also includes an opening of the size specified in Fig 3.

Subject to verification of easy evacuation of injured person on a stretcher the vertical opening 850 mm x 620 mm with wider upper half than 600 mm, while the lower half may be less than 600 mm with the overall height not less than 850 mm is considered an acceptable alternative to the traditional opening of 600 mm x 800 mm with corner radii of 300 mm.

If a vertical opening is at a height of more than 600 mm steps and handgrips are to be provided. In such arrangements it is to be demonstrated that an injured person can be easily evacuated.

Figure 3 : Minimum size of manholes



4) Circular access openings to type C tanks shall have a diameter of not less than 600 mm.

b) The dimensions referred to in [1.5.6], item a) 2) and [1.5.6] may be decreased, if the requirements of [1.5.6] can be met to the satisfaction of the Society.

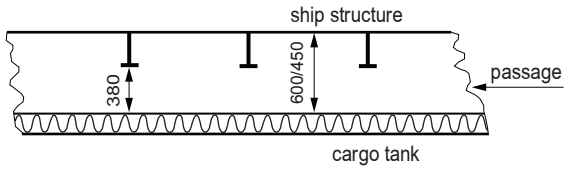
c) Where cargo is carried in a containment system requiring a secondary barrier, the requirements of [1.5.6], item a)2) and [1.5.6], item a)3) do not apply to spaces separated from a hold space by a single gastight steel boundary. Such spaces shall be provided only with direct or indirect access from the weather deck, not including any enclosed non-hazardous area.

d) Access required for inspection shall be a designated access through structures below and above cargo tanks, which shall have at least the cross- sections as required by [1.5.6], item a)3).

e) For the purpose of [1.5.4] or [1.5.5], the following shall apply:

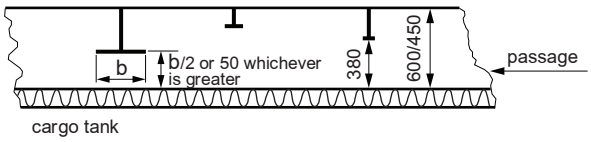
1) Where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements shall be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, shall be at least 450 mm for a curved tank surface (e.g. for a type C tank), or 600 mm for a flat tank surface (e.g. for a type A tank) (see Fig 4)

Figure 4 :



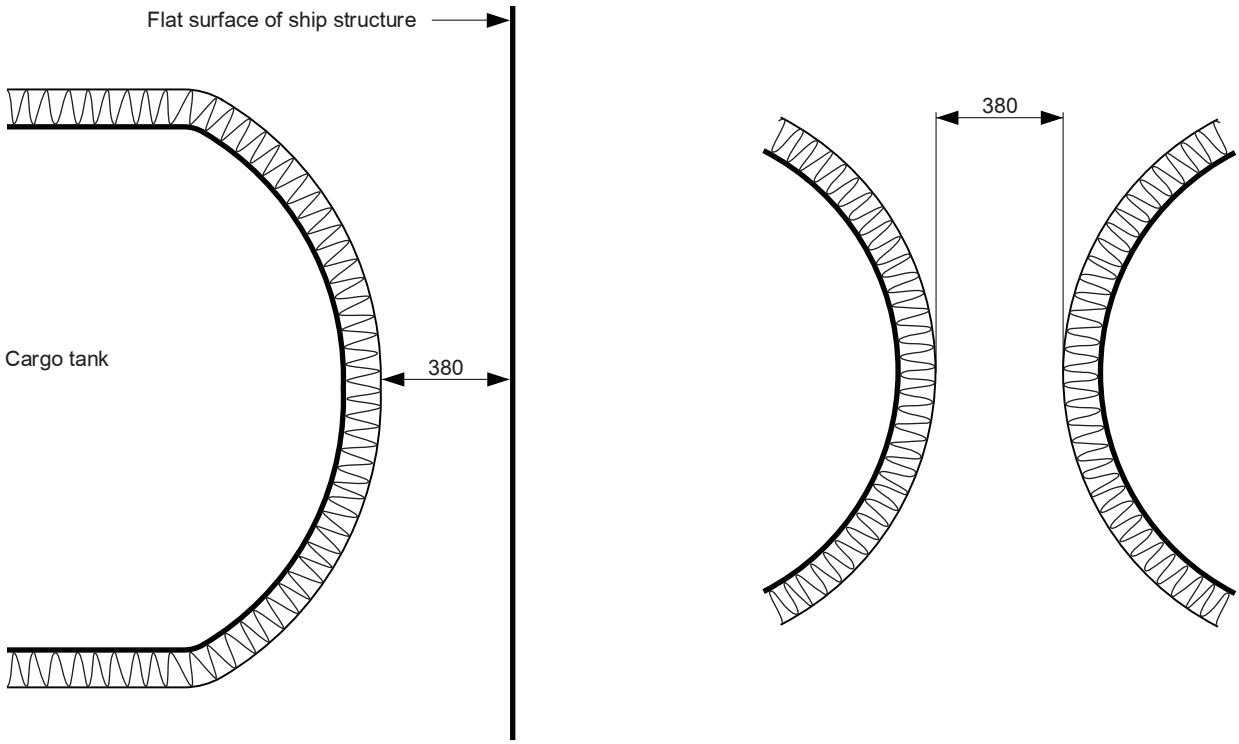
2) Where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected shall be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger (see Fig 5)

Figure 5 :



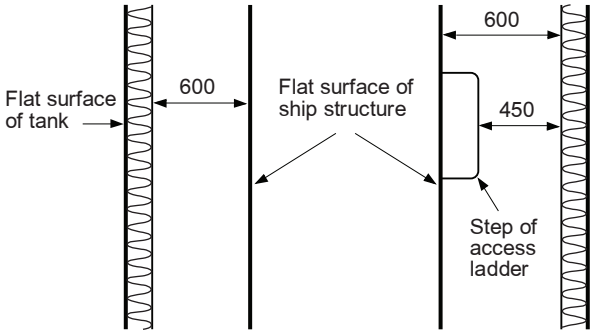
3) If for inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces shall be at least 380 mm (see Fig 6). Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface

Figure 6 :



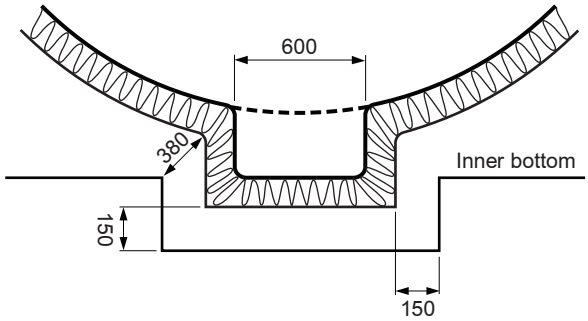
4) If for inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces shall be at least 600 mm. Where fixed access ladders are fitted, a clearance of at least 450 mm shall be provided for access (see Fig 7)

Figure 7 :



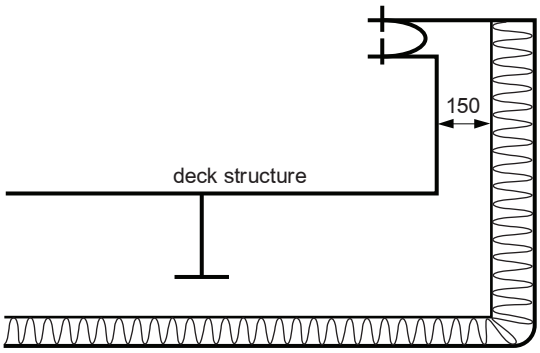
5) The minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well shall not be less than those shown in Fig 8 (Fig 8 shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm). If there is no suction well, the distance between the cargo tank sump and the inner bottom shall not be less than 50 mm

Figure 8 :



6) The distance between a cargo tank dome and deck structures shall not be less than 150 mm (see Fig 9)

Figure 9 :



7) Fixed or portable staging shall be installed as necessary for inspection of cargo tanks, cargo tank supports and restraints (e.g. anti-pitching, anti-rolling and anti-flotation chocks), cargo tank insulation etc. This staging shall not impair the clearances specified in [1.5.6], item e)1) to [1.5.6], item e) 4), and

8) If fixed or portable ventilation ducting shall be fitted in compliance with Ch 9, Sec 12, [1.2.2], such ducting shall not impair the distances required under [1.5.6], item e)1) to [1.5.6], item e) 4).

1.5.7 *Access from the open weather deck to non-hazardous areas shall be located outside the hazardous areas as defined in Ch 9, Sec 10, unless the access is by means of an airlock in accordance with [1.6].*

1.5.8 *Turret compartments shall be arranged with two independent means of access/egress.*

1.5.9 *Access from a hazardous area below the weather deck to a non-hazardous area is not permitted.*

1.6 Airlocks

1.6.1 *Access between hazardous area on the open weather deck and non-hazardous spaces shall be by means of an airlock. This shall consist of two self-closing, substantially gastight, steel doors without any holding back arrangements, capable of maintaining the overpressure, at least 1,5 m but no more than 2,5 m apart. The airlock space shall be artificially ventilated from a non-hazardous area and maintained at an overpressure to the hazardous area on the weather deck.*

1.6.2 Air-locks are to be such as to provide easy passage and are to cover a deck area of not less than 1,5 m². Air-locks are to be kept unobstructed and may not be employed for other uses, such as storage.

1.6.3 A differential pressure monitoring device shall be provided for monitoring the satisfactory functioning of pressurization of non-hazardous spaces protected by airlocks. Airflow sensors are considered an acceptable alternative in spaces having a ventilation rate not less than 30 air changes per hour.

In spaces where the ventilation rate is less than 30 air changes per hour and where airflow sensors are fitted as an alternative, in addition to the alarms required in [1.6.5], arrangements are to be made to de-energise electrical equipment which is not of the certified safe type if more than one airlock door is moved from the closed position.

1.6.4 *Where spaces are protected by pressurization, the ventilation shall be designed and installed in accordance with recognized standards.*

Note 1: Such as the recommended publication by the International Electrotechnical Commission, in particular IEC 60092-502:1999.

However, where the prescriptive requirements in the present Rules and IEC 60092-502 are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.6.5 *An audible and visible alarm system to give a warning on both sides of the airlock shall be provided. The visible alarm shall indicate if one door is open. The audible alarm shall sound if doors on both sides of the airlock are moved from the closed positions.*

The alarm systems are to be of the intrinsically safe type. However, signalling lamps may be of a safe type authorised for the dangerous spaces in which they are installed.

1.6.6 *In ships carrying flammable products, electrical equipment that is located in spaces protected by airlocks and not of the certified safe type, shall be de-energized in case of loss of overpressure in the space.*

1.6.7 Lack of overpressure or air flow is not to imply the stopping of motors driving compressors used for the boil-off system mentioned in Ch 9, Sec 16; therefore, such engines are to be of the certified safe type and the relevant control appliance is to be fitted in a non-gas-dangerous space.

The requirement above is not applicable if, during manoeuvring and operations in port, only fuel oil is used or when the automatic transfer from gas to fuel oil, as per Ch 9, Sec 16, [6.2], operates also when such electric motors are stopped without causing the shut-off of the boiler.

After any loss of the overpressure, the spaces protected by airlocks are to be ventilated for the time necessary to give at least 10 air changes prior to energising the non-safe type electrical installations.

1.6.8 *Electrical equipment for manoeuvring, anchoring and mooring, as well as emergency fire pumps that are located in spaces protected by airlocks, shall be of a certified safe type.*

1.6.9 *The airlock space shall be monitored for cargo vapours (see Ch 9, Sec 13, [6.1.2]).*

1.6.10 *Subject to the requirements of the International Convention on Load Lines in force, the door sill shall not be less than 300 mm in height.*

1.7 Bilge, ballast and oil fuel arrangements

1.7.1 Dry spaces within the cargo area are to be fitted with a bilge or drain arrangement not connected to the machinery space.

Spaces not accessible at all times are to be fitted with sounding arrangements.

Spaces without a permanent ventilation system are to be fit- ted with a pressure/vacuum relief system or with air pipes.

1.7.2 Bilge arrangements for holds containing cargo tanks and for interbarrier spaces are to be operable from the weather deck.

1.7.3 The diameter of the bilge main may be smaller than the diameter specified in Pt C, Ch 1, Sec 10, [6.8.1], provided that this diameter is not less than twice the value given in Pt C, Ch 1, Sec 10, [6.8.3]. This reduction of diameter, however, is not applicable to the determination of the capacity of fire pumps according to Pt C, Ch 1, Sec 10, [6.7.4].

1.7.4 With reference to the means to ascertain leakages in holds and/or in interbarrier spaces, the following requirements apply:

a) The above-mentioned means is to be suitable to ascertain the presence of water:
   - in holds containing type C independent tanks
   - in holds and interbarrier spaces outside the secondary barrier

b) The above-mentioned means is to be suitable to ascertain the presence of liquid cargo in the spaces adjacent to cargo tanks which are not type C independent tanks.

Where the aforesaid spaces may be affected by water leakages from the adjacent ship structures, the means is also to be suitable to ascertain the presence of water.

Where the above-mentioned means is constituted by electrical level switches, the relevant circuits are to be of the intrinsically safe type and signals are to be transduced to the wheelhouse and to the cargo control station, if fitted.

1.7.5 *Where cargo is carried in a cargo containment system not requiring a secondary barrier, suitable drainage arrangements for the hold spaces that are not connected with the machinery space shall be provided. Means of detecting any leakage shall be provided.*

1.7.6 *Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The suction shall not lead to pumps inside the machinery space. Means of detecting such leakage shall be provided.*

1.7.7 *The hold or interbarrier spaces of type A independent tank ships shall be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements shall provide for the return of any cargo leakage to the liquid cargo piping.*

1.7.8 *Arrangements referred to in [1.7.7] shall be provided with a removable spool piece.*

1.7.9 *Ballast spaces, including wet duct keels used as ballast piping, oil fuel tanks and non-hazardous spaces, may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps, and the discharge from the pumps is led directly overboard with no valves or manifolds in either line that could connect the line from the duct keel to lines serving non-hazardous spaces. Pump vents shall not be open to machinery spaces.*

Note 1: For ballast tanks separated by a single gastight boundary from cargo tanks for which no secondary barrier is required - e.g. ballast tanks adjacent to integral tanks -, discharge arrangements are to be outside machinery spaces and accommodation spaces but filling arrangements may be in the machinery spaces provided that such arrangements ensure filling from tank deck level and a non-return valve and removable spool piece are fitted.

Note 2: The requirements of "Pump vents should not be open to machinery spaces" and "Pump vents shall not be open to machinery spaces" apply only to pumps in the machinery spaces serving dry duct keels through which ballast piping passes.

1.8 Bow and stern loading and unloading arrangements

1.8.1 *Subject to the requirements of this section and Ch 9, Sec 5, cargo piping may be arranged to permit bow or stern loading and unloading.*

1.8.2 *Bow or stern loading and unloading lines that are led past accommodation spaces, service spaces or control stations shall not be used for the transfer of products requiring a type 1G ship. Bow or stern loading and unloading lines shall not be used for the transfer of toxic products as specified in Ch 9, Sec 1, [4.1.51], where the design pressure is above 2,5 MPa.*

1.8.3 *Portable arrangements shall not be permitted.*

1.8.4

a) *Entrances, air inlets,* air outlets *and openings to accommodation spaces, service spaces, machinery spaces and controls stations, shall not face the cargo shore connection location of bow or stern loading and unloading arrangements. They shall be located on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the length of the ship, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo shore connection location of the bow or stern loading and unloading arrangements.*

b) *Windows and sides cuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type.*

c) *In addition, during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side shall be kept closed.*

d) *Where, in the case of small ships, compliance with [1.2.5] and [1.8.4] is not possible,* the Society *may approve relaxations from the above requirements.*

1.8.5 *Deck openings and air inlets and outlets to spaces within distances of 10 m from the cargo shore connection location shall be kept closed during the use of bow or stern loading or unloading arrangements.*

1.8.6 *Fire fighting arrangements for the bow or stern loading and unloading areas shall be in accordance with Ch 9, Sec 11, [1.3.2], item d) and Ch 9, Sec 11, [1.4.7].*

1.8.7 Devices to stop cargo pumps and cargo compressors and to close cargo valves are to be fitted in a position from which it is possible to keep under control the loading/unloading manifolds.

1.8.8 *Means of communication between the cargo control station and the shore connection location shall be provided and, where applicable, certified for use in hazardous areas.*

1.9 Emergency towing arrangements

1.9.1 The requirements of Pt B, Ch 12, Sec 4, [3] are to be complied with on ships of not less than 20000 t deadweight.

Section 4 Cargo Containment

Symbols

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Pt B, Ch 4, Sec 1

R_m : Minimum ultimate tensile strength, in N/mm^2, of the material

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified

k : Material factor for steel, defined in Pt B, Ch 4, Sec 1, [4.2]

s : Spacing, in mm, of ordinary stiffeners

d_{shr} : Effective shear depth, in mm, as defined in Pt B, Ch 4, Sec 6, [1.4.4]

ℓ_{bdg} : Effective bending span, in m, of ordinary stiffeners defined in Pt B, Ch 4, Sec 6

ℓ_{shr} : Effective shear span, in m, of ordinary stiffeners defined in Pt B, Ch 4, Sec 6

α_p : Correction factor for the panel aspect ratio, to be taken as follows:

$$\alpha_p = 1,2 - \frac{b}{2,1\ a}$$

to be taken not greater than 1,0

b : Breadth of plate panel, in mm, as defined in Pt B, Ch 4, Sec 6, [2.1.1]

T_{SC} : Scantling draught, in m, defined in Pt B, Ch 1, Sec 3, [2.1.6].

1 General

1.1 Scope

1.1.1 *The purpose of this Section is to ensure the safe containment of cargo under all design and operating conditions having regard to the nature of the cargo carried. This will include measures to:*

- *provide strength to withstand defined loads*
- *maintain the cargo in a liquid state*
- *design for or protect the hull structure from low temperature exposure*
- *prevent the ingress of water or air into the cargo containment system.*

1.2 Definitions

1.2.1 *A cold spot is a part of the hull or thermal insulation surface where a localized temperature decrease occurs with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/ temperature control systems required in Ch 9, Sec 7.*

1.2.2 *Design vapour pressure P_0 is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.*

1.2.3 *Design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported in the cargo tanks.*

1.2.4 *Independent tanks are self-supporting tanks. They do not form part of the ship's hull and are not essential to the hull strength. There are three categories of independent tank, which are referred to in [8], [9] and [10].*

1.2.5 *Integral tanks are tanks that form a structural part of the hull and are influenced in the same manner by the loads that stress the adjacent hull structure. Integral tanks are covered in [12].*

1.2.6 *Semi-membrane tanks are non-self-supporting tanks in the loaded condition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure. Semi-membrane tanks are covered in [13].*

1.2.7 *In addition to the definitions given in Ch 9, Sec 1, the definitions given in this Section shall apply throughout Part D, Chapter 9.*

1.2.8 *Membrane tanks are non-self-supporting tanks that consist of a thin liquid and gastight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in [11].*

1.2.9 For membrane tanks, the supports are provided by all elements holding the containment system, such as any local supporting devices connecting to the ship inner hull (for example, small pillars or similar elements in insulation boxes).

1.3 Application

1.3.1 *Unless otherwise specified in [8] to [13], the requirements of [2] to [7] and Ch 9, Sec 20 shall apply to all types of tanks including those covered in [14].*

2 Cargo containment

2.1 Functional requirement

2.1.1 *The design life of the cargo containment system shall not be less than the design life of the ship.*

2.1.2 *Cargo containment systems shall be designed for North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Lesser environmental conditions, consistent with the expected usage, may be accepted by* the Society *for cargo containment systems used exclusively for restricted navigation. Greater environmental conditions may be required for cargo containment systems operated in conditions more severe than the North Atlantic environment.*

2.1.3 *Cargo containment systems shall be designed with suitable safety margins:*

- *to withstand, in the intact condition, the environmental conditions anticipated for the cargo containment system's design life and the loading conditions appropriate for them, which include full homogeneous and partial load conditions, partial filling within defined limits and ballast voyage loads; and*
- *being appropriate for uncertainties in loads, structural modeling, fatigue, corrosion, thermal effects, material variability, ageing and construction tolerances.*

2.1.4 *The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. The specific design conditions which shall be considered for the design of each cargo containment system are given in [8] to [13]. There are three main categories of design conditions:*

a) Ultimate design conditions – the cargo containment system structure and its structural components shall withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design shall take into account proper combinations of the following loads:

- *internal pressure*
- *external pressure*
- *dynamic loads due to the motion of the ship*
- *thermal loads*
- *sloshing loads*
- *loads corresponding to ship deflections*
- *tank and cargo weight with the corresponding reaction in way of supports*
- *insulation weight*
- *loads in way of towers and other attachments; and*
- *test loads.*

b) Fatigue design conditions – the cargo containment system structure and its structural components shall not fail under accumulated cyclic loading.

c) Accident design condition:

The cargo containment system shall meet the following criteria:

- *Collision: the cargo containment system shall be protectively located in accordance with Ch 9, Sec 2, [4.1.1] and withstand the collision loads specified in [3.5.2] without deformation of the supports, or the tank structure in way of the supports, likely to endanger the tank structure.*
- *Fire: the cargo containment systems shall sustain, without rupture, the rise in internal pressure specified in Ch 9, Sec 8, [4.1] under the fire scenarios envisaged therein.*
- *Flooded compartment causing buoyancy on tank: the anti-flotation arrangements shall sustain the upward force, specified in [3.5.3], and there shall be no endangering plastic deformation to the hull.*
- Unfavourable static heel scenario: the cargo containment systems shall sustain, without rupture, a static angle within the range 0° to 30°.

2.1.5 *Measures shall be applied to ensure that scantlings required meet the structural strength provisions and be maintained throughout the design life. Measures may include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting. Corrosion allowance need not be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control, such as inerting around the cargo tank, or where the cargo is of a corrosive nature,* the Society *may require a suitable corrosion allowance.*

2.1.6 *An inspection/survey plan for the cargo containment system shall be developed and approved by* the Society. *The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo containment system's life and, in particular, all necessary in-service survey and maintenance that was assumed when selecting cargo containment system*

design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal equipment, shall be designed and built to ensure safety during operations, inspection and maintenance (see Ch 9, Sec 3, [1.5]).

2.2 Cargo containment safety principles

2.2.1 *The containment systems shall be provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level.*

2.2.2 *However, the size and configuration or arrangement of the secondary barrier may be reduced where an equivalent level of safety is demonstrated in accordance with the requirements of [2.2.3] to [2.2.5], as applicable.*

2.2.3 *Cargo containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low, but where the possibility of leakages through the primary barrier cannot be excluded, shall be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages. The arrangements shall comply with the following requirements:*

- *failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall have a sufficiently long development time for remedial actions to be taken; and*
- *failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank.*

2.2.4 *No secondary barrier is required for cargo containment systems, e.g. type C independent tanks, where the probability for structural failures and leakages through the primary barrier is extremely low and can be neglected.*

2.2.5 *No secondary barrier is required where the cargo temperature at atmospheric pressure is at or above – 10°C.*

2.3 Secondary barriers in relation to tank types

2.3.1 *Secondary barriers in relation to the tank types defined in [8] to [13] shall be provided in accordance with Tab 1.*

2.4 Design of secondary barriers

2.4.1 Secondary barrier extent

The extent of the secondary barrier is to be not less than that necessary to protect the hull structures assuming that the cargo tank is breached at a static angle of heel of 30°, with an equalisation of the liquid cargo in the tank (see Fig 1).

Note 1: The "liquid level" given in Fig 1 is considered at the maximum allowable filling level in the cargo tank

2.4.2 *Where the cargo temperature at atmospheric pressure is not below – 55°C, the hull structure may act as a secondary barrier based on the following:*

- *the hull material shall be suitable for the cargo temperature at atmospheric pressure as required by [5.2.4]; and*
- *the design shall be such that this temperature will not result in unacceptable hull stresses.*

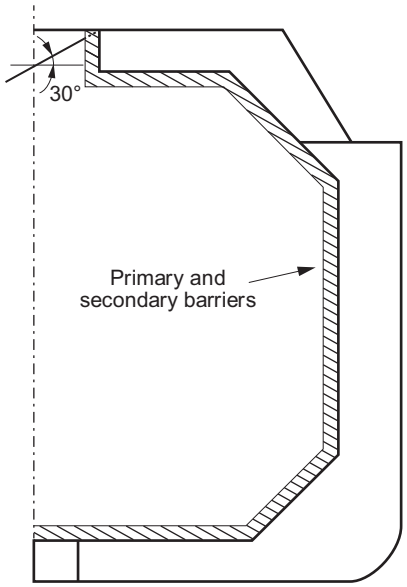
Table 1 : Secondary barriers in relation to tank types

Cargo temperature at atmospheric pressure		–10°C and above	Below –10°C down to –55°C	Below –55°C
Basic tank type		No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral			Tank type not normally allowed **(1)**	
Membrane			Complete secondary barrier	
Semi-membrane			Complete secondary barrier **(2)**	
Independent	type A		Complete secondary barrier	
	type B		Partial secondary barrier	
	type C		No secondary barrier required	

(1) A complete secondary barrier shall normally be required if cargoes with a temperature at atmospheric pressure below -10°C are permitted in accordance with [12.1].

(2) In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support, the Society may, after special consideration, accept a partial secondary barrier.

Figure 1 : Secondary barrier extension



2.4.3 *The design of the secondary barrier shall be such that:*

a) It is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different criteria apply for particular voyages, taking into account the load spectrum referred to in [4.6.6]

b) Physical, mechanical, or operational events within the cargo tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa

c) Failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers

d) It is capable of being periodically checked for its effectiveness by means acceptable to the Society. *This may be by means of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with* the Society. Requirements for tightness tests of secondary barriers are detailed in [6.4.4].

e) The methods required in item d) shall be approved by the Society *and shall include, where applicable to the test procedure:*

- *details on the size of defect acceptable and the location within the secondary barrier, before its liquid-tight effectiveness is compromised*
- *accuracy and range of values of the proposed method for detecting defects in item a)*
- *scaling factors to be used in determining the acceptance criteria, if full scale model testing is not undertaken; and*
- *effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test; and*

f) The secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°.

2.5 Partial secondary barriers and primary barrier small leak protection system

2.5.1 *Partial secondary barriers as permitted in [2.2.3] shall be used with a small leak protection system and meet all the requirements in [2.4.3]. The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquid cargo down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.*

2.5.2 *The capacity of the partial secondary barrier shall be determined, based on the cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in [4.6.6], after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.*

2.5.3 *The required liquid leakage detection may be by means of liquid sensors, or by an effective use of pressure, temperature or gas detection systems, or any combination thereof.*

2.6 Supporting arrangements

2.6.1 The supporting arrangements are to comply with the requirements defined in [7.1].

2.7 Associated structure and equipment

2.7.1 *Cargo containment systems shall be designed for the loads imposed by associated structure and equipment. This includes pump towers, cargo domes, cargo pumps and piping, stripping pumps and piping, nitrogen piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles, and instrumentation systems (such as pressure, temperature and strain gauges).*

2.8 Thermal insulation

2.8.1 *Thermal insulation shall be provided, as required, to protect the hull from temperatures below those allowable (see [5.2]) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Ch 9, Sec 7.*

2.8.2 *In determining the insulation performance, due regard shall be given to the amount of the acceptable boil-off in association with the reliquefaction plant on board, main propulsion machinery or other temperature control system.*

2.9 Use of cargo heater to raise the cargo temperature

2.9.1 Where a cargo heater, intended to raise the cargo temperature to a value permissible for cargo tanks, is envisaged, the following requirements are to be complied with:

- The piping and valves involved are to be suitable for the design loading temperature
- A thermometer is to be fitted at the heater outlet. It is to be set at the design temperature of the tanks and, when activated, it is to give a visual and audible alarm. This alarm is to be installed in the cargo control station or, when such a station is not foreseen, in the wheelhouse.
- The following note is to be written on the Certificate of Fitness: "The minimum permissible temperature in the cargo preheater is..... °C".

3 Design loads

3.1 General

3.1.1 *This section defines the design loads to be considered with regard to the requirements in [4]. This includes:*

- *load categories (permanent, functional, environmental and accidental) and the description of the loads;*
- *the extent to which these loads shall be considered depending on the type of tank, and is more fully detailed in the following paragraphs; and*
- *tanks, together with their supporting structure and other fixtures, that shall be designed taking into account relevant combinations of the loads described below.*

3.2 Permanent loads

3.2.1 Gravity loads

The weight of tank, thermal insulation, loads caused by towers and other attachments shall be considered.

3.2.2 Permanent external loads

Gravity loads of structures and equipment acting externally on the tank shall be considered.

3.3 Functional loads

3.3.1 *Loads arising from the operational use of the tank system shall be classified as functional loads. All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered. As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:*

- *internal pressure*
- *external pressure*
- *thermally induced loads*
- *vibration*
- *interaction loads*
- *loads associated with construction and installation*
- *test loads*
- *static heel loads; and*
- *weight of cargo.*

3.3.2 Internal pressure

a) In all cases, including item b), P_o shall not be less than MARVS.

b) For cargo tanks, where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P_o shall not be less than the gauge vapour pressure of the cargo at a temperature of 45°C except as follows:

- *lower values of ambient temperature may be accepted by* the Society *for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required; and*
- *for ships on voyages of restricted duration, P_o may be calculated based on the actual pressure rise during the voyage, and account may be taken of any thermal insulation of the tank.*

c) Subject to special consideration by the Society *and to the limitations given in [8] to [13], for the various tank types, a vapour pressure P_h higher than P_o may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced. Any relief valve setting resulting from this paragraph shall be recorded in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.*

d) Where the vapour pressure in harbour conditions is greater than P_o, defined in [1.2.2], this value is to be specified in the operating instructions for the ship's Master.

e) The internal pressure P_{eq} results from the vapour pressure P_o or P_h plus the maximum associated dynamic liquid pressure P_{gd}, but not including the effects of liquid sloshing loads.

The internal pressure P_{eq} is to be taken as follows:

- for harbour conditions:
  $P_{eq} = P_{ls}$
- for seagoing conditions:
  $P_{eq} = P_{ls} + P_{ld}$

where:

P_{ls} : Static pressure due to liquid in tank, in kN/m^2, as defined in Pt B, Ch 5, Sec 6, [1.2.1], with P_{pv} taken equal to P_o or P_h, as appropriate according to items a) to d)

P_{ld} : Dynamic pressure due to liquid in tank, in kN/m^2, as defined in Pt B, Ch 5, Sec 6, [1.3.1].

Guidance formulae for associated dynamic liquid pressure P_{gd} are given in Ch 9, App 1, [1.1] as an alternative for seagoing conditions.

Note 1: The dynamic liquid pressure P_{gd} given in Ch 9, App 1, [1.1] includes the effect of gravity.

3.3.3 External pressure

External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

3.3.4 Thermally induced loads

Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below –55°C.

Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see Ch 9, Sec 7, [2].

For normal service, the upper ambient design temperature is to taken as:

- sea: 32°C
- air: 45°C.

For service in particularly hot or cold zones, these ambient design temperatures are to be increased or decreased, to the satisfaction of the Society. The overall capacity of the system is to be such that it can control the pressure within the design conditions without venting to atmosphere.

3.3.5 Vibration

The potentially damaging effects of vibration on the cargo containment system shall be considered.

3.3.6 Interaction loads

The static component of loads resulting from interaction between cargo containment system and the hull structure, as well as loads from associated structure and equipment, shall be considered.

3.3.7 Loads associated with construction and installation

Loads or conditions associated with construction and installation, e.g. lifting, shall be considered.

3.3.8 Test loads

Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in [8] to [13].

3.3.9 Static heel loads

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° shall be considered.

Guidance for calculation of static pressure for 30° heel angle is given in Ch 9, App 1, [3].

3.3.10 Other loads

Any other loads not specifically addressed, which could have an effect on the cargo containment system, shall be taken into account.

3.4 Environmental loads

3.4.1 Definition

Environmental loads are defined as those loads on the cargo containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

3.4.2 Loads due to ship motion

a) *The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading.*

b) *The ship's motion shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:*

- *vertical acceleration: motion accelerations of heave, pitch and, possibly, roll (normal to the ship base);*
- *transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and*
- *longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.*

c) *Methods to predict accelerations due to ship motion shall be proposed and approved by* the Society.

d) *The accelerations are to be taken as defined in Pt B, Ch 5, Sec 3.*

As an alternative, guidance formulae for acceleration components are given in Ch 9, App 1, [1.2].

e) *Ships for restricted service may be given special consideration.*

3.4.3 Dynamic interaction loads

Account shall be taken of the dynamic component of loads resulting from interaction between cargo containment systems and the hull structure, including loads from associated structures and equipment.

3.4.4 Sloshing loads

The sloshing loads on a cargo containment system and internal components shall be evaluated based on allowable filling levels.

When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

The sloshing loads may be disregarded for type C tanks where wash bulkheads are positioned so as to limit a risk of resonance of the cargo movements (see Pt B, Ch 11, Sec 4, [1.5]).

Guidance for calculation of sloshing pressure for membrane tanks is given in Ch 9, Sec 1, [2] and, as applicable, in [3.4.5].

3.4.5 Methodology to determine dynamic design sloshing loads

Methodology to determine dynamic design sloshing loads on the boundaries of a membrane cargo tank at its partial filling due to the sloshing effects for all its operational filling levels is to comply with the following minimum functional requirements:

a) Methodology:

The methodology is to contain the following input data on source specifications describing the operation during the whole ship's design life, including:

1) The ship's main particulars including the ship lines.

2) The geometry of cargo tanks at the primary barrier level, the arrangement of cargo containments over the full breadth and length.

3) The following density and kinematic viscosity values of LNG, at –163°C to be considered:

- LNG density is equal to 470 kg/m^3
- LNG kinematic viscosity is equal to 0.2857 m^2/s

4) The operational filling levels:

- standard filling levels correspond to:
  - 0 to 10% H and
  - 70% H to 98% V
- partial filling levels correspond to 10% to 70% H

where:

H : Maximum height of the tank, in m, taken at the primary barrier level.

If the cargo containment design does not comply with or is not checked against the partial filling levels, the partial filling levels are not allowed; this restriction of the ship operation is to be traced on ship certificate.

5) The ship speed and distribution law of heading.

The characteristics of ship's loading conditions (the centre of gravity and centre of buoyancy position, metacentric height as per the trim and stability booklet) and the corresponding roll radius of gyration for each loading condition.

6) Statistics on irregular sea parameters (the provisions of IACS Recommendation No. 34 are to be met) the environmental conditions:

The environmental data for sloshing analysis is to refer to North Atlantic route with significant wave height envelope fitted to 40-year return period. North Atlantic trade route conditions are defined by Standard Wave Data (IACS Rec. No. 34).

7) For ice class notations, the design speed for ice condition operations is to be provided.

b) In general, the loads are to be determined for all the cargo tanks where the partial filling is provided. In case of the available tanks identical in terms of geometrical features, it is allowed to determine the loads for those tanks where the maximum sloshing loads are expected. In addition, the methodology is to contain substantiation for the tanks selected for calculation regarding:

- geometrical features and shapes of the tanks
- tank position.

c) Mandatory seakeeping analysis.

A seakeeping analysis taking into account the coupling between the ship motions and the internal liquid motions within the cargo tanks is to be carried out. The calculated ship motions (6 degrees of freedom) are directly used for sloshing model tests. Methodology is to contain the ship's rolling calculations. As a result of the calculation, the characteristics of oscillating movements are to be obtained for all types of rolling at irregular seas applicable to all selected operating conditions (amplitude versus frequency response characteristics or implementation on a time scale). During the rolling calculation, the methods may be applied based on the three-dimensional potential theory and other pitching and rolling calculation methods agreed with the Society.

The input data for this seakeeping analysis are as follows:

- ship lines (see a) above)
- ship's loading conditions and the corresponding roll radius of gyration (see a) above)
- LNG cargo tanks arrangement and geometry (see a) above)
- operational filling levels (see a) above)
- environmental conditions including ice condition operations (See a) above).

The output of the seakeeping analysis are the ship's motions time series (6 degrees of freedom) for the sloshing model tests.

d) Mandatory sloshing model test:

Methodology is to contain the results of model sloshing tests in design cargo tanks. The design sloshing loads acting on the boundaries of the membrane cargo tanks are to be determined by the mandatory sloshing model tests. These design sloshing loads are to be determined for all the cargo tanks and for all operational filling levels.

The sloshing model test program is to comply with the following minimum requirements:

- all assumptions used during model tests are to be specified
- the description of the used test bench and equipment used for measuring and processing the measurement results are to be provided for approval to the Society
- the justification for the value of scaling load factor is to be provided
- the irregular time histories are to be considered for the ship's motions, the ship's oscillating movement at irregular seas is to be modelled (ship's motion characteristics are to be scaled in the model test based on the Froude similarity criterion)
- the duration of each model test and scope of parameters characterizing each test is to be agreed by the Society.

The sloshing model test report is to include description of statistical analysis of model test results. The long-term approach is to be considered for the evaluation of the design sloshing loads. The description of statistical methods for the derivation of short-term as well as long-term sloshing loads distribution that is required to determine the maximum design loads on the boundaries of the cargo tanks is to be provided.

e) Sister ships:

When determining the maximum design loads, the results of model tests performed for sister ships with similar main dimensions and geometrical features of cargo tanks may be used provided the Society's agreement. Feasible use of the results of earlier tests is to be justified considering the review of the compliance degree of, at least, the following characteristics:

- the selected initial technical data
- the selected design cargo tanks
- the rolling and pitching seakeeping analysis results and a comparison of the initial and the target ship global accelerations results
- the main assumptions used during model tests.

3.4.6 Snow and ice loads

Snow and icing shall be considered, if relevant.

3.4.7 Loads due to navigation in ice

Loads due to navigation in ice shall be considered for vessels intended for such service.

3.5 Accidental loads

3.5.1 Definition

Accidental loads are defined as loads that are imposed on a cargo containment system and its supporting arrangements under abnormal and unplanned conditions.

3.5.2 Collision loads

The collision load shall be determined based on the cargo containment system under fully loaded condition with an inertial force corresponding to 0,5 g in the forward direction and 0,25 g in the aft direction, where g is gravitational acceleration.

Guidance for calculation of dynamic pressure, to be considered in addition to static pressure, is given in Ch 9, App 1, [4]

3.5.3 Loads due to flooding on ship

For independent tanks, loads caused by the buoyancy of an empty tank in a hold space flooded to the summer load draught shall be considered in the design of the anti-flotation chocks and the supporting hull structure.

4 Structural integrity

4.1 General

4.1.1 *The structural design shall ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This shall take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness*

4.1.2 *The structural integrity of cargo containment systems shall be demonstrated by compliance with [8] to [13], as appropriate, for the cargo containment system type.*

4.1.3 *The structural integrity of cargo containment system types that are of novel design and differ significantly from those covered by [8] to [13] shall be demonstrated by compliance with [14] to ensure that the overall level of safety provided in this Section is maintained.*

4.2 Structural analyses

4.2.1 Analysis

a) *The design analyses shall be based on accepted principles of statics, dynamics and strength of materials.*

b) *Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.*

c) *When determining responses to dynamic loads, the dynamic effect shall be taken into account where it may affect structural integrity.*

4.2.2 Load scenarios

a) *For each location or part of the cargo containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously shall be considered.*

b) *The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service, and conditions shall be considered.*

4.2.3 *When the static and dynamic stresses are calculated separately, and unless other methods of calculation are justified, the total stresses shall be calculated according to:*

$$\sigma_x = \sigma_{x,st} \pm \sqrt{\sum (\sigma_{x,dyn})^2}$$

$$\sigma_y = \sigma_{y,st} \pm \sqrt{\sum (\sigma_{y,dyn})^2}$$

$$\sigma_z = \sigma_{z,st} \pm \sqrt{\sum (\sigma_{z,dyn})^2}$$

$$\tau_{xy} = \tau_{xy,st} \pm \sqrt{\sum (\tau_{xy,dyn})^2}$$

$$\tau_{xz} = \tau_{xz,st} \pm \sqrt{\sum (\tau_{xz,dyn})^2}$$

$$\tau_{yz} = \tau_{yz,st} \pm \sqrt{\sum (\tau_{yz,dyn})^2}$$

where:

$\sigma_{x,st}$, $\sigma_{y,st}$, $\sigma_{z,st}$, $\tau_{xy,st}$, $\tau_{xz,st}$ *and* $\tau_{yz,st}$ *are static stresses; and*

$\sigma_{x,dyn}$, $\sigma_{y,dyn}$, $\sigma_{z,dyn}$, $\tau_{xy,dyn}$, $\tau_{xz,dyn}$ *and* $\tau_{yz,dyn}$ *are dynamic stresses,*

each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

4.3 Stress categories

4.3.1 *For the purpose of stress evaluation, stress categories are defined in this section as follows:*

- *normal stress is the component of stress normal to the plane of reference.*
- *membrane stress is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.*
- *bending stress is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.*
- *shear stress is the component of the stress acting in the plane of reference.*
- *primary stress is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations.*
- *primary general membrane stress is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.*
- *primary local membrane stress arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local, if:*

  $S_1 \leq 0,5 \sqrt{Rt}$

  $S_2 \geq 2,5 \sqrt{Rt}$

  where:

  S_1 : *Distance in the meridional direction over which the equivalent stress exceeds 1,1 f*

  S_2 : *Distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded*

  R : *Mean radius of the vessel*

  t : *Wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded; and*

  f : *Allowable primary general membrane stress.*
- *secondary stress is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.*

4.4 Design conditions

4.4.1 *All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in [4.5] to [4.7], and the load scenarios are covered by [4.2.2].*

4.5 Ultimate design condition

4.5.1 *Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the Code provisions.*

a) Plastic deformation and buckling shall be considered.

b) Analysis shall be based on characteristic load values as follows:
- *permanent loads: expected values*
- *functional loads: specified values*
- *environmental loads: for wave loads: most probable largest load encountered during 10^8 wave encounters.*

c) For the purpose of ultimate strength assessment, the following material parameters apply:
- *R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.*
- *R_m = specified minimum tensile strength at room temperature (N/mm^2).*

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloys, the respective R_e and R_m of the welds, after any applied heat treatment, shall be used. In such cases, the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in cargo containment systems.

The above properties shall correspond to the minimum specified mechanical properties of the material, including the weld metal in the as-fabricated condition. Subject to special consideration by the Society*, account may be taken of the enhanced yield stress and tensile strength at low temperature. The temperature on which the material properties are based shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.*

d) The equivalent stress σ_C (von Mises, Huber) shall be determined by:

$$\sigma_C = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3(\tau_{xz}^2 + \tau_{xy}^2 + \tau_{yz}^2)^2}$$

where:

σ_x : *Total normal stress in x-direction*

σ_y : *Total normal stress in y-direction*

σ_z : *Total normal stress in z-direction*

τ_{xy} : *Total shear stress in x-y plane*

τ_{xz} : *Total shear stress in x-z plane; and*

τ_{yz} : *Total shear stress in y-z plane.*

The above values shall be calculated as described in [4.2.3].

e) Allowable stresses for materials other than those covered by Ch 9, Sec 6 shall be subject to approval by the Society *in each case.*

f) Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

4.6 Fatigue design condition

4.6.1 *The fatigue design condition is the design condition with respect to accumulated cyclic loading.*

4.6.2 *Where a fatigue analysis is required, the cumulative effect of the fatigue load shall comply with:*

$$\sum \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \leq C_w$$

where:

n_i : *Number of stress cycles at each stress level during the life of the tank*

N_i : *Number of cycles to fracture for the respective stress level according to the Wohler (S-N) curve*

$n_{Loading}$: *Number of loading and unloading cycles during the life of the tank, not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle*

Note 1: 1000 cycles normally corresponds to 20 years of operation.

$N_{Loading}$: *Number of cycles to fracture for the fatigue loads due to loading and unloading; and*

C_w : *Maximum allowable cumulative fatigue damage ratio.*

The fatigue damage shall be based on the design life of the tank but not less than 10^8 wave encounters.

4.6.3 *Where required, the cargo containment system shall be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the cargo containment system. Consideration shall be given to various filling conditions.*

4.6.4

a) Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

b) The S-N curves shall be based on a 97,6% probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable C_w values specified in [4.6.7] to [4.6.9].

4.6.5 *Analysis shall be based on characteristic load values as follows:*

- *permanent loads: expected values*
- *functional loads: specified values or specified history*
- *environmental loads: expected load history, but not less than 10^8 cycles.*

If simplified dynamic loading spectra are used for the estimation of the fatigue life, they shall be specially considered by the Society.

4.6.6

a) *Where the size of the secondary barrier is reduced, as is provided for in [2.2.3], fracture mechanics analyses of fatigue crack growth shall be carried out to determine:*

- *crack propagation paths in the structure*
- *crack growth rate*
- *the time required for a crack to propagate to cause a leakage from the tank*
- *the size and shape of through thickness cracks; and*
- *the time required for detectable cracks to reach a critical state.*

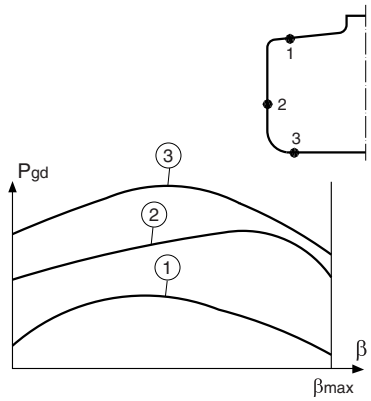
The fracture mechanics are, in general, based on crack growth data taken as a mean value plus two standard deviations of the test data.

b) *In analysing crack propagation, the largest initial crack not detectable by the inspection method applied shall be assumed, taking into account the allowable non-destructive testing and visual inspection criterion, as applicable.*

c) *Crack propagation analysis under the condition specified in [4.6.7]: the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in Fig 2. Load distribution and sequence for longer periods, such as in [4.6.8] and [4.6.9] shall be approved by* the Society.

d) *The arrangements shall comply with [4.6.7] to [4.6.9], as applicable.*

Figure 2 : Simplified load distribution



σ_0 is the most probable maximum stress over the life of the ship

Response cycle scale is logarithmic; the value of 2.10^5 is given as an example of estimate

4.6.7 *For failures that can be reliably detected by means of leakage detection, C_w shall be less than or equal to 0,5. Predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, shall not be less than 15 days, unless different requirements apply for ships engaged in particular voyages.*

4.6.8 *For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections, C_w shall be less than or equal to 0,5. Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three times the inspection interval.*

4.6.9 *In particular locations of the tank, where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria shall be applied as a minimum: C_w shall be less than or equal to 0,1. Predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three times the lifetime of the tank.*

4.7 Accident design condition

4.7.1 *The accident design condition is a design condition for accidental loads with extremely low probability of occurrence.*

4.7.2 *Analysis shall be based on the characteristic values as follows:*

- *permanent loads: expected values*
- *functional loads: specified values*
- *environmental loads: specified values*
- *accidental loads: specified values or expected values.*

4.7.3 *Loads mentioned in [3.3.9] and [3.5] need not be combined with each other or with wave-induced loads.*

5 Materials

5.1 General

5.1.1 *The purpose of this article is to ensure that the cargo containment system, the thermal insulation, adjacent ship structure and other materials in the cargo containment system are constructed from materials of suitable properties for the conditions they will experience, both in normal service and in the event of failure of the primary barrier, where applicable.*

5.2 Materials forming ship structure

5.2.1 *To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the cargo temperature is below – 10°C. The following assumptions shall be made in this calculation:*

a) The primary barrier of all tanks shall be assumed to be at the cargo temperature.

b) In addition to item a), where a complete or partial secondary barrier is required, it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only.

c) For worldwide service, ambient temperatures shall be taken as 5°C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and, conversely, lower values may be fixed by the Society *for ships trading to areas where lower temperatures are expected during the winter months.*

For the temperature calculation performed in view of the selection of steel grade for hull structures adjacent to the cargo containment system but not directly subject to the outside, air temperature is to be taken in accordance with the technical documentation submitted in the scope of the ship project review.

When the additional class notation **COLD BASIC (H t_{DH}, E t_{DE})** or **COLD (H t_{DH}, E t_{DE})** is assigned to the ship, two sets of temperature calculations are required, as defined in Pt F, Ch 8, Sec 4, [5.1.7]. The most stringent result is to be selected to determine the grade steel used in the hull structure.

d) Still air and seawater conditions shall be assumed, i.e. no adjustment for forced convection.

e) Degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations, as defined in [5.4.6] and [5.4.7], shall be assumed.

f) The cooling effect of the rising boil-off vapour from the leaked cargo shall be taken into account, where applicable.

g) Credit for hull heating may be taken in accordance with [5.2.5], provided the heating arrangements are in compliance with [5.2.6].

h) No credit shall be given for any means of heating, except as described in [5.2.5]; and

i) For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

The ambient temperatures used in the design, described in this paragraph, shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

5.2.2 *The shell and deck plating of the ship and all stiffeners attached thereto shall be in accordance with recognized standards. If the calculated temperature of the material in the design condition is below –5°C due to the influence of the cargo temperature, the material shall be in accordance with Ch 9, Sec 6, Tab 6*

5.2.3 *The materials of all other hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of cargo temperature and that do not form the secondary barrier, shall also be in accordance with Ch 9, Sec 6, Tab 6. This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.*

5.2.4 *The hull material forming the secondary barrier shall be in accordance with Ch 9, Sec 6, Tab 3. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Ch 9, Sec 6, Tab 3 shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.*

5.2.5 *Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in Ch 9, Sec 6, Tab 6. In the calculations required in [5.2.1], credit for such heating may be taken in accordance with the following:*

a) For any transverse hull structure

b) For longitudinal hull structure referred to in [5.2.2] and [5.2.3] where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of + 5°C for air and 0°C for seawater with no credit taken in the calculations for heating; and

c) As an alternative to item b), for longitudinal bulkhead between cargo tanks, credit may be taken for heating, provided the material remain suitable for a minimum design temperature of – 30°C, or a temperature 30°C lower than that determined by [5.2.1] with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with requirements of Part B, Chapter 6 for both when those bulkhead(s) are considered effective and not.

5.2.6 *The means of heating referred to in [5.2.5] shall comply with the following requirements:*

a) The heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to not less than 100% of the theoretical heat requirement

b) The heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with [5.2.5] a) shall be supplied from the emergency source of electrical power; and

c) The design and construction of the heating system shall be included in the approval of the containment system by the Society.

With reference to application of a) to c), the following requirements is to be considered:

- where the above requirements are met by duplication of the system components, i.e., heaters, glycol circulation pumps, electrical control panel, auxiliary boilers etc., all electrical components of at least one of the systems are to be supplied from the emergency source of electrical power.
- where duplication of the primary source of heat, e.g., oil-fired boiler is not feasible, alternative proposals may be accepted such as an electric heater capable of providing 100% of the theoretical heat requirement provided and supplied by an individual circuit arranged separately on the emergency switchboard. Other solutions may be considered towards satisfying the requirements of [5.2.5] provided a risk assessment is conducted to the satisfaction of the Society. The requirement of the previous bullet point continues to apply to all other electrical components in the system.

5.2.7 Segregation of heating plant

Where a hull heating system complying with [5.2.5] is installed, this system is to be contained solely within the cargo area or the drain returns from the hull heating coils in the wing tanks, cofferdams and double bottom are to be led to a degassing tank. The degassing tank is to be located in the cargo area and the vent outlets are to be located in a safe position and fitted with a flame screen.

Note 1: In the case of an indirect heating system applied to the heating of cofferdams, degassing tank is not mandatory.

5.2.8 First loaded voyage

Attention is drawn to the requirements of Ch 9, Sec 1, [6.2.4] regarding the satisfactory operation of the heating plant, that is to be ascertained during the first full loading and the subsequent first unloading of ships carrying liquefied natural gases (LNG) in bulk.

5.3 Materials of primary and secondary barrier

5.3.1 *Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with Ch 9, Sec 6, Tab 2, Ch 9, Sec 6, Tab 3 and Ch 9, Sec 6, Tab 4.*

5.3.2 *Materials, either non-metallic or metallic but not covered by Ch 9, Sec 6, Tab 2, Ch 9, Sec 6, Tab 3 and Ch 9, Sec 6, Tab 4 used in the primary and secondary barriers may be approved by* the Society, *considering the design loads that they may be subjected to, their properties and their intended use.*

5.3.3 *Where non-metallic materials, including composites, are used for, or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:*

- *compatibility with the cargoes*
- *ageing*
- *mechanical properties*
- *thermal expansion and contraction*
- *abrasion*
- *cohesion*
- *resistance to vibrations*
- *resistance to fire and flame spread; and*
- *resistance to fatigue failure and crack propagation.*

5.3.4 *The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and +5°C below the minimum design temperature, but not lower than −196°C.*

5.3.5 *Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes shall also be tested as described above.*

5.3.6 *Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in* Appendix 4 of the IGC Code.

5.3.7 *Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire-retardant barrier.*

5.4 Thermal insulation and other materials used in cargo containment systems

5.4.1 *Load-bearing thermal insulation and other materials used in cargo containment systems shall be suitable for the design loads.*

5.4.2 *Thermal insulation and other materials used in cargo containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:*

- *compatibility with the cargoes*
- *solubility in the cargo*
- *absorption of the cargo*
- *shrinkage*
- *ageing*
- *closed cell content*
- *density*
- *mechanical properties, to the extent that they are subjected to cargo and other loading effects, thermal expansion and contraction*
- *abrasion*
- *cohesion*
- *thermal conductivity*
- *resistance to vibrations*
- *resistance to fire and flame spread; and*
- *resistance to fatigue failure and crack propagation.*

5.4.3 *The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than –196°C.*

5.4.4 *Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it shall have suitable fire resistance properties in accordance with recognized standards or be covered with a material having low flame-spread characteristics and forming an efficient approved vapour seal.*

5.4.5 *Thermal insulation that does not meet recognized standards for fire resistance may be used in hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame-spread characteristics and that forms an efficient approved vapour seal.*

5.4.6 *Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.*

5.4.7 *Where powder or granulated thermal insulation is used, measures shall be taken to reduce compaction in service and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the cargo containment system.*

5.4.8 The materials for insulation are to be approved by the Society.

The approval of bonding materials, sealing materials, lining constituting a vapour barrier or mechanical protection is to be considered by the Society on a case-by-case basis. In any event, these materials are to be chemically compatible with the insulation material.

A particular attention is to be paid to the continuity of the insulation in way of tank supports.

5.4.9 Before applying the insulation, the surfaces of the tank structures or of the hull are to be carefully cleaned.

5.4.10 Where applicable, the insulation system is to be suitable to be visually examined at least on one side.

5.4.11 When the insulation is sprayed or foamed, the minimum steel temperature at the time of application is to be not less than the temperature given in the specification of the insulation.

6 Construction processes

6.1 General

6.1.1 *The purpose of this article is to define suitable construction processes and test procedures in order to ensure, as far as reasonably practical, that the cargo containment system will perform satisfactorily in service in accordance with the assumptions made at the stage design.*

6.2 Weld joint design

6.2.1 *All welded joints of the shells of independent tanks shall be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds shall also be designed with full penetration.*

The applicability of the expression "For dome-to-shell connections only" is clarified as follows:

- welded corners (i.e. corners made of weld metal) are not to be used in the main tank shell construction, i.e. corners between shell side (sloped plane surfaces parallel to hopper or top side inclusive if any) and bottom or top of the tank, and between tank end transverse bulkheads and bottom, top or shell sides (sloped plane surfaces inclusive if any) of the tank. Instead, tank corners which are constructed using bent plating aligned with the tank surfaces and connected with in-plane welds are to be used.
- tee welds can be accepted for other localised constructions of the shell such as suction well, sump, dome, etc. where tee welds of full penetration type are also to be used.

Note 1: This requirement is applicable to independent tanks of type A or type B, primarily constructed of plane surfaces. This includes the tank corners which are constructed using bent plating which is aligned with the tank surfaces and connected with in-plane welds.

6.2.2 *Welding joint details for type C independent tanks, and for the liquid-tight primary barriers Design for gluing of type B independent tanks primarily constructed of curved surfaces, shall be as follows:*

- *all longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure; and*
- *the bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a standard acceptable to* the Society. *All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.*

This requirement is applicable to type C independent tanks including bi-lobe tanks, primarily constructed of curved surfaces fitted with a centreline bulkhead. The applicability of the expression "Other edge preparations" is clarified as follows:

- cruciform full penetration welded joints in a bi-lobe tank with centreline bulkhead can be accepted for the tank structure construction at tank centreline welds with bevel preparation subject to the approval of the Society, based on the results of the tests carried out at the approval of the welding procedure.

6.2.3 *Where applicable, all the construction processes and testing, except that specified in [6.4], shall be done in accordance with the applicable provisions of Ch 9, Sec 6.*

6.2.4 The following provisions apply to independent tanks:

- tracing, cutting and shaping are to be carried out so as to prevent, at the surface of the pieces, the production of defects detrimental to their use. In particular, marking the plates by punching and starting welding arcs outside the welding zone are to be avoided.
- before welding, the edges to be welded are to be carefully examined, with possible use of non-destructive examination, in particular when chamfers are carried out.
- in all cases, the working units are to be efficiently protected against bad weather.
- the execution of provisional welds, where any, is to be subjected to the same requirements as the constructional welds. After elimination of the fillets, the area is to be carefully ground and inspected (the inspection is to include, if necessary, a penetrant fluid test).
- all welding consumables are subject to agreement. Welders are also to be agreed.

6.3 Design for gluing and other joining processes

6.3.1 *The design of the joint to be glued (or joined by some other process except welding) shall take account of the strength characteristics of the joining process.*

6.4 Testing

6.4.1 *All cargo tanks and process pressure vessels shall be subjected to hydrostatic or hydropneumatic pressure testing in accordance with [8] to [13], as applicable for the tank type.*

6.4.2 *All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in [6.4.1].*

6.4.3 *Requirements with respect to inspection of secondary barriers shall be decided by* the Society *in each case, taking into account the accessibility of the barrier (see [2.4.3]).*

6.4.4 For containment systems with glued secondary barriers:

- at the time of construction, a tightness test is to be carried out in accordance with approved system designers' procedures and acceptance criteria before and after initial cooldown. Low differential pressures tests are not considered an acceptable test.
- if the designer's threshold values are exceeded, an investigation is to be carried out and additional testing such as thermographic or acoustic emissions testing is to be carried out.
- the values recorded are to be used as reference for future assessment of secondary barrier tightness.

For containment systems with welded metallic secondary barriers, a tightness test after initial cooldown is not required.

6.4.5 The Society *may require that for ships fitted with novel type B independent tanks, or tanks designed according to [14.1] at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.*

6.4.6 *The overall performance of the cargo containment system shall be verified for compliance with the design parameters during the first full loading and discharging of the cargo, in accordance with the survey procedure and requirements in IGC Code, 1.6, and the requirements of* the Society. *Records of the performance of the components and equipment essential to verify the design parameters, shall be maintained and be available to* the Society.

6.4.7 *Heating arrangements, if fitted in accordance with [5.2.5] and [5.2.6], shall be tested for required heat output and heat distribution.*

6.4.8 *The cargo containment system shall be inspected for cold spots during, or immediately following, the first loaded voyage. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with recognized standards.*

6.4.9 If the tests are performed while the cargo tanks are filled or partially filled, they are to be performed at the minimum service temperature, as far as practicable.

6.4.10 The reliquefaction and inert gas production systems, if any, and the installation, if any, for use of gas as fuel for boilers and internal combustion engines are also to be tested to the satisfaction of the Surveyor.

6.4.11

- all operating data and temperatures read during the first voyage of the loaded ship are to be sent to the Society
- attention is drawn to the requirements of Ch 9, Sec 1, [6.2.4] regarding the cold spots examination that is to be carried out during the first loaded voyage.

6.4.12 All data and temperatures read during subsequent voyages are to be kept at the disposal of the Society for a suitable period of time.

7 Supports

7.1 Supporting arrangement

7.1.1 *The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in [3.2] to [3.5], where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.*

7.1.2 *Supports and supporting arrangements shall withstand the loads defined in [3.3.9] and [3.5], but these loads need not be combined with each other or with wave-induced loads*

7.1.3 The reaction forces in way of tank supports are to be transmitted as directly as possible to the hull primary supporting members, minimising stress concentrations.

Where the reaction forces are not in the plane of primary members, web plates and brackets are to be provided in order to transmit these loads by means of shear stresses.

7.1.4 Special attention is to be paid to continuity of structure between circular tank supports and the primary supporting members of the ship.

7.1.5 Openings in tank supports and hull structures in way of tank supports are to be minimized and local strengthening may be necessary.

7.1.6 Insulating materials for tank supports are to be type approved by the Society.

Note 1: In addition to the justification of mechanical properties, the water absorption of the material should not be more than 6% when determined in accordance with DIN 53 495.

7.2 Calculation of reaction forces in way of tank supports

7.2.1 The reaction forces in way of tank supports are to be obtained from the structural analysis of the tank or stiffening rings in way of tank supports, considering the loads specified in [3.2] to [3.5].

The final distribution of the reaction forces at the supports is not to show any tensile forces.

7.3 Checking criteria

7.3.1 The supports of independent tanks of type A and type B which are primarily constructed of plane surfaces are to be checked in accordance with [7.4] and the following criteria:

a) For supports analysed through beam model, it is to be checked that the combined stress σ_C, in N/mm^2, is in compliance with the following formula:

$\sigma_C \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, defined in Tab 2 for each acceptance criteria.

b) For supports analysed through finite element model, the yield criteria, defined in Pt B, Ch 8, App 1, [5.2.3] for standard mesh size or in Pt B, Ch 8, App 2, [4.1.3] for fine mesh models, are to be checked.

Table 2 : Beam model: Allowable stresses σ_{ALL}, in N/mm^2 in all types of supports

Acceptance criteria	AC-1	AC-2	AC-3 **(1)**
σ_{ALL}, in N/mm^2	The lower of: • 0,9 R_m / 2,66 • 0,9 R_{eH} / 1,33	The lower of: • R_m / 2,66 • R_{eH} / 1,33	0,85 Ry
(1) Flooding, static heel 30° and collision conditions are to be checked considering AC-3 criteria			

7.3.2 The supports of independent tanks of type C are to be checked in accordance with [7.6] and the criteria given in [7.3.1]

7.3.3 The cylindrical skirts supporting independent tanks of type B which are primarily constructed of bodies of revolution are to be checked in accordance with [7.6] and the criteria given in [9.3] and [9.5].

7.4 Supports of independent tanks of type A and type B primarily constructed of plane surfaces

7.4.1 *For parts, such as supporting structures, not otherwise covered by the requirements of the Code, stresses shall be determined by direct calculations, taking into account the loads referred to in [3.2] to [3.5] as far as applicable, and the ship deflection in way of supporting structures.*

7.4.2 *The tanks with supports shall be designed for the accidental loads specified in [3.5]. These loads need not be combined with each other or with environmental loads.*

7.4.3 Moreover the tanks with supports are also to be designed for a static angle of heel of 30°.

7.4.4 Vertical supports

The structure of the tank and of the ship is to be reinforced in way of the vertical supports so as to withstand the reactions and the corresponding moments.

For the purpose of this assessment, the frictional coefficient of the vertical supports is to be taken equal to 0,3 unless duly justified.

Dam plates, fitted to secure the wood, are to be designed to withstand, in all seagoing load cases and assuming a failure of the resin holding the wood, an horizontal force taken equal to the minimum between:

- 10% of the vertical reaction on the support
- the horizontally accelerated weight of the tank in a direction perpendicular to the dam plates and distributed among all the vertical supports.

7.4.5 Antirolling supports

Antirolling supports are to be checked under transverse and vertical reactions, as defined in [7.2.1] for the inclined ship conditions, and applied on the maximum weight of the full tank.

Antirolling supports are also to be checked for a static angle of heel of 30°.

For the purpose of this assessment, the frictional coefficient of the vertical supports is to be taken equal to 0,1 unless duly justified.

7.4.6 Antipitching supports

Antipitching supports are to be checked under longitudinal and vertical reactions, as defined in [7.2.1] for the upright conditions, and applied on the maximum weight of the full tank.

7.4.7 Anticollision supports

Anticollision supports are to be provided to withstand a collision force acting on the tank taken respectively equal to:

- one half of the weight of the tank and cargo in the forward direction
- one quarter of the weight of the tank and cargo in the aft direction.

Antipitching supports may be combined with anticollision supports.

7.4.8 Antiflotation supports

a) Anti-flotation arrangements shall be provided for independent tanks and capable of withstanding the loads defined in [3.5.3] without plastic deformation likely to endanger the hull structure.

b) Adequate clearance between the tanks and the hull structures is to be provided in all operating conditions.

Antiflotation supports are to be provided and are to be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the scantling draught T_{sc}.

7.5 Supports of independent tanks of type B primarily constructed of bodies of revolution

7.5.1 Cylindrical skirt

Cylindrical skirts supporting spherical independent tanks of type B are to be checked under longitudinal, transverse and vertical reactions, as defined in [7.2.1] for the upright and inclined conditions, and applied on the tank assumed full.

Antipitching supports are also to be checked for the following accidental conditions:

- static angle of heel of 30°
- collision force acting on the tank taken respectively equal to:
  - one half of the weight of the tank and cargo in the forward direction
  - one quarter of the weight of the tank and cargo in the aft direction.
- flooding loads defined in [3.5.3].

7.6 Supports of type C independent tanks

7.6.1 *The tanks with supports shall be designed for the accidental loads specified in [3.5]. These loads need not be combined with each other or with environmental loads.*

7.6.2 Moreover the tanks with supports are also to be designed for a static angle of heel of 30°.

8 Type A independent tanks

8.1 Design basis

8.1.1 *Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with recognized standards. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_o shall be less than 0.07 MPa.*

8.1.2 *If the cargo temperature at atmospheric pressure is below –10°C, a complete secondary barrier shall be provided as required in [2.3]. The secondary barrier shall be designed in accordance with [2.4].*

8.2 Structural analyses

8.2.1 *A structural analysis shall be performed taking into account the internal pressure as indicated in [3.3.2], and the interaction loads with the supporting and keying system as well as a reasonable part of the ship's hull.*

8.3 Ultimate design condition

8.3.1 *For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of R_m /2,66 or R_{eH} /1,33 for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and R_{eH} are defined in [4.5], item c). However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c, as defined in [4.5], item d), may be increased over that indicated above to a stress acceptable to* the Society. *Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.*

8.3.2 *Tank boundary scantlings shall meet at least the requirements of* the Society *for deep tanks taking into account the internal pressure as indicated in [3.3.2] and any corrosion allowance required by [2.1.5].*

8.3.3 Plating

a) The net thickness of plating subjected to lateral pressure, in mm, is to be checked according to Pt B, Ch 7, Sec 4, [1.1.1], considering:

$P = P_{eq}$

$$C_a = C_{a\text{-}max}\min\left[1;\frac{R_m}{1,50R_{eH}}\right]$$

where:

P_{eq} : Internal lateral pressure, in kN/m², in the tank, as defined in [3.3.2] item e)

b) The net thickness of plating subjected to testing pressure, in mm, is to be checked according to Pt B, Ch 7, Sec 4, [1.1.1], considering:

$P = P_{ST}$

$$C_a = \min\left[1;\frac{R_m}{1,50R_{eH}}\right]$$

where:

P_{ST} : Testing pressure, in kN/m², obtained according to [8.5].

c) For sloshing loads:

- The net thickness of plating subjected to sloshing pressure is to be checked according to Pt B, Ch 11, Sec 4, [2.1.1]

$$C_a = C_{a\text{-}max}\min\left[1;\frac{R_m}{1,50R_{eH}}\right]$$

- The net thickness of plating subjected to sloshing impact pressure is to be checked according to Pt B, Ch 7, Sec 4, [4.1.1], considering:

$$C_a = \min\left[1;\frac{R_m}{1,50R_{eH}}\right]$$

8.3.4 Ordinary stiffeners

a) The net section modulus Z, in cm³, and the net web thickness t_w, in mm, of ordinary stiffeners subjected to lateral pressure are to be checked according to Pt B, Ch 7, Sec 5, [1.1] considering:

$P = P_{eq}$

$$C_s = C_t = \min\left[\frac{1}{1,33};\frac{R_m}{2,66R_{eH}}\right]$$

where:

P_{eq} : Internal lateral pressure, in kN/m², as defined in [3.3.2] item e)

b) The net section modulus Z, in cm³, and the net web thickness t_w, in mm, of ordinary stiffeners subjected to testing pressure are to be checked according to Pt B, Ch 7, Sec 5, [1.1] considering:

$P = P_{ST}$

where:

P_{ST} : Testing pressure, in kN/m², obtained according to [8.5].

$$C_s = C_t = \min\left[\frac{1}{1,33};\frac{R_m}{2,66R_{eH}}\right]$$

c) For sloshing loads:

- The net section modulus Z, in cm³, of ordinary stiffeners subjected to sloshing pressure, including longitudinals, is to be checked according to Pt B, Ch 11, Sec 4, [2.2.1], considering:

$$C_s = \min\left[\frac{1}{1,33};\frac{R_m}{2,66R_{eH}}\right]$$

- The net plastic section modulus Z_{pl}, in cm³, and the net web thickness t_w, in mm, of ordinary stiffeners subjected to sloshing impact pressure are to be checked according to Pt B, Ch 7, Sec 5, [1.3.1], considering:

$$C_s = C_t = \min\left[\frac{1}{1,33};\frac{R_m}{2,66R_{eH}}\right]$$

8.3.5 Primary supporting members

a) The scantlings of primary supporting members are to be not less than those obtained considering the lateral pressure P_{IGC} defined in [3.3.2], item e) and checking criteria specified in d).

When calculating the internal pressure, the tank dome part to be considered in the accepted total tank volume is to be calculated according to Ch 9, App 1, [1.1.2].

b) Checking criteria:

- for primary supporting members analysed through beam model, it is to be checked that the combined stress, in N/mm^2, is in compliance with the following formula:

  $\sigma_C \leq \sigma_{ALL}$

  where:

  σ_{ALL} : Allowable stress, in N/mm^2, to be taken as:

  $$\sigma_{ALL} = \min\left[\frac{R_m}{2,66}; \frac{R_{eH}}{1,33}\right]$$

- for primary supporting members analysed through finite element model, the yield criteria are those corresponding to the AC-1 or AC-2 acceptance criteria defined in Pt B, Ch 8, App 1, [5.2.3] and Pt B, Ch 8, App 2, [4.1.3] , considering R_y as follows for the determination of λ_y and λ_f:

  $$R_y = \min\left[R_{eH}; \frac{R_m}{1,50}\right]$$

8.3.6 Buckling

The scantlings of cargo tank structure of type A independent tanks are to comply with the buckling requirements given in Pt B, Ch 9, Sec 1 for the AC-1 or AC-2 acceptance criteria, as applicable.

8.4 Accident design conditions

8.4.1 *The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in [2.1.4], item c) and [3.5], as relevant.*

8.4.2 *When subjected to the accidental loads specified in [3.5]* and [3.3.9], *the stress shall comply with the acceptance criteria specified in [8.3], modified as appropriate, taking into account their lower probability of occurrence.*

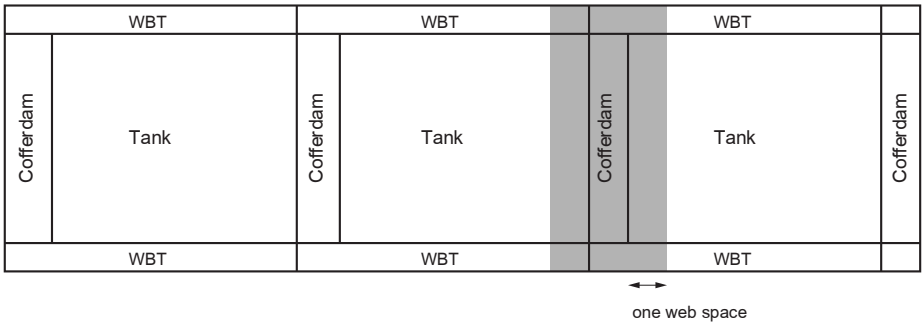
8.4.3 Collision condition

For collision loads, the lateral pressure to be considered is to be calculated according to [3.5.2].

The verification is to be carried out for structural members of transverse bulkhead up to the first adjacent web frame, as shown in Fig 3.

Buckling check is not required for collision condition.

Figure 3 : Extent of structural assessment for collision condition



8.4.4 Heel condition

For static heel loads, the lateral pressure to be considered is to be calculated according to [3.3.9].

Buckling check is not required for heel condition.

8.4.5 Plating

Plating is to be checked according to the requirements given in Part B, Chapter 7, Section 4, considering:

$$C_a = \min\left[1; \frac{R_m}{1,50R_{eH}}\right]$$

8.4.6 Ordinary stiffeners

Ordinary stiffeners are to be checked according to the requirements given in Part B, Chapter 7, Section 5, considering:

$$C_s = C_t = C_{comb} = \min\left[1; \frac{R_m}{1,50R_{eH}}\right]$$

8.4.7 Primary supporting members

Primary structural members analyzed by means of beam model are to be checked according to the requirements given in Part B, Chapter 7, Section 6, considering:

$$C_s = C_t = C_{comb} = \min\left[0,90;\frac{0,90R_m}{1,50R_{eH}}\right]$$

For primary supporting members analysed through finite element model, the yield criteria are those corresponding to the acceptance criteria AC-3 defined in Pt B, Ch 8, App 1, [5.2.3] and Pt B, Ch 8, App 2, [4.1.3], considering R_y as follows for the determination of λ_y, λ_{yperm}, λ_f and λ_{fperm}:

$$R_y = \min\left[R_{eH};\frac{R_m}{1,50}\right]$$

8.5 Testing

8.5.1 Testing

All type A independent tanks shall be subjected to a hydrostatic or hydropneumatic test. This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions shall simulate, as far as practicable, the design loading of the tank and of its support structure, including dynamic components, while avoiding stress levels that could cause permanent deformation.

8.5.2 The conditions in which testing is performed are to simulate as far as possible the actual loading on the tank and its supports.

8.5.3 When testing takes place after installation of the cargo tank, provision is to be made prior to the launching of the ship in order to avoid excessive stresses in the ship structures.

9 Type B independent tanks

9.1 Design basis

9.1.1 *Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks), the design vapour pressure P_o shall be less than 0,07 MPa.*

9.1.2 *If the cargo temperature at atmospheric pressure is below –10°C, a partial secondary barrier with a small leak protection system shall be provided as required in [2.3]. The small leak protection system shall be designed according to [2.5].*

9.2 Structural analyses

9.2.1 *The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:*

- *plastic deformation*
- *buckling*
- *fatigue failure; and*
- *crack propagation.*

Finite element analysis or similar methods and fracture mechanics analysis, or an equivalent approach, shall be carried out.

9.2.2 *A three-dimensional analysis shall be carried out to evaluate the stress levels, including interaction with the ship's hull. The model for this analysis shall include the cargo tank with its supporting and keying system, as well as a reasonable part of the hull.*

9.2.3 Analysis criteria

The analysis of the primary supporting members of the tank subject to lateral pressure based on a three dimensional model is to be carried out according to the following requirements:

- the structural modeling is to comply with the requirements in Pt B, Ch 8, App 1, [2.4]
- the stress calculation is to comply with the requirements in Pt B, Ch 8, App 1, [5.2.1]
- the model extension is to comply with [9.2.4]
- the wave hull girder loads and the wave pressures to be applied on the model are to comply with [9.2.5]
- the inertial loads to be applied on the model are to comply with [3.3.2].

9.2.4 Model extension

The longitudinal extension of the structural model is to comply with Pt B, Ch 8, App 1, [2.2.1]. In any case, the structural model is to include the hull and the tank with its supporting and keying system.

9.2.5 Wave hull girder loads and wave pressures

A complete analysis of the particular ship accelerations and motions in irregular waves, and of the response of the ship and its cargo tanks to these forces and motions shall be performed, unless the data is available from similar ships.

Wave hull girder loads and wave pressures are to be obtained as the most probable the ship may experience during its operating life, for a probability level of 10^{-8}.

Calculation are to be submitted to the Society for approval, unless these data are available from similar ships.

9.3 Ultimate design condition

9.3.1 Plating and ordinary stiffeners

The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks.

Scantlings of plating and ordinary stiffeners are to be calculated according to [8.3].

9.3.2 Primary supporting members

a) Type B independent tanks primarily constructed of bodies of revolution, including the cylindrical skirt

1) The equivalent stresses of primary supporting members of type B independent tanks primarily constructed of bodies of revolution are to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_E : Equivalent stress, in N/mm^2, to be obtained from the formula in [4.5.1] item d) for each of the following stress categories, defined in:

- primary general membrane stress
- primary local membrane stress
- primary bending stress
- secondary stress

σ_{ALL} : Allowable stress defined as follows:

- for finite element analysis based on standard mesh models in sea going condition: see item 2)
- for finite element analysis based on fine mesh models or other design conditions: the allowable stress defined in item 2) is to be multiplied by the factors defined in Tab 4.

Note 1: Standard mesh and fine mesh are defined in Part B, Chapter 8.

2) For type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses shall not exceed:

$\sigma_m \leq f$

$\sigma_L \leq 1,5\ f$

$\sigma_b \leq 1,5\ F$

$\sigma_L + \sigma_b \leq 1,5\ F$

$\sigma_m + \sigma_b \leq 1,5\ F$

$\sigma_m + \sigma_b + \sigma_g \leq 3,0\ F$

$\sigma_L + \sigma_b + \sigma_g \leq 3,0\ F$

where:

σ_m : *Equivalent primary general membrane stress*

σ_L : *Equivalent primary local membrane stress*

σ_b : *Equivalent primary bending stress*

σ_g : *Equivalent secondary stress*

f : *The lesser of (R_m / A) or (R_e / B); and*

F : *The lesser of (R_m / C) or (R_e / D)*

with R_m and R_e as defined in [4.5.1], item c). With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in [4.3] are referred. The values A and B (and C and D) *shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least minimum values as per Tab 3.*

The above figures may be altered, taking into account the design condition considered in acceptance with the Society.

b) Type B independent tanks, primarily constructed of plane surfaces

1) The equivalent stresses of primary supporting members of type B independent tanks primarily constructed of plane surfaces are to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_E : Equivalent stress, in N/mm^2, to be obtained from the formulae in Pt B, Ch 8, App 1, [5.2.1], as a result of direct calculations to be carried out in accordance with [9.2.3]

σ_{ALL} : Allowable stress defined as follows:

- for finite element analysis based on standard mesh models in sea going condition: see item 2)
- for finite element analysis based on fine mesh models or other design conditions, the allowable stresses σ_{ALL} is to be taken equal to:

$\sigma_{ALL} = min\ (\alpha R_m; \beta R_e)$

where

α *and* β *are defined in Tab 5.*

Note 2: Standard mesh and fine mesh are defined in Part B, Chapter 8.

2) *For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis shall not exceed:*

- *for nickel steels and carbon-manganese steels, the lesser of R_m /2 or R_e /1,2;*
- *for austenitic steels, the lesser of R_m / 2,5 or R_e / 1,2; and*
- *for aluminium alloys, the lesser of R_m /2.5 or R_e /1,2.*

The above figures may be amended, taking into account the locality of the stress, stress analysis methods and design condition considered in acceptance with the Society.

Table 3 : Minimum values of material coefficients

	Nickel steels and carbon manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	2	1,6	1,5
C	3	3	3
D	1,5	1,5	1,5

Table 4 : Finite element allowable stresses factors for spherical type B independent tanks

Design condition	Type of finite element model	
	Global standard mesh	Local fine mesh (only applicable to the supporting skirt)
Harbour (AC-1)	0,8	• Elements not adjacent to welding: 1,36 • Elements adjacent to welding: 1,20
Ultimate (AC-2)	1,0	• Elements not adjacent to welding: 1,70 • Elements adjacent to welding: 1,50
Accidental (AC-3)	1,2	• Elements not adjacent to welding: 2,00 • Elements adjacent to welding: 1,80

Table 5 : Finite element allowable stresses coefficients for prismatic type B independent tanks

Design condition	Materials	Standard mesh model		Fine mesh model			
				Not adjacent to weld		Adjacent to weld	
		α	β	α	β	α	β
Harbour (AC-1)	Nickel steels Carbon-manganese steels	0,40	0,67	0,68	1,13	0,60	1,00
	Austenitic steels Aluminium alloys	0,32	0,67	0,54	1,13	0,48	1,00
Ultimate (AC-2)	Nickel steels Carbon-manganese steels	0,50	0,83	0,85	1,42	0,75	1,25
	Austenitic steels Aluminium alloys	0,40	0,83	0,68	1,42	0,6	1,25
Accidental (AC-3)	Nickel steels Carbon-manganese steels	0,59	1,00	1,00	1,70	0,88	1,50
	Austenitic steels Aluminium alloys	0,50	1,00	0,85	1,70	0,75	1,50

9.3.3 Buckling

a) Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable.

b) The scantlings of plating and ordinary stiffeners of type B independent tanks are to comply with the buckling requirements given in Pt B, Ch 9, Sec 1 for the AC-1 or AC-2 acceptance criteria, as applicable respectively for harbour and seagoing conditions.

c) A local buckling check is to be carried out according to Pt B, Ch 9, Sec 1 for plate panels which constitute primary supporting members for the AC-1 or AC-2 acceptance criteria, as applicable respectively for harbour and seagoing conditions.

In performing this check, the stresses in the plate panels are to be obtained from direct calculations to be carried out in accordance with [9.2.3].

9.4 Fatigue design condition

9.4.1 *Fatigue and crack propagation assessment shall be performed in accordance with [4.6]. The acceptance criteria shall comply with [4.6.7], [4.6.8], [4.6.9] depending on the detectability of the defect.*

9.4.2 *Fatigue analysis shall consider construction tolerances.*

9.4.3 *Where deemed necessary by* the Society*, model tests may be required to determine stress concentration factors and fatigue life of structural elements.*

9.4.4 Fatigue analysis

a) General

The fatigue analysis is to be performed for areas where high wave induced stresses or large stress concentrations are expected, for welded joints and parent material. Such areas are to be defined by the Designer and agreed by the Society on a case-by-case basis.

b) Material properties

The material properties affecting fatigue of the items checked are to be documented. Where this documentation is not available, the Society may request to obtain these properties from experiments performed in accordance with recognised standards.

c) Wave loads

In upright ship and in inclined ship conditions the wave loads to be considered for the fatigue analysis of the tank include:

- maximum and minimum wave hull girder loads and wave pressures, to be obtained from a complete analysis of the ship motion and accelerations in irregular waves, to be submitted to the Society for approval, unless these data are available from similar ships. These loads are to be obtained as the most probable the ship may experience during its operating life, for a probability level of 10^{-8}.
- maximum and minimum inertial pressures, to be obtained from the formulae in [3.3.2] as a function of the arbitrary direction β.

d) Simplified stress distribution for fatigue analysis

The simplified long-term distribution of wave loads indicated in [4.6.6], item c) may be represented by means of 8 stress ranges, each characterised by an alternating stress $\pm \sigma_i$ and a number of cycles n_i (see Fig 4). The corresponding values of σ_i and n_i are to be obtained from the following formulae:

$$\sigma_i = \sigma_0\left(1{,}0625 - \frac{i}{8}\right)$$

$$n_i = 0{,}9 \cdot 10^i$$

where:

σ_i : Stress (i = 1, 2,..., 8), in N/mm^2 (see Fig 4)

σ_0 : Most probable maximum stress over the life of the ship, in N/mm^2, for a probability level of 10^{-8}

n_i : Number of cycles for each stress σ_i considered (i = 1, 2,..., 8).

e) Conventional cumulative damage

For each structural detail for which the fatigue analysis is to be carried out, the conventional cumulative damage is to be calculated according to the following procedure:

- the long-term value of hot spot stress range $\Delta\sigma_{S,0}$ is to be obtained from the following formula:

$$\Delta\sigma_{S,0} = |\sigma_{S,MAX} - \sigma_{S,MIN}|$$

where:

$\sigma_{S,MAX}$, $\sigma_{S,MIN}$: Maximum and minimum hot spot stress to be obtained from a structural analysis carried out in accordance with Part B, Chapter 10 and NI611, where the wave loads are those defined in [9.4.4] item c).

- the long-term value of the notch stress range $\Delta\sigma_{N,0}$ is obtained from the formulae in Pt B, Ch 10, Sec 1 as a function of the hot spot stress range $\Delta\sigma_{S,0}$.
- the long-term distribution of notch stress ranges $\Delta\sigma_{N,I}$ is to be calculated. Each stress range $\Delta\sigma_{N,I}$ of the distribution, corresponding to n_i stress cycles, is obtained from the formulae in item d), where σ_0 is taken equal to $\Delta\sigma_{N,0}$.
- for each notch stress range $\Delta\sigma_{N,I}$, the number of stress cycles N_I which cause the fatigue failure is to be obtained by means of S-N curves corresponding to the as-rolled condition (see Fig 5). The criteria adopted for obtaining the S-N curves are to be documented. Where this documentation is not available, the Society may require the curves to be obtained from experiments performed in accordance with recognised standards.
- the conventional cumulative damage for the i notch stress ranges $\Delta\sigma_{N,I}$ is to be obtained from the formula in [4.6.2].

f) Check criteria

The conventional cumulative damage, to be calculated according to item e) is to be not greater than C_W, defined in [4.6.2].

Figure 4 : Simplified stress distribution for fatigue analysis

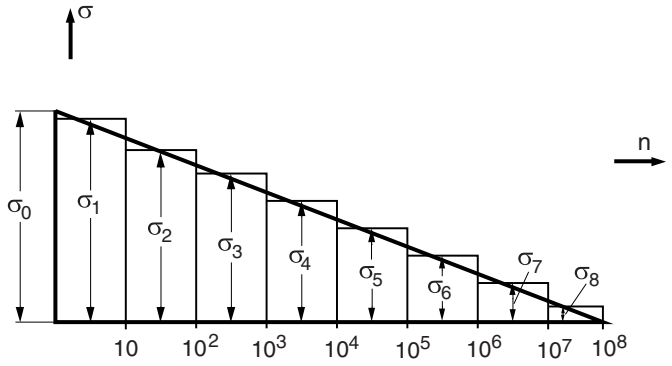
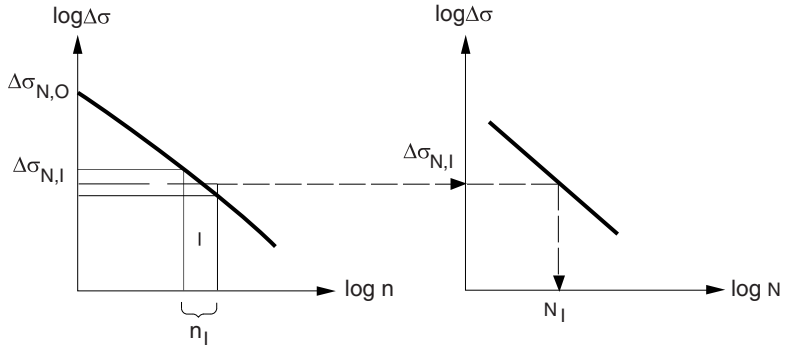


Figure 5 : Fatigue check based on conventional cumulative damage method



9.4.5 Crack propagation analysis

a) General

The crack propagation analysis is to be carried out for highly stressed areas. The latter are to be defined by the Designer and agreed by the Society on a case-by-case basis. Propagation rates in the parent material, weld metal and heat-affected zone are to be considered.

The following checks are to be carried out:

- crack propagation from an initial defect, in order to check that the defect will not grow and cause a brittle fracture before the defect is detected; this check is to be carried out according to item d)
- crack propagation from an initial through thickness defect, in order to check that the defect, resulting in a leakage, will not grow and cause a brittle fracture less than 15 days after its detection; this check is to be carried out according to item e).

b) Material properties

The material fracture mechanical properties used for the crack propagation analysis, i.e. the properties relating the crack propagation rate to the stress intensity range at the crack tip, are to be documented for the various thicknesses of parent material and weld metal alike. Where this documentation is not available, the Society may request to obtain these properties from experiments performed in accordance with recognised standards.

c) Simplified stress distribution for crack propagation analysis

The simplified wave load distribution indicated in [4.6.6] item c) may be represented over a period of 15 days by means of 5 stress ranges, each characterised by an alternating stress $\pm \sigma_i$ and number of cycles, n_i (see Fig 6). The corresponding values of σ_i and n_i are to be obtained from the following formulae:

$$\sigma_i = \sigma_0\left(1,1 - \frac{i}{5,3}\right)$$

$$n_i = 0,913 \cdot 10^i$$

where:

σ_i : Stress (i = 1,06; 2,12; 3,18; 4,24; 5,30), in N/mm^2 (see Fig 6)

σ_0 : Defined in [9.4.4], item d)

n_i : Number of cycles for each stress σ_i considered (i = 1,06; 2,12; 3,18; 4,24; 5,30).

d) Crack propagation analysis from an initial defect

It is to be checked that an initial crack will not grow, under wave loading based on the stress distribution in [9.4.4] d), beyond the allowable crack size.

The initial size and shape of the crack is to be considered by the Society on a case-by-case basis, taking into account the structural detail and the inspection method.

The allowable crack size is to be considered by the Society on a case-by-case basis; in any event, it is to be taken less than that which may lead to a loss of effectiveness of the structural element considered.

e) Crack propagation analysis from an initial through thickness defect

It is to be checked that an initial through thickness crack will not grow, under dynamic loading based on the stress distribution in item c), beyond the allowable crack size.

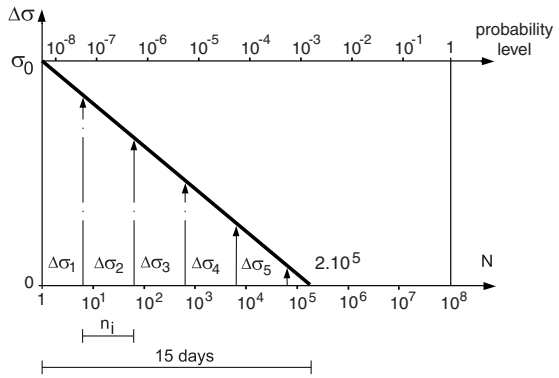
The initial size of the through thickness crack is to be taken not less than that through which the minimum flow size that can be detected by the monitoring system (e.g. gas detectors) may pass.

The allowable crack size is to be considered by the Society on a case-by-case basis; in any event, it is to be taken far less than the critical crack length, defined in item f).

f) Critical crack length

The critical crack length is the crack length from which a brittle fracture may initiate and it is to be considered by the Society on a case-by-case basis. In any event, it is to be evaluated for the most probable maximum stress experienced by the structural element in the ship life, which is equal to the stress in the considered detail obtained from the structural analysis to be performed in accordance with [9.2.3].

Figure 6 : Simplified stress distribution for crack propagation analysis



9.5 Accident design condition

9.5.1 *The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in [2.1.4], item c) and [3.5], as applicable.*

9.5.2 *When subjected to the accidental loads specified in [3.5]* and [3.3.9], *the stress shall comply with the acceptance criteria specified in [9.3], modified as appropriate, taking into account their lower probability of occurrence.*

9.5.3 Collision and heel conditions

The tank plating and ordinary stiffeners are to be checked for collision and heel loads using pressures and criteria defined in [8.4.3].

The tank primary supporting members are to be checked for collision and heel loads using pressures defined in respectively [3.5.2] and [3.3.9] according to the AC-3 criteria defined in [9.3.2] for accidental design conditions.

9.6 Testing

9.6.1 *Type B independent tanks shall be subjected to a hydrostatic or hydropneumatic test as follows:*

- *the test shall be performed as required in [8.5] for type A independent tanks; and*
- *in addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment.*

9.6.2 The conditions in which testing is performed are to simulate as far as possible the actual loading on the tank and its supports.

9.6.3 When testing takes place after installation of the cargo tank, provision is to be made prior to the launching of the ship in order to avoid excessive stresses in the ship structures.

9.7 Marking

9.7.1 *Any marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.*

10 Type C independent tanks

10.1 Design basis

10.1.1 *The design basis for type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in item [10.1.2] is intended to ensure that the dynamic stress is sufficiently low, so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.*

10.1.2 *The design vapour pressure, in MPa, shall not be less than:*

$P_o = 0.2 + AC(\rho_r)^{1,5}$

where:

$$A = 0{,}00185 \left(\frac{\sigma_m}{\Delta\sigma_A}\right)^2$$

with:

σ_m : *Design primary membrane stress*

$\Delta\sigma_A$: *Allowable dynamic membrane stress (double amplitude at probability level $Q = 10^{-8}$) and equal to:*

- *55 N/mm² for ferritic-perlitic, martensitic and austenitic steel*
- *25 N/mm² for aluminium alloy (5083-O)*

C : *A characteristic tank dimension to be taken as the greatest of the following:*

- h
- $0{,}75\ b$
- $0{,}45\ \ell$

with

h : *Height of tank (dimension in ship's vertical direction), in m*

b : *Width of tank (dimension in ship's transverse direction), in m*

ℓ : *Length of tank (dimension in ship's longitudinal direction), in m*

ρ_r : *The relative density of the cargo ($\rho_r = 1$ for fresh water) at the design temperature.*

When a specified design life of the tank is longer than 10^8 wave encounters, $\Delta\sigma_A$ shall be modified to give equivalent crack propagation corresponding to the design life.

10.1.3 The Society *may allocate a tank complying with the criteria of type C tank minimum design pressure as in [10.1.2], to a type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.*

10.2 Shell thickness

10.2.1 *The shell thickness shall be as follows:*

a) *For pressure vessels, the thickness calculated according to [10.2.4] shall be considered as a minimum thickness after forming, without any negative tolerance.*

b) *For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, shall not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.*

c) *The welded joint efficiency factor to be used in the calculation according to [10.2.4] shall be 0,95 when the inspection and the non-destructive testing referred to in Ch 9, Sec 6, [5.6.8] are carried out. This figure may be increased up to 1 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels,* the Society *may accept partial non-destructive examinations, but not less than those of Ch 9, Sec 6, [5.6.7], depending on such factors as the material used, the design temperature, the nil-ductility transition temperature of the material, as fabricated, and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0,85 shall be adopted. For special materials, the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.*

10.2.2 *The design liquid pressure defined in [3.3.2] shall be taken into account in the internal pressure calculations.*

10.2.3 *The design external pressure P_e, in MPa, used for verifying the buckling of the pressure vessels, shall not be less than that given by:*

$P_e = P_1 + P_2 + P_3 + P_4$

where:

P_1 : *Setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves, P_1 shall be specially considered, but shall not, in general, be taken as less than 0,025 MPa*

P_2 : *The set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere $P_2=0$*

P_3 : *Compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both shall be taken into account; and*

P_4 : *External pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere $P_4 = 0$.*

10.2.4 *Scantlings based on internal pressure shall be calculated as follows: the thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in [3.3.2], including flanges, shall be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with recognized standards.*

10.2.5 *Stress analysis in respect of static and dynamic loads shall be performed as follows:*

- *pressure vessel scantlings shall be determined in accordance with [10.2.1] to [10.2.4] and [10.3].*
- *calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in [3.2] to [3.5] shall be used, as applicable. Stresses in way of the supporting structures shall be to a recognized standard acceptable to* the Society. *In special cases, a fatigue analysis may be required by* the Society.
- *if required by* the Society, *secondary stresses and thermal stresses shall be specially considered.*

10.3 Ultimate design condition

10.3.1 The type C independent cargo tanks are to comply with the requirements of Pt C, Ch 1, Sec 3 related to class 1 pressure vessels. The allowable stresses are defined in [10.3.2].

10.3.2 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$

$\sigma_L \leq 1,5\ f$

$\sigma_b \leq 1,5\ f$

$\sigma_L + \sigma_b \leq 1,5\ f$

$\sigma_m + \sigma_b \leq 1,5\ f$

$\sigma_m + \sigma_b + \sigma_g \leq 3,0\ f$

$\sigma_L + \sigma_b + \sigma_g \leq 3,0\ f$

where:

σ_m : *Equivalent primary general membrane stress*

σ_L : *Equivalent primary local membrane stress*

σ_b : *Equivalent primary bending stress*

σ_g : *Equivalent secondary stress*

f : *The lesser of (R_m / A) or (R_e / B)*

with R_m and R_e as defined in [4.5], item c). With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in [4.3] are referred. The values A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and shall have at least the minimum values as per Tab 6.

Table 6 : Minimum values of material coefficients

	Nickel steels and carbon manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	1,5	1,5	1,5

10.3.3 Buckling

Buckling criteria shall be as follows: the thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

10.3.4 Stiffening rings in way of tanks supports

a) Structural model:

The stiffening rings in way of supports of horizontal cylindrical tanks are to be modeled as circumferential beams constituted by web, flange, doubler plate, if any, and plating attached to the stiffening rings.

b) Width of attached plating:

On each side of the web, the width of the attached plating to be considered for the yielding and buckling checks of the stiffening rings, as in item e) and item f), respectively, is to be obtained, in mm, from the following formulae:

- for cylindrical shell:

$$b = 0,78\sqrt{rt}$$

- for longitudinal bulkheads (in the case of lobe tanks):

$$b = 20\ t_b$$

where:

r : Mean radius, in mm, of the cylindrical shell

t : Shell thickness, in mm

t_b : Bulkhead thickness, in mm.

A doubler plate, if any, may be considered as belonging to the attached plating.

c) Boundary conditions:

The boundary conditions of the stiffening ring are to be modeled as follows:

- circumferential forces applied on each side of the ring, whose resultant is equal to the shear force in the tank and calculated through the bi-dimensional shear flow theory
- reaction forces in way of tank supports, to be obtained according to [7.2].

d) Lateral pressure:

The lateral pressure to be considered for the check of the stiffening rings is to be obtained from [3.3.2].

e) Yielding check:

The equivalent stress in stiffening rings in way of supports is to comply with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

where:

σ_E : Equivalent stress in stiffening rings calculated for the load cases defined in [7.1.2] and to be obtained from the following formula:

$$\sigma_E = \sqrt{(\sigma_N + \sigma_B)^2 + 3\tau^2}$$

σ_N : Normal stress, in N/mm^2, in the circumferential direction of the stiffening ring

σ_B : Bending stress, in N/mm^2, in the circumferential direction of the stiffening ring

τ : Shear stress, in N/mm^2, in the stiffening ring

σ_{ALL} : Allowable stress, in N/mm^2, to be taken equal to the lesser of the following values:

- 0,57 R_m
- 0,85 R_{eH}

f) Buckling check:

The buckling strength of the stiffening rings is to be checked in compliance with the applicable formulae in Pt B, Ch 9, Sec 1.

10.4 Fatigue design condition

10.4.1 *For large type C independent tanks, where the cargo at atmospheric pressure is below –55°C,* the Society *may require additional verification to check their compliance with [10.1.1] regarding static and dynamic stress.*

10.5 Accident design condition

10.5.1 *The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in [2.1.4], item c) and [3.5], as applicable.*

10.5.2 *When subjected to the accidental loads specified in [3.5]* and [3.3.9]*, the stress shall comply with the acceptance criteria specified in [10.3.1], modified as appropriate taking into account their lower probability of occurrence.*

10.5.3 Collision condition

The structure of the tank is to be checked for collision loads using pressure and criteria defined in [8.4.3].

10.5.4 Heel condition

The structure of the tank is to be checked for heel loads using pressure and criteria defined in [8.4.4].

10.6 Testing

10.6.1 *Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1,5 P_o. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90% of the yield stress of the material. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0,75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.*

10.6.2 *The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.*

10.6.3 *The pressure shall be held for 2 h per 25 mm of thickness, but in no case less than 2 h.*

10.6.4 *Where necessary for cargo pressure vessels, a hydropneumatic test may be carried out under the conditions prescribed in [10.6.1] to [10.6.3].*

10.6.5 *Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of [10.6.1] shall be fully complied with.*

10.6.6 *After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test which may be performed in combination with the pressure testing referred to in [10.6.1].*

10.6.7 *Pneumatic testing of pressure vessels other than cargo tanks shall only be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.*

10.6.8 The conditions in which testing is performed are to simulate as far as possible the actual loading on the tank and its supports.

10.6.9 When testing takes place after installation of the cargo tank, provision is to be made prior to the launching of the ship in order to avoid excessive stresses in the ship structures.

10.7 Marking

10.7.1 *The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.*

11 Membrane tanks

11.1 Design Basis

11.1.1 *The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.*

11.1.2 *If the cargo temperature at atmospheric pressure is below –10°C, a complete secondary barrier shall be provided as required in [2.3]. The secondary barrier shall be designed according to [2.4].*

11.1.3 *A systematic approach based on analysis and testing shall be used to demonstrate that the system will provide its intended function in consideration of the events identified in service as specified in [11.2.1].*

11.1.4 *The design vapour pressure Po shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value, but less than 0,07 MPa.*

11.1.5 *The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.*

11.1.6 *The thickness of the membranes shall not normally exceed 10 mm.*

11.1.7 *The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with Ch 9, Sec 9, [1.2.1], shall be sufficient to allow for effective means of gas detection.*

11.2 Design consideration

11.2.1 *Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:*

a) Ultimate design events:
- *tensile failure of membranes*
- *compressive collapse of thermal insulation*
- *thermal ageing*
- *loss of attachment between thermal insulation and hull structure*
- *loss of attachment of membranes to thermal insulation system*
- *structural integrity of internal structures and their supporting structures; and*
- *failure of the supporting hull structure.*

b) Fatigue design events:
- *fatigue of membranes including joints and attachments to hull structure*
- *fatigue cracking of thermal insulation*
- *fatigue of internal structures and their supporting structures; and*
- *fatigue cracking of inner hull leading to ballast water ingress.*

c) Accident design events:
- *accidental mechanical damage (such as dropped objects inside the tank while in service)*
- *accidental overpressurization of thermal insulation spaces*
- *accidental vacuum in the tank; and*
- *water ingress through the inner hull structure.*

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

11.2.2 *The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with [11.1.3].*

11.3 Loads and loads combinations

11.3.1 *Particular consideration shall be given to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the cargo tank, the sloshing effects, hull vibration effects, or any combination of these events.*

11.4 Structural analysis

11.4.1 *Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the cargo containment and associated structures, e.g. structures as defined in [2.7], shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.*

11.4.2 *Structural analyses of the hull shall take into account the internal pressure as indicated in [3.3.2]. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.*

11.4.3 *The analyses referred to in [11.4.1] and [11.4.2] shall be based on the particular motions, accelerations and response of ships and cargo containment systems.*

11.5 Structural details

11.5.1 Cut-outs and connections in membrane tanks

For ordinary stiffeners located below the upper deck level and subject to sloshing loads, cut-outs made in inner hull and cofferdam bulkhead for their passage through the vertical webs are to be closed by collar plates welded to the inner hull or transverse bulkhead plating.

Where deemed necessary, adequate reinforcements are to be fitted in the double hull and transverse cofferdams at connection of the cargo containment system to the hull structure. Details of the connection are to be submitted to the Society for approval.

11.6 Ultimate design condition

11.6.1 *The structural resistance of every critical component, subsystem or assembly shall be established, in accordance with [11.1.3], for in-service conditions.*

11.6.2 *The choice of strength acceptance criteria for the failure modes of the cargo containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.*

11.6.3 *The inner hull scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in [3.3.2] and the specified appropriate requirements for sloshing load as defined in [3.4.4].*

11.7 Fatigue design condition

11.7.1 *Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.*

11.7.2 *The fatigue calculations shall be carried out in accordance with [4.6], with relevant requirements depending on:*

- *the significance of the structural components with respect to structural integrity; and*
- *availability for inspection.*

11.7.3 *For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_w shall be less than or equal to 0,5.*

11.7.4 *Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in [4.6.8].*

11.7.5 *Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in [4.6.9].*

11.7.6 At design stage, the fatigue assessment aims to ensure that critical details are adequately designed to reach at least the fatigue life required in [4.6.2]. The associated fatigue assessment methodology is based on S-N curve/cumulative damage approach as mentioned in [4.6.1].

Fatigue assessment may be performed either by means of S-N curve/cumulative damage approach at design stage or for life extension for example as stated in [4.6.1] or by means of fracture mechanics analysis for repair decision when cracks are detected as mentioned in [4.6.6] to [4.6.9].

11.7.7 The following structural details are to be checked for fatigue:

a) Singular point of metallic membrane:
   - knots, i.e. intersections between corrugations
   - corrugations or raised edges
   - end of corrugations or raised edges

b) Attachment of primary and secondary barrier on:
   - the corners (dihedron and trihedron)
   - the cargo domes
   - the pump towers support

c) Connection of the cargo dome with hull

d) Cargo dome pipe penetrations

e) Connection of the pump tower support with double bottom

f) Structures of the pump tower

In case of specific arrangement, the Society may ask additional fatigue assessments for specific structural details not listed above.

11.7.8 The S-N curves and the fracture mechanics material characteristics are to be validated by the Society for minimal temperature that the cargo containment system elements under consideration may reach for the corresponding materials.

11.7.9 For the considered materials, the effects of corrosive environment on fatigue life are to be taken into account by means of:

- increase of stress in the considered detail due to thickness decrease induced by corrosion phenomenon
- decrease of fatigue strength

In general, for stainless steels and for aluminium alloys, no corrosion effect has to be considered for the fatigue strength.

11.7.10 The fatigue phenomenon is normally divided in two different domains:

- high stress, low-cycle fatigue occurring for a low number of cycles, less than 10^4, in the range of plastic deformations
- low stress, high-cycle fatigue occurring for a large number of cycles more than 10^4, in the range of elastic deformations

As required in [4.6.3], the low and high cycles are to be considered for the fatigue life verification.

11.7.11 The fatigue assessment of structural details at design stage is to be performed according to S-N curves approach.

Fatigue assessment is to be performed for structural details in order to prevent all the fatigue failure modes possibly occurring.

The stress assessment methods for each of these fatigue failure modes is to be agreed by the Society.

11.7.12 The post-weld treatment of joints treated by grinding, TIG dressing or other local means are disregarded for reducing the fatigue damage.

11.7.13 When designing the cold stamping of membrane parts, it is necessary to take into account the permanent plastic deformations arising in the material.

11.8 Accident design condition

11.8.1 *The containment system and the supporting hull structure shall be designed for the accidental loads specified in [3.5]. These loads need not be combined with each other or with environmental loads.*

11.8.2 *Additional relevant accident scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside tanks.*

11.9 Design development testing

11.9.1 *The design development testing required in [11.1.3], shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype-scaled model of the complete cargo containment system. Testing conditions considered in the analytical and physical models shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in [2.4.3] may be based on the results of testing carried out on the prototype-scaled model.*

11.9.2 *The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.*

11.10 Testing

11.10.1 *All tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.*

11.10.2 *All hold structures supporting the membrane shall be tested for tightness before installation of the cargo containment system.*

11.10.3 *Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.*

11.10.4 The testing of membrane tanks is to comply with the requirements in Pt B, Ch 13, Sec 6.

11.11 Certification of materials and products

11.11.1 Material and products used in membrane cargo containment system are to be certified and tested according to the requirements of Tab 7.

Table 7 : Certification of materials and products

No.	Materials and Products	Product Certification			
		TA / DA **(10)**	Raw material certificate	Examination and testing	Product Certificate
MEMBRANE CARGO CONTAINMENT SYSTEM WITH FOAM INSULATION IN GENERAL USE					
1	Stainless steel plates	TA		X	C
2	Aluminium for reinforcement elements	TA		X	C
3	Staples	N/A	W		W
4	Inner hull studs, nuts, and washers	N/A	W		W
5	Stainless steel studs, nuts, and washers	DA			C
6	Expansion rivets	TA	W		W
7	Stainless steel corners prefabricated elements	TA	C	X	C
8	Anchor strips for primary barrier	TA	C	X	C
9	Primary barrier components (e.g. membrane sheets and elements)	DA	C	X	C
10	Plywood	TA			W
11	Glass wool	TA			W
12	Glass cloth	TA			W
13	Low density foam (LDF) panel	TA			W/C **(3)**
14	Reinforced polyurethane foam (R-PUF, HD R-PUF) panel	TA			C
15	Load bearing mastic	TA **(1)**		X	W
16	Insulating panel adhesive	TA **(2)**			W
17	Adhesive for secondary barrier	TA **(2)**			W
18	Paint for inner hull protection	TA			W
19	Thermal protection	N/A			W
20	Secondary barrier components (e.g. rigid and flexible material)	TA		X	C
21	Primary block assembly prefabricated elements	DA	W		C
22	Flat wall panels prefabricated elements	TA	C	X **(4) (5)**	C
23	Top bridge pads prefabricated elements	TA	C	X **(4) (5)**	C
24	Flat joints based on glass wool	TA			W
25	Corner panels prefabricated elements	TA	C	X **(4) (5)**	C
26	Single legs prefabricated elements	DA	W	X	C
27	Aluminium wedges	TA	C		W
MEMBRANE CARGO CONTAINMENT SYSTEM WITH PLYWOOD BOXES INSULATION IN GENERAL USE					
1	Fe-Ni alloy (36% Nickel) strips	TA		X	C
2	Fe-Ni (36% Nickel) welding filler metal	TA		X	C
4	Studs, nuts, washers, coupler sockets, staples and screws	N/A	W		W
9	Plywood	TA			W
10	Glass wool	TA			W
11	Glass cloth	TA			W
12	Glass wool (for insulating box)	TA			W
13	Reinforced polyurethane foam (R-PUF)	TA			C
14	Load bearing mastic	TA **(1)**		X	W
15	Insulating panel adhesive	DA			W
16	Glue	DA			W
17	Anti-sticking film	N/A			W
18	Thermal protection	N/A			W
19	Insulating material	TA			W
20	Insulating boxes prefabricated elements	DA	W		W
21	Flat wall panels	TA	C	X **(4) (5)**	C
22	Plywood cleat	DA			W
23	Perlite	TA			W

No.	Materials and Products	Product Certification			
		TA / DA **(10)**	Raw material certificate	Examination and testing	Product Certificate
OTHER COMPONENTS					
1	Densified wood laminated for pipe guide tower	DA	C		C **(6)**
2	Pump tower: • cargo/fuel pipings • supporting structure	DA	W/C **(7)**	X h **(9)** ndt **(8)**	C **(9)**
3	Pump Tower Base Support	DA	C	X ndt **(8)**	C
4	Dome Cover	DA	C	X ndt **(8)** **(9)**	C **(9)**
5	Dome Seat	DA	C	X ndt **(8)**	C
6	Sump well	DA	C	X ndt **(8)**	C

Note 1: Definitions:

TA : A type approval is required.
DA : A design approval of the product is required, either for the specific unit produced, or using the type approval procedure.
C : A Society certificate is required.
W : A manufacturer's document is required.
N/A : Not applicable
X : Examinations and tests are required
h : Hydraulic pressure test (or equivalent)
ndt : Non-destructive tests as per Rules.

(1) Test to be witnessed by attending surveyors unless otherwise agreed
(2) Tensile tests for TA
(3) C for Polyurethane Foam, W for Polyestyrene
(4) Review of bonders operators qualifications
(5) Review of bonding and other fabrication or testing qualifications including Flat, Corner and Tri-way panels
(6) In the case of shipbuilder's own manufacturing, no certificate would be issued after inspection unless explicitly required
(7) C for cargo pipings, W for supporting structure
(8) - Review of welders, and NDT operators qualifications
- Review of welding, NDT and other fabrication or testing qualifications
- Survey of the fabrication and witnessing of NDT at random
(9) For cargo pipings, See Ch 9, Sec 5
(10) In case of assemblies combining several items, the highest design assessment scheme applies to the assembly, i.e. if design assessment scheme TA applies to at least one of the component of the assembly, TA applies to the whole assembly.

12 Integral tanks

12.1 Design basis

12.1.1 *Integral tanks that form a structural part of the hull and are affected by the loads that stress the adjacent hull structure shall comply with the following:*

- *the design vapour pressure P_o as defined in [1.2.2] shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, P_o may be increased to a higher value, but less than 0,07 MPa*
- *integral tanks may be used for products, provided the boiling point of the cargo is not below –10°C. A lower temperature may be accepted by* the Society *subject to special consideration, but in such cases a complete secondary barrier shall be provided; and*
- *products required by Ch 9, Sec 19 to be carried in type 1G ships shall not be carried in integral tanks.*

12.2 Structural analysis

12.2.1 *The structural analysis of integral tanks shall be in accordance with recognized standards.*

12.2.2 The net scantlings of plating, ordinary stiffeners and primary supporting members of integral tanks are to be not less than those obtained from Part B, Chapter 7, where the hull girder loads and the internal pressure are to be calculated according to Part B, Chapter 5.

12.3 Ultimate design condition

12.3.1 *The tank boundary scantlings shall meet the requirements for deep tanks, taking into account the internal pressure a indicated in [3.3.2].*

12.3.2 *For integral tanks, allowable stresses shall normally be those given for hull structure in the requirements of* the Society.

12.4 Accident design condition

12.4.1 *The tanks and the tank supports shall be designed for the accidental loads specified in [2.1.4], item c) and [3.5], as relevant.*

12.4.2 *When subjected to the accidental loads specified in [3.5]* and [3.3.9]*, the stress shall comply with the acceptance criteria specified in [12.3], modified as appropriate, taking into account their lower probability of occurrence.*

12.5 Testing

12.5.1 *All integral tanks shall be hydrostatically or hydropneumatically tested.The test shall be performed so that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.*

12.5.2 The testing of integral tanks is to comply with the requirements in Pt B, Ch 13, Sec 6.

13 Semi-membrane tanks

13.1 Design basis

13.1.1 *Semi-membrane tanks are non-self-supporting tanks when in the loaded condition and consist of a layer, parts of which are supported through thermal insulation by the adjacent hull structure, whereas the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.*

13.1.2 *The design vapour pressure P_o shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value, but less than 0,07 MPa.*

13.1.3 *For semi-membrane tanks the relevant requirements in this section for independent tanks or for membrane tanks shall be applied as appropriate.*

13.1.4 *In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support,* the Society *may, after special consideration, accept a partial secondary barrier.*

13.2 Testing

13.2.1 The testing of semi-membrane tanks is to comply with the requirements in Pt B, Ch 13, Sec 6.

14 Cargo containment systems of novel configuration

14.1 Limit state design for novel concepts

14.1.1 *Cargo containment systems that are of a novel configuration that cannot be designed using [8] to [13] shall be designed using this sub-article and Articles [2] and [3], and also Articles [4], [5] and [6] as applicable. Cargo containment system design according to this section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using [8] to [13].*

14.1.2 *The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in [2.1.4]. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.*

14.1.3 *For each failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states. The limit states are divided into the three following categories:*

- *ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation; under intact (undamaged) conditions.*
- *fatigue limit states (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.*
- *accident limit states (ALS), which concern the ability of the structure to resist accidental situations.*

14.1.4 *The procedure and relevant design parameters of the limit state design shall comply with the Standards for the Use of limit state methodologies in the design of cargo containment systems of novel configuration (LSD Standard), as set out in* Appendix 5 of the IGC Code.

Section 5 Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems

1 General

1.1

1.1.1 *The requirements of this Section shall apply to products and process piping, including vapour piping, gas fuel piping and vent lines of safety valves or similar piping. Auxiliary piping systems not containing cargo are exempt from the general requirements of this Section.*

1.1.2 Cargo and process pipings have to comply with the applicable requirements of Pt C, Ch 1, Sec 10 for class I pressure piping, unless otherwise specified in IGC Code or in the present Article.

1.1.3 *The requirements for type C independent tanks provided in Ch 9, Sec 4 may also apply to process pressure vessels. If so required, the term "pressure vessels" as used in Ch 9, Sec 4, covers both type C independent tanks and process pressure vessels.*

1.1.4 *Process pressure vessels include surge tanks, heat exchangers and accumulators that store or treat liquid or vapour cargo.*

1.1.5 Process pressure vessels handling cargo are to be considered as class 1 pressure vessels, in accordance with Pt C, Ch 1, Sec 3, [1.4.1].

2 System requirements

2.1

2.1.1 The connections, if any, to the cargo tanks of relief valve discharges fitted on the liquid phase cargo piping are not to be fitted with shut-off valves, but are to be provided with non-return valves in the proximity of the tanks.

2.1.2 Overpressure relief valves on cargo pumps may be omitted in the case of centrifugal pumps having a maximum delivery head, the delivery valve being completely closed, not greater than that permitted for the piping.

2.1.3 *The cargo handling and cargo control systems shall be designed taking into account the following:*

- *prevention of an abnormal condition escalating to a release of liquid or vapour cargo*
- *the safe collection and disposal of cargo fluids released*
- *prevention of the formation of flammable mixtures*
- *prevention of ignition of flammable liquids or gases and vapours released, and*
- *limiting the exposure of personnel to fire and other hazards.*

2.2 Arrangements: General

2.2.1 *Any piping system that may contain cargo liquid or vapour shall:*

- *be segregated from other piping systems, except where interconnections are required for cargo-related operations such as purging, gas-freeing or inerting. The requirements of Ch 9, Sec 9, [1.4.5] shall be taken into account with regard to preventing back-flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections*
- *except as provided in Ch 9, Sec 16, not pass through any accommodation space, service space or control station or through a machinery space other than a cargo machinery space*
- *be connected to the cargo containment system directly from the weather decks except where pipes installed in a vertical trunkway or equivalent are used to traverse void spaces above a cargo containment system and except where pipes for drainage, venting or purging traverse cofferdams*
- *be located in the cargo area above the weather deck except for bow or stern loading and unloading arrangements in accordance with Ch 9, Sec 3, [1.8], emergency cargo jettisoning piping systems in accordance with [3.1], turret compartment systems in accordance with [3.3] and except in accordance with Ch 9, Sec 16, and*
- *be located inboard of the transverse tank location requirements of Ch 9, Sec 2, [4.1.1], except for athwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning piping systems.*

2.2.2 *Suitable means shall be provided to relieve the pressure and remove liquid cargo from loading and discharging crossover headers; likewise, any piping between the outermost manifold valves and loading arms or cargo hoses to the cargo tanks, or other suitable location, prior to disconnection.*

2.2.3 *Piping systems carrying fluids for direct heating or cooling of cargo shall not be led outside the cargo area unless a suitable means is provided to prevent or detect the migration of cargo vapour outside the cargo area (see Ch 9, Sec 13, [6.1.2], item f)).*

2.2.4 *Relief valves discharging liquid cargo from the piping system shall discharge into the cargo tanks. Alternatively, they may discharge to the cargo vent mast, if means are provided to detect and dispose of any liquid cargo that may flow into the vent system. Where required to prevent overpressure in downstream piping, relief valves on cargo pumps shall discharge to the pump suction.*

3 Arrangements for cargo piping outside the cargo area

3.1 Emergency cargo jettisoning

3.1.1 *If fitted, an emergency cargo jettisoning piping system shall comply with [2.2], as appropriate, and may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them. If an emergency cargo jettisoning piping system is permanently installed, a suitable means of isolating the piping system from the cargo piping shall be provided within the cargo area.*

3.2 Bow and stern loading arrangements

3.2.1 *Subject to the requirements of Ch 9, Sec 3, [1.8], this sub-article and [10.1], cargo piping may be arranged to permit bow or stern loading and unloading.*

3.2.2 *Arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.*

3.3 Turret compartment transfer systems

3.3.1 *For the transfer of liquid or vapour cargo through an internal turret arrangement located outside the cargo area, the piping serving this purpose shall comply with [2.2], as applicable, [10.2] and the following:*

a) Pping shall be located above the weather deck, except for the connection to the turret

b) Portable arrangements shall not be permitted, and

c) Arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces for isolation from the cargo piping shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.

3.4 Gas fuel piping systems

3.4.1 *Gas fuel piping in machinery spaces shall comply with all applicable requirements of this Section in addition to the requirements of Ch 9, Sec 16.*

4 Design pressure

4.1

4.1.1 *The design pressure P_o, used to determine minimum scantlings of piping and piping system components, shall be not less than the maximum gauge pressure to which the system may be subjected in service. The minimum design pressure used shall not be less than 1 MPa gauge, except for open-ended lines or pressure relief valve discharge lines, where it shall be not less than the lower of 0,5 MPa gauge, or 10 times the relief valve set pressure.*

4.1.2 *The greater of the following design conditions shall be used for piping, piping systems and components, based on the cargoes being carried:*

- *for vapour piping systems or components that may be separated from their relief valves and which may contain some liquid, the saturated vapour pressure at a design temperature of 45°C. Higher or lower values may be used (see Ch 9, Sec 4, [3.3.2], item b)), or*
- *for systems or components that may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C. Higher or lower values may be used (see Ch 9, Sec 4, [3.3.2], item b)), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature, or*
- *the MARVS of the cargo tanks and cargo processing systems, or*
- *the pressure setting of the associated pump or compressor discharge relief valve, or*
- *the maximum total discharge or loading head of the cargo piping system considering all possible pumping arrangements or the relief valve setting on a pipeline system.*

Note 1: For each piping section, the maximum pressure value among those applicable in paragraph above is to be considered.

4.1.3 *Those parts of the liquid piping systems that may be subjected to surge pressures shall be designed to withstand this pressure* and relevant justifications are to be submitted.

4.1.4 *The design pressure of the outer pipe or duct of gas fuel systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively, for gas fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.*

The design pressure of the outer pipe or duct is either of the following:

- the maximum pressure that can act on the outer pipe or equipment enclosure after the inner pipe rupture as documented by suitable calculations taking into account the venting arrangements; or
- for gas fuel systems with inner pipe working pressure greater than 1 Mpa, the "maximum built-up pressure arising in the annular space", after the inner pipe rupture, which is to be calculated in accordance with [4.1.5].

The expression "duct" means to include the equipment enclosure required in Ch 9, Sec 16, [4.3] (e.g. GVU enclosure) as well as the structural pipe duct intended to contain any release of gas from inner pipe or equipment. The term "structural pipe duct" means an outer duct forming part of a structure such as a hull structure or superstructure or deck house, where permitted, other than gas valve unit rooms.

4.1.5 For high-pressure piping the design pressure of the ducting is to be taken as the higher of the following:

a) The maximum built up pressure:
   - Static pressure in way of the rupture resulting from the gas flowing in the annular space

b) Local instantaneous peak pressure in way of the rupture:
   - This pressure is to be taken as the critical pressure and is given by the following expression:

$$p^* = p_0\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

with:

p_0 : Maximum working pressure of the inner pipe

k : Constant pressure specific heat divided by the constant volume specific heat:

$k = C_p / C_v$

$k = 1{,}31$ for CH_4

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1,5 (R_m / 1,5) when subjected to the above pressure. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports must then be submitted.

5 Cargo system valve requirements

5.1

5.1.1 *Every cargo tank and piping system shall be fitted with manually operated valves for isolation purposes as specified in this Article.*

In addition, remotely operated valves shall also be fitted, as appropriate, as part of the emergency shutdown (ESD) system the purpose of which is to stop cargo flow or leakage in the event of an emergency when cargo liquid or vapour transfer is in progress. The ESD system is intended to return the cargo system to a safe static condition so that any remedial action can be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within the cargo transfer pipework. The equipment to be shut down on ESD activation includes manifold valves during loading or discharge, any pump or compressor, etc., transferring cargo internally or externally (e.g. to shore or another ship/barge) and cargo tank valves, if the MARVS exceeds 0,07 MPa.

5.1.2 Cargo tank connections

All liquid and vapour connections, except for safety relief valves and liquid level gauging devices, shall have shutoff valves located as close to the tank as practicable. These valves shall provide full closure and shall be capable of local manual operation. They may also be capable of remote operation.

For cargo tanks with a MARVS exceeding 0,07 MPa gauge, the above connections shall also be equipped with remotely controlled ESD valves. These valves shall be located as close to the tank as practicable. A single valve may be substituted for the two separate valves, provided the valve complies with the requirements of Ch 9, Sec 18, [3.2] and provides full closure of the line.

5.2 Cargo manifold connections

5.2.1 *One remotely controlled ESD valve shall be provided at each cargo transfer connection in use to stop liquid and vapour transfer to or from the ship. Transfer connections not in use shall be isolated with suitable blank flanges.*

5.2.2 *If the cargo tank MARVS exceeds 0,07 MPa, an additional manual valve shall be provided for each transfer connection in use, and may be inboard or outboard of the ESD valve to suit the ship's design.*

5.3

5.3.1 *Excess flow valves may be used in lieu of ESD valves, if the diameter of the protected pipe does not exceed 50 mm. Excess flow valves shall close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping including fittings, valves and appurtenances protected by an excess flow valve shall have a capacity greater than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding the area of a 1 mm diameter circular opening to allow equalization of pressure after a shutdown activation.*

5.3.2 *Cargo tank connections for gauging or measuring devices need not be equipped with excess flow valves or ESD valves, provided that the devices are constructed so that the outward flow of tank contents cannot exceed that passed by a 1,5 mm diameter circular hole.*

In case of tanks with an MARVS not exceeding 0.07 MPa, the outward flow of tank contents can exceed that passed by a 1,5 mm diameter circular hole.

5.3.3 *All pipelines or components which may be isolated in a liquid full condition shall be protected with relief valves for thermal expansion and evaporation.*

Note 1: For pipe sections that would be closed by ESD system, a fire scenario is to be considered for sizing, as defined in [5.3.4].

5.3.4 *All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0,05 m^3 entrapped shall be provided with PRVs sized for a fire condition.*

5.3.5 Pressure relief valves are to be set to discharge at a pressure not greater than the design pressure such that the overpressure during discharge does not exceed 110% of the design pressure, as defined in Ch 9, Sec 8.

6 Cargo transfer arrangements

6.1 General

6.1.1 When two or more pumps located in different cargo tanks are operating at the same time discharging into a common header, the stopping of the pumps is to activate an alarm at the centralised cargo control location.

6.1.2 *Where cargo transfer is by means of cargo pumps that are not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank, and the design shall be such that failure of one cargo pump or means of transfer will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.*

6.1.3 *The procedure for transfer of cargo by gas pressurization shall preclude lifting of the relief valves during such transfer. Gas pressurization may be accepted as a means of transfer of cargo for those tanks where the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation. If the cargo tank relief valves or set pressure are changed for this purpose, as it is permitted in accordance with Ch 9, Sec 8, [2.1.9] and Ch 9, Sec 8, [2.1.10], the new set pressure shall not exceed P_h as is defined in Ch 9, Sec 4, [3.3.2].*

6.2 Vapour return connections

6.2.1 *Connections for vapour return to the shore installations shall be provided.*

6.3 Cargo tank vent piping systems

6.3.1 *The pressure relief system shall be connected to a vent piping system designed to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition.*

6.4 Cargo sampling connections

6.4.1 *Connections to cargo piping systems for taking cargo liquid samples shall be clearly marked and shall be designed to minimize the release of cargo vapours. For vessels permitted to carry toxic products, the sampling system shall be of a closed loop design to ensure that cargo liquid and vapour are not vented to atmosphere.*

Note 1: These requirements are only applicable if such a sampling system is fitted on board. Connections used for control of atmosphere in cargo tanks during inerting or gassing up are not considered as cargo sampling connections.

6.4.2 *Liquid sampling systems shall be provided with two valves on the sample inlet. One of these valves shall be of the multi-turn type to avoid accidental opening, and shall be spaced far enough apart to ensure that they can isolate the line if there is blockage, by ice or hydrates for example.*

6.4.3 *On closed loop systems, the valves on the return pipe shall also comply with [6.4.2].*

6.4.4 *The connection to the sample container shall comply with recognized standards and be supported so as to be able to support the weight of a sample container. Threaded connections shall be tack-welded, or otherwise locked, to prevent them being unscrewed during the normal connection and disconnection of sample containers. The sample connection shall be fitted with a closure plug or flange to prevent any leakage when the connection is not in use.*

6.4.5 *Sample connections used only for vapour samples may be fitted with a single valve in accordance with Articles [5], [8] and [13], and shall also be fitted with a closure plug or flange.*

6.4.6 *Sampling operations shall be undertaken as prescribed in IGC Code, Chapter 18, [18.9].*

6.5 Cargo filters

6.5.1 *The cargo liquid and vapour systems shall be capable of being fitted with filters to protect against damage by extraneous objects. Such filters may be permanent or temporary, and the standards of filtration shall be appropriate to the risk of debris, etc., entering the cargo system. Means shall be provided to indicate that filters are becoming blocked, and to isolate, depressurize and clean the filters safely.*

Means to indicate that filters are becoming blocked and filter maintenance is required is to be provided for fixed in-line filter arrangement and portable filter installations where dedicated filter housing piping is provided.

Where portable filters for fitting to manifold presentation flanges are used without dedicated filter housing, and these can be visually inspected after each loading and discharging operation, no additional arrangements for indicating blockage or facilitating drainage are required.

7 Installation requirements

7.1 Design for expansion and contraction

7.1.1 *Provision shall be made to protect the piping, piping system and components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. The preferred method outside the cargo tanks is by means of offsets, bends or loops, but multi-layer bellows may be used if offsets, bends or loops are not practicable.*

7.2 Precautions against low temperature

7.2.1 *Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections and at pump seals, protection for the hull beneath shall be provided.*

7.2.2 Where the piping system is intended for liquids having a boiling point lower than 30°C, permanent means to avoid possibility of contact between leaks and hull structures are to be provided in all those locations where leakage might be expected, such as shore connections, pump seals, flanges subject to frequent dismantling, etc.

7.2.3 The means to detect the presence of liquid cargo may be constituted by electrical level switches whose circuit is intrinsically safe. The alarm signals given by the level switches are to be transmitted to the wheelhouse and to the cargo control station, if provided.

7.2.4 High temperature pipes are to be thermally isolated from the adjacent structures. In particular, the temperature of pipelines is not to exceed 220°C in gas-dangerous zones.

7.3 Water curtain

7.3.1 *For cargo temperatures below –110°C, a water distribution system shall be fitted in way of the hull under the shore connections to provide a low-pressure water curtain for additional protection of the hull steel and the ship's side structure. This system is in addition to the requirements of Ch 9, Sec 11, [1.3.2], d), and shall be operated when cargo transfer is in progress.*

Note 1: The flow is to be the same as required for water-spray system defined in Ch 9, Sec 11.

7.4 Bonding

7.4.1 *Where tanks or cargo piping and piping equipment are separated from the ship's structure by thermal isolation, provision shall be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded. Except where bonding straps are used, it shall be demonstrated that the electrical resistance of each joint or connection is less than 1MΩ.*

7.4.2 Bonding straps are required for cargo and slop tanks, piping systems and equipment which are not permanently connected to the hull of the ship, for example:

a) Independent cargo tanks

b) Cargo tank piping systems which are electrically separated from the hull of the ship

c) Pipe connections arranged for the removal of the spool pieces.

Where bonding straps are required, they are to be:

a) Clearly visible so that any shortcoming can be clearly detected

b) Designed and sited so that they are protected against mechanical damage and are not affected by high resistivity contamination, e.g. corrosive products or paint

c) Easy to install and replace.

8 Piping fabrication and joining details

8.1 General

8.1.1 *The requirements of this Article apply to piping inside and outside the cargo tanks. Relaxation from these requirements may be accepted, in accordance with recognized standards for piping inside cargo tanks and open-ended piping.*

8.2 Direct connections

8.2.1 *The following direct connection of pipe lengths, without flanges, may be considered:*

- *butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than –10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas backup on the first pass. For design pressures in excess of 1 MPa and design temperatures of –10°C or colder, backing rings shall be removed*
- *slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, shall only be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than –55°C, and*
- *screwed couplings complying with recognized standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.*

8.3 Flanged connections

8.3.1 *Flanges in flanged connections shall be of the welded neck, slip-on or socket welded type.*

8.3.2 *Flanges shall comply with recognized standards for their type, manufacture and test. For all piping, except open ended, the following restrictions apply:*

- *for design temperatures colder than –55°C, only welded-neck flanges shall be used, and*
- *for design temperatures colder than –10°C, slip-on flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm.*

8.4 Expansion joints

8.4.1 *Where bellows and expansion joints are provided in accordance with [7.1], the following requirements apply:*

- *if necessary, bellows shall be protected against icing, and*
- *slip joints shall not be used except within the cargo tanks.*

8.5 Other connections

8.5.1 *Piping connections shall be joined in accordance with [8.2] to [8.4], but for other exceptional cases* the Society *may consider alternative arrangements.*

9 Welding, post-weld heat treatment and non-destructive testing

9.1 General

9.1.1 *Welding shall be carried out in accordance with Ch 9, Sec 6, [5].*

9.2 Post-weld heat treatment

9.2.1 *Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels.* The Society *may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.*

9.3 Non-destructive testing

9.3.1 *In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the requirements of this Article, the following tests shall be required:*

a) 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with design temperatures colder than –10°C, and with inside diameters of more than 75 mm, or wall thicknesses greater than 10 mm

b) When such butt-welded joints of piping sections are made by automatic welding procedures approved by the Society, *then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed, the extent of examination shall be increased to 100% and shall include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently, and*

c) For other butt-welded joints of pipes not covered by items a) and b), spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.

10 Installation requirements for cargo piping outside the cargo area

10.1 Bow and stern loading arrangements

10.1.1 *The following requirements shall apply to cargo piping and related piping equipment located outside the cargo area:*

- *cargo piping and related piping equipment outside the cargo area shall have only welded connections. The piping outside the cargo area shall run on the weather decks and shall be at least 0,8 m inboard, except for athwartships shore connection piping. Such piping shall be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location, it shall also be capable of being separated by means of a removable spool piece and blank flanges, when not in use, and*
- *the piping shall be full penetration butt-welded and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at the shore connection.*

10.2 Turret compartment transfer systems

10.2.1 *The following requirements shall apply to liquid and vapour cargo piping where it is run outside the cargo area:*

- *cargo piping and related piping equipment outside the cargo area shall have only welded connections, and*
- *the piping shall be full penetration butt-welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at connections to cargo hoses and the turret connection.*

10.3 Gas fuel piping

10.3.1 *Gas fuel piping, as far as practicable, shall have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to Ch 9, Sec 16, [4.3], and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be subjected to full radiographic or ultrasonic inspection.*

11 Piping system component requirements

11.1 General

11.1.1 *Piping systems shall be designed in accordance with recognized standards.*

11.2 Piping scantlings

11.2.1 *The following criteria shall be used for determining pipe wall thickness.*

11.2.2 *The wall thickness of pipes t, in mm, shall not be less than:*

$$t = \frac{t_o + b + c}{1 - \frac{a}{100}}$$

where:

t_o : *Theoretical thickness, in mm, determined by the following formula:*

$$t_o = \frac{P \cdot D}{2K \cdot e + P}$$

with:

P : *Design pressure, in MPa, referred to in Article [4]*

D : *Outside diameter, in mm*

K : *Allowable stress, in N/mm², referred to in [11.3]*

e : *Efficiency factor equal to 1 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases, an efficiency factor of less than 1, in accordance with recognized standards, may be required, depending on the manufacturing process*

b : *Allowance for bending, in mm. The value of b shall be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b shall be:*

$$b = \frac{D \cdot t_o}{2,5r}$$

with:

r : *Mean radius of the bend, in mm*

c : *Corrosion allowance, in mm. If corrosion or erosion is expected, the wall thickness of the piping shall be increased over that required by other design requirements. This allowance shall be consistent with the expected life of the piping*

a : *Negative manufacturing tolerance for thickness, in %.*

11.2.3 Piping subject to green seas

In particular for piping subject to green seas, the design pressure P in the formula in [4.1] is to be replaced by an equivalent pressure P' given by the following formula:

$$P' = \frac{1}{2}\left(P + \sqrt{P^2 + 6R'K\frac{D_C}{D}}\right)$$

where:

K : Allowable stress, in MPa.

K is to be the lower of (R/2,7) and (R_e/1,8),

where:

R : Specified minimum tensile strength at room temperature, in MPa

R_e : Specified lower minimum yield stress or 0,2% yield stress at room temperature, in MPa

D : External diameter of the pipe, in mm

D_C : External diameter of the pipe taking into account the insulation (in mm), whose thickness is to be taken at least equal to:

40 mm if D ≤ 50 mm
80 mm if D ≥ 150 mm

Intermediate values are to be determined by interpolation.

R' : Drag corresponding to the effect of green seas, in MPa, such as given in Tab 1 as a function of the location of the pipes and of their height H (in m) above the deepest loadline; intermediate values are to be determined by interpolation.

11.2.4 *The minimum wall thickness shall be in accordance with recognized standards.*

11.2.5 *Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by [11.2.2] or, if this is impracticable or would cause excessive local stresses, these loads may be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to: supporting structures, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.*

11.3 Allowable stress

11.3.1 *For pipes, the allowable stress K referred to in the formula in [11.2] is the lower of the following values:*

$$\frac{R_m}{A} \text{ or } \frac{R_e}{B}$$

where:

R_m : *Specified minimum tensile strength at room temperature, in N/mm²*

R_e : *Specified minimum yield stress at room temperature, in N/mm². If the stress-strain curve does not show a defined yield stress, the 0,2% proof stress applies.*

The values of A and B shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, and have values of at least A = 2,7 and B = 1,8.

11.4 High-pressure gas fuel outer pipes or ducting scantlings

11.4.1 *In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of a straight section of pipe or ducting shall not exceed the tensile strength divided by 1,5 (R_m/1,5) when subjected to the design pressure specified in Article [4]. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.*

11.5 Stress analysis

11.5.1 *When the design temperature is –110°C or lower, a complete stress analysis, taking into account all the stresses due to the weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system shall be submitted to* the Society. *For temperatures above –110°C, a stress analysis may be required by* the Society *in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration shall be given to thermal stresses even though calculations are not submitted. The analysis may be carried out according to a code of practice acceptable to* the Society.

11.5.2 When such an analysis is required, it is to be carried out in accordance with the requirements listed below. Subject to this condition, calculations in accordance with recognised standards are admitted by the Society.

11.5.3 The calculations are to be made for every possible case of operation, but only those leading to the most unfavourable results are required to be submitted.

Table 1 : Drag R' corresponding to the effect of green seas (in MPa)

External diameter of pipe **(1)**	Aft of the quarter of the ship's length			Forward of the quarter of the ship's length		
	H ≤ 8	H = 13	H ≥ 18	H ≤ 8	H = 13	H ≥ 18
≤ 25	0,015	0,0025	0,0015	0,022	0,0035	0,0015
50	0,014	0,0025	0,0015	0,020	0,0035	0,0015
75	0,011	0,0025	0,0015	0,016	0,0035	0,0015
100	0,007	0,0025	0,0015	0,007	0,0035	0,0015
≥150	0,005	0,0025	0,0015	0,007	0,0035	0,0015
(1) D_C if the pipe is insulated, D otherwise.						

11.5.4 Loads to be taken for calculation

The calculations are to be carried out taking into account the following loads:

a) Piping not subject to green seas:
- pressure
- weight of the piping with insulation and of the internal fluid
- contraction

b) Piping subject to green seas that is liable to be in operation at sea and in port:
- pressure
- weight of the piping with insulation and of the internal fluid
- green seas
- contraction
- ship motion accelerations

c) Piping subject to green seas that is in operation only in port; the more severe of the following two combinations of loads:
- pressure
- weight of the piping with insulation and of the internal fluid
- contraction

and
- weight of the piping with insulation
- green seas
- expansion, assuming that the thermal stresses are fully relaxed.

11.5.5 Green sea directions

When green seas are considered, their effects are to be studied, unless otherwise justified, in the following three directions:
- axis of the ship
- vertical
- horizontal, perpendicular to the axis of the ship. The load on the pipes is the load R' defined in [11.2.3].

11.5.6 Stress intensity

The stress intensity is to be determined as specified in the formulae in Pt C, Ch 1, Sec 10, [2.3.2] for pipes intended for high temperatures:

a) For primary stresses resulting from:
   - pressure
   - weight
   - green seas

b) For primary stresses and secondary stresses resulting from contraction.

11.5.7 Stress intensity limits

a) For the first case, the stress intensity is to be limited to the lower of:
   $0,8\ R_e$ and $0,4\ R_m$

b) For the second case, the stress intensity is to be limited to the lower of:
   $1,6\ R_e$ and $0,8\ R_m$.

11.5.8 Piping with expansion devices

For piping fitted with expansion devices, their characteristics are to be submitted to the Society. Where these characteristics are such that the forces and moments at the ends of the devices are negligible for the contraction they must absorb, the calculation of the loads due to contraction in the corresponding piping is not required. It is, however, to be checked that the stress intensity corresponding to the primary stresses does not exceed the limits given in [11.5.7].

11.5.9 Flexibility coefficient

The flexibility coefficient of elbows is to be determined from the formulae given in Pt C, Ch 1, Sec 10, [2.3.2]for pipes intended for high temperatures.

11.5.10 Local stresses

Particular attention is to be paid to the calculation of local stresses in the assemblies subjected to axial forces and bending moments. The Society reserves the right to request additional justifications or local strengthening where considered necessary.

11.6 Flanges, valves and fittings

11.6.1 *Flanges, valves and other fittings shall comply with recognized standards, taking into account the material selected and the design pressure defined in Article [4]. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.*

11.6.2 *For flanges not complying with a recognized standard, the dimensions of flanges and related bolts shall be to the satisfaction of* the Society.

11.6.3 For flanges not complying with a standard, the dimensions and type of gaskets are to be to the satisfaction of the Society.

11.6.4 *All emergency shutdown valves shall be of the "fail-closed" type (see [13.3.1] and Ch 9, Sec 18, [3.2]),* i.e. emergency shutdown valves are to close automatically in case of fire (due to loss of actuating power).

11.6.5 *The design and installation of expansion bellows shall be in accordance with recognized standards and be fitted with means to prevent damage due to over-extension or compression.*

11.6.6 Expansion joints are to be protected from extensions and compressions greater than the limits fixed for them and the connected piping is to be suitably supported and anchored. Bellow expansion joints are to be protected from mechanical damage.

11.7 Ship's cargo hoses

11.7.1 Ship's cargo hoses are to be type approved by the Society.

11.7.2 All hoses are to be tested at the plant of manufacturer in the presence of the Surveyor. An alternative survey scheme, BV Mode I as per NR320, may be agreed with the Society.

11.7.3 *Liquid and vapour hoses used for cargo transfer shall be compatible with the cargo and suitable for the cargo temperature.*

11.7.4 *Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose will be subjected to during cargo transfer.*

11.7.5 *Each new type of cargo hose, complete with end-fittings, shall be prototype-tested at a normal ambient temperature, with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test shall demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the upper and lower extreme service temperature. Hoses used for prototype testing shall not be used for cargo service.*

Thereafter, before being placed in service, each new length of cargo hose produced shall be hydrostatically tested at ambient temperature to a pressure not less than 1,5 times its specified maximum working pressure, but not more than two fifths of its bursting pressure. The hose shall be stencilled, or otherwise marked, with the date of testing, its specified maximum working pressure and, if used in services other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure shall not be less than 1 MPa gauge.

12 Materials

12.1

12.1.1 *The choice and testing of materials used in piping systems shall comply with the requirements of Ch 9, Sec 6, taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open-ended vent piping, provided that the temperature of the cargo at the pressure relief valve setting is not lower than –55°C, and that no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open-ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi-membrane tanks.*

12.1.2 *Materials having a melting point below 925°C shall not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation shall be provided.*

12.1.3 Aluminised pipes may be fitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

Note 1: The paragraph [12.1.2] of the Revised IGC Code does not apply to valves installed on cargo lines or gas supply machinery.

The valve use of Teflon or PTFE will only be allowed if the valve is tested in fire and Teflon (or PTFE) can only be used for internal seals of the valve.

12.1.4 Cargo piping insulation system

Cargo piping systems shall be provided with a thermal insulation system as required to minimize heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces.

Where applicable, due to location or environmental conditions, insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage.

Note 1: The expression “a thermal insulation system as required to minimize heat leak into the cargo during transfer operations” means that properties of the piping insulation are to be taken into consideration when calculating the heat balance of the containment system and capacity of the pressure/temperature control system.

Note 2: The expression “cargo piping systems shall be provided with a thermal insulation system as required... to protect personnel from direct contact with cold surfaces” means that surfaces of cargo piping systems with which personnel is likely to contact under normal conditions are to be protected by a thermal insulation, with the exception of the following examples:

- surfaces of cargo piping systems which are protected by physical screening measures to prevent such direct contact
- surfaces of manual valves, having extended spindles that protect the operator from the cargo temperature, and
- surfaces of cargo piping systems whose design temperature (to be determined from inner fluid temperature) is above minus 10°C.

12.1.5 *Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt-laden atmosphere, adequate measures to avoid this occurring shall be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection.*

A protective coating is to be applied on cargo pipes made in 304L and located on the open deck. Cargo pipes made in 316L are not required to be coated.

12.1.6 A Society certificate is to be provided for the raw material of parts of valves or pumps that will be in direct contact with cargo and with a working temperature below –55°C.

13 Testing requirements

13.1 General

13.1.1 The piping components mentioned in the present Article are subject to a type approval by the Society.

13.2 Cargo pumps and gas/reliquefaction/refrigeration compressors

13.2.1 Compressors and pumps are to be suitable for their intended purpose. All equipment and machinery are to be adequately designed and installed to ensure suitability within a marine environment with due consideration to Pt C, Ch 3, Sec 6, Tab 1 and Pt C, Ch 1, Sec 1, [2]. Such items to be considered would include, but not be limited to:

a) Environmental

b) Shipboard vibrations and accelerations

c) Effects of pitch, heave and roll motions, etc., and

d) Physical and chemical properties of product.

The manufacturer is to submit documentation indicating the equipment has been designed to comply with the above criteria.

13.2.2 Cargo pumps

Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Surveyor.

For the design assessment of the pumps, ISO 13709:2009 and ISO 24490:2016, as applicable, can be used. Other applicable recognized standards acceptable to the Society may be considered.

a) Material testing

Tests for pump materials need not be witnessed by the Surveyor except for the boundary components, which are in direct contact with the medium and for a design temperature below –55 °C in accordance with Ch 9, Sec 6, [2.1.2].

Note 1: The following pump components can, for example, be considered boundary components:

- for centrifugal type pump: impeller, inducer, guide vane, casing, shaft and coupling
- for reciprocating type pump: cylinder cover, valve cover, cylinder liner, piston and piston rod, crankshaft, crank case.

b) Prototype testing

Prototype testing is to include hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test but must be of sufficient length to include at least one bearing and sealing arrangements. After completion of tests, the pump is to be opened out for examination.

The vibration criteria of machinery and equipment are to be provided by the pump manufacturer. These are to be compared against an applicable internationally recognized standard (see Note 2), as applied to the design, and are to be accepted by the Society.

Note 2: The following standards can be used as guidance:

- ISO 7919-3:2009/AMD 1:2017, Mechanical vibration - Evaluation of machine vibration by measurements on rotating shafts - Part 3: Coupled industrial machines
- ISO 10816-3:2009/AMD 1: 2017, Evaluation of machine vibration by measurements on non-rotating parts - Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ
- ISO 10816-7:2009, Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts
- ISO 10816-8:2014, Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 8: Reciprocating compressor systems
- ISO 20816-1:2016, Mechanical vibration - Measurement and evaluation of machine vibration - Part 1: General Guidelines
- ISO 20816-8:2018, Mechanical vibration - Measurement and evaluation of machine vibration - Part 8: Reciprocating compressor systems.

c) Unit Production Testing

All pumps are to be tested at the plant of manufacturer in the presence of the Surveyor. Testing is to include hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water.

As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a pump may be issued subject to the following:

- the pump has been approved as required by [13.2.2] item a) and item b), and
- the manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and
- the quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

13.2.3 Gas cargo and reliquefaction/refrigeration compressors

Each size and type of compressor is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Surveyor.

For the design assessment of the gas compressors, API standards API617:2014 (w. Errata 1:2016), API618:2016 or API619:2010, as applicable, can be used. Other applicable recognized standards acceptable to the Society may be considered.

a) Material testing

Tests for compressor materials need not be witnessed by the Surveyor except for the boundary components, which are in direct contact with the medium and for a design temperature below –55 °C in accordance with Ch 9, Sec 6, [2.1.2].

Note 1: The following compressor components can, for example, be considered boundary components:

- for centrifugal type compressor: impeller, inducer, guide vane, casing, shaft and coupling
- for reciprocating type compressor: cylinder cover, valve cover, cylinder liner, piston and piston rod, crankshaft, crank case.

b) Prototype testing

Prototype testing is to be consistent with the applicable standard as applied for design assessment and is to include hydrostatic test of the compressor pressure boundary components, mechanical running test and a performance test. The hydrostatic test is to be carried out at a pressure equal to 1,5 times the design pressure (or 1,25 times the design pressure where the test fluid is compressible) and for, at least, 30 minutes. The mechanical running test and performance tests are to include recording of the gas used, temperatures, pressures, testing of alarms and shut down, pressure relief devices and vibration measurements to ensure that the limits do not exceed those proposed by the manufacturer and that other features relating to the performance of the equipment are in accordance with the specification. Similarly, during the performance test, power consumption and the gas loads are to be recorded.

The vibration criteria of machinery and equipment are to be provided by manufacturers, consistent with the applicable recognized standard (see Note 2 in [13.2.2], item b)) as applied to the design. Otherwise, when the data on the vibration criteria are not available, justification is to be submitted for criteria used as reference in terms of overall Root Mean Square (RMS) vibrational velocity value for normal operation conditions.

Alternative limits, demonstrated by fatigue calculations, may be accepted by the Society.

c) Unit Production Testing

Each compressor is to be tested at the plant of manufacture in the presence of the Surveyor. Testing is to include hydrostatic test of the compressor pressure boundary components. The hydrostatic test is to be carried out at a pressure equal to 1,5 times the design pressure (or 1,25 times the design pressure where the test fluid is compressible) and for, at least, 30 minutes.

As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a compressor may be issued subject to the following:

- the compressor has been approved as required by [13.2.2] item a) and item b), and
- the manufacturer has a recognised quality system that has been assessed and certified by the Society subject to periodic audits, and
- the quality control plan contains a provision to subject each compressor to the hydrostatic test of the compressor body equal to 1,5 times the design pressure (or 1,25 times the design pressure where the test fluid is compressible) for, at least, 30 minutes, and a mechanical running and performance test. The manufacturer is to maintain records of such tests.

d) Installation

The complete compressor assembly connected to the vessel systems is to be subjected to a leak test using air or other suitable medium, to a pressure depending on the leak detection method applied. The test is to be performed in presence of the Surveyor and considered satisfactory when no joint leaks are observed.

13.3 Type testing of valves

13.3.1 General

Each type of valve intended to be used at a working temperature below –55°C shall be subject to the following type tests:

- *each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures for bi-directional flow and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of* the Society. *During the testing, satisfactory operation of the valve shall be verified*
- *the flow or capacity shall be certified to a recognized standard for each size and type of valve*

Note 1: For pressure relief valves (PRVs) that are subject to requirement of Ch 9, Sec 8, [2.1.7], the flow or capacity are to be certified by the Society.

For other types of valves, the manufacturer is to certify the flow properties of the valves based on tests carried out according to recognized standards.

- *pressurized components shall be pressure tested to at least 1,5 times the rated pressure, and*
- *for emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard acceptable to* the Society.

Note 2: Refer to SIGTTO Publication on "The Selection and Testing of Valves for LNG Applications".

Note 3: "Emergency shutdown valves, with materials having melting temperatures lower than 925°C" does not include an emergency shutdown valve in which components made of materials having melting temperatures lower than 925°C do not contribute to the shell or seat tightness of the valve.

13.3.2 Type approval

Each size and type of valve intended to be used at a working temperature below –55°C is to be approved through design assessment and prototype testing. Prototype testing for all valves to the minimum design temperature or lower and to a pressure not lower than the maximum design pressure foreseen for the valves is to be witnessed in the presence of the Surveyor. Prototype testing is to include hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure, and cryogenic testing consisting of valve operation or safety valve set pressure, and leakage verification. In addition, for valves other than safety valves, a seat and stem leakage test at a pressure equal to 1,1 times the design pressure.

For valves intended to be used at a working temperature above –55°C, prototype testing is not required.

13.3.3 Unit production testing

All valves are to be tested at the plant of manufacturer in the presence of the Surveyor. Testing is to include hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure for all valves, seat and stem leakage test at a pressure equal to 1,1 times the design pressure for valves other than safety valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below –55°C. The set pressure of safety valves is to be tested at ambient temperature.

For valves used for isolation of instrumentation in piping not greater than 25mm, unit production testing need not be witnessed by the surveyor. Records of testing are to be available for review.

As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a valve may be issued, subject to an alternative survey scheme as per Rule Note NR320 as amended, and the following:

- the valve has been approved as required by [13.3.2] for valves intended to be used at a working temperature below –55°C, and
- the manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and
- the quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure for all valves and seat and stem leakage test at a pressure equal to 1,1 times the design pressure for valves other than safety valves. The set pressure of safety valves is to be tested at ambient temperature. The manufacturer is to maintain records of such tests, and
- cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below –55°C in the presence of the Surveyor.

13.4 Type testing of expansion bellows

13.4.1 General

The following type tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Society*, on those installed within the cargo tanks:*

- *elements of the bellows, not pre-compressed, shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than 5 min*
- *a pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer, without permanent deformation*
- *a cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature, and*
- *a cyclic fatigue test (ship deformation) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2000000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.*

13.4.2 Unit production testing

All bellows are to be tested at the plant of manufacturer in the presence of the Surveyor. Testing is to include hydro- static test of the bellow at a pressure equal to 1,5 times the design pressure. An alternative survey scheme, BV Mode I as per NR320, may be agreed with the Society.

13.5 System testing requirements

13.5.1 *The requirements of this sub-article shall apply to piping inside and outside the cargo tanks.*

13.5.2 *After assembly, all cargo and process piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1,5 times the design pressure (1,25 times the design pressure where the test fluid is compressible) for liquid lines and 1,5 times the maximum system working pressure (1,25 times the maximum system working pressure where the test fluid is*

compressible) for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship, as defined in Pt C, Ch 1, Sec 10, [20.5.1]. *Joints welded on board shall be tested to at least 1,5 times the design pressure.*

Note 1: IMO wanted to distinguish between the pneumatic test with air or other gas (compressible fluid) and the hydraulic test with water (incompressible fluid).

13.5.3 *After assembly on board, each cargo and process piping system shall be subjected to a leak test using air, or other suitable medium, to a pressure depending on the leak detection method applied.*

13.5.4 *In double wall gas-fuel piping systems, the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.*

The expression “duct” means to include the equipment enclosure required in Ch 9, Sec 16, [4.3] (e.g. GVU enclosure) as well as the structural pipe duct intended to contain any release of gas from inner pipe or equipment. The term “structural pipe duct” means an outer duct forming part of a structure such as a hull structure or superstructure or deck house, where permitted, other than gas valve unit rooms.

The expression “maximum pressure at gas pipe rupture” is the maximum pressure to which the outer pipe or duct is subjected after the inner pipe rupture and for testing purposes it is the same as the design pressure used in [4.1.4].

13.5.5 *All piping systems, including valves, fittings and associated equipment for handling cargo or vapours, shall be tested under normal operating conditions not later than at the first loading operation, in accordance with recognized standards.*

13.5.6 Attention is drawn to the requirements of Ch 9, Sec 1, [6.2.4] regarding the examination of the on-deck cargo piping system, that are to be conducted on ships carrying liquefied natural gases (LNG) in bulk during the first full loading and the subsequent first unloading of the ship.

13.6 Emergency shutdown valves

13.6.1 *The closing characteristics of emergency shutdown valves used in liquid cargo piping systems shall be tested to demonstrate compliance with Ch 9, Sec 18, [3.2.1], item c). This testing may be carried out on board after installation.*

Section 6 Materials of Construction and Quality Control

1 Definitions

1.1

1.1.1 *Where reference is made in this Section to A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to recognized standards.*

1.1.2 Piece

A piece is the rolled product from a single slab or billet or from a single ingot, if this is rolled directly into plates, strips, sections or bars.

1.1.3 Batch

A batch is the number of items or pieces to be accepted or rejected together, on the basis of the tests to be carried out on a sampling basis. The size of a batch is given in the recognized standards.

1.1.4 Controlled rolling (CR)

Controlled rolling (CR) is a rolling procedure in which the final deformation is carried out in the normalizing temperature range, resulting in a material condition generally equivalent to that obtained by normalizing.

1.1.5 Thermo-mechanical controlled processing (TMCP)

Thermo-mechanical controlled processing (TMCP) is a procedure that involves strict control of both the steel temperature and the rolling reduction. Unlike CR, the properties conferred by TMCP cannot be reproduced by subsequent normalizing or other heat treatment. The use of accelerated cooling on completion of TMCP may also be accepted, subject to approval by the Society. *The same applies for the use of tempering after completion of TMCP.*

1.1.6 Accelerated cooling (AcC)

Accelerated cooling (AcC) is a process that aims to improve mechanical properties by controlled cooling with rates higher than air cooling, immediately after the final TMCP operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TMCP and AcC cannot be reproduced by subsequent normalizing or other heat treatment.

2 Scope and general requirements

2.1

2.1.1 *This Section gives the requirements for metallic and non-metallic materials used in the construction of the cargo system. This includes requirements for joining processes, production process, personnel qualification, NDT and inspection and testing including production testing. The requirements for rolled materials, forgings and castings are given in Article [4] and in Tab 2 to Tab 6. The requirements for weldments are given in Article [5], and the guidance for non-metallic materials is given in* Appendix 4 of the IGC Code. *A quality assurance/ quality control programme shall be implemented to ensure that the requirements of this Article [2] are complied with.*

2.1.2 *The manufacture, testing, inspection and documentation shall be in accordance with recognized standards and the specific requirements given in the Code.*

2.1.3 *Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat-treated condition, in accordance with the applicable table of this Section, and the weld properties shall be determined in the heat treated condition in accordance with Article [5]. In cases where a post-weld heat treatment is applied, the test requirements may be modified at the discretion of* the Society.

3 General test requirements and specifications

3.1 Tensile test

3.1.1 *Tensile testing shall be carried out in accordance with recognized standards.*

3.1.2 *Tensile strength, yield stress and elongation shall be to the satisfaction of* the Society. *For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.*

Note 1: The test specimens and mechanical testing procedures for materials are defined in NR216 Materials and Welding, and reference should be made to international standard as ISO, etc...

3.2 Toughness test

3.2.1 *Acceptance tests for metallic materials shall include Charpy V-notch toughness tests, unless otherwise specified by* the Society. *The specified Charpy V-notch requirements are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens shall be in accordance with recognized standards. The testing and requirements for specimens smaller than 5 mm in size shall be in accordance with recognized standards. Minimum average values for subsized specimens shall be as defined in Tab 1.*

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

Table 1 : Minimum average energy values for subsized specimens

Charpy V-notch specimen size (mm)	Minimum average energy of three specimens
10 x 10	KV
10 x 7,5	5/6 KV
10 x 5,0	2/3 KV
Note 1:KV : Energy values, in J, specified in Tab 2 to Tab 5.	

3.2.2 *For base metal, the largest size Charpy V-notch specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in Fig 1.*

Note 1: In the case where the material thickness is 40mm or below, the Charpy V-notch impact test specimens are to be cut with their edge within 2mm from the "as rolled" surface with their longitudinal axes either parallel or transverse to the final direction of rolling of the material.

3.2.3 *For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen shall be approximately 1 mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded section. The specimens shall be taken generally at each of the five following locations, as shown in Fig 2: on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.*

Figure 1 : Orientation of base metal test specimen

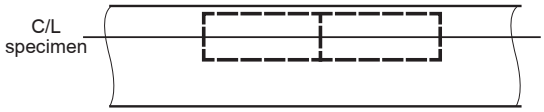
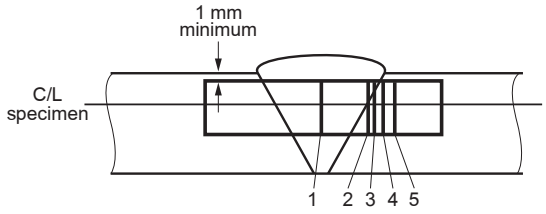
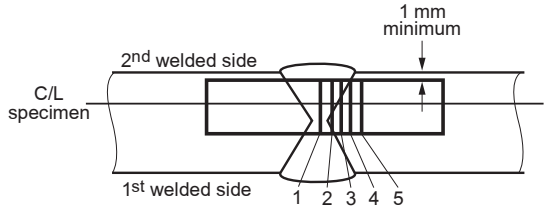


Figure 2 : Orientation of weld test specimen



Single-V butt weld



Double-V butt weld

3.2.4 *If the average value of the three initial Charpy V-notch specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results be combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.*

3.3 Bend test

3.3.1 *The bend test may be omitted as a material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with recognized standards.*

3.3.2 *The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of* the Society. *However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.*

3.4 Section observation and other testing

3.4.1 *Macrosection, microsection observations and hardness tests may also be required by* the Society, *and they shall be carried out in accordance with recognized standards, where required.*

4 Requirements for metallic materials

4.1 General requirements for metallic materials

4.1.1 The use of high manganese austenitic steel for cryogenic service may be permitted in accordance with IACS Recommendation No.169.

Refer also to IMO Circular MSC.1/Circ.1599/Rev.3: Interim guidelines on the application of high manganese austenitic steel for cryogenic service.

4.1.2 The use of alternative metallic materials not defined in this section may be permitted subject to agreement with the Society and in accordance with IMO Circular MSC.1/Circ.1622/Rev.1: Revised guidelines for the acceptance of alternative metallic materials for cryogenic service in ships carrying liquefied gases in bulk and ships using gases or other low-flashpoint fuels.

4.1.3 The use of aluminium coatings is prohibited in the cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo gas may accumulate.

4.1.4 *The requirements for materials of construction are shown in the tables as follows:*

- *Tab 2: Plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C*
- *Tab 3: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to –55°C*
- *Tab 4: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C*
- *Tab 5: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to –165°C*
- *Tab 6: Plates and sections for hull structures required by Ch 9, Sec 4, [6.2.2] and Ch 9, Sec 4, [6.2.3].*

4.1.5 Impact tests are required for:

- castings in steel grades 304, 304L, 321 and 347 when the service temperature is below –60°C
- castings in steel grades 316 and 316L (which contain molybdenum) at any temperature. A reduction of the tests may be granted for design temperatures above –60°C after examination of each case by the Society.

Table 2 : Plates, pipes (seamless and welded) -see Note 1 and Note 2-, sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C

CHEMICAL COMPOSITION AND HEAT TREATMENT
• Carbon-manganese steel
• Fully killed fine grain steel
• Small additions of alloying elements by agreement with the Society
• Composition limits to be approved by the Society
• Normalized, or quenched and tempered **(1)**

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS			
Sampling frequency	• Plates	Each “piece” to be tested	
	• Sections and forgings	Each “batch” to be tested	
Mechanical properties	• Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 **(2)**	
Toughness (Charpy V-notch test)	• Plates	Transverse test pieces. Minimum average energy value (KV) 27 J	
	• Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41 J	
	• Test temperature **(3)**	Thickness t (mm)	Test temperature
		t ≤ 20	0°C
		20 < t ≤ 40	–20°C
		40 < t ≤ 50 **(4)**	–20°C **(5)**
		40 < t ≤ 50 **(4)**	–30°C **(6)**

(1) A controlled rolling procedure or TMCP may be used as an alternative.

(2) Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Society. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

(3) This Table is generally applicable for material thicknesses t up to 40 mm. Proposals for greater thicknesses shall be approved by the Society.

(4) A further set of impact test at mid thickness for products with t>40mm is required except rolled steels specified in NR216, Ch 3, Sec 2 and NR216, Ch 3, Sec 3.

(5) Applies to type C independent tanks and process pressure vessels. In addition, post-weld stress relief heat treatment shall be performed. Exemption to post-weld stress relief heat treatment based on alternative approach (e.g. Engineering Critical Assessment) shall be approved by the Society or shall be to recognized standards.

(6) Applies to cargo tank other than type C.

Note 1: For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by the Society.

Note 2: Charpy V-notch impact tests are not required for pipes.

Table 3 : Plates, sections and forgings -see Note 1- for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to –55°C

CHEMICAL COMPOSITION AND HEAT TREATMENT
• Carbon-manganese steel
• Fully killed, aluminium treated fine grain steel
• Chemical composition (ladle analysis): C: 0,16% max **(1)** ; Mn: 0,70-1,60% ; Si: 0,10-0,50% ; S: 0,025% max ; P: 0,025% max
• Optional additions: Alloys and grain refining elements may be generally in accordance with the following: Ni: 0,80% max ; Cr: 0,25% max ; Mo: 0,08% max ; Cu:0,35% max ; Nb: 0,05% max ; V: 0,10% max Al content total: 0,020% min (acid soluble: 0,015% min)
• Normalized, or quenched and tempered **(2)**

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS		
Sampling frequency	• Plates	Each "piece" to be tested
	• Sections and forgings	Each "batch" to be tested
Mechanical properties	• Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 **(3)**
Toughness (Charpy V-notch test)	• Plates	Transverse test pieces. Minimum average energy value (KV) 27 J
	• Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41 J
	• Test temperature, t ≤ 25 mm **(4)**	5°C below the design temperature or –20°C, whichever is lower

(1) By special agreement with the Society, the carbon content may be increased to 0,18% maximum, provided the design temperature is not lower than –40°C.

(2) A controlled rolling procedure or TMCP may be used as an alternative.

(3) Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Society. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

(4) This Table is applicable for material thicknesses t up to 25 mm. For material thicknesses of more than 25 mm, Charpy V-notch tests shall be conducted at the following temperatures:

Thickness t (mm)	Test temperature
25 mm < t ≤ 30 mm	10°C below the design temperature or –20°C, whichever is lower
30 mm < t ≤ 35 mm	15°C below the design temperature or –20°C, whichever is lower
35 mm < t ≤ 40 mm	20°C below the design temperature
40 mm < t ≤ 50 mm **(a)**	5°C below the design temperature or –20°C, whichever is lower **(b)**
40 mm < t ≤ 45 mm **(a)**	25°C below the design temperature **(c)**
45 mm < t ≤ 50 mm **(a)**	30°C below the design temperature **(c)**

The impact energy value shall be in accordance with the Table for the applicable type of test specimen.

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or –20°C, whichever is lower.

For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness.

(a) A further set of impact test at mid thickness for products with t > 40 mm is required except rolled steels specified in NR216, Ch 3, Sec 2 and NR216, Ch 3, Sec 3.

(b)
- For design temperatures below 0°C and strictly down to -10°C:
  Applies to type C independent tanks and process pressure vessels. In addition, post-weld stress relief heat treatment shall be performed. Exemption to post-weld stress relief heat treatment based on alternative approach (e.g. Engineering Critical Assessment) shall be approved by the Society or shall be to recognized standards.
- For design temperatures below -10°C and down to -55°C:
  [6.2.2] applies with regards to post-weld stress relief heat treatment. Exemption to post-weld stress relief heat treatment based on alternative approach (e.g. Engineering Critical Assessment) shall be approved by the Society or shall be to recognized standards.

(c) Applies to cargo tank other than type C.

Note 1: The Charpy V-notch and chemistry requirements for forgings may be specially considered by the Society.

Note 2: For materials exceeding 25 mm in thickness for which the test temperature is –60°C or lower, the application of specially treated steels or steels in accordance with Table 4 may be necessary.

Table 4 : Plates, sections and forgings -see Note 1- for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C

Minimum design temperature **(1)**	CHEMICAL COMPOSITION **(2)** AND HEAT TREATMENT	Impact test temperature	
–60°C	1,5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP **(4)**	t ≤ 25 mm **(9)**	–65°C
–65°C	2,25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP **(4) (5)**		–70°C
–90°C	3,5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP **(4) (5)**		–95°C
–105°C	5,0% nickel steel – normalized or normalized and tempered or quenched and tempered **(4) (5) (6)**		–110°C
–165°C	9,0% nickel steel – double normalized and tempered or quenched and tempered **(4)**	**(3)**	–196°C
–165°C	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated **(7) (8)**		–196°C
–165°C	Aluminium alloys, such as type 5083 annealed		Not required
–165°C	Austenitic Fe-Ni alloy (36% nickel). Heat treatment as agreed		Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS		
Sampling frequency	• Plates	Each "piece" to be tested
	• Sections and forgings	Each "batch" to be tested
Toughness (Charpy V-notch test)	• Plates	Transverse test pieces. Minimum average energy value (KV) 27 J
	• Sections and forgings	Longitudinal test pieces. Minimum average energy value (KV) 41 J

(1) The requirements for design temperatures below –165°C shall be specially agreed with the Society.

(2) The chemical composition limits shall be in accordance with recognized standards.

(3) For 9,0% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.

(4) TMCP nickel steels will be subject to acceptance by the Society.

(5) A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Society.

(6) A specially heat treated 5,0% nickel steel, for example triple heat treated 5,0% nickel steel, may be used down to –165°C, provided that the impact tests are carried out at –196°C.

(7) The impact test of austenitic stainless steel is required only for service temperature less than –105°C.

(8) Impact tests may be omitted subject to agreement with the Administration.

(9) This Table is applicable for material thicknesses t up to 25 mm. For materials 1,5% Ni, 2,25% Ni, 3,5% Ni and 5,0% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted at the following temperatures:

Thickness t (mm)	Test temperature
25 mm < t ≤ 30 mm	10°C below the design temperature
30 mm < t ≤ 35 mm	15°C below the design temperature
35 mm < t ≤ 40 mm	20°C below the design temperature
40 mm < t ≤ 45 mm **(a)**	25°C below the design temperature
45 mm < t ≤ 50 mm **(a)**	30°C below the design temperature

The energy value shall be in accordance with the Table for the applicable type of test specimen.

(a) A further set of impact test at mid thickness for products with t>40mm is required.

Note 1: The impact test required for forgings used in critical applications shall be subject to special consideration by the Society.

Table 5 : Pipes (seamless and welded) -see Note 1-, forgings and castings -see Note 2- for cargo and process piping for design temperatures below 0°C and down to –165°C

Minimum design temperature **(1)**	CHEMICAL COMPOSITION **(2)** AND HEAT TREATMENT	Impact test, t ≤ 25 mm	
		Test temperature	Minimum average energy (KV)
–55°C	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed **(4)**	**(3)**	27 J
–65°C	2,25% nickel steel. Normalized, normalized and tempered or quenched and tempered **(4)**	–70°C	34 J
–90°C	3,5% nickel steel. Normalized, normalized and tempered or quenched and tempered **(4)**	–95°C	34 J
–165°C	9,0% nickel steel **(5)**. Double normalized and tempered or quenched and tempered	–196°C	41 J
	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated **(6) (7)**	–196°C	41 J
	Aluminium alloys, such as type 5083 annealed	Not required	

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS	
Sampling frequency	• Each "batch" to be tested
Toughness (Charpy V-notch test)	• Impact test: longitudinal test pieces

(1) The requirements for design temperatures below –165°C shall be specially agreed with the Society.
(2) The chemical composition limits shall be in accordance with recognized standards.
(3) The test temperature shall be 5°C below the design temperature or –20°C, whichever is lower.
(4) A lower design temperature may be specially agreed with the Society for quenched and tempered materials.
(5) This chemical composition is not suitable for castings.
(6) The impact test of austenitic stainless steel other than castings is required only for service temperature less than -105°C.
(7) Impact tests may be omitted subject to agreement with the Administration.
Note 1: The use of longitudinally or spirally welded pipes shall be specially approved by the Society.
Note 2: The requirements for forgings and castings may be subject to special consideration by the Society.

Table 6 : Plates and sections for hull structures required by Ch 9, Sec 4, [6.2.2] and Ch 9, Sec 4, [6.2.3]

Minimum design temperature of hull structure	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0°C and above **(1)**	Recognized standards							
–5°C and above **(2)**	Recognized standards							
down to –5°C	15	25	30	50	25	45	50	50
down to –10°C	x	20	25	50	20	40	50	50
down to –20°C	x	x	20	50	x	30	50	50
down to –30°C	x	x	x	40	x	20	40	50
below –30°C	In accordance with Tab 3, except that the thickness limitation given in Tab 3 and in footnote **(4)** of that Table does not apply.							

(1) For the purpose of Ch 9, Sec 4, [6.2.3]
(2) For the purpose of Ch 9, Sec 4, [6.2.2].
Note 1:
x : Steel grade not to be used.

5 Welding of metallic materials and non-destructive testing

5.1 General

5.1.1 *This Article shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of* the Society, *impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.*

Note 1: This requirement is also applicable for austenitic steels and aluminium alloy.

5.2 Welding consumables

5.2.1 *Consumables intended for welding of cargo tanks shall be in accordance with recognized standards. Deposited weld metal tests and butt weld tests shall be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests shall be in accordance with recognized standards. The chemical composition of the deposited weld metal shall be recorded for information.*

The content of this requirement is also to cover process pressure vessels and secondary barriers.

5.3 Welding procedure tests for cargo tanks and process pressure vessels

5.3.1 *Welding procedure tests for cargo tanks and process pressure vessels are required for all butt welds.*

5.3.2 *The test assemblies shall be representative of:*

- *each base material*
- *each type of consumable and welding process, and*
- *each welding position.*

5.3.3 *For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator.*

5.3.4 *The following welding procedure tests for cargo tanks and process pressure vessels shall be carried out in accordance with Article [3], with specimens made from each test assembly:*

- *cross-weld tensile tests*
- *longitudinal all-weld testing, where required by the recognized standards*
- *transverse bend tests, which may be face, root or side bends. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels*
- *one set of three Charpy V-notch impacts, generally at each of the following locations, as shown in Fig 2:*
  - *centreline of the weld*
  - *fusion line*
  - *1 mm from the fusion line*
  - *3 mm from the fusion line, and*
  - *5 mm from the fusion line, and*
- *macrosection, microsection and hardness survey may also be required.*

5.3.5 *Each test shall satisfy the following requirements:*

- *tensile tests: cross-weld tensile strength shall not be less than the specified minimum tensile strength for the appropriate parent materials. For materials such as aluminium alloys, reference shall be made to Ch 9, Sec 4, [4.5.1], item c) with regard to the requirements for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture shall be recorded for information.*
- *bend tests: no fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces, and*

  As an alternative to the bend test indicated, a test over a mandrel having a diameter equal to 3 times the thickness with a bend angle up to 120° may be required.
- *Charpy V-notch impact tests: Charpy V-notch tests shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV), shall be no less than 27 J. The weld metal requirements for subsize specimens and single energy values shall be in accordance with [3.2]. The results of fusion line and heat-affected zone impact tests shall show a minimum average energy (KV) in accordance with the transverse or longitudinal requirements of the base material, whichever is applicable, and for subsize specimens, the minimum average energy (KV) shall be in accordance with [3.2]. If the material thickness does not permit machining either full-size or standard subsize specimens, the testing procedure and acceptance standards shall be in accordance with recognized standards.*

5.3.6 *Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties.*

5.4 Welding procedure tests for piping

5.4.1 *Welding procedure tests for piping shall be carried out and shall be similar to those detailed for cargo tanks in [5.3].*

5.5 Production weld tests

5.5.1 *For all cargo tanks and process pressure vessels, except integral and membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with* the Society. *Tests, other than those specified in [5.5.2] to [5.5.5] may be required for cargo tanks or secondary barriers.*

5.5.2 *The production tests for type A and type B independent tanks and semi-membrane tanks shall include bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The tests shall be made for each 50 m of weld. The Charpy V-notch tests shall be made with specimens having the notch alternately located in the centre of the weld and in the heat-affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches shall be in the centre of the weld.*

5.5.3 *For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in [5.5.2]. Tensile tests shall meet the requirements of [5.3.5].*

5.5.4 *The quality assurance/quality control programme shall ensure the continued conformity of the production welds as defined in the material manufacturers quality manual.*

5.5.5 *The test requirements for integral and membrane tanks are the same as the applicable test requirements listed in [5.3].*

5.6 Non-destructive testing

5.6.1 For the fabrication of independent cargo tanks, the requirements for the entity carrying out NDT are as follows:

- In case of non-destructive testing carried out by an independent company from the manufacturer or shipyard, such company has to comply with the requirements for the independent NDT service supplier as set out in NR669 “Requirements for non-destructive testing suppliers”.
- In case of non-destructive testing carried out directly by the shipyard or manufacturer, the requirements for the internal NDT department as set out in NR669 “Requirements for non-destructive testing suppliers” are to be complied with.

5.6.2 The following provisions apply to independent tanks:

a) Tracing, cutting and shaping are to be carried out so as to prevent, at the surface of the pieces, the production of defects detrimental to their use. In particular, marking the plates by punching and starting welding arcs outside the welding zone are to be avoided.

b) Before welding, the edges to be welded are to be carefully examined, with possible use of non-destructive examination, in particular when chamfers are carried out.

c) In all cases, the working units are to be efficiently protected against bad weather.

d) The execution of provisional welds, where any, is to be subjected to the same requirements as the constructional welds. After elimination of the fillets, the area is to be carefully ground and inspected (the inspection is to include, if necessary, a penetrant fluid test).

e) All welding consumables are subject to agreement. Welders are also to be agreed.

5.6.3 *All test procedures and acceptance standards shall be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used, in principle, to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but, in addition, supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained.*

5.6.4 *For type A independent tanks and semi-membrane tanks, where the design temperature is below –20°C, and for type B independent tanks, regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in [5.6.3].*

5.6.5 *Where the design temperature is higher than –20°C, all full penetration butt welds in way of intersections and at least 10% of the remaining full penetration welds of tank structures shall be subjected to radiographic testing or ultrasonic testing under the same conditions as described in [5.6.3].*

5.6.6 *In each case, the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods, as considered necessary.*

5.6.7 *For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:*

a) Total non-destructive testing referred to in Ch 9, Sec 4, [10.2]:

- *Radiographic testing:*
  - *all butt welds over their full length*
- *Non-destructive testing for surface crack detection:*
  - *all welds over 10% of their length*
  - *reinforcement rings around holes, nozzles, etc., over their full length.*

As an alternative, ultrasonic testing as described in [5.6.3] may be accepted as a partial substitute for the radiographic testing. In addition, the Society *may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.*

b) Partial non-destructive testing referred to in Ch 9, Sec 4, [10.2]:

- *Radiographic testing:*
  - *all butt-welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed*
- *Non-destructive testing for surface crack detection:*
  - *reinforcement rings around holes, nozzles, etc., over their full length*
- *Ultrasonic testing:*
  - *as may be required by* the Society *in each instance.*

5.6.8 *The quality assurance/quality control programme shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual.*

5.6.9 *Inspection of piping shall be carried out in accordance with the requirements of Ch 9, Sec 5.*

5.6.10 *The secondary barrier shall be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing.*

6 Other requirements for construction in metallic materials

6.1 General

6.1.1 *Inspection and non-destructive testing of welds shall be in accordance with the requirements of [5.5] and [5.6]. Where higher standards or tolerances are assumed in the design, they shall also be satisfied.*

6.2 Independent tank

6.2.1 *For type C tanks and type B tanks primarily constructed of bodies of revolution, the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards. The tolerances shall also be related to the buckling analysis referred to in Ch 9, Sec 4, [9.3], item b) and Ch 9, Sec 4, [10.3], item b).*

6.2.2 *For type C tanks of carbon and carbon-manganese steel, post-weld heat treatment shall be performed after welding, if the design temperature is below –10°C. Post-weld heat treatment in all other cases and for materials other than those mentioned above shall be to recognized standards. The soaking temperature and holding time shall be to the recognized standards.*

6.2.3 *In the case of type C tanks and large cargo pressure vessels of carbon or carbon-manganese steel, for which it is difficult to perform the heat treatment, mechanical stress relieving by pressurizing may be carried out as an alternative to the heat treatment and subject to the following conditions:*

- *complicated welded pressure vessel parts such as sumps or domes with nozzles, with adjacent shell plates shall be heat treated before they are welded to larger parts of the pressure vessel*
- *the mechanical stress relieving process shall preferably be carried out during the hydrostatic pressure test required by Ch 9, Sec 4, [10.6], by applying a higher pressure than the test pressure required by Ch 9, Sec 4, [10.6], item a). The pressurizing medium shall be water*
- *for the water temperature, Ch 9, Sec 4, [10.6], item b) applies*
- *stress relieving shall be performed while the tank is supported by its regular saddles or supporting structure or, when stress relieving cannot be carried out on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure*
- *the maximum stress relieving pressure shall be held for 2 h per 25 mm of thickness, but in no case less than 2 h*

- *the upper limits placed on the calculated stress levels during stress relieving shall be the following:*
  - *equivalent general primary membrane stress: 0,9 R_e*
  - *equivalent stress composed of primary bending stress plus membrane stress: 1,35 R_e, where R_e is the specific lower minimum yield stress or 0,2% proof stress at test temperature of the steel used for the tank*
- *strain measurements will normally be required to prove these limits for at least the first tank of a series of identical tanks built consecutively. The location of strain gauges shall be included in the mechanical stress relieving procedure to be submitted in accordance with [6.2.3]*
- *the test procedure shall demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again up to the design pressure*
- *high-stress areas in way of geometrical discontinuities such as nozzles and other openings shall be checked for cracks by dye penetrant or magnetic particle inspection after mechanical stress relieving. Particular attention in this respect shall be paid to plates exceeding 30 mm in thickness*
- *steels which have a ratio of yield stress to ultimate tensile strength greater than 0,8 shall generally not be mechanically stress relieved. If, however, the yield stress is raised by a method giving high ductility of the steel, slightly higher rates may be accepted upon consideration in each case*
- *mechanical stress relieving cannot be substituted for heat treatment of cold formed parts of tanks, if the degree of cold forming exceeds the limit above which heat treatment is required*
- *the thickness of the shell and heads of the tank shall not exceed 40 mm. Higher thicknesses may be accepted for parts which are thermally stress relieved*
- *local buckling shall be guarded against, particularly when tori-spherical heads are used for tanks and domes, and*
- *the procedure for mechanical stress relieving shall be to a recognized standard.*

6.3 Secondary barriers

6.3.1 *During construction, the requirements for testing and inspection of secondary barriers shall be approved or accepted by* the Society *(see Ch 9, Sec 4, [2.4.3], item e) and Ch 9, Sec 4, [2.4.3], item f)).*

6.4 Semi-membrane tanks

6.4.1 *For semi-membrane tanks, the relevant requirements in Article [6] for independent tanks or for membrane tanks shall be applied as appropriate.*

6.5 Membrane tanks

6.5.1 *The quality assurance/quality control programme shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme.*

7 Non-metallic materials

7.1 General

7.1.1 *The information in* Appendix 4 of the IGC Code *is given for guidance in the selection and use of these materials, based on the experience to date.*

Section 7 Cargo Pressure / Temperature Control

1 Methods of control

1.1 General

1.1.1 *With the exception of tanks designed to withstand full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, cargo tanks' pressure and temperature shall be maintained at all times within their design range by either one, or a combination of, the following methods:*

- *reliquefaction of cargo vapours*
- *thermal oxidation of vapours*
- *pressure accumulation, and*
- *liquid cargo cooling.*

1.1.2 *For certain cargoes, where required by Ch 9, Sec 17, the cargo containment system shall be capable of withstanding the full vapour pressure of the cargo under conditions of the upper ambient design temperatures, irrespective of any system provided for dealing with boil-off gas.*

1.1.3 *Venting of the cargo to maintain cargo tank pressure and temperature shall not be acceptable except in emergency situations.* The Society *may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea. This may also be permitted in port with the authorization of the port Administration.*

2 Design of systems

2.1 General

2.1.1 *For normal service, the upper ambient design temperature shall be:*

- *sea: 32°C*
- *air: 45°C.*

For service in particularly hot or cold zones, these design temperatures shall be increased or decreased, to the satisfaction of the Society. *The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.*

2.1.2 Any subcooling units and reliquefaction units installed on board are to be considered as essential service as per Pt C, Ch 2, Sec 1, [3.11.3].

2.1.3 Subject to special consideration by the Society and to Shipowner agreement, the requirement stated in [2.1.2] may be waived if justifications are provided to demonstrate that these systems are not essential for the boil-off gas management.

3 Reliquefaction of cargo vapours

3.1

3.1.1 In general, in addition to the requirements of this Article, the specific requirements stated in Part C and Part D, Chapter 9 of the Rules for various machinery and equipment are also applicable to refrigerating installation components.

3.1.2 Attention is drawn to the requirements of Ch 9, Sec 1, [6.2.4] regarding the satisfactory operation of the reliquefaction plant, if installed, and of any other equipment fitted for the burning of cargo vapours, that is to be ascertained during the first full loading and the subsequent first unloading of ships carrying liquefied natural gasses (LNG) in bulk.

3.1.3 General

The reliquefaction system may be arranged in one of the following ways:

a) A direct system, where evaporated cargo is compressed, condensed and returned to the cargo tanks

b) An indirect system, where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed

c) A combined system, where evaporated cargo is compressed and condensed in a cargo/refrigerant heat exchanger and returned to the cargo tanks, and

d) If the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases, as far as reasonably practicable, are disposed of without venting to atmosphere.

Note 1: The requirements of Ch 9, Sec 17 and Ch 9, Sec 19 may preclude the use of one or more of these systems or may specify the use of a particular system.

3.1.4 Compatibility

Refrigerants used for reliquefaction shall be compatible with the cargo they may come into contact with. In addition, when several refrigerants are used and may come into contact, they shall be compatible with each other.

3.2 Refrigerating installation components

3.2.1 Pressure vessels and heat exchangers

a) Pressure vessels of refrigerating plants are to comply with the relevant requirements of Pt C, Ch 1, Sec 3 and Ch 9, Sec 5.

b) Notch toughness of steels used in low temperature plants is to be suitable for the thickness and the lowest design temperature. A check of the notch toughness properties may be required where the working temperature is below minus 40°C.

3.2.2 Piping systems

a) Refrigerant pipes are generally to be regarded as pressure pipes.

b) Refrigerant pipes are to be considered as belonging to the following classes:

- class I: where they are intended for ammonia or toxic and flammable substances
- class II: for other refrigerants

c) In general, the pipes conveying the cooling medium are not to come into direct contact with the ship's structure; they are to be carefully insulated on their run outside the refrigerated spaces, and more particularly when passing through bulkheads and decks.

d) The materials used for the pipes are to be appropriate to the fluids that they convey. Copper, brass, bronze and other copper alloys are not to be used for pipes likely to convey ammonia. Methods proposed for joining such pipes are to be submitted to the Society for consideration.

e) Notch toughness of the steels used is to be suitable for the application concerned.

f) Where necessary, cooling medium pipes within refrigerated spaces or embedded in insulation are to be externally protected against corrosion; for steel pipes, this protection is to be ensured by galvanisation or equivalent. All useful precautions are to be taken to protect the joints of such pipes against corrosion.

3.3 Refrigerants

3.3.1 Prohibited refrigerants

The use of the following refrigerants is not allowed for shipboard installations:

- Methyl chloride
- R11 - Trichloromonofluoromethane (C Cl3 F)

3.3.2 Statutory requirements

Particular attention is to be paid to any limitation on the use of refrigerants imposed by the Administration of the State whose flag the ship is flying.

4 Thermal oxidation of vapours

4.1 General

4.1.1 Article [8] states that unless an alternative means of controlling the cargo pressure/temperature is provided to the satisfaction of the Society, a standby unit (or units) affording spare capacity at least equal to the largest required single unit is (are) to be fitted.

For the purpose of complying with the above, a suitable alternative means of pressure/temperature control would be:

a) Auxiliary boiler(s) capable of burning the boil-off vapours and disposing of the generated steam or an alternative waste heat system acceptable to the Society. Consideration will be given to systems burning only part of the boil-off vapour if it can be shown that MARVS will not be reached within a period of 21 days.

b) Controlled venting of cargo vapours as specified in [1.1.3] if permitted by the Administration concerned.

4.1.2 *Maintaining the cargo tank pressure and temperature by means of thermal oxidation of cargo vapours, as defined in Ch 9, Sec 1, [4.1.50] and Ch 9, Sec 16, [2] shall be permitted only for LNG cargoes. In general:*

- *thermal oxidation systems shall exhibit no externally visible flame and shall maintain the uptake exhaust temperature below 535°C*
- *arrangement of spaces where oxidation systems are located shall comply with Ch 9, Sec 16, [3] and supply systems shall comply with Ch 9, Sec 16, [4], and*
- *if waste gases coming from any other system are to be burnt, the oxidation system shall be designed to accommodate all anticipated feed gas compositions.*

4.2 Thermal oxidation systems

4.2.1 *Thermal oxidation systems shall comply with the following:*

- *each thermal oxidation system shall have a separate uptake*
- *each thermal oxidation system shall have a dedicated forced draught system, and*
- *combustion chambers and uptakes of thermal oxidation systems shall be designed to prevent any accumulation of gas.*

4.2.2 Gas combustion units are to comply with the provisions of Pt C, Ch 1, Sec 3, [7].

4.3 Burners

4.3.1 *Burners shall be designed to maintain stable combustion under all design firing conditions.*

4.4 Safety

4.4.1 *Suitable devices shall be installed and arranged to ensure that gas flow to the burner is cut off unless satisfactory ignition has been established and maintained.*

4.4.2 *Each oxidation system shall have provision to manually isolate its gas fuel supply from a safely accessible position.*

4.4.3 *Provision shall be made for automatic purging the gas supply piping to the burners by means of an inert gas, after the extinguishing of these burners.*

4.4.4 *In case of flame failure of all operating burners for gas or oil or for a combination thereof, the combustion chambers of the oxidation system shall be automatically purged before relighting.*

4.4.5 *Arrangements shall be made to enable the combustion chamber to be manually purged.*

5 Pressure accumulation systems

5.1 General

5.1.1 *The containment system insulation, design pressure or both shall be adequate to provide for a suitable margin for the operating time and temperatures involved. No additional pressure and temperature control system is required. Conditions for acceptance shall be recorded in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.*

Note 1: The operating time corresponds to a period not less than 21 days.

6 Liquid cargo cooling

6.1 General

6.1.1 *The bulk cargo liquid may be refrigerated by coolant circulated through coils fitted either inside the cargo tank or onto the external surface of the cargo tank.*

7 Segregation

7.1 General

7.1.1 *Where two or more cargoes that may react chemically in a dangerous manner are carried simultaneously, separate systems as defined in Ch 9, Sec 1, [4.1.45], each complying with availability criteria as specified in [8], shall be provided for each cargo. For simultaneous carriage of two or more cargoes that are not reactive to each other but where, due to properties of their vapour, separate systems are necessary, separation may be by means of isolation valves.*

8 Availability

8.1 General

8.1.1 *The availability of the system and its supporting auxiliary services shall be such that:*

a) In case of a single failure of a mechanical non-static component or a component of the control systems, the cargo tanks' pressure and temperature can be maintained within their design range without affecting other essential services

Note 1: "mechanical non-static component" refers to pumps, fan or compressors.

Note 2: "component of the control systems" refers to electronical cards.

b) Redundant piping systems are not required

c) *Heat exchangers that are solely necessary for maintaining the pressure and temperature of the cargo tanks within their design ranges shall have a standby heat exchanger, unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external resources. Where an additional and separate method of cargo tank pressure and temperature control is fitted that is not reliant on the sole heat exchanger, then a standby heat exchanger is not required.*

A single heat exchanger without margin (i.e. designed for 100% capacity) may also be not duplicated if another means of pressure/temperature control is provided with a capacity that is at least equivalent to the missing 25% capacity for the heat exchanger, and

d) *For any cargo heating or cooling medium, provisions shall be made to detect the leakage of toxic or flammable vapours into an otherwise safe location or overboard in accordance with Ch 9, Sec 13, [6]. Any vent outlet from this leak detection arrangement shall be to a safe location and be fitted with a flame screen.*

Any non-static component (e.g. pump, compressor, fan) is to be duplicated in such a way that a single failure of one of these components will not impair the performance of the pressure/temperature control system. Static components such as piping or heat exchanger are not necessarily to be duplicated: no redundancy is required for piping and heat exchangers having an operational margin (+25% capacity).

Section 8 Vent Systems for Cargo Containment

1 General

1.1

1.1.1 *All cargo tanks shall be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold spaces and interbarrier spaces, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in Ch 9, Sec 7 shall be independent of the pressure relief systems.*

2 Pressure relief systems

2.1 General

2.1.1 *Cargo tanks, including deck tanks, shall be fitted with a minimum of two pressure relief valves (PRVs), each being of equal size within manufacturer's tolerances and suitably designed and constructed for the prescribed service.*

2.1.2 *Interbarrier spaces shall be provided with pressure relief devices.*

For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.

2.1.3 Protection of interbarrier spaces

a) The relieving capacity of pressure relief devices of interbarrier spaces surrounding independent type B cargo tanks may be determined on the basis of the method given in Article [2]; however, the leakage rate is to be determined in accordance with Ch 9, Sec 4, [2.5.2].

b) The relieving capacity of pressure relief devices for interbarrier spaces of membrane and semi-membrane tanks is to be evaluated on the basis of specific membrane/semi-membrane tank design.

c) The relieving capacity of pressure relief devices for interbarrier spaces adjacent to integral type cargo tanks may, if applicable, be determined as for type A independent cargo tanks.

2.1.4 Size of pressure relief devices

The combined relieving capacity, in m^3/s, of the pressure relief devices for interbarrier spaces surrounding type A independent cargo tanks where the insulation is fitted to the cargo tanks may be determined by the following formula:

$$Q_{sa} = 3{,}4 \cdot A_C \cdot \frac{\rho}{\rho_V} \cdot \sqrt{h}$$

where:

Q_{sa} : Minimum required discharge rate of air in standard conditions of 273 K and 1,013 bar

A_C : Design crack opening area, in m^2, equal to:

$$A_C = \frac{\pi}{4} \cdot \delta \cdot l$$

where:

δ : Maximum crack opening width, in m, equal to:

$\delta = 0{,}2\ t$

t being the thickness of tank bottom plating, in m

l : Design crack length, in m, equal to the diagonal of the largest plate panel of the tank bottom (see Fig 1)

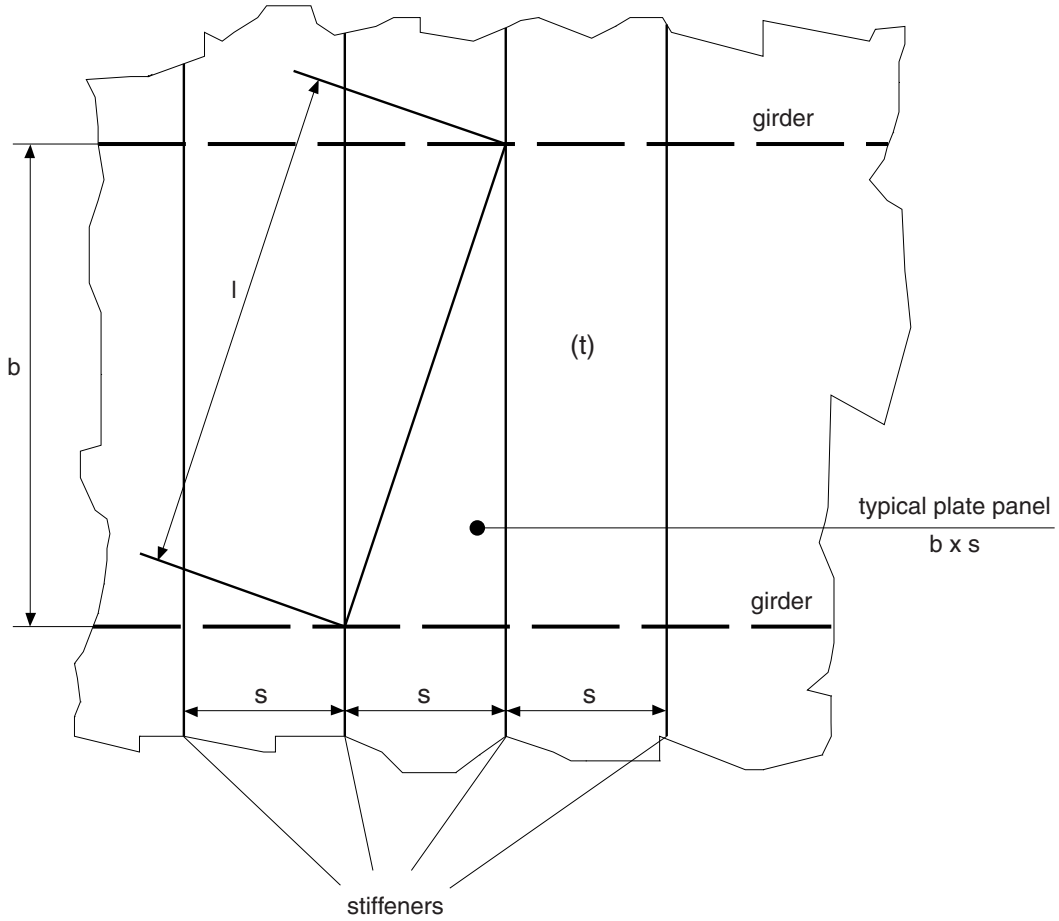
h : Maximum liquid height above tank bottom plus 10 × MARVS, in m

ρ : Density of product liquid phase, in kN/m^3, at the set pressure of the interbarrier space relief device

ρ_V : Density of product vapour phase, in kN/m^3, at the set pressure of the interbarrier space relief device and a temperature of 273 K.

2.1.5 *The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Where two or more PRVs are fitted, valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.*

Figure 1 : Determination of l



2.1.6 *The following temperature requirements apply to PRVs fitted to pressure relief systems:*

- *PRVs on cargo tanks with a design temperature below 0°C shall be designed and arranged to prevent their becoming inoperative due to ice formation*
- *the effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs*
- *PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted, provided that fail-safe operation of the PRV is not compromised, and*
- *sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage.*

2.1.7 Valve testing

a) PRVs shall be type-tested. Type tests shall include:

- *verification of relieving capacity*
- *cryogenic testing when operating at design temperatures colder than –55°C*
- *seat tightness testing, and*
- *pressure containing parts are pressure tested to at least 1,5 times the design pressure.*

PRVs shall be tested in accordance with recognized standards.

Note 1: ISO 21013-1:2008 - Cryogenic vessels - Pressure-relief accessories for cryogenic service - part 1: Reclosable pressure-relief valves; and ISO 4126-1; 2004 Safety devices for protection against excessive pressure - part 1 and part 4: Safety valves.

b) Each PRV shall be tested to ensure that:

- *it opens at the prescribed pressure setting, with an allowance not exceeding ± 10% for 0 to 0,15 MPa, ± 6% for 0,15 to 0,30 MPa, ± 3% for 0,30 MPa and above*
- *seat tightness is acceptable, and*
- *pressure containing parts will withstand at least 1,5 times the design pressure.*

2.1.8 *PRVs shall be set and sealed by* the Society*, and a record of this action, including the valves' set pressure, shall be retained on board the ship.*

2.1.9 *Cargo tanks may be permitted to have more than one relief valve set pressure in the following cases:*

- *installing two or more properly set and sealed PRVs and providing means, as necessary, for isolating the valves not in use from the cargo tank, or*
- *installing relief valves whose settings may be changed by the use of a previously approved device not requiring pressure testing to verify the new set pressure. All other valve adjustments shall be sealed.*

2.1.10 *Changing the set pressure under the provisions of [2.1.9] and the corresponding resetting of the alarms referred to in Ch 9, Sec 13, [4.1.2] shall be carried out under the supervision of the Master in accordance with approved procedures and as specified in the ship's operating manual. Changes in set pressure shall be recorded in the ship's log and a sign shall be posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.*

2.1.11 *In the event of a failure of a cargo tank-installed PRV, a safe means of emergency isolation shall be available:*

a) Procedures shall be provided and included in the cargo operations manual (see IGC Code 18.2).

b) The procedures shall allow only one of the cargo tank installed PRVs to be isolated.

Note 1: The basic principle is to ensure a safe isolation before removing the PRV for maintenance. The use of balloons can be a solution and accepted in principle, but their efficiency (tightness) shall be demonstrated. A procedure to reinstall or change the balloon after use shall also be prepared. For systems where the outlets of several PRVs are connected to a common vent header, safe isolation means, where balloons are used, one balloon at the inlet of the PRV and one at the outlet.

c) Isolation of the PRV shall be carried out under the supervision of the Master. This action shall be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at the PRV.

d) The tank shall not be loaded until the full relieving capacity is restored.

2.1.12 *Each PRV installed on a cargo tank shall be connected to a venting system, which shall be:*

- *so constructed that the discharge will be unimpeded and directed vertically upwards at the exit*
- *arranged to minimize the possibility of water or snow entering the vent system*
- *arranged such that the height of vent exits shall not be less than B/3 or 6 m, whichever is the greater, above the weather deck, and*
- *6 m above working areas and walkways.*

2.1.13 The height of vent exits as indicated in [2.1.12] is also to be measured above storage tanks and cargo liquid lines, where applicable.

2.1.14 *Cargo PRV vent exits shall be arranged at a distance at least equal to B or 25 m, whichever is less, from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.*

For ships less than 90 m in length, smaller distances may be permitted.

All other vent outlets connected to the cargo containment system shall be arranged at a distance of at least 10 m, measured horizontally, *from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.*

In the case of carriage of flammable and/or toxic products, the vent exits are to be arranged at a distance of at least 5 m, measured horizontally, from exhaust ducts and at least 10 m, measured horizontally, from intake ducts serving cargo pump rooms and/or cargo compressor rooms.

2.1.15 *All other cargo vent outlets not dealt with in other chapters shall be arranged in accordance with [2.1.12] and [2.1.14]. Means shall be provided to prevent liquid overflow from vent mast outlets, due to hydrostatic pressure from spaces to which they are connected.*

Installing knockout drums is deemed an acceptable solution to prevent liquid overflow from vent mast outlets. Other solutions may be considered provided it is demonstrated that liquid will never reach the outlet of the vent mast in case of any single failure.

2.1.16 *If cargoes that react in a dangerous manner with each other are carried simultaneously, a separate pressure relief system shall be fitted for each one.*

2.1.17 *In the vent piping system, means for draining liquid from places where it may accumulate shall be provided. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.*

Note 1: The words 'draining liquid' means, in this paragraph water, and/or snow.

2.1.18 *Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of extraneous objects without adversely affecting the flow. Other requirements for protection screens apply when carrying specific cargoes (see Ch 9, Sec 17, [9] and Ch 9, Sec 17, [21]).*

2.1.19 *All vent piping shall be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.*

2.1.20 *PRVs shall be connected to the highest part of the cargo tank above deck level. PRVs shall be positioned on the cargo tank so that they will remain in the vapour phase at the filling limit (FL) as defined in Ch 9, Sec 15, under conditions of 15° list and 0,015 L trim, where L is defined in Ch 9, Sec 1, [4.1.31].*

2.1.21 *The adequacy of the vent system fitted on tanks loaded in accordance with Ch 9, Sec 15, [1.5.2] shall be demonstrated, taking into account IMO resolution A.829(19)). A relevant certificate shall be permanently kept on board the ship. For the purposes of this paragraph, vent system means:*

- *the tank outlet and the piping to the PRV*
- *the PRV, and*
- *the piping from the PRVs to the location of discharge to the atmosphere, including any interconnections and piping that joins other tanks.*

3 Vacuum protection systems

3.1 General

3.1.1 *Cargo tanks not designed to withstand a maximum external pressure differential 0,025 MPa, or tanks that cannot withstand the maximum external pressure differential that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by thermal oxidation, shall be fitted with:*

a) Two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank and refrigeration equipment, if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank, or

b) Vacuum relief valves with a gas flow capacity at least equal to the maximum cargo discharge rate per cargo tank, set to open at a pressure sufficiently below the external design differential pressure of the cargo tank.

3.1.2 *Subject to the requirements of Ch 9, Sec 17, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and shall be arranged to minimize the possibility of the entrance of water or snow. If cargo vapour is admitted, it shall be from a source other than the cargo vapour lines.*

3.1.3 *The vacuum protection system shall be capable of being tested to ensure that it operates at the prescribed pressure.*

4 Sizing of pressure relieving system

4.1 Sizing of pressure relief valves

4.1.1 *PRVs shall have a combined relieving capacity for each cargo tank to discharge the greater of the following, with not more than a 20% rise in cargo tank pressure above the MARVS:*

a) The maximum capacity of the cargo tank inerting system, if the maximum attainable working pressure of the cargo tank inerting system exceeds the MARVS of the cargo tanks, or

b) Vapours generated under fire exposure computed using the following formula:

$Q = FGA^{0,82}$

where:

Q : Minimum required rate of discharge, in m^3/s, of air at standard conditions of 273,15 Kelvin (K) and 0,1013 MPa

F : Fire exposure factor for different cargo types as follows:

- *1,0 for tanks without insulation located on deck*
- *0,5 for tanks above the deck, when insulation is approved by* the Society. *Approval will be based on the use of a fireproofing material, the thermal conductance of insulation and its stability under fire exposure*
- *0,5 for uninsulated independent tanks installed in holds*
- *0,2 for insulated independent tanks inholds (or uninsulated independent tanks in insulated holds)*
- *0,1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds)*
- *0,1 for membrane and semi-membrane tanks. For independent tanks partly protruding through the weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck*

A : External surface area of the tank, in m^2, as defined in Ch 9, Sec 1, [4.1.15], for different tank types, as shown in Fig 2

Note 1: L_{min}, for non-tapered tanks, is the smaller of the horizontal dimensions of the flat bottom of the tank. For tapered tanks, as would be used for the forward tank, L_{min} is the smaller of the length and the average width.

- For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is equal to or less than $L_{min}/10$, A is to be taken equal to the external surface area minus flat bottom surface area
- For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is greater than $L_{min}/10$, A is to be taken equal to the external surface area.

G : Gas factor according to formula:

$$G = \frac{12,4}{LD}\sqrt{\frac{ZT}{M}}$$

with:

T : *Temperature in degrees Kelvin at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set*

L : *Latent heat of the material being vaporized at relieving conditions, in kJ/kg*

D : *A constant based on relation of specific heats and is calculated as follows:*

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

k : *Ratio of specific heats at relieving conditions, and the value of which is between 1,0 and 2,2. If k is not known, D = 0,606 shall be used*

Z : *Compressibility factor of the gas at relieving conditions. If not known, Z = 1 shall be used*

M : *Molecular mass of the product.*

The gas factor of each cargo to be carried shall be determined and the highest value shall be used for PRV sizing.

The required mass flow of air at relieving conditions is given by the formula:

$M_{air} = Q\,\rho_{air}$

where:

ρ_{air} : *Density of air, taken equal to 1,296 kg/m³ (air at 273,15 K and 0,1013 MPa).*

4.2 Sizing of vent pipe system

4.2.1 *Pressure losses upstream and downstream of the PRVs shall be taken into account when determining their size to ensure the flow capacity required by [4.1].*

4.3 Upstream pressure losses

4.3.1 *The pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with [4.1].*

4.3.2 *Pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome.*

4.3.3 *Pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.*

4.4 Downstream pressure losses

4.4.1 *Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.*

4.4.2 *The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, shall not exceed the following values:*

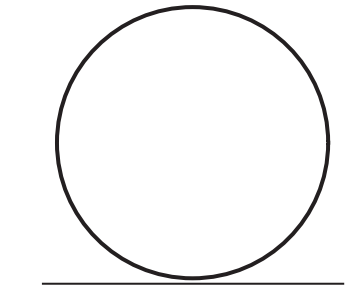
- *for unbalanced PRVs:10% of MARVS*
- *for balanced PRVs:30% of MARVS, and*
- *for pilot operated PRVs:50% of MARVS.*

Alternative values provided by the PRV manufacturer may be accepted.

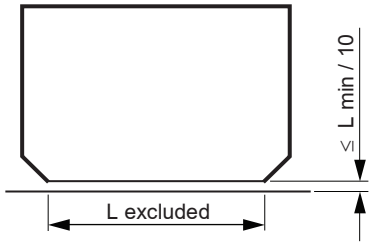
4.5 Blow-down

4.5.1 *To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0,02 MARVS at the rated capacity.*

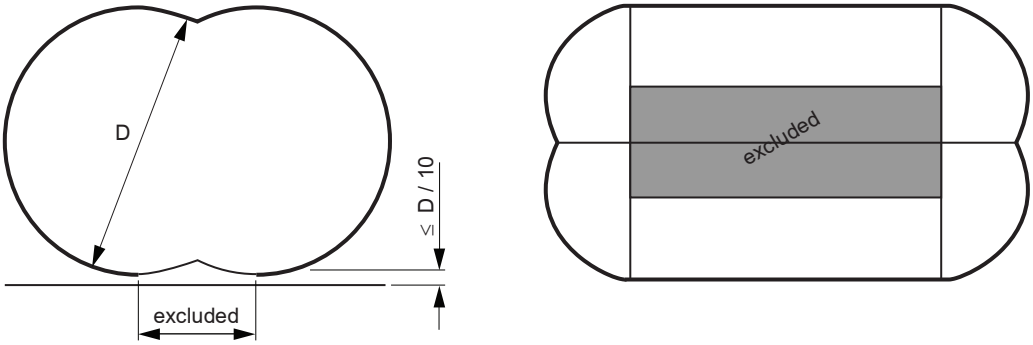
Figure 2 : External surface area of the tank



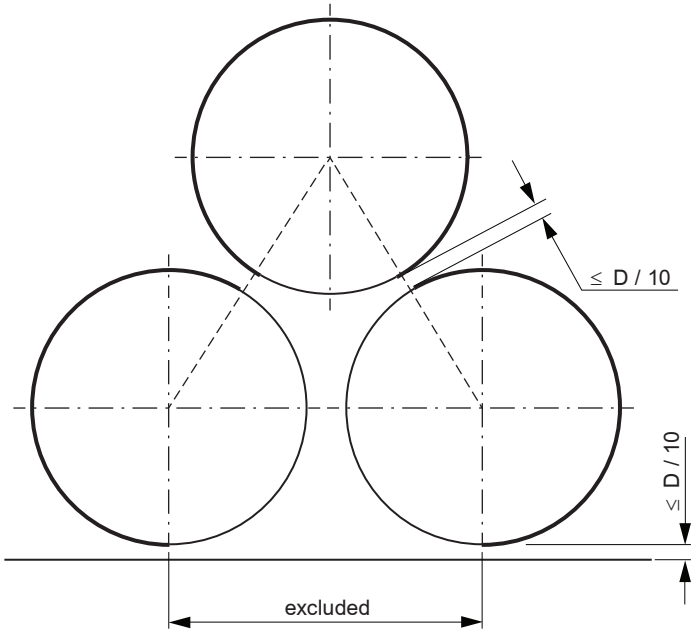
Cylindrical tanks with spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks



Prismatic tanks



Bilole tanks



Horizontal cylindrical tanks arrangement

Section 9 Cargo Containment System Atmosphere Control

1 General

1.1 Atmosphere control within the cargo containment system

1.1.1 *A piping system shall be arranged to enable each cargo tank to be safely gas-freed, and to be safely filled with cargo vapour from a gas-free condition. The system shall be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.*

1.1.2 *For flammable cargoes, the system shall be designed to eliminate the possibility of a flammable mixture existing in the cargo tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.*

1.1.3 *Piping systems that may contain flammable cargoes shall comply with [1.1.1] and [1.1.2].*

1.1.4 *A sufficient number of gas sampling points shall be provided for each cargo tank and cargo piping system to adequately monitor the progress of atmosphere change. Gas sampling connections shall be fitted with a single valve above the main deck, sealed with a suitable cap or blank (see Ch 9, Sec 5, [6.4.5]).*

1.1.5 *Inert gas utilized in these procedures may be provided from the shore or from the ship.*

1.2 Atmosphere control within the hold spaces (cargo containment systems other than type C independent tanks)

1.2.1 *Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days.*

1.2.2 *Alternatively, subject to the restrictions specified in Ch 9, Sec 17, the spaces referred to in [1.2.1] requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.*

1.2.3 *For non-flammable gases, the spaces referred to in [1.2.1] and [1.2.2] may be maintained with a suitable dry air or inert atmosphere.*

1.3 Environmental control of spaces surrounding type C independent tanks

1.3.1 *Spaces surrounding cargo tanks that do not have secondary barriers shall be filled with suitable dry inert gas or dry air and be maintained in this condition with make-up inert gas provided by a shipboard inert gas generation system, shipboard storage of inert gas, or with dry air provided by suitable air drying equipment. If the cargo is carried at ambient temperature, the requirement for dry air or inert gas is not applicable.*

1.3.2 As far as the requirements relevant to the dew point are concerned, the following additional provisions apply:

a) Where cargo tank insulation is not protected from water vapour penetration by means of an effective vapour barrier, accepted by the Society, the maximum value of the dew point is to be less than the design temperature

b) Where cargo tank insulation is protected by an effective vapour barrier, accepted by the Society, the maximum value of the dew point is to be less than the minimum temperature which may be found on any surface within the spaces filled with dry inert gas or dry air

c) The temperature of the hull structures adjacent to cargo tanks is not to become lower than the minimum permissible working temperature, specified in Ch 9, Sec 6 for the steel grade employed for such hull structures

d) The capacity of dry air or inert gas equipment to produce dry air is to be verified in workshop

e) Means are to be provided on board to measure the dryness of the hold space atmosphere. The equipment may be portable provided permanent connections and/or sampling pipes are fitted.

1.4 Inerting

1.4.1 *Inerting refers to the process of providing a non-combustible environment. Inert gases shall be compatible chemically and operationally at all temperatures likely to occur within the spaces and the cargo. The dew points of the gases shall be taken into consideration.*

1.4.2 Precautions are to be taken to minimise the risk that static electricity generated by the inert gas system may become a source of ignition.

1.4.3 *Where inert gas is also stored for fire-fighting purposes, it shall be carried in separate containers and shall not be used for cargo services.*

1.4.4 *Where inert gas is stored at temperatures below 0°C, either as a liquid or as a vapour, the storage and supply system shall be designed so that the temperature of the ship's structure is not reduced below the limiting values imposed on it.*

1.4.5 *Arrangements to prevent the backflow of cargo vapour into the inert gas system that are suitable for the cargo carried, shall be provided. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves or equivalent devices and, in addition, a removable spool piece shall be fitted in the inert gas main in the cargo area. When not in use, the inert gas system shall be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.*

1.4.6 *The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc., shall be provided for controlling pressure in these spaces.*

1.4.7 *Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.*

1.5 Inert gas production on board

1.5.1 Attention is drawn to the requirements of Ch 9, Sec 1, [6.2.4] regarding the satisfactory operation of the inert gas generating plant and of the associated control system that is to be ascertained during the first full loading and the subsequent first unloading of ships carrying liquefied natural gasses (LNG) in bulk.

1.5.2

a) Spaces associated with cargo containment adjacent to cargo tanks containing flammable products having a flashpoint equal to or less than 60°C are to kept in an inert gas environment.

b) Inert gas generating systems are to be considered as essential services and are to comply with the applicable Sections of the Rules, as far as applicable.

c) Where, in addition to inert gas produced on board, it is possible to introduce dry air into the above mentioned spaces, where this is acceptable depending on the type of cargo tank adopted, or to introduce inert gas from a supply existing on board, it is not necessary that standby or spare components for the inert gas system are kept on board.

1.5.3 *The equipment shall be capable of producing inert gas with an oxygen content at no time greater than 5% by volume, subject to the special requirements of Ch 9, Sec 17. A continuous-reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5% oxygen content by volume, subject to the requirements of Ch 9, Sec 17.*

1.5.4 *An inert gas system shall have pressure controls and monitoring arrangements appropriate to the cargo containment system.*

1.5.5 *Spaces containing inert gas generation plants shall have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces. Inert gas piping shall not pass through accommodation spaces, service spaces or control stations.*

1.5.6 *Combustion equipment for generating inert gas shall not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using a catalytic combustion process.*

1.6 Engineering specifications for nitrogen / inert gas systems

1.6.1 Requirements of:

- Pt C, Ch 4, Sec 15, [13.3.2], item b)
- Pt C, Ch 4, Sec 15, [13.3.2], item d)
- Pt C, Ch 4, Sec 15, [13.3.4], item b)
- Pt C, Ch 4, Sec 15, [13.3.4], item c)
- Pt C, Ch 4, Sec 15, [13.3.4], item e) 1) regarding oxygen content and power supply to the indicating devices
- Pt C, Ch 4, Sec 15, [13.3.4], item e) 4)
- Pt C, Ch 4, Sec 15, [13.5.2] and
- Pt C, Ch 4, Sec 15, [13.5.3],

apply to the systems.

1.6.2 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with Pt C, Ch 4, Sec 15, [13.3.1], item b) 5). In addition to Pt C, Ch 4, Sec 15, [13.3.2], item d), the system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

1.6.3 The feed air treatment system fitted to remove free water, particles and traces of oil from the compressed air as required by Pt C, Ch 4, Sec 15, [13.5.2], item b), is also to preserve the specification temperature.

1.6.4 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck.

Note 1: "safe location" needs to address the two types of discharges separately:

- oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
  - outside of hazardous area;
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets
- nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

1.6.5 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

1.6.6 The two non-return devices as required by Pt C, Ch 4, Sec 15, [13.3.3], item a) 1) are to be fitted in the inert gas main. The non-return devices are to comply with Pt C, Ch 4, Sec 15, [13.3.3], item a) 2) and Pt C, Ch 4, Sec 15, [13.3.3], item a) 3); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by Pt C, Ch 4, Sec 15, [13.3.3], item a) 1) may be substituted by two non-return valves.

Section 10 Electrical Installations

1 General

1.1 Application

1.1.1 The requirements in this Section apply, in addition to those contained in Part C, Chapter 2 to gas carriers.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, Tab 1 the following are to be submitted for approval:

a) Plan of hazardous areas

b) Document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas

c) Diagrams of tank level indicator systems, high level alarm systems and overflow control systems where requested.

1.3 Definitions

1.3.1 *For the purpose of this Section, unless expressly provided otherwise, the definitions below shall apply.*

1.3.2 Hazardous area

Hazardous area is an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Note 1: Examples of hazardous area zoning may be found in Tab 1.

1.3.3 Zone 0 hazardous

Zone 0 hazardous area is an area in which an explosive gas atmosphere is present continuously or is present for long periods.

1.3.4 Zone 1 hazardous

Zone 1 hazardous area is an area in which an explosive gas atmosphere is likely to occur in normal operation.

1.3.5 Zone 2 hazardous

Zone 2 hazardous area is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so infrequently and for a short period only.

1.3.6 Non-hazardous

Non-hazardous area is an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

1.4 General requirements

1.4.1 *Electrical installations shall be such as to minimize the risk of fire and explosion from flammable products.*

1.4.2 Suitable arrangements are to be provided, to the satisfaction of the Society, so as to prevent the possibility of gases or vapours passing from a hazardous area to another area through runs of cables or their conduits.

1.4.3 *Electrical installations shall be in accordance with recognized standards.*

Note 1: Refer to the recommendation published by the International Electrotechnical Commission in particular to publication IEC 60092-502:1999.

However, where the prescriptive requirements in the present Rules and IEC 60092-502 are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.4.4 *Electrical equipment or wiring shall not be installed in hazardous areas, unless essential for operational purposes or safety enhancement.*

1.4.5 *Where electrical equipment is installed in hazardous areas as provided in [1.4.4], it shall be selected, installed and maintained in accordance with standards not inferior to those acceptable to the* Society. The types of electrical equipment admitted, depending on the zone where they are installed, are specified in Pt C, Ch 2, Sec 3, [10]. *Equipment for hazardous areas shall be* type approved by the Society. *Automatic isolation of non-certified equipment on detection of a flammable gas shall not be accepted as an alternative to the use of certified equipment.*

1.4.6 *To facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into* zone 0, 1 and 2 according to [1.3]. The different spaces are to be classified according to Tab 1.

Table 1 : Space descriptions and hazardous area zones

No.	Description of spaces	Hazardous area
1	The interior of cargo tanks, any pipework of pressure-relief or other venting systems for cargo, pipes and equipment containing the cargo or developing flammable gases and vapours	Zone 0
2	Interbarrier spaces, hold spaces where cargo is carried in a cargo containment system requiring a secondary barrier	Zone 0
3	Void space adjacent to, above or below integral cargo tanks	Zone 1
4	Hold spaces where cargo is carried in a cargo containment system not requiring a secondary barrier	Zone 1
5	Cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks	Zone 1
6	Cargo pump rooms and cargo compressor rooms	Zone 1
7	Enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tank bulkheads, unless protected by a diagonal plate acceptable to the society	Zone 1
8	Spaces, other than cofferdam, adjacent to and below the top of a cargo tank (for example, trunks, passageways and hold)	Zone 1
9	Areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets, cargo compressor room ventilation outlets and cargo tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation	Zone 1
10	Areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet	Zone 1
11	Areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams, cargo compressor room entrances, cargo compressor room ventilation inlets or other zone 1 spaces	Zone 1
12	Areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2,4 m above the deck	Zone 1
13	Areas on open deck over the cargo area where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck	Zone 1
14	Compartments for cargo hoses	Zone 1
15	Enclosed or semi-enclosed spaces in which pipes containing cargoes are located	Zone 1
16	A space separated from a hold space, where cargo is carried in a cargo tank requiring a secondary barrier, by a single gastight boundary	Zone 1
17	Enclosed or semi-enclosed spaces in which pipes containing cargo products for boil-off gas fuel burning systems are located, unless special precautions approved by the society are provided to prevent product gas escaping into such spaces	Zone 1
18	Areas of 1,5 m surrounding a space of zone 1	Zone 2
19	Spaces 4 m beyond the cylinder and 4 m beyond the sphere defined in item 10	Zone 2
20	The spaces forming an airlock as defined in Ch 9, Sec 3, [1.6]	Zone 2
21	Areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service area and 3 m beyond these up to a height of 2,4 m above the deck.	Zone 2
22	Areas on open deck over the cargo area where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck surrounding open or semi-enclosed spaces of zone 1.	Zone 2
23	Spaces forward of the open deck areas to which reference is made in 13 and 22, below the level of the main deck, and having an opening on to the main deck or at a level less than 0,5 m above the main deck, unless: • the doors and all openings are in non-hazardous area; and • the spaces are mechanically ventilated	Zone 2
24	An area within 2,4 m of the outer surface of a cargo tank where such surface is exposed to the weather.	Zone 2

1.4.7 *Electrical generation and distribution systems, and associated control systems shall be designed such that a single fault will not result in the loss of ability to maintain cargo tank pressures, as required by Ch 9, Sec 7, [8.1.1], item a) and hull structure temperature, as required by Ch 9, Sec 4, [5.2.1], item f), within normal operating limits. Failure modes and effects shall be analysed and documented to a standard not inferior to those acceptable to the Administration.*

Note 1: IEC 60812, Edition 2.0 2006-01 "Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA)".

1.4.8 *The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be located in a non-hazardous area.*

1.4.9 *Electrical depth sounding or log devices and impressed current cathodic protection system anodes or electrodes shall be housed in gastight enclosures.*

1.4.10 *Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems. Arrangements shall be made to automatically shut down the motors in the event of low-liquid level. This may be accomplished by sensing low pump discharge pressure, low motor current or low liquid level. This shutdown shall be alarmed at the cargo control station. Cargo pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.*

1.5 System of supply

1.5.1 Acceptable systems of supply

The following systems of generation and distribution of electrical energy are acceptable

a) Direct current:
   - two-wire insulated

b) Alternating current:
   - single-phase, two-wire insulated
   - three-phase, three-wire insulated.

In insulated distribution systems, no current carrying part is to be earthed, other than:

a) Through an insulation level monitoring device

b) Through components used for the suppression of interference in radio circuits.

1.5.2 Earthed system with hull return

Earthed systems with hull return are not permitted, with the following exceptions to the satisfaction of the Society:

a) Impressed current cathodic protective systems

b) Limited and locally earthed systems, such as starting and ignition systems of internal combustion engines, provided that any possible resulting current does not flow directly through any hazardous area

c) Insulation level monitoring devices, provided that the circulation current of the device does not exceed 30 mA under the most unfavourable conditions.

1.5.3 Earthed systems without hull return

Earthed systems without hull return are not permitted, with the following exceptions:

a) Earthed intrinsically safe circuits and the following other systems to the satisfaction of the Society

b) Power supplies, control circuits and instrumentation circuits in non-hazardous areas where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions, or

c) Limited and locally earthed systems, such as power distribution systems in galleys and laundries to be fed through isolating transformers with the secondary windings earthed, provided that any possible resulting hull current does not flow directly through any hazardous area, or

d) Alternating current power networks of 1,000 V root mean square (line to line) and over, provided that any possible resulting current does not flow directly through any hazardous area; to this end, if the distribution system is extended to areas remote from the machinery space, isolating transformers or other adequate means are to be provided.

1.6 Earth detection

1.6.1 Monitoring of circuits in hazardous areas

The devices intended to continuously monitor the insulation level of all distribution systems are also to monitor all circuits, other than intrinsically safe circuits, connected to apparatus in hazardous areas or passing through such areas. An audible and visual alarm is to be given, at a manned position, in the event of an abnormally low level of insulation.

1.7 Mechanical ventilation of hazardous spaces

1.7.1 Electric motors driving fans of the ventilating systems of hazardous spaces are to be located outside the ventilation ducting.

1.7.2 Motors driving ventilating fans may be located within the ducting provided that they are of a certified safe type.

1.7.3 The materials used for the fans and their housing are to be in compliance with Pt C, Ch 4, Sec 1, [2.33].

1.7.4 Cargo compressor rooms and other enclosed spaces which contain cargo-handling equipment and similar spaces in which work is performed on the cargo should be fitted with mechanical ventilation systems, capable of being controlled from outside such spaces.

1.7.5 Provisions are to be made to ventilate the spaces defined in [1.7.4] prior to entering the compartment and operating the equipment.

2 Hazardous locations and types of equipment

2.1 Electrical equipment permitted in gas-dangerous spaces and zones

2.1.1 A space separated by a gastight boundaries from a hazardous area may be classified as zone 0, 1, 2 or considered as non hazardous, taking into account the sources of release inside that space and its conditions of ventilation.

2.1.2 Access door and other openings are not to be provided between an area intended to be considered as non-hazardous and a hazardous area or between a space intended to be considered as zone 2 and a zone 1, except where required for operational reasons.

2.1.3 In enclosed or semi-enclosed spaces having a direct opening into any hazardous space or area, electrical installations are to comply with the requirements for the space or area to which the opening leads.

2.1.4 Where a space has an opening into an adjacent, more hazardous space or area, it may be made into a less hazardous space or non-hazardous space, taking into account the type of separation and the ventilation system.

2.1.5 A differential pressure monitoring device or a flow monitoring device, or both, are to be provided for monitoring the satisfactory functioning of pressurisation of spaces having an opening into a more hazardous zone.

In the event of loss of the protection by the over-pressure or loss of ventilation in spaces classified as zone 1 or zone 2, protective measures are to be taken.

2.2 Submerged cargo pumps

2.2.1 Exceptions

Submerged cargo pumps are not permitted in connection with the following cargoes:

- diethyl ether
- vinyl ethyl ether
- ethylene oxide
- propylene oxide
- mixtures of ethylene oxide and propylene oxide.

2.2.2 Submerged electric motors

In addition to the requirements of [1.4.10], where submerged electric motors are employed, means are to be provided, e.g. by the arrangements specified in Ch 9, Sec 17, [6] to avoid the formation of explosive mixtures during loading, cargo transfer and unloading.

3 Product classification

3.1 Temperature class and explosion group

3.1.1 Tab 2 specifies temperature class and explosion group data for the products indicated in Ch 9, Sec 19. The data shown in brackets have been derived from similar products.

Table 2 : Temperature class and explosion group of certain products

Product name	Temperature class	Explosion group
Acetaldehyde	T4	II A
Ammonia anhydrous	T1	II A
Butadiene	T2	II B
Butane	T2	II A
Butane/propane mixture	T2	II A
Butylenes	T3	II A
Carbon dioxide	NF	NF

Product name	Temperature class	Explosion group
Chlorine	NF	NF
Diethyl ether	T4	II B
Dimethylamine	T2	II A
Dimethyl ether	T3	II B
Ethane	T1	II A
Ethyl chloride	T2	II A
Ethylene	T2	II B
Ethylene oxide	T2	II B
Ethylene oxide propylene oxide mixture (max. 30% w/w ethylene oxide)	T2	II B
Isoprene	T3	II B
Isopropylamine	T2	II A
Methane	T1	II A
Methyl acetylene propadiene mixture	T4	II A
Methyl bromide	T3	II A
Methyl chloride	T1	II A
Monoethylamine	T2	II A
Nitrogen	NF	NF
Pentane (all isomers)	(T2)	(II A)
Pentene (all isomers	(T3)	(II B)
Propane	T1	II A
Propylene	T2	II B
Propylene oxide	T2	II B
Refrigerant gases	NF	NF
Sulphur dioxide	(T3)	(II B)
Vinyl chloride	T2	II A
Vinyl ethyl ether	T3	II B
Vinylidene chloride	T2	II A

Section 11 Fire Protection and Extinction

1 General

1.1 Fire safety requirements

1.1.1 *The requirements for tankers in SOLAS chapter II-2 shall apply to ships covered by the Code, irrespective of tonnage including ships of less than 500 gross tonnage, except that:*

a) regulations 4.5.1.6 and 4.5.10 do not apply

b) requirements of 10.4 and 10.5 shall apply as they would apply to tankers of 2,000 gross tonnage and over

c) regulation 10.5.6 shall apply to ships of 2,000 gross tonnage and over

d) the regulations of SOLAS chapter II-2 related to tankers listed in Tab 1 do not apply and are replaced by requirements of this Chapter as detailed in Tab 1

e) regulations 13.3.4 and 13.4.3 shall apply to ships of 500 gross tonnage and over.

Table 1 :

SOLAS Chapter II-2 Regulation	Replaced by the following requirements
10.10	[1.6]
4.5.1.1 and 4.5.1.2	Ch 9, Sec 3
4.5.5	Relevant requirements in this Section
10.8	[1.3] and [1.4]
10.9	[1.5]
10.2	from [1.2.1] to [1.2.4]

1.1.2 *All sources of ignition shall be excluded from spaces where flammable vapour may be present, except as otherwise provided in Ch 9, Sec 10 and Ch 9, Sec 16.*

1.1.3 The maximum temperature of the steam and heating media in the cargo area is to be adjusted to take into account the temperature class of the cargo.

1.1.4 *The provisions of this Section shall apply in conjunction with Ch 9, Sec 3.*

1.1.5 *For the purposes of fire fighting, any weather deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space shall be included in the cargo area.*

1.2 Fire mains and hydrants

1.2.1 *Irrespective of size, ships carrying products that are subject to the Code shall comply with the requirements of regulation II-2/10.2 of the SOLAS Convention, as applicable to cargo ships, except that the required fire pump capacity and fire main and water service pipe diameter shall not be limited by the provisions of regulations II-2/10.2.2.4.1 and II-2/10.2.1.3, when a fire pump is used to supply the water-spray system, as permitted by [1.3.5]. The capacity of this fire pump shall be such that these areas can be protected when simultaneously supplying two jets of water from fire hoses with 19 mm nozzles at a pressure of at least 0.5 MPa gauge.*

1.2.2 *The arrangements shall be such that at least two jets of water can reach any part of the deck in the cargo area and those portions of the cargo containment system and tank covers that are above the deck. The necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of regulations II-2/10.2.1.5.1 and II-2/10.2.3.3 of the SOLAS Convention, with hose lengths as specified in regulation II-2/10.2.3.1.1. In addition, the requirements of regulation II-2/10.2.1.6 shall be met at a pressure of at least 0.5 MPa gauge.*

1.2.3 *Stop valves shall be fitted in any crossover provided and in the fire main or mains in a protected location, before entering the cargo area and at intervals ensuring isolation of any damaged single section of the fire main, so that [1.2.2] can be complied with using not more than two lengths of hoses from the nearest fire hydrant. The water supply to the fire main serving the cargo area shall be a ring main supplied by the main fire pumps or a single main supplied by fire pumps positioned fore and aft of the cargo area, one of which shall be independently driven.*

1.2.4 *Nozzles shall be of an approved dual-purpose type (i.e. spray/jet type) incorporating a shutoff.*

1.2.5 *After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.*

1.2.6 When the ship is fitted with a total flooding high expansion foam system protecting the engine-room (to comply with Pt C, Ch 4, Sec 6, [3.1.1], item b) and Pt C, Ch 4, Sec 6, [4.2.1]) and the emergency fire pump is intended to supply sea water to this system and to the water-spray system in pursuance of [1.3.6], then, the emergency fire pump is to be sized to cover the foam system for dealing with an engine-room fire, when the main fire pumps are disabled. On the basis of the principle of dealing with one single fire incident at a time, the emergency fire pump does not need to be sized to cover all three systems above (i.e. water-spray, hydrants and foam) at the same time and only needs to be sized to cover the most demanding area and required systems, as follows:

- the foam system + two hydrants; or
- the water-spray system + two hydrants;

whichever is greater.

1.3 Water-spray system

1.3.1 A stop valve is to be fitted on the water-spray main as close as possible to the poop front so that the accommodation spaces are always protected in the case of a spray-main failure.

1.3.2 *On ships carrying flammable and/or toxic products, a water-spray system, for cooling, fire prevention and crew protection shall be installed to cover:*

a) Exposed cargo tank domes, any exposed parts of cargo tanks and any part of cargo tank covers that may be exposed to heat from fires in adjacent equipment containing cargo such as exposed booster pumps/heaters/re-gasification or re-liquefaction plants, hereafter addressed as gas process units, positioned on weather decks

b) Exposed on-deck storage vessels for flammable or toxic products

c) Gas process units positioned on deck

d) Cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided

e) All exposed emergency shut-down (ESD) valves in the cargo liquid and vapour pipes, including the master valve for supply to gas consumers

f) Exposed boundaries facing the cargo area, such as bulkheads of superstructures and deckhouses normally manned, cargo machinery spaces, store-rooms containing high fire-risk items and cargo control rooms. Exposed horizontal boundaries of these areas do not require protection unless detachable cargo piping connections are arranged above or below. Boundaries of unmanned forecastle structures not containing high fire-risk items or equipment do not require water-spray protection

g) Exposed lifeboats, liferafts and muster stations facing the cargo area, regardless of distance to cargo area, and

Note 1: The survival crafts on board including remote survival crafts required by SOLAS III/31.1.4 facing the cargo area are to be protected by a water-spray system taking into consideration cargo area extension for fire-fighting purposes as stated in [1.1.5].

Remote liferafts located in areas covered by water-spray protection as required in item f) may be considered as adequately protected.

h) Any semi-enclosed cargo machinery spaces and semi-enclosed cargo motor room.

Ships intended for operation as listed in Ch 9, Sec 1, [2.1.10] shall be subject to special consideration (see [1.3.5]).

The water-spray system mentioned in [1.3.2] is also to cover boundaries of spaces containing internal combustion engines and/or fuel treatment units, of store-rooms for flammable liquids having a flashpoint equal to or less than 60°C and of paint lockers.

1.3.3 *The system shall be capable of covering all areas mentioned in [1.3.2], with a uniformly distributed water application rate of at least 10 litre/m^2/min for the largest projected horizontal surfaces and 4 litre/m^2/min for vertical surfaces. For structures having no clearly defined horizontal or vertical surface, the capacity of the water-spray system shall not be less than the projected horizontal surface multiplied by 10 ℓ/m^2/min.*

1.3.4 *On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves shall be fitted in the main supply line(s) in the water-spray system, at intervals not exceeding 40 m, for the purpose of isolating damaged sections. Alter- natively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position outside the cargo area. A section protecting any area included in [1.3.2], items a) and b), shall cover at least the entire athwartship tank grouping in that area. Any gas process unit(s) included in [1.3.2] may be served by an independent section.*

The number and location of spray nozzles are to be suitable to spread the sprayed water uniformly on areas to be protected.

1.3.5 *The capacity of the water-spray pumps shall be capable of simultaneous protection of the greater of the following:*

a) Any two complete athwartship tank groupings, including any gas process units within these areas, or

Note 1: The expression "two complete athwartship tank groupings" means any two groups of tanks where one group is defined as tanks located in transverse direction from ship side to ship side. Where there is only one cargo tank occupying a hold space from ship side to ship side, it will be considered as a "grouping" for the purpose of this requirement.

"Any two complete athwartship tank groupings" represents an area equal to the combined area of the two largest tank groupings including any gas process units within these areas.

b) For ships intended for operation as listed in Ch 9, Sec 1, [2.1.10], necessary protection subject to special consideration under [1.3.2] of any added fire hazard and the adjacent athwartship tank grouping,

in addition to surfaces specified in [1.3.2] Alternatively, the main fire pumps may be used for this service, provided that their total capacity is increased by the amount needed for the water-spray system. In either case, a connection, through a stop valve, shall be made between the fire main and water-spray system main supply line outside the cargo area.

1.3.6 *The boundaries of superstructures and deckhouses normally manned, and lifeboats, liferafts and muster areas facing the cargo area, shall also be capable of being served by one of the fire pumps or the emergency fire pump, if a fire in one compartment could disable both fire pumps.*

If all the fire pumps supplying the water-spray system (for covering the superstructures and deckhouses) may be disabled due to a fire in any one compartment; then the emergency fire pump is to be sized to cover:

- the water-spray system for the boundaries of the superstructures and deckhouses, and lifeboats, liferafts and muster areas facing the cargo area; and
- two fire hydrants as required by [1.2.2].

Note 1: The term "fire pumps" where not qualified by the word "emergency" refers to the fire pumps required in accordance with Pt C, Ch 4, Sec 6, [1.2.6], item b).

Note 2: The expression "fire in one compartment" means a compartment provided with A-class boundaries in which is located the fire pump(s), or the source of power of the fire pump(s), serving the water-spray system in accordance with [1.3.5].

1.3.7 *Water pumps normally used for other services may be arranged to supply the water-spray system main supply line.*

1.3.8 *All pipes, valves, nozzles and other fittings in the water-spray system shall be resistant to corrosion by seawater. Piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C. The water-spray system shall be arranged with in-line filters to prevent blockage of pipes and nozzles. In addition, means shall be provided to back-flush the system with fresh water.*

Where fuel oil tanks are installed at the after end of the aftermost hold space or at the forward end of the forwardmost hold space instead of cofferdams as allowed for in requirement of Ch 9, Sec 3, [1.1.3] and Ch 9, Sec 3, [1.1.4], the weather deck area above these tanks is to be regarded as a "cargo area" for the purpose of applying this requirement.

1.3.9 *Remote starting of pumps supplying the water-spray system and remote operation of any normally closed valves in the system shall be arranged in suitable locations outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the protected areas.*

1.3.10 *After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.*

1.4 Dry chemical powder fire-extinguishing systems

1.4.1 *Ships in which the carriage of flammable products is intended shall be fitted with fixed dry chemical powder fire-extinguishing systems, approved by* the Society *based on IMO Circular MSC.1/Circ.1315 for the purpose of fire fighting on the deck in the cargo area, including any cargo liquid and vapour discharge and loading connections on deck and bow or stern cargo handling areas, as applicable.*

Note 1: Dry chemical powder is to based on potassium bicarbonate.

1.4.2 *The system shall be capable of delivering powder from at least two hand hose lines, or a combination of monitor/hand hose lines, to any part of the exposed cargo liquid and vapour piping, load/unload connection and exposed gas process units.*

1.4.3 *The dry chemical powder fire-extinguishing system shall be designed with not less than two independent units. Any part required to be protected by [1.4.2] shall be capable of being reached from not less than two independent units with associated controls, pressurizing medium fixed piping, monitors or hand hose lines. For ships with a cargo capacity of less than 1,000 m^3, only one such unit need be fitted. A monitor shall be arranged to protect any load/unload connection area and be capable of actuation and discharge both locally and remotely. The monitor is not required to be remotely aimed, if it can deliver the necessary powder to all required areas of coverage from a single position. One hose line shall be provided at both port- and starboard side at the end of the cargo area facing the accommodation and readily available from the accommodation.*

1.4.4 Powder systems are to be in accordance with the following requirements:

a) Two powder units, even if mutually connected through a common main, may be considered independent on condition that non-return valves or other arrangements suitable to prevent powder from passing from one unit to the other are fitted.

b) The powder units which constitute the system are to contain, in general, the same powder quantity and, when they are not grouped together in a single position, they are to be uniformly located over the area to be protected.

c) Where powder units are grouped together in a single position or, in the case of ships having a cargo capacity less than 1000 m^3, a single powder unit is installed, the said units are to be located aft of the cargo area.

1.4.5 *The capacity of a monitor shall be not less than 10kg/s. Hand hose lines shall be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3.5 kg/s. The maximum discharge rate shall allow operation by one man. The length of a hand hose line shall not exceed 33m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a fluidized state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather resistant housing or covers and be readily accessible.*

1.4.6 *Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration shall be given where areas to be protected are substantially higher than the monitor or hand hose reel locations.*

1.4.7 *Ships fitted with bow/stern load/unload connections shall be provided with independent dry powder unit protecting the cargo liquid and vapour piping, aft or forward of the cargo area, by hose lines and a monitor covering the bow/stern load/unload complying with the requirements from [1.4.1] to [1.4.6].*

1.4.8 *Ships intended for operation as listed in Ch 9, Sec 1, [2.1.10] shall be subject to special consideration.*

1.4.9 *After installation, the pipes, valves, fittings and assembled systems shall be subjected to a tightness test and functional testing of the remote and local release stations. The initial testing shall also include a discharge of sufficient amounts of dry chemical powder to verify that the system is in proper working order. All distribution piping shall be blown through with dry air to ensure that the piping is free of obstructions.*

Testing arrangements are to involve the discharge using dry chemical powder from all monitors and hand hose lines on board but it is not required that there is a full discharge of the installed quantity of dry powder. This testing can also be used to satisfy the requirement that the piping is free of obstructions, in lieu of blowing through with dry air all the distribution piping. However, after the completion of this testing, the system, including all monitors and hand hose lines, are to be blown through with dry air but only for the purpose of the system subsequently being clear from any residues of dry chemical powder.

1.5 Enclosed spaces containing cargo handling equipment

1.5.1 In pump rooms and cargo compressor rooms, at least two portable extinguishers of a recognised type are to be fitted.

1.5.2 *Enclosed spaces meeting the criteria of cargo machinery spaces in* Ch 9, Sec 1, [4.1.11]*, and the cargo motor room within the cargo area of any ship, shall be provided with a fixed fire-extinguishing system complying with the provisions of the* Pt C, Ch 4, Sec 15 *and taking into account the necessary concentrations/application rate required for extinguishing gas fires.*

1.5.3 Audible alarms fitted to warn of the release of fire extinguishing medium into pump rooms, are to be of the pneumatic type or electric type.

a) In cases where the periodic testing of pneumatically operated alarms is required, CO_2 operated alarms should not be used owing to the possibility of the generation of static electricity in the CO_2 cloud. Air operated alarms may be used provided the air supply is clean and dry.

b) When electrically operated alarms are used, the arrangements are to be such that the electric actuating mechanism is located outside the pump room except where the alarms are certified intrinsically safe.

1.5.4 *Enclosed spaces meeting the criteria of cargo machinery spaces in Ch 9, Sec 3, [1.3], within the cargo area of ships that are dedicated to the carriage of a restricted number of cargoes, shall be protected by an appropriate fire-extinguishing system for the cargo carried.*

1.5.5 *Turret compartments of any ship shall be protected by internal water spray, with an application rate of not less than 10 litre/m^2/min of the largest projected horizontal surface. If the pressure of the gas flow through the turret exceeds 4 MPa, the application rate shall be increased to 20 litre/m^2/min.*

The system shall be designed to protect all internal surfaces, i.e.:

- any horizontal internal surface (e.g. platform) is to be protected
- additional nozzles are to be provided if necessary
- the area of the internal surfaces has to be added to the largest projected horizontal surface in order to determine the required water capacity.

1.6 Firefighter’s outfits

1.6.1 *Every ship carrying flammable products shall carry firefighter's outfits complying with the requirements of regulation ll-2/10.10 of the SOLAS Convention, as in Tab 2.*

Table 2 :

Total cargo capacity	Number of outfits
5,000 m^3 and below	4
Above 5,000 m^3	5

1.6.2 *Additional requirements for safety equipment are given in Ch 9, Sec 14.*

1.6.3 *Any breathing apparatus required as part of a firefighter's outfit shall be a self-contained compressed air-operated breathing apparatus having a capacity of at least 1,200 litres of free air.*

Section 12 Artificial Ventilation in the Cargo Area

1 General

1.1 Scope

1.1.1 *The requirements of this Section replace the requirements of SOLAS regulations II-2/4.5.2.6 and 4.5.4.1, as amended.*

1.2 Spaces required to be entered during normal cargo handling operations

1.2.1 *Electric motor rooms, cargo compressor and pump-rooms, spaces containing cargo handling equipment and other enclosed spaces where cargo vapours may accumulate shall be fitted with fixed artificial ventilation systems capable of being controlled from outside such spaces. The ventilation shall be run continuously to prevent the accumulation of toxic and/or flammable vapours, with* a differential pressure monitoring device or flow monitoring device to indicate any loss of the required ventilating capacity. *A warning notice requiring the use of such ventilation prior to entering shall be placed outside the compartment.*

1.2.2 *Artificial ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid accumulation of flammable, toxic or asphyxiant vapours, and to ensure a safe working environment.*

1.2.3 *The ventilation system shall have a capacity of not less than 30 changes of air per hour, based upon the total volume of the space. As an exception, non-hazardous cargo control rooms may have eight changes of air per hour.*

1.2.4 *Where a space has an opening into an adjacent more hazardous space or area, it shall be maintained at an overpressure. It may be made into a less hazardous space or non-hazardous space by overpressure protection in accordance with recognized standards.*

1.2.5 *Ventilation ducts, air intakes and exhaust outlets serving artificial ventilation systems shall be positioned in accordance with recognized standards.*

Note 1: Refer to the recommendation published by the International Electrotechnical Commission, in particular, to publication IEC 60092-502:1999.

However, where the prescriptive requirements in the present Rules and IEC 60092-502 are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.2.6 Ventilation ducts are to be arranged at a suitable height from the weather deck. This height is not to be less than 2,4 m for intake ducts.

Note 1: Hazardous areas for this purpose are those mentioned in [1.2.11] For other spaces which are gas-dangerous only due to their position, some relaxation may be granted.

1.2.7 Ventilation ducts are to be fitted with metallic fire dampers provided with “open” and “closed” signs. These dampers are to be arranged in the open, in a readily accessible position.

1.2.8 In particular, the discharges from ventilation systems which may contain hazardous vapours are to be located not less than 8 m from the nearest air intake or opening to accommodation, service and control station spaces or other safe spaces, and from all possible sources of ignition.

1.2.9 Ventilation intakes and outlets and openings of accommodation spaces, control stations and other gas-safe spaces are to be located in a designated safe area and at least 1,5 m from any hazardous area.

1.2.10 The air inlets and discharges of the ventilation systems are to be situated so that recirculation of the vented vapours does not occur and are to be arranged at a distance from each other in the horizontal direction of not less than 3 m.

1.2.11 *Ventilation ducts serving hazardous areas shall not be led through accommodation, service and machinery spaces or control stations, except as allowed in Ch 9, Sec 16.*

1.2.12 *Electric motors' driving fans shall be placed outside the ventilation ducts that may contain flammable vapours. Ventilation fans shall not produce a source of ignition in either the ventilated space or the ventilation system associated with the space. For hazardous areas, ventilation fans and ducts, adjacent to the fans, shall be of non-sparking construction,* complying with Pt C, Ch 4, Sec 1, [2.33], and *as defined below:*

- *impellers or housing of non-metallic construction, with due regard being paid to the elimination of static electricity*
- *impellers and housing of non-ferrous materials*
- *impellers and housing of austenitic stainless steel, and*
- *ferrous impellers and housing with design tip clearance of not less than 13 mm.*

Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places.

1.2.13 The shafting penetration of motors driving fans through bulkheads and decks of dangerous spaces or through ventilation ducts is to be fitted with a gastight sealing device, of the oil- seal type or equivalent, deemed suitable by the Society.

1.2.14 *Where fans are required by this Section, full required ventilation capacity for each space shall be available after failure of any single fan, or spare parts shall be provided comprising a motor, starter spares and complete rotating element, including bearings of each type.*

1.2.15 *Protection screens of not more than 13 mm square mesh shall be fitted to outside openings of ventilation ducts.*

1.2.16 *Where spaces are protected by pressurization, the ventilation shall be designed and installed in accordance with recognized standards.*

Note 1: Refer to the recommendation published by the International Electrotechnical Commission, in particular, to publication IEC 60092-502:1999.

However, where the prescriptive requirements in the present Rules and IEC 60092-502 are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.3 Spaces not normally entered

1.3.1 Both fixed and portable systems are to guarantee the efficient ventilation of such spaces in relation to the relative density, in respect of the air, and to the toxicity of the gases transported. The type of portable fans and their connection to the spaces served are to be approved by the Society. In no case are portable electrical fans acceptable.

1.3.2 *Enclosed spaces where cargo vapours may accumulate shall be capable of being ventilated to ensure a safe environment when entry into them is necessary. This shall be capable of being achieved without the need for prior entry.*

1.3.3 *For permanent installations, the capacity of 8 air changes per hour shall be provided and for portable systems, the capacity of 16 air changes per hour.*

1.3.4 *Fans or blowers shall be clear of personnel access openings, and shall comply with [1.2.12].*

Section 13 Instrumentation and Automation Systems

1 General

1.1

1.1.1 The instrumentation is to be of a type approved by the Society.

1.1.2 Attention is drawn to the requirements of Ch 9, Sec 1, [6.2.4] regarding the satisfactory operation of the cargo control and monitoring system and of the level alarm system, that is to be ascertained during the first full loading and the subsequent first unloading of ships carrying liquefied natural gasses (LNG) in bulk.

1.1.3 *Each cargo tank shall be provided with a means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices shall be installed in the liquid and vapour piping systems, in cargo refrigeration installations.*

1.1.4 *If loading and unloading of the ship is performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank shall be concentrated in one control position.*

1.1.5 The following information and alarms are to be concentrated in the positions specified in this requirement:

a) The following is to be transduced to the "cargo control room" and the "control position" as defined in Ch 9, Sec 3, [1.4.1]:
- the indication signalling the presence of water and/or liquid cargo in holds or interbarrier spaces
- the cargo heater low temperature alarm required in Ch 9, Sec 4, [1.2.3]
- the alarm signalling the presence of liquid cargo in the vent main as per in Ch 9, Sec 5, [2.2.4].
- the indication of the hull temperature and the hull structure low temperature alarm required in [7.2.2].
- the alarm signalling the automatic shutdown of electrically driven submerged pumps required in Ch 9, Sec 10, [1.4.10].
- the indication of the cargo level and the cargo tank high level alarm required in [2.1.1].
- the indication of the vapour space pressure and the vapour space pressure gauges of each cargo tank and associated high and low pressure alarms required in [4.1].
- the gas detection equipment alarm required in [6.1.13]
- the cargo compressor high temperature alarm required in Ch 9, Sec 17, [4.1.2] item b)
- the alarm for automatic shutdown of the cargo compressor for high pressure or high temperature, as required in Ch 9, Sec 17, [16.1.4] item d)

When the cargo system is not remote controlled and therefore the aforesaid "control positions" are not required, the above-mentioned controls, information and alarms are to be located in a suitable, easily accessible location.

If this position is an enclosed space, it is to comply with the requirements in Ch 9, Sec 3, [1.3.7]. This position should preferably be located in the wheelhouse.

b) Independently of the above, the following is to be transduced to the wheelhouse:
1) the alarm signalling the presence of water and/or liquid cargo in holds or interbarrier spaces
2) the cargo heater low temperature alarm required in Ch 9, Sec 4, [1.2.3]
3) the alarm signalling the presence of liquid cargo in the vent main as per Ch 9, Sec 5, [2.2.4]
4) the indication of the pressure value in the vapour space of each cargo tank mentioned in [4.1]; such indication is to give the setting pressure value of the relief valve and the minimum allowable pressure value in the cargo tank concerned
5) the high pressure and low pressure alarms, when required, for cargo tanks as per [4.1]
6) the hull structure low temperature alarm required in [7.2.2]
7) the gas detection equipment alarm required in [6.1.13]
8) the cargo compressor high temperature alarm required in Ch 9, Sec 17, [4.1.2] item b)
9) the alarm for automatic shutdown of the cargo compressor for high pressure or high temperature, as required in Ch 9, Sec 17, [16.1.4] item d)

c) Where the cargo control room is located within the accommodation spaces and is readily accessible, the alarms in [3.1.5] may be grouped in a single audible and visual alarm except for the indication and alarms in [1.1.5] item b) 4), item b) 5) and item b) 7), which are to be independent from each other.

d) The high level and high or low pressure audible and visual alarms for cargo tanks as per [3.1.1] and [3.1.4] and the alarm signalling the presence of liquid in the vent main are to be located in such a position as to be clearly heard and identifiable by the personnel in charge of loading operation control.

1.1.6 *Instruments shall be tested to ensure reliability under the working conditions, and recalibrated at regular intervals. Test procedures for instruments and the intervals between recalibration shall be in accordance with manufacturer's recommendations.*

2 Level indicators for cargo tanks

2.1 General

2.1.1 *Each cargo tank shall be fitted with liquid level gauging device(s), arranged to ensure that a level reading is always obtainable whenever the cargo tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the cargo tank and at temperatures within the cargo operating temperature range.*

2.1.2 *Where only one liquid level gauge is fitted, it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.*

In order to assess whether or not only one level gauge is acceptable in relation to the aforesaid sentence, the expression "can be maintained" means that any part of the level gauge other than passive parts can be overhauled while the cargo tank is in service.

Note 1: Passive parts are those parts assumed not subject to failures under normal service conditions.

2.1.3 Where level gauges containing cargo are arranged outside the tank they serve, means are to be provided to shut them off automatically in the event of failure.

2.1.4 *Cargo tank liquid level gauges may be of the following types, subject to special requirements for particular cargoes shown in Ch 9, Sec 19, Tab 1, column "Gauging":*

a) indirect devices, which determine the amount of cargo by means such as weighing or in-line flow metering

b) Closed devices which do not penetrate the cargo tank, such as devices using radio-isotopes or ultrasonic devices

c) Closed devices which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If closed gauging device is not mounted directly onto the tank, it shall be provided with a shutoff valve located as close as possible to the tank, and

d) Restricted devices which penetrate the tank and, when in use, permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation shall ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices shall be so designed that the maximum opening does not exceed 1.5 mm diameter or equivalent area, unless the device is provided with an excess flow valve.

3 Overflow control

3.1 General

3.1.1 *Except as provided in [3.1.5], each cargo tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.*

3.1.2 The sensor for automatic closing of the loading valve for overflow control may be combined with the liquid level indicators required by [2.1.1].

3.1.3 *An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full.*

Note 1: The words 'to prevent the tank from becoming liquid full' in paragraph [3.1.3] have the following meaning:

At no time during the loading, transport or unloading of the cargo including fire conditions will the tank be more than 98% liquid full, except as permitted by Ch 9, Sec 15, [1.1.3]. These requirements, together with those of Ch 9, Sec 8, [2.1.20], are intended to ensure that the pressure relief valves remain in the vapour phase.

3.1.4 *The emergency shutdown valve referred to in **5.5** and Ch 9, Sec 18, [3] may be used for this purpose. If another valve is used for this purpose, the same information as referred to in Ch 9, Sec 18, [3.2.1],item c) shall be available on board. During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, alternative arrangements such as limiting the loading rate shall be used.*

3.1.5 *A high liquid level alarm and automatic shut-off of cargo tank filling need not be required, when the cargo tank:*

- *is a pressure tank with a volume not more than 200 m^3, or*
- *is designed to withstand the maximum possible pressure during the loading operation, and such pressure is below that of the set pressure of the cargo tank relief valve.*

3.1.6 *The position of the sensors in the tank shall be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high-level alarms shall be conducted by raising the cargo liquid level in the cargo tank to the alarm point.*

Note 1: The expression "each dry docking" is considered to be the survey of the outside of the ship's bottom required for the renewal of the Cargo Ship Safety Construction Certificate and or the Cargo Ship Safety Certificate.

3.1.7 *All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to cargo operation in accordance with IGC Code, 18.6.2.*

3.1.8 *Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated, continuous visual indication shall be given at the relevant control station(s) and the navigation bridge.*

4 Pressure monitoring

4.1 General

4.1.1 *The vapour space of each cargo tank shall be provided with a direct reading gauge. Additionally, an indirect indication shall be provided at the control position required by [1.1.4]. Maximum and minimum allowable pressures shall be clearly indicated.*

4.1.2 *A high-pressure alarm and, if vacuum protection is required* as defined in Ch 9, Sec 8, [3], *a low-pressure alarm shall be provided on the navigation bridge and at the control position required by [1.1.4]. Alarms shall be activated before the set pressures are reached.* The low pressure alarm is also to be located in the cargo control room.

4.1.3 *For cargo tanks fitted with PRVs which can be set at more than one set pressure in accordance with Ch 9, Sec 8, [2.1.9], high-pressure alarms shall be provided for each set pressure.*

4.1.4 *Each cargo-pump discharge line and each liquid and vapour cargo manifold shall be provided with at least one pressure indicator.*

4.1.5 *Local-reading manifold pressure indication shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.*

4.1.6 *Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indication.*

4.1.7 *All pressure indications provided shall be capable of indicating throughout the operating pressure range.*

5 Temperature indicating devices

5.1 General

5.1.1 *Each cargo tank shall be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level. The lowest temperature for which the cargo tank has been designed, as shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, shall be clearly indicated by means of a sign on or near the temperature indicating devices.*

5.1.2 *The temperature indicating devices shall be capable of providing temperature indication across the expected cargo operating temperature range of the cargo tanks.*

5.1.3 *Where thermowells are fitted, they shall be designed to minimize failure due to fatigue in normal service.*

6 Gas detection

6.1 General

6.1.1 *Gas detection equipment shall be installed to monitor the integrity of the cargo containment, cargo handling and ancillary systems, in accordance with this section.*

6.1.2 *A permanently installed system of gas detection and audible and visual alarms shall be fitted in:*

a) All enclosed cargo and cargo machinery spaces (including turrets compartments) containing gas piping, gas equipment or gas consumers

b) Other enclosed or semi-enclosed spaces where cargo vapours may accumulate, including interbarrier spaces and hold spaces for independent tanks other than type C tanks

c) Airlocks

d) Spaces in gas-fired internal combustion engines, referred to in Ch 9, Sec 16, [7.8.3]

e) Ventilation hoods and gas ducts required by Ch 9, Sec 16

f) Cooling/heating circuits, as required by Ch 9, Sec 7, [8.1.1], item d)

g) Inert gas generator supply headers, and

h) Motor rooms for cargo handling machinery.

In addition, the gas detection system is also to serve spaces adjacent to pump rooms and compressor rooms.

6.1.3 *Gas detection equipment shall be designed, installed and tested in accordance with recognized standards and shall be suitable for the cargoes to be carried in accordance with Ch 9, Sec 19, Tab 1, column "Vapour detection".*

Note 1: IEC 60079-29-1 - Explosive atmospheres - Gas detectors - Performance requirements of detectors for flammable gases.

6.1.4 *Where indicated by an "A" in Ch 9, Sec 19, Tab 1, column "Vapour detection" ships certified for carriage of non-flammable products, oxygen deficiency monitoring shall be fitted in cargo machinery spaces and hold spaces for independent tanks other than type C tanks. Furthermore, oxygen deficiency monitoring equipment shall be installed in enclosed or semi-enclosed spaces containing equipment that may cause an oxygen-deficient environment such as nitrogen generators, inert gas generators or nitrogen cycle refrigerant systems.*

Two oxygen sensors are to be positioned at appropriate locations in the space or spaces containing the inert gas system, in accordance with Pt C, Ch 4, Sec 15, [13.3.4], item e) 4), for all gas carriers, irrespective of the carriage of cargo indicated by an "A" in column "f" in Ch 9, Sec 19, Tab 1.

6.1.5 *In the case of toxic products or both toxic and flammable products, except when Ch 9, Sec 19, Tab 1, column "Special requirements" refers to Ch 9, Sec 17, [5.1.3], portable equipment can be used for the detection of toxic products as an alternative to a permanently installed system. This equipment shall be used prior to personnel entering the spaces listed in [6.1.2] and at 30-minute intervals while they remain in the space.*

6.1.6 *In the case of gases classified as toxic products, hold spaces and interbarrier spaces shall be provided with a permanently installed piping system for obtaining gas samples from the spaces. Gas from these spaces shall be sampled and analysed from each sampling head location.*

6.1.7 *Permanently installed gas detection shall be of the continuous detection type, capable of immediate response. Where not used to activate safety shutdown functions required by [6.1.9] and Ch 9, Sec 16, sampling type detection may be accepted.*

6.1.8 *When sampling type gas detection equipment is used, the following requirements shall be met:*

- *the gas detection equipment shall be capable of sampling and analysing for each sampling head location sequentially at intervals not exceeding 30 min*
- *individual sampling lines from sampling heads to the detection equipment shall be fitted, and*
- *pipe runs from sampling heads shall not be led through non-hazardous spaces except as permitted by [6.1.9].*

6.1.9 *The gas detection equipment may be located in a non-hazardous space, provided that the detection equipment such as sample piping, sample pumps, solenoids and analysing units are located in a fully enclosed steel cabinet with the door sealed by a gasket. The atmosphere within the enclosure shall be continuously monitored. At gas concentrations above 30% lower flammable limit (LFL) inside the enclosure, the gas detection equipment shall be automatically shut down.*

Gas analysing units are to be in compliance with the requirements in Ch 7, Sec 6, [7.4].

6.1.10 *Where the enclosure cannot be arranged directly on the forward bulkhead, sample pipes shall be of steel or equivalent material and be routed on their shortest way. Detachable connections, except for the connection points for isolating valves required in [6.1.13] and analysing units, are not permitted.*

6.1.11 *When gas sampling equipment is located in a non-hazardous space, a flame arrester and a manual isolating valve shall be fitted in each of the gas sampling lines. The isolating valve shall be fitted on the non-hazardous side. Bulkhead penetrations of sample pipes between hazardous and non-hazardous areas shall maintain the integrity of the division penetrated. The exhaust gas shall be discharged to the open air in a safe location.*

6.1.12 *In every installation, the number and the positions of detection heads shall be determined with due regard to the size and layout of the compartment, the compositions and densities of the products intended to be carried and the dilution from compartment purging or ventilation and stagnant areas.*

Sampling heads in cargo holds are not to be located in positions where bilge water may collect.

6.1.13 *Any alarms status within a gas detection system required by this section shall initiate an audible and visible alarm:*

- *on the navigation bridge*
- *at the relevant control station(s) where continuous monitoring of the gas levels is recorded, and*
- *at the gas detector readout location.*

6.1.14 *In the case of flammable products, the gas detection equipment provided for hold spaces and interbarrier spaces that are required to be inerted shall be capable of measuring gas concentrations of 0% to 100% by volume.*

6.1.15 *Alarms shall be activated when the vapour concentration by volume reaches the equivalent of 30% LFL in air.*

6.1.16 *For membrane containment systems, the primary and secondary insulation spaces shall be able to be inerted and their gas content analysed individually.*

Note 1: Gas Concentrations in the Insulation Spaces of Membrane LNG Carriers, March 2007 (published by SIGTTO).

The alarm in the secondary insulation space shall be set in accordance with [6.1.15], that in the primary space is set at a value approved by the Society.

6.1.17 *For other spaces described by [6.1.2], alarms shall be activated when the vapour concentration reaches 30% LFL and safety functions required by Ch 9, Sec 16 shall be activated before the vapour concentration reaches 60% LFL. The crankcases of internal combustion engines that can run on gas shall be arranged to alarm before 100% LFL.*

6.1.18 *Gas detection equipment shall be so designed that it may readily be tested. Testing and calibration shall be carried out at regular intervals. Suitable equipment for this purpose shall be carried on board and be used in accordance with the manufacturer's recommendations. Permanent connections for such test equipment shall be fitted.*

6.1.19 *Every ship shall be provided with at least two sets of portable gas detection equipment that meet the requirement of [6.1.3] or an acceptable national or international standard.*

For ships intended to carry toxic and flammable gases, two sets for toxic gases and two sets for flammable gases are to be provided.

6.1.20 *A suitable instrument for the measurement of oxygen levels in inert atmospheres shall be provided.*

7 Additional requirements for containment systems requiring a secondary barrier

7.1 Integrity of barriers

7.1.1 *Where a secondary barrier is required, permanently installed instrumentation shall be provided to detect when the primary barrier fails to be liquid-tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation shall consist of appropriate gas detecting devices according to [6]. However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.*

7.1.2 Upon special approval, appropriate temperature indicating devices may be accepted by the Society instead of gas detecting devices when the cargo temperature is not lower than –55°C.

7.2 Temperature indication devices

7.2.1 *The number and position of temperature-indicating devices shall be appropriate to the design of the containment system and cargo operation requirements.*

7.2.2 *When cargo is carried in a cargo containment system with a secondary barrier, at a temperature lower than -55°C, temperature-indicating devices shall be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices shall give readings at regular intervals and, where applicable, alarm of temperatures approaching the lowest for which the hull steel is suitable.*

7.2.3 The temperatures are to be continuously recorded at regular intervals. Audible and visual alarms are to be automatically activated when the hull steel temperature approaches the lowest temperature for which the steel has been approved.

7.2.4 *If cargo is to be carried at temperatures lower than -55°C, the cargo tank boundaries, if appropriate for the design of the cargo containment system, shall be fitted with a sufficient number of temperature-indicating devices to verify that unsatisfactory temperature gradients do not occur.*

7.2.5 *For the purposes of design verification and determining the effectiveness of the initial cooldown procedure on a single or series of similar ships, one tank shall be fitted with devices in excess of those required in [7.2.1]. These devices may be temporary or permanent and only need to be fitted to the first ship, when a series of similar ships is built.*

8 Automation systems

8.1 General

8.1.1

The requirements of this section shall apply where automation systems are used to provide instrumented control, monitoring/alarm or safety functions required by this Code.

8.1.2 *Automation systems shall be designed, installed and tested in accordance with recognized standards.*

Note 1: Refer to the recommendations for computer-based systems contained in the standard published by the International Electrotechnical Commission, IEC 60092-504:2001 "Electrical installations in ships - Special features - Control and instrumentation".

8.1.3 *Hardware shall be capable of being demonstrated to be suitable for use in the marine environment by type approval or other means.*

8.1.4 *Software shall be designed and documented for ease of use, including testing, operation and maintenance.*

8.1.5 *The user interface shall be designed such that the equipment under control can be operated in a safe and effective manner at all times.*

8.1.6 *Automation systems shall be arranged such that a hardware failure or an error by the operator does not lead to an unsafe condition. Adequate safeguards against incorrect operation shall be provided.*

8.1.7 *Appropriate segregation shall be maintained between control, monitoring/alarm and safety functions to limit the effect of single failures. This shall be taken to include all parts of the automation systems that are required to provide specified functions, including connected devices and power supplies.*

8.1.8 *Automation systems shall be arranged such that the software configuration and parameters are protected against unauthorized or unintended change.*

8.1.9 *A management of change process shall be applied to safeguard against unexpected consequences of modification. Records of configuration changes and approvals shall be maintained on board.*

8.1.10 *Processes for the development and maintenance of integrated systems shall be in accordance with recognized standards. These processes shall include appropriate risk identification and management.*

Note 1: Refer to the International Electrotechnical Commission standard ISO/IEC 15288:2008 Systems and software engineering - System life cycle processes, and ISO 17894:2005 Ships and marine technology - Computer applications - General principles for the development and use of programmable electronic systems in marine applications.

9 System integration

9.1 General

9.1.1 *Essential safety functions shall be designed such that risks of harm to personnel or damage to the installation or the environment are reduced to a level acceptable to the* Society, *both in normal operation and under fault conditions. Functions shall be designed to fail-safe. Roles and responsibilities for integration of systems shall be clearly defined and agreed by relevant parties.*

9.1.2 *Functional requirements of each component subsystem shall be clearly defined to ensure that the integrated system meets the functional and specified safety requirements and takes account of any limitations of the equipment under control.*

9.1.3 *Key hazards of the integrated system shall be identified using appropriate risk-based techniques.*

Note 1: "Integrated system" means a combination of computer-based systems which are used for the control, monitoring/alarm and safety functions required for the carriage, handling and conditioning of cargo liquid and vapours and are interconnected in order to allow communication between computer-based systems and to allow centralized access to monitoring/alarm and safety information and/or command/control.

9.1.4 *The integrated system shall have a suitable means of reversionary control.*

9.1.5 *Failure of one part of the integrated system shall not affect the functionality of other parts, except for those functions directly dependent on the defective part.*

9.1.6 *Operation with an integrated system shall be at least as effective as it would be with individual stand-alone equipment or systems.*

9.1.7 *The integrity of essential machinery or systems, during normal operation and fault conditions, shall be demonstrated.*

Section 14 Personnel Protection

1 General

1.1 Protective equipment

1.1.1 *Suitable protective equipment, including eye protection to a recognized national or international standard, shall be provided for protection of crew members engaged in normal cargo operations, taking into account the characteristics of the products being carried.*

1.1.2 *Personal protective and safety equipment required in this Section shall be kept in suitable, clearly marked lockers located in readily accessible places.*

1.1.3 *The compressed air equipment shall be inspected at least once a month by a responsible officer and the inspection logged in the ship's records. This equipment shall also be inspected and tested by a competent person at least once a year.*

1.2 First-aid equipment

1.2.1 *A stretcher that is suitable for hoisting an injured person from spaces below deck shall be kept in a readily accessible location.*

1.2.2 *The ship shall have onboard medical first-aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) for the cargoes listed on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shown in* Appendix 2 of the IGC Code.

1.3 Safety equipment

1.3.1 *Sufficient, but not less than three complete sets of safety equipment shall be provided in addition to the firefighter's outfits required by Ch 9, Sec 11, [1.6.1]. Each set shall provide adequate personal protection to permit entry and work in a gas-filled space. This equipment shall take into account the nature of the cargoes, listed on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shown in* Appendix 2 of the IGC Code.

1.3.2 *Each complete set of safety equipment shall consist of:*

a) One self-contained positive pressure air-breathing apparatus incorporating full face mask, not using stored oxygen and having a capacity of at least 1,200 litre of free air. Each set shall be compatible with that required by Ch 9, Sec 11, [1.6.1]

b) Protective clothing, boots and gloves to a recognized standard

c) Steel-cored rescue line with belt, and

d) Explosion-proof lamp.

1.3.3 *An adequate supply of compressed air shall be provided and shall consist of:*

a) At least one fully charged spare air bottle for each breathing apparatus required by [1.3.1]

b) An air compressor of adequate capacity capable of continuous operation, suitable for the supply of high-pressure air of breathable quality, and

c) A charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by [1.3.1].

1.4 Personal protection requirements for individual products

1.4.1 *Requirements of this section shall apply to ships carrying products for which those paragraphs are listed in Ch 9, Sec 19, Tab 1 column "Special requirements".*

1.4.2 *Suitable respiratory and eye protection for emergency escape purposes shall be provided for every person on board, subject to the following:*

a) Filter-type respiratory protection is unacceptable

b) Self-contained breathing apparatus shall have at least a duration of service of 15 min, and

c) Emergency escape respiratory protection shall not be used for fire fighting or cargo-handling purposes and shall be marked to that effect.

1.4.3 *One or more suitably marked decontamination showers and eyewash stations shall be available on deck, taking into account the size and layout of the ship. The showers and eyewashes shall be operable in all ambient conditions.*

1.4.4 The showers and eye wash are to be fitted with a heating system, or other suitable installation, in order to avoid any ice formation in their piping.

1.4.5 *The protective clothing required under [1.3.2], item b), shall be gastight.*

Section 15 Filling Limits for Cargo Tanks

1 General

1.1 Definitions

1.1.1 Filling limit

Filling limit (FL) means the maximum liquid volume in a cargo tank relative to the total tank volume when the liquid cargo has reached the reference temperature.

1.1.2 Loading limit

Loading limit (LL) means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

1.1.3 Reference temperature

Reference temperature means (for the purposes of this Section only):

a) When no cargo vapour pressure/temperature control, as referred to in Ch 9, Sec 7, is provided, the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs, and

b) When a cargo vapour pressure/temperature control, as referred to in Ch 9, Sec 7, is provided, the temperature of the cargo upon termination of loading, during transport or at unloading, whichever is the greatest.

1.1.4 Ambient design temperature for unrestricted service

Ambient design temperature for unrestricted service means sea temperature of 32°C and air temperature of 45°C. However, lesser values of these temperatures may be accepted by the Society *for ships operating in restricted areas or on voyages of restricted duration, and account may be taken in such cases of any insulation of the tanks. Conversely, higher values of these temperatures may be required for ships permanently operating in areas of high-ambient temperature.*

1.2 General requirements

1.2.1 *The maximum filling limit of cargo tanks shall be so determined that the vapour space has a minimum volume at reference temperature allowing for:*

- *tolerance of instrumentation such as level and temperature gauges*
- *volumetric expansion of the cargo between the PRV set pressure and the maximum allowable rise stated in Ch 9, Sec 8, [4], and*
- *an operational margin to account for liquid drained back to cargo tanks after completion of loading, operator reaction time and closing time of valves, see Ch 9, Sec 5, [5] and Ch 9, Sec 18, [3.2.1], item d).*

1.3 Default filling limit

1.3.1 *The default value for the filling limit (FL) of cargo tanks is 98% at the reference temperature. Exceptions to this value shall meet the requirements of [1.4].*

1.4 Determination of increased filling limit

1.4.1 *A filling limit greater than the limit of 98% specified in [1.3] may be permitted under the trim and list conditions specified in Ch 9, Sec 8, [2.1.20], providing:*

a) No isolated vapour pockets are created within the cargo tank

b) The PRV inlet arrangement shall remain in the vapour space, and

c) Allowances need to be provided for:

- *volumetric expansion of the liquid cargo due to the pressure increase from the MARVS to full flow relieving pressure in accordance with Ch 9, Sec 8, [4.1].*
- *an operational margin of minimum 0,1% of tank volume, and*
- *tolerances of instrumentation such as level and temperature gauges.*

1.4.2 *In no case shall a filling limit exceeding 99.5% at reference temperature be permitted.*

1.4.3 The PRV inlet, as defined in [1.4.1], item b), is to be remain in the vapour space at a minimum distance of 40% of the diameter of the suction funnel measured at the centre of the funnel above the liquid level under conditions of 15° list and 0,015L trim.

1.4.4 The following method may be used to determine the allowance defined in [1.4.1], item c). The Society may accept other methods to determine the allowance provided the method meets an equivalent level of safety.

The parameters specified under [1.4.1], item c) may be expressed by the expansion factor α_T, in %, to be determined as follows:

$$\alpha_T = \sqrt{\alpha_1^2 + \alpha_2^2} + \alpha_3 + \alpha_4$$

where:

α_1 : Relative increase in liquid volume, in %, due to tolerance of level gauges:

$$\alpha_1 = \frac{dV}{dh} \times \frac{\Delta h}{V} \times 100$$

where:

dV/dh : Variation of tank volume per metre filling height at the filling height h, in m^3/m

h : Filling height, in m, at the filling limit FL to be investigated (FL>98%)

V : Accepted total tank volume, in m^3

Δh : Max. total tolerance of level gauges, in m

α_2 : Relative increase in liquid volume, in %, due to the tolerance of temperature gauges:

$$\alpha_2 = \beta \Delta T$$

where:

β : volumetric thermal expansion coefficient at reference temperature, in %/°K

ΔT : max. tolerance of temperature gauge, in °K

α_3 : Expansion of cargo volume, in %, due to pressure rise when pressure relief valves are relieving at maximum flow rate:

$$\alpha_3 = 100\left(\frac{\rho_{PRV}}{\rho_{PRV1,2}} - 1\right)$$

where:

ρ_{PRV} : cargo density at reference conditions (corresponding to the temperature of the cargo at set opening pressure of the pressure relief valve (PRV))

$\rho_{PRV1.2}$: cargo density corresponding to the temperature of the cargo at 1,2 times the set opening pressure of the pressure relief valve (PRV)

α_4 : Operational margin of 0,1%.

1.5 Maximum loading unit

1.5.1 *The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula:*

$$LL = FL \times \frac{\rho_R}{\rho_L}$$

where:

LL : *loading limit as defined in [1.1.2], expressed in percentage*

FL : *filling limit as specified in [1.3] or [1.4], expressed in percentage*

ρ_R : *relative density of cargo at the reference temperature, and*

ρ_L : *relative density of cargo at the loading temperature.*

1.5.2 The Society *may allow type C tanks to be loaded according to the formula in [1.5.1] with the relative density ρ_R provided that the tank vent system has been approved in accordance with Ch 9, Sec 8, [2.1.21]:*

Note 1: ρ_R is the relative density of cargo at the highest temperature that the cargo may reach upon termination of loading, during transport, or at unloading, under the ambient design temperature conditions described in [1.1.4].

This paragraph does not apply to products requiring a type 1G ship.

1.6 Information to be provided to the Master

1.6.1 *A document shall be provided to the ship, specifying the maximum allowable loading limits for each cargo tank and product, at each applicable loading temperature and maximum reference temperature. The information in this document shall be approved by* the Society.

1.6.2 *Pressures at which the PRVs have been set shall also be stated in the document.*

1.6.3 *A copy of the above document shall be permanently kept on board by the master.*

Section 16 Use of Cargo as Fuel

1 General

1.1

1.1.1 *Except as provided for in [9], methane (LNG) is the only cargo whose vapour or boil-off gas may be utilized in machinery spaces of category A, and, in these spaces, it may be utilized only in systems such as boilers, inert gas generators, internal combustion engines, gas combustion unit and gas turbines.*

1.1.2 Liquefied gas carriers using LPG as fuel are to comply with the requirements of Article [9].

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for cargo used as fuel are mentioned in Tab 1 and as applicable in Tab 4.

Table 1 : Documents to be submitted for cargo used as fuel

No.	I/A **(1)**	Documents to be submitted
1	I	General arrangement plan of the machinery spaces containing gas consumers
2	I	Description of the entire plant
3	A	Diagram of the gas fuel supply system
4	A	Complete list of the safety, gas detection and alarm equipment
5	A	Drawings of the boilers
6	I	Detailed drawings of the gas inlet and fuel inlet equipment
7	I	Gas characteristics
8	A	General arrangement plan of the gas handling plant, including gas compressors, prime movers and gas preheaters
9	A	Drawings of the gas storage tanks
10	A	Drawings of the gas compressors and preheaters
(1) A: to be submitted for approval; I: to be submitted for information.		

2 Use of cargo vapour as fuel

2.1 General

2.1.1 *This section addresses the use of cargo vapour as fuel in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units and gas turbines.*

2.1.2 *For vaporized LNG, the fuel supply system shall comply with the requirements of [4.1], [4.2] and [4.3].*

2.1.3 *For vaporized LNG, gas consumers shall exhibit no visible flame and shall maintain the uptake exhaust temperature below 535°C.*

3 Arrangement of spaces containing gas consumers

3.1 General

3.1.1 *Spaces in which gas consumers are located shall be fitted with a mechanical ventilation system that is arranged to avoid areas where gas may accumulate, taking into account the density of the vapour and potential ignition sources. The ventilation system shall be separated from those serving other spaces.*

3.1.2 *Gas detectors shall be fitted in these spaces, particularly where air circulation is reduced. The gas detection system shall comply with the requirements of Ch 9, Sec 13.*

3.1.3 *Electrical equipment located in the double wall pipe or duct specified in [4.3] shall comply with the requirements of Ch 9, Sec 10.*

3.1.4 *All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space and be fitted with a flame screen.*

In case of high pressure gas supply, means are to be taken to manage the large gas influx without release to atmosphere.

4 Gas fuel supply

4.1 General

4.1.1 *The requirements of this section shall apply to gas fuel supply piping outside of the cargo area. Fuel piping shall not pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. The routeing of the pipeline shall take into account potential hazards, due to mechanical damage, in areas such as stores or machinery handling areas.*

4.1.2 Gas piping is to be installed in accordance with the requirements of Ch 9, Sec 5, [2.2].

4.1.3 Gas piping is to be suitably earthed and in accordance with the requirement of Ch 9, Sec 5, [7.4.1].

4.1.4 Piping, valves and fittings are to be hydrostatically tested, after assembly on board, to 1,5 times the working pressure but to not less than 7 bar. Subsequently, they are to be pneumatically tested to ascertain that all the joints are perfectly tight. The outer pipe or duct of double wall gas-fuel piping systems are to be in accordance with the requirement of Ch 9, Sec 5, [13.5.4].

4.1.5 *Provision shall be made for inerting and gas-freeing that portion of the gas fuel piping systems located in the machinery space.*

4.1.6 Classes of gas fuel piping systems

a) Purpose of the classes of piping systems

Piping systems are subdivided into three classes, denoted as class I, class II and class III, for the purpose of acceptance of materials, selection of joints, heat treatment, welding, pressure testing and the certification of fittings.

b) Determination of the classes of piping systems

Piping classes I, II and III are to be determined in accordance with the provisions of:

- Tab 2 for gas fuel piping
- Tab 3 for all vent pipes and open ended lines, including:
  - discharge lines from thermal relief valves (see Ch 9, Sec 5, [5.3.3])
  - vent lines from the gas supply lines to consumers (see [4.6.1])
  - purging lines from engines and other gas consumers.

Table 2 : Classes of gas fuel piping systems

Design conditions		Class of the gas piping		
Design pressure	Design temperature	Single wall arrangement	Double wall arrangement	
			Inner pipe	Outer pipe **(1)**
p = 10 bar **(2)**	any	Class I	Class II	Class II
p > 10 bar	any	Class I	Class I	Class II
(1) The design pressure of the outer pipe or duct of fuel systems is to comply with Ch 9, Sec 5, [4.1.4] **(2)** The design pressure is not to be taken less than 10 bar. See Ch 9, Sec 5, [4.1.1]				

Table 3 : Classes of vent pipes and bleed lines

Design conditions		Class of the gas vent piping		
Vent pipe design pressure	Vent pipe design temperature	Single wall arrangement	Double wall arrangement	
			Inner pipe	Outer pipe **(1)**
p = 5 bar **(2)**	any	Class III	Class III	Class III
p > 5 bar and p ≤ 10 bar **(3)**	any	Class II	Class III	Class III
P > 10 bar **(3)**	any	Class I	Class II	Class III
(1) The design pressure of the outer pipe or duct of vent pipes or open ended lines is to comply with Ch 9, Sec 5, [4.1.4] **(2)** The design pressure of the vent pipes or open ended lines is not to be taken less than 5 bar. See Ch 9, Sec 5, [4.1.1] **(3)** The design pressure of the vent pipes or open ended lines is not to be less than the maximum expected pressure, which is to be justified				

4.2 Leak detection

4.2.1 *Continuous monitoring and alarms shall be provided to indicate a leak in the piping system in enclosed spaces and shut down the relevant gas fuel supply.*

4.3 Routeing of fuel supply pipes

4.3.1 *Fuel piping may pass through or extend into enclosed spaces other than those mentioned [4.1], provided it fulfils one of the following conditions:*

a) it is of a double-wall design with the space between the concentric pipes pressurized with inert gas at a pressure greater than the gas fuel pressure. The master gas fuel valve, as required by [4.6], closes automatically upon loss of inert gas pressure, or

b) it is installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour and is arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation is in accordance with Ch 9, Sec 12, as applicable. The ventilation is always in operation when there is fuel in the piping and the master gas fuel valve, as required by [4.6], closes automatically if the required air flow is not established and maintained by the exhaust ventilation system. The inlet or the duct may be from a non-hazardous machinery space, and the ventilation outlet is in a safe location.

4.3.2 The gas valve unit rooms are to be:

a) Gastight toward other enclosed spaces

b) Equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour and arranged to maintain a pressure less than the atmospheric pressure, and

c) Able to withstand the maximum built-up pressure arising in the room in case of a gas pipe rupture, as documented by suitable calculations taking into account the ventilation arrangements.

4.4 Requirements for gas fuel supply with pressure greater than 1 MPa

4.4.1 *Fuel delivery lines between the high-pressure fuel pumps/compressors and consumers shall be protected with a double-walled piping system capable of containing a high pressure line failure, taking into account the effects of both pressure and low temperature. A single-walled pipe in the cargo area up to the isolating valve(s) required by [4.6] is acceptable.*

4.4.2 *The arrangement in [4.3.1], item b) may also be acceptable providing the pipe or trunk is capable of containing a high pressure line failure, according to the requirements of [4.7] and taking into account the effects of both pressure and possible low temperature and providing both inlet and exhaust of the outer pipe or trunk are in the cargo area.*

4.4.3 High pressure gas piping systems are to be checked for sufficient constructive strength by carrying out stress analysis taking into account the stresses due to the weight of the piping system including acceleration load, when significant, internal pressure and loads induced by hog and sag of the ship (see also Ch 9, Sec 5, [11.4.1]).

In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of straight section of pipe or ducting is to be in accordance with requirement [11.4.1].

4.4.4 All valves and expansion joints used in high pressure gas fuel supply lines are to be of an approved type.

4.4.5 The possibility of fatigue failure of the high pressure gas piping due to vibration is to be considered.

4.4.6 The possibility of pulsation of gas fuel supply pressure caused by the high pressure gas compressor is to be considered.

4.4.7 Gas fuel piping may pass through or extend into machinery spaces or gas-safe spaces other than accommodation spaces, service spaces and control stations provided that they fulfil one of the following conditions:

a) The system complies with [4.3.1], and in addition, with items 1) to 3) below:

   1) The pressure in the space between concentric pipes is monitored continuously. Alarm is to be issued and the automatic valves specified in [4.5.1] (hereafter referred to as “interlocked gas valves”) and the master gas fuel valves specified in [4.6] (hereafter referred to as “master gas valves”) are to be closed before the pressure drops to below the inner pipe pressure (however, an interlocked gas valve connected to the vent outlet is to be opened).

   2) The construction and strength of the outer pipes are to comply with the requirements of Ch 9, Sec 5.

   3) It is to be so arranged that the inside of the gas fuel supply piping system between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

b) The system complies with [4.3.1], and, in addition, with items 1) to 4) below:

1) The materials, construction and strength of protection pipes or ducts and mechanical ventilation systems are to be sufficiently durable against bursting and rapid expansion of high pressure gas in the event of gas pipe burst.

2) The capacity of mechanical ventilating systems is to be determined considering the flow rate of gas fuel and construction and arrangement of protective pipes or ducts, as deemed appropriate by the Society.

3) The air intakes of mechanical ventilating systems are to be provided with non-return devices effective for gas fuel leaks. However, if a gas detector is fitted at the air intakes, this requirement may be dispensed with.

4) The number of flange joints of protective pipes or ducts is to be minimised; or

c) Alternative arrangements to those given in a) and b) will be specially considered by the Society based upon an equivalent level of safety.

4.4.8 Joints on the entire length of the gas fuel supply lines are to be butt-welded joints with full penetration and to be fully radiographed, except where specially approved by the Society.

4.4.9 Pipe joints other than welded joints at the locations specifically approved by the Society are to comply with the appropriate standards recognised by the Society, or with joints whose structural strength has been verified through test analysis as deemed appropriate by the Society.

4.4.10 For all butt-welded joints of high pressure gas fuel supply lines, post-weld heat treatment is to be performed depending on the kind of material.

4.5 Gas consumer isolation

4.5.1 *The supply piping of each gas consumer unit shall be provided with gas fuel isolation by automatic double block and bleed, vented to a safe location, under both normal and emergency operation. The automatic valves shall be arranged to fail to the closed position on loss of actuating power. In a space containing multiple consumers, the shutdown of one shall not affect the gas supply to the others.*

4.5.2 The automatic double block and bleed indicated in [4.5.1] are to be capable of being manually operated.

4.5.3 It is to be possible to operate the valves indicated in [4.5.1] locally and from each control platform. They are to close automatically under the following service conditions:

a) Whenever the gas pressure varies by more than 10% or, in the case of supercharged engines, if the differential pressure between gas and charging air is no longer constant

b) In the event of one of the following fault situations:

1) Gas supply to boiler burners

- insufficient air supply for complete combustion of the gas
- extinguishing of the pilot burner for an operating burner, unless the gas supply line to every individual burner is equipped with a quick-closing valve that automatically cuts off the gas
- low pressure of the gas

2) Gas supply to internal combustion engines

- failure of supply to pilot fuel injection pump
- drop of engine speed below the lowest service speed.

4.6 Spaces containing gas consumers

4.6.1 *It shall be possible to isolate the gas fuel supply to each individual space containing a gas consumer(s) or through which fuel gas supply piping is run, with an individual master valve, which is located within the cargo area. The isolation of gas fuel supply to a space shall not affect the gas supply to other spaces containing gas consumers if they are located in two or more spaces, and it shall not cause loss of propulsion or electrical power.*

4.6.2 *If the double barrier around the gas supply system is not continuous due to air inlets or other openings, or if there is any point where single failure will cause leakage into the space, the individual master valve for the space shall operate under the following circumstances:*

a) Automatically, by:

- *gas detection within the space*
- *leak detection in the annular space of a double-walled pipe*
- *leak detection in other compartments inside the space, containing single-walled gas piping*; in particular the GVU compartment
- *loss of ventilation in the annular space of a double-walled pipe, and*
- *loss of ventilation in other compartments inside the space, containing single-walled gas piping,* in particular the GVU compartment *and*

b) Manually, from within the space and at least one remote location.

4.6.3 *If the double barrier around the gas supply system is continuous, an individual master valve located in the cargo area may be provided for each gas consumer inside the space. The individual master valve shall operate under the following circumstances:*

a) Automatically, by:

- *leak detection in the annular space of a double-walled pipe served by that individual master valve*
- *leak detection in other compartments containing single-walled gas piping that is part of the supply system served by the individual master valve, and*
- *loss of ventilation or loss of pressure in the annular space of a double-walled pipe, and*

b) Manually, from within the space and at least one remote location.

4.7 Piping and ducting construction

4.7.1 *Gas fuel piping in machinery spaces shall comply with Ch 9, Sec 5, [1] to Ch 9, Sec 5, [9], as applicable. The piping shall, as far as practicable, have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to [4.3], and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be fully radiographed.*

4.8 Gas detection

4.8.1 *Gas detection systems provided in accordance with the requirements of this Section shall activate the alarm at 30% LFL and shut down the master gas fuel valve required by [7.5] at not more than 60% LFL (see Ch 9, Sec 13, [6.1.17]).*

5 Gas fuel plant and related storage tanks

5.1 Provision of gas fuel

5.1.1 *All equipment (heaters, compressors, vaporizers, filters, etc.) for conditioning the cargo and/or cargo boil off vapour for its use as fuel, and any related storage tanks, shall be located in the cargo area. If the equipment is in an enclosed space, the space shall be ventilated according to Ch 9, Sec 12, [1.2] and be equipped with a fixed fire-extinguishing system, according to Ch 9, Sec 11, [1.5], and with a gas detection system according to Ch 9, Sec 13, [6], as applicable.*

5.1.2 Means for purging of flammable gases before opening are to be provided in the equipment for making up gas.

5.1.3 Where the equipment (heaters, compressors, filters) for making up the gas for its use as fuel and the storage tanks are located on the weather deck, they are to be suitably protected from atmospheric agents and the sea.

5.2 Remote stops

5.2.1 *All rotating equipment utilized for conditioning the cargo for its use as fuel shall be arranged for manual remote stop from the engine-room. Additional remote stops shall be located in areas that are always easily accessible, typically cargo control room, navigation bridge and fire control station.*

5.2.2 *The fuel supply equipment shall be automatically stopped in the case of low suction pressure or fire detection. Unless expressly provided otherwise, the requirements of Ch 9, Sec 18, [3] need not apply to gas fuel compressors or pumps when used to supply gas consumers.*

a) The compressors are to be capable of being remotely stopped from an always and easily accessible, non-dangerous position in the open, and also from the engine room.

b) In addition, the compressors are to be capable of automatically stopping when the suction pressure reaches a certain value depending on the setting pressure of the vacuum relief valves of the cargo tanks.

c) The automatic shutdown device of the compressors is to have a manual resetting.

5.3 Compressors

5.3.1 Miscellaneous requirements

a) Low pressure piston-type compressors are to be fitted with relief valves discharging to a position in the open, such as not to give rise to hazards.

b) Volumetric compressors are to be fitted with pressure/vacuum relief valves discharging into the suction line of the compressor.

c) The size of the pressure relief valves is to be determined in such a way that, with the delivery valve kept closed, the maximum pressure does not exceed the maximum working pressure by more than 10%.

d) The compressors are to be automatically stopped by the emergency shutdown system of the cargo valves.

e) The compressors are to be fitted with shut-off valves and flame screens on both the suction and delivery sides.

5.4 Heating and cooling mediums

5.4.1 *If the heating or cooling medium for the gas fuel conditioning system is returned to spaces outside the cargo area, provisions shall be made to detect and alarm the presence of cargo/cargo vapour in the medium. Any vent outlet shall be in a safe position and fitted with an effective flame screen of an approved type.*

a) Operation of the heaters is to be automatically regulated depending on the gas temperature at the heater outlet.

b) Before it is returned to the machinery space, the heating medium (steam or hot water) is to go through a degassing tank located in the cargo area.

c) The vent outlet is to be in a safe position, having regards of source of ignition and fitted with a flame screen.

5.5 Piping and pressure vessels

5.5.1 *Piping or pressure vessels fitted in the gas fuel supply system shall comply with Ch 9, Sec 5*

6 Special requirements for main boilers

6.1 Arrangements

6.1.1 *Each boiler shall have a separate exhaust uptake.*

6.1.2 *Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.*

6.1.3 Boilers are to be located as high as possible in boiler spaces and are to be of the membrane wall type or equivalent, so as to create a space with forced air circulation between the membrane wall and the boiler casing.

6.1.4 *Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.*

6.1.5 The Society may, at its discretion, require gas detectors to be fitted in those combustion chamber areas where gas could accumulate, as well as the provision of suitable air nozzles.

6.2 Combustion equipment

6.2.1 *The burner systems shall be of dual type, suitable to burn either: oil fuel or gas fuel alone, or oil and gas fuel simultaneously.*

6.2.2 *Burners shall be designed to maintain stable combustion under all firing conditions.*

6.2.3 *An automatic system shall be fitted to change over from gas fuel operation to oil fuel operation without interruption of the boiler firing, in the event of loss of gas fuel supply.*

6.2.4 *Gas nozzles and the burner control system shall be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by* the Society *to light on gas fuel.*

6.3 Safety

6.3.1 *There shall be arrangements to ensure that gas fuel flow to the burner is automatically cut-off, unless satisfactory ignition has been established and maintained.*

6.3.2 *On the pipe of each gas-burner, a manually operated shut-off valve shall be fitted.*

6.3.3 *Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.*

6.3.4 A mechanical device is to be installed to prevent the gas valve from opening until the air and the fuel oil controls are in the ignition position. A flame screen, which may be incorporated in the burner, is to be fitted on the pipe of each gas burner.

6.3.5 *The automatic fuel changeover system required by [6.2.3] shall be monitored with alarms to ensure continuous availability.*

6.3.6 *Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.*

6.3.7 *Arrangements shall be made to enable the boilers to be manually purged.*

7 Special requirements for gas-fired internal combustion engines

7.1 General

7.1.1 *Dual fuel engines are those that employ gas fuel (with pilot oil) and oil fuel. Oil fuels may include distillate and residual fuels. Gas only engines are those that employ gas fuel only.*

7.2 Gas fuel supply to engines with fuel injection pressure greater than 1 MPa

7.2.1 Flame arresters are to be provided at the inlet to the gas supply manifold for the engine.

7.2.2 Arrangements are to be made so that the gas supply to the engine can be shut off manually from the starting platform or any other control position.

7.2.3 The arrangement and installation of the gas piping are to provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of the engines without risk of fatigue failure.

7.2.4 The connecting of gas line and protection pipes or ducts as per [4.2.1] to the gas fuel injection valves is to provide complete coverage by the protection pipe or ducts.

7.3 Shut-off of gas fuel supply with pressure greater than 1 MPa

7.3.1 Fuel supply shut-off

In addition to the causes specified in [4.5.1], supply of gas fuel to engines is to be shut-off by the interlocked gas valves in the event of the following abnormalities:

a) Abnormality specified in Pt C, Ch 1, App 2

b) Engine stops due to any cause.

7.3.2 Master gas valve shut-off

In addition to the causes specified in [4.6], the master gas valve is to be closed in the event of any of the following:

a) The oil mist detector or bearing temperature detector specified in Pt C, Ch 1, App 2 detects abnormality

b) Any kind of gas fuel leakage is detected

c) Abnormality specified in Pt C, Ch 1, App 2.

7.3.3 Automatic operation

The master gas valve is to close automatically upon activation of the interlocked gas valves.

7.4 Emergency stop of dual fuel engines with fuel injection pressure greater than 1 MPa

7.4.1 Dual fuel engines are to be stopped before the gas concentration detected by the gas detectors specified in [3.1.2] reaches 60% of the lower flammable limit.

7.5 Requirements on dual fuel engines

7.5.1 Specific requirements on internal combustion engines supplied by gas are given in Pt C, Ch 1, App 2.

7.6 Arrangements

7.6.1 *When gas is supplied in a mixture with air through a common manifold, flame arrestors shall be installed before each cylinder head.*

7.6.2 *Each engine shall have its own separate exhaust.*

7.6.3 *The exhausts shall be configured to prevent any accumulation of unburnt gaseous fuel.*

7.6.4 *Unless designed with the strength to withstand the worst case overpressure due to ignited gas leaks, air inlet manifolds, scavenge spaces, exhaust system and crank cases shall be fitted with suitable pressure relief systems. Pressure relief systems shall lead to a safe location, away from personnel.*

A suitable pressure relief system for air inlet manifolds, scavenge spaces and exhaust system is to be provided unless designed to accommodate the worst-case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation regarding the hazard potential of overpressure in air inlet manifolds, scavenge spaces and exhaust system is to be carried out and reflected in the safety concept of the engine.

In the case of crankcases, the explosion relief valves, as required by Regulation 27.4 of SOLAS Chapter II-1 as amended by IMO resolutions up to MSC.436(99), are to be considered suitable for the gas operation of the engine. For engines not covered by said Regulation, a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase is to be carried out.

In the case of air inlet and exhaust systems, explosion relief devices are to fulfill the requirements mentioned in Pt C, Ch 1, Sec 2, Pt C, Ch 1, App 2 and Pt C, Ch 1, App 8.

7.6.5 *Each engine shall be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.*

7.7 Combustion equipment

7.7.1 *Prior to admission of gas fuel, correct operation of the pilot oil injection system on each unit shall be verified.*

7.7.2 *For a spark ignition engine, if ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve, this shall be automatically shut off and the starting sequence terminated. It shall be ensured that any unburnt gas mixture is purged from the exhaust system.*

7.7.3 *For dual-fuel engines fitted with a pilot oil injection system, an automatic system shall be fitted to change over from gas fuel operation to oil fuel operation with minimum fluctuation of the engine power.*

7.7.4 *In the case of unstable operation on engines with the arrangement in [7.7.3] when gas firing, the engine shall automatically change to oil fuel mode.*

7.8 Safety

7.8.1 *During stopping of the engine, the gas fuel shall be automatically shut off before the ignition source.*

7.8.2 *Arrangements shall be provided to ensure that there is no unburnt gas fuel in the exhaust gas system prior to ignition.*

7.8.3 *Crankcases, sumps, scavenge spaces and cooling system vents shall be provided with gas detection (see Ch 9, Sec 13, [6.1.17]).*

7.8.4 *Provision shall be made within the design of the engine to permit continuous monitoring of possible sources of ignition within the crank case. Instrumentation fitted inside the crankcase shall be in accordance with the requirements of Ch 9, Sec 10.*

7.8.5 *Means shall be provided to monitor and detect poor combustion or misfiring that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down. Instrumentation fitted inside the exhaust system shall be in accordance with the requirements of Ch 9, Sec 10.*

8 Special requirements for gas turbine

8.1 Arrangements

8.1.1 *Each turbine shall have its own separate exhaust.*

8.1.2 *The exhausts shall be appropriately configured to prevent any accumulation of unburnt gas fuel.*

8.1.3 *Unless designed with the strength to withstand the worst case overpressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a non-hazardous location, away from personnel.*

8.2 Combustion equipment

8.2.1 *An automatic system shall be fitted to change over easily and quickly from gas fuel operation to oil fuel operation with minimum fluctuation of the engine power.*

8.3 Safety

8.3.1 *Means shall be provided to monitor and detect poor combustion that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down.*

8.3.2 *Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.*

9 Alternative fuels and technologies

9.1 General

9.1.1 *If acceptable to* the Society, *other cargo gases may be used as fuel, providing that the same level of safety as natural gas in this Code is ensured.*

9.1.2 *The use of cargoes identified as toxic products shall not be permitted.*

Note 1: In the case of an ammonia carrier intended to use its cargo as fuel, the Flag Administration is to be consulted to consider such possibility and to agree on the approval process to be followed.

9.1.3 *For cargoes other than LNG, the fuel supply system shall comply with the requirements of [4.1], [4.2], [4.3] and [5], as applicable, and shall include means for preventing condensation of vapour in the system.*

9.1.4 *Liquefied gas fuel supply systems shall comply with [4.5].*

9.1.5 *In addition to the requirements of [4.3.1], item b), both ventilation inlet and outlet shall be located outside the machinery space. The inlet shall be in a non-hazardous area and the outlet shall be in a safe location.*

9.2 Specific requirements for the use of LPG as fuel

9.2.1 In addition to the documents listed in Tab 1 and Ch 9, Sec 1, Tab 2, the documentation to be submitted for the use of LPG as fuel is listed in Tab 4.

Table 4 : Additional documentation to be submitted for the use of LPG as fuel

No.	I/A **(1)**	Documents to be submitted
1	I	Information about the range of LPG compositions acceptable for gas fuel consumers
2	I	Risk assessment report as mentioned in [9.2.5]
3	I	Numerical calculations supporting the determination of the ventilation capacity and of the positioning of gas detection heads as mentioned in [9.2.5]
(1) A: to be submitted for approval; I: to be submitted for information.		

9.2.2 Definitions

a) *LPG is composed of propane (C3H8), butane (C4H10), or a propane-butane mixture and may contain small amounts of other hydrocarbons and impurities. It can be in either a liquefied or gaseous state. LPG in the liquefied state is referred to as LPG liquid, and LPG in the gaseous state is referred to as LPG vapour.*

b) *A gas fuel consumer is any unit within the ship using cargo vapour or liquid as a fuel.*

9.2.3 General requirements for LPG cargo used as fuel

a) *Single failure is not to cause leakage of fuel into the space where fuel consumers are installed.*

b) *Effectiveness of the ventilation and detection for LPG leakage is to be ensured taking into account characteristics of LPG.*

c) *Fuel supply systems are to be designed to prevent fuel from unintended phase changes in processing of fuel supply to consumers considering vapour pressure at the working temperature, as follows:*

   1) *Where fuel is supplied in the gaseous state, measures are to be taken so that the temperature of fuel is not lowered to the dew point at the working pressure; and*

   2) *Where fuel is supplied in the liquid state, measures should be taken so that the pressure of fuel is not lowered to the vapour pressure at the working temperature.*

d) *Vent, purging and bleed lines of fuel supply systems should be designed to prevent LPG liquid from being released into the atmosphere.*

9.2.4 Supplementary requirements

a) *In accordance with the principles of paragraph 9.1, LPG cargoes may be utilized in machinery spaces of category A. In these spaces, it may be utilized only in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units and gas turbines.*

b) *The LPG fuel supply systems and LPG fuel consumers are to be designed for operation with the possible range of composition of the intended fuel. Information about the range of acceptable compositions is to be provided on board.*

c) *LPG fuel consumers are to exhibit no external visible flame and are to maintain the uptake exhaust temperature sufficiently below the auto-ignition temperature of the fuel. In a mixture of gases, the component with the lowest auto-ignition temperature is to be the appropriate reference.*

d) *LPG vapour or liquid may be used as fuel in systems referenced in item a).*

e) *Provision is to be made for inerting and venting to a safe location the gas fuel piping systems located in the machinery space. For permanent installations, the inert gas piping connected to the fuel piping is to be fitted with double block and bleed valves. In addition, a non-return valve is to be installed in the inert gas piping upstream of the double block and bleed valves. For liquid fuel supply systems, consideration is to be given to draining the piping without release of liquid to the atmosphere.*

f) *The supply and return piping of each gas consumer unit are to be provided with fuel isolation by automatic double block and bleed, vented to a safe location, under both normal and emergency operation. The automatic valves are to be arranged to fail to the closed position on loss of actuating power. In a space containing multiple consumers, the shutdown of one is not to affect the gas fuel supply to the others. For liquid fuel supply systems, the piping is to be drained without release of liquid to the atmosphere.*

g) *Gas nozzles and the burner control system are to be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the Society, to ignite on gas fuel.*

9.2.5 Additional provisions

a) *Risk assessment*

1) *A risk assessment is to be conducted of the LPG fuel arrangements to document an equivalent level of safety to utilizing LNG as fuel. Consideration is to be given to the hazards associated with the arrangement, operation and maintenance of the fuel system, considering reasonably foreseeable failures.*

2) *The risk assessment is to address the consequences of fuel leakage, considering the properties of LPG gas and its accumulation or escape into another space.*

b) *Arrangements of spaces containing gas fuel consumers*

1) *A single failure of fuel systems in the machinery space is not to lead to a gas release in the machinery space. Fuel piping is to be of double wall design or ducted and the outer boundary is to be continuous in the space. Non-continuous double barriers are not to be used under the circumstances described in [4.6.2].*

2) *The air inlet of the annular space is not to be in the machinery space. In addition, the air inlet of the annular space is to be in a location which would be safe in the absence of the air inlet. Consideration is to be given to the risk of liquid carry-over resulting from a liquid leak.*

c) *Fuel supply*

1) *Where fuel supply systems supply LPG liquid, vent and purging is to lead to a fuel tank, gas-liquid separator or similar device. Heating of the gas-liquid separator may be required for ships operating in cold areas.*

2) *Fuel supply systems referenced in item 1) and vent mast are to be fitted with an inert gas purging interface and should include a means for preventing condensation of vapour in the system.*

3) *In application of [4.3.1], item b, the ventilation inlets for the double wall piping and ducts should be in a non-hazardous area, away from ignition sources. Ventilation outlets for the double wall piping and ducts should be in the cargo area.*

4) Efficient means of detection of clogging of filters mounted on the fuel supply lines are to be fitted.

5) Replacement or recovery of the clogged filters are to be possible without exposing the crew to a potential projection of fluids at a pressure more than 0,5MPa.

d) *Fuel plant ventilation and gas detection*

1) *In addition to the requirements of [3.1.1] and [5.1.1], special consideration is to be given to the density and lower explosion limit (LEL) of LPG vapour. Ventilation capacity, including ventilation inlet and outlet location, are to be supported by numerical calculations, such as a computational fluid dynamics (CFD) analysis. Notwithstanding, for spaces within the cargo area, on the open deck and containing LPG fuel conditioning equipment, the requirements of Ch 9, Sec 12, [1.2.3] are to apply.*

2) *In addition to the requirements of Ch 9, Sec 13, [6.1.12], gas detection heads are to be fitted in spaces where LPG vapour may accumulate particularly where air circulation is reduced or near the bottom of the space. The suitability of their location is to be supported by numerical calculations, such as a CFD analysis or physical smoke test.*

e) *Combustion equipment*

1) *Gas fuel consumer exhaust gas temperature is to be continuously monitored.*

2) *Gas turbines are to be fitted with a gas-tight enclosure unless fuel supply piping meets the requirements of [4.3.1]. The consequences of gas leakage are to be evaluated based on the risk assessment in [9.2.5], item a).*

Section 17 Special Requirements

1 General

1.1 Application

1.1.1 *The requirements of this Section are applicable where reference thereto is made in Ch 9, Sec 19, Tab 1, column "Special requirements".*

These requirements are additional to the general requirements of this Chapter.

2 Materials of construction

2.1 General

2.1.1 *Materials that may be exposed to cargo during normal operations shall be resistant to the corrosive action of the gases. In addition, the following materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment normally in direct contact with the cargo liquid or vapour shall not be used for certain products as specified in Ch 9, Sec 19, Tab 1, column "Special requirements":*

a) Mercury, copper and copper-bearing alloys, and zinc

b) Copper, silver, mercury, magnesium and other acetylide-forming metals

c) Aluminium and aluminium-bearing alloys

d) Copper, copper alloys, zinc and galvanized steel

e) Aluminium, copper and alloys of either, and

f) Copper and copper-bearing alloys with greater than 1% copper.

Materials "exposed to cargo" are those constituting systems, cargo appliances or arrangements which are in contact with (liquid or vapour) cargo in normal operating conditions.

3 Independent tanks

3.1 General

3.1.1 *Products shall be carried in independent tanks only.*

3.1.2 *Products shall be carried in type C independent tanks, and the requirements of Ch 9, Sec 7, [1.1.2] shall apply. The design pressure of the cargo tank shall take into account any padding pressure or vapour discharge unloading pressure.*

4 Refrigeration systems

4.1 General

4.1.1 *Only the indirect system described in Ch 9, Sec 7, [3.1.3], item b) shall be used.*

4.1.2 *For a ship engaged in the carriage of products that readily form dangerous peroxides, recondensed cargo shall not be allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:*

a) Using the indirect system described in Ch 9, Sec 7, [3.1.3], item b), with the condenser inside the cargo tank, or

b) Using the direct system or combined system described in Ch 9, Sec 7, [3.1.3], item a) and in Ch 9, Sec 7, [3.1.3], item c) respectively, or the indirect system described in Ch 9, Sec 7, [3.1.3], item b) with the condenser outside the cargo tank, and designing the condensate system to avoid any places in which liquid could collect and be retained. Where this is impossible, inhibited liquid shall be added upstream of such a place.

4.1.3 *If the ship is to consecutively carry products as specified in [4.1.2] with a ballast passage between, all uninhibited liquid shall be removed prior to the ballast voyage. If a second cargo is to be carried between such consecutive cargoes, the reliquefaction system shall be thoroughly drained and purged before loading the second cargo. Purging shall be carried out using either inert gas or vapour from the second cargo, if compatible. Practical steps shall be taken to ensure that polymers or peroxides do not accumulate in the cargo system.*

5 Cargoes requiring type 1G ship

5.1 General

5.1.1 *All butt-welded joints in cargo piping exceeding 75 mm in diameter shall be subject to 100% radiography.*

5.1.2 *Gas sampling lines shall not be led into or through non-hazardous areas. Alarms referred to in Ch 9, Sec 13, [6.1.2] shall be activated when the vapour concentration reaches the threshold limiting value.*

5.1.3 *The alternative of using portable gas detection equipment in accordance with Ch 9, Sec 13, [6.1.5] shall not be permitted.*

5.1.4 *Cargo control rooms shall be located in a non-hazardous area and, additionally, all instrumentation shall be of the indirect type.*

5.1.5 *Personnel shall be protected against the effects of a major cargo release by the provision of a space within the accommodation area that is designed and equipped to the satisfaction of* the Society.

5.1.6 *Notwithstanding the requirements in Ch 9, Sec 3, [1.2.5], access to forecastle spaces shall not be permitted through a door facing the cargo area, unless airlock in accordance with Ch 9, Sec 3, [1.6] is provided.*

5.1.7 *Notwithstanding the requirements in Ch 9, Sec 3, [1.2.13], access to control rooms and machinery spaces of turret systems shall not be permitted through doors facing the cargo area.*

6 Exclusion of air from vapour spaces

6.1 General

6.1.1 *Air shall be removed from cargo tanks and associated piping before loading and, then, subsequently excluded by:*

a) Introducing inert gas to maintain a positive pressure. Storage or production capacity of the inert gas shall be sufficient to meet normal operating requirements and relief valve leakage. The oxygen content of inert gas shall, at no time, be greater than 0.2% by volume, or

b) Control of cargo temperatures such that a positive pressure is maintained at all times.

7 Moisture control

7.1 General

7.1.1 *For gases that are non-flammable and may become corrosive or react dangerously with water, moisture control shall be provided to ensure that cargo tanks are dry before loading and that, during discharge, dry air or cargo vapour is introduced to prevent negative pressures. For the purposes of this paragraph, dry air is air that has a dew point of – 45°C or below at atmospheric pressure.*

8 Inhibition

8.1 General

8.1.1 *Care shall be taken to ensure that the cargo is sufficiently inhibited to prevent self-reaction (e.g. polymerization or dimerization) at all times during the voyage. Ships shall be provided with a certificate from the manufacturer stating:*

a) Name and amount of inhibitor added

- As an alternative to the addition of inhibited liquid, it may be accepted that, at the end of each refrigeration period, the liquid is completely removed from the refrigeration system by means of vapour from compressors or by means of inert gas. In such case, the following wording is to be entered on the Certificate of Fitness:

  "At the end of each refrigeration period, the liquid is to be completely removed from the refrigeration system by means of vapour from compressors or by means of inert gas."
- On the cargo compressor delivery side, a temperature switch is to be fitted, set at a suitable temperature, depending on the characteristics of the product carried (e.g. 60°C for butadiene), giving a visual and audible alarm on the navigation bridge and in the cargo control station, if any, which causes the compressor to stop when such temperature is exceeded.

b) Date inhibitor was added and the normally expected duration of its effectiveness

c) Any temperature limitations affecting the inhibitor, and

d) The action to be taken should the length of the voyage exceed the effective lifetime of the inhibitors.

9 Flame screens on vent outlets

9.1 General

9.1.1 *When carrying a cargo referenced to this section, cargo tank vent outlets shall be provided with readily renewable and effective flame screens or safety heads of an approved type. Due attention shall be paid in the design of flame screens and vent heads, to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Flame screens shall be removed and replaced by protection screens, in accordance with Ch 9, Sec 8, [2.1.18], when carrying cargoes not referenced to this section.*

10 Maximum allowable quantity of cargo per tank

10.1 General

10.1.1 *When carrying a cargo referenced to this section, the quantity of the cargo shall not exceed 3,000 m^3 in any one tank.*

11 Cargo pumps and discharge arrangements

11.1 General

11.1.1 *The vapour space of cargo tanks equipped with submerged electric motor pumps shall be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.*

11.1.2 *The cargo shall be discharged only by deepwell pumps or by hydraulically operated submerged pumps. These pumps shall be of a type designed to avoid liquid pressure against the shaft gland.*

11.1.3 *Inert gas displacement may be used for discharging cargo from type C independent tanks, provided the cargo system is designed for the expected pressure.*

12 Ammonia

12.1 General

12.1.1 *Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon-manganese steel or nickel steel. To minimize the risk of this occurring, measures detailed in [12.1.2] to [12.1.8] shall be taken, as appropriate.*

12.1.2 *Where carbon-manganese steel is used, cargo tanks, process pressure vessels and cargo piping shall be made of fine-grained steel with a specified minimum yield strength not exceeding 355 N/mm^2, and with an actual yield strength not exceeding 440 N/mm^2. One of the following constructional or operational measures shall also be taken:*

a) Lower strength material with a specified minimum tensile strength not exceeding 410 N/mm^2 shall be used, or

b) Cargo tanks, etc., shall be post-weld stress relief heat treated, or

c) Carriage temperature shall be maintained, preferably at a temperature close to the product's boiling point of – 33°C, but in no case at a temperature above – 20°C, or

d) The ammonia shall contain not less than 0.1% w/w water, and the master shall be provided with documentation confirming this.

12.1.3 *If carbon-manganese steels with higher yield properties are used other than those specified in [12.1.2], the completed cargo tanks, piping, etc., shall be given a post-weld stress relief heat treatment.*

12.1.4 *Process pressure vessels and piping of the condensate part of the refrigeration system shall be given a post-weld stress relief heat treatment when made of materials mentioned in [12.1.1].*

12.1.5 *The tensile and yield properties of the welding consumables shall exceed those of the tank or piping material by the smallest practical amount.*

12.1.6 *Nickel steel containing more than 5% nickel and carbon-manganese steel, not complying with the requirements of [12.1.2] and [12.1.3], are particularly susceptible to ammonia stress corrosion cracking and shall not be used in containment and piping systems for the carriage of this product.*

12.1.7 *Nickel steel containing not more than 5% nickel may be used, provided the carriage temperature complies with the requirements specified in [12.1.2], item c).*

12.1.8 *To minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2,5 ppm w/w. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature T in Tab 1:*

Table 1 : Oxygen content

T (°C)	O_2 (% v/v)
– 30 and below	0,90
– 20	0,50
– 10	0,28
0	0,16
10	0,10
20	0,05
30	0,03
Note 1: Oxygen percentages for intermediate temperatures may be obtained by direct interpolation	

13 Chlorine

13.1 Cargo containment system

13.1.1 *The capacity of each tank shall not exceed 600 m^3 and the total capacity of all cargo tanks shall not exceed 1200 m^3.*

13.1.2 *The tank design vapour pressure shall not be less than 1,35 MPa (see Ch 9, Sec 7, [1.1.2] and [3.1.2]).*

13.1.3 *Parts of tanks protruding above the upper deck shall be provided with protection against thermal radiation, taking into account total engulfment by fire.*

13.1.4 *Each tank shall be provided with two PRVs. A bursting disc of appropriate material shall be installed between the tank and the PRVs. The rupture pressure of the bursting disc shall be 0,1 MPa lower than the opening pressure of the pressure relief valve, which shall be set at the design vapour pressure of the tank but not less than 1,35 MPa gauge. The space between the bursting disc and the relief valve shall be connected through an excess flow valve to a pressure gauge and a gas detection system. Provisions shall be made to keep this space at or near the atmospheric pressure during normal operation.*

Chlorine discharge from pressure relief valves is to be led to an absorption device deemed suitable by the Society.

13.1.5 *Outlets from PRVs shall be arranged in such a way as to minimize the hazards on board the ship as well as to the environment. Leakage from the relief valves shall be led through the absorption plant to reduce the gas concentration as far as possible. The relief valve exhaust line shall be arranged at the forward end of the ship to discharge outboard at deck level with an arrangement to select either port or starboard side, with a mechanical interlock to ensure that one line is always open.*

13.1.6 The Society *and the port Administration may require that chlorine is carried in a refrigerated state at a specified maximum pressure.*

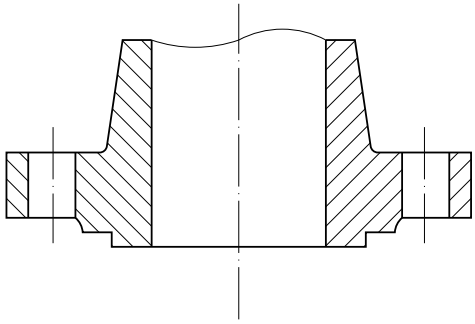
13.2 Cargo piping systems

13.2.1 *Cargo discharge shall be performed by means of compressed chlorine vapour from shore, dry air or another acceptable gas, or fully submerged pumps. Cargo discharge compressors on board ships shall not be used for this. The pressure in the vapour space of the tank during discharging shall not exceed 1,05 MPa gauge.*

13.2.2 *The design pressure of the cargo piping system shall be not less than 2,1 MPa gauge. The internal diameter of the cargo pipes shall not exceed 100 mm. Only pipe bends shall be accepted for compensation of pipeline thermal movement. The use of flanged joints shall be restricted to a minimum and, when used, the flanges shall be of the welding neck type with tongue and groove.*

13.2.3 A welding neck type flange deemed suitable is shown in Fig 1 as an example.

Figure 1 : Suitable neck type flange



13.2.4
Relief valves of the cargo piping system shall discharge to the absorption plant, and the flow restriction created by this unit shall be taken into account when designing the relief valve system (see Ch 9, Sec 8, [4.3] and Ch 9, Sec 8, [4.4]).

13.3 Materials

13.3.1 *The cargo tanks and cargo piping systems shall be made of steel suitable for the cargo and for a temperature of – 40°C, even if a higher transport temperature is intended to be used.*

13.3.2 *The tanks shall be thermally stress relieved. Mechanical stress relief shall not be accepted as an equivalent.*

13.4 Instrumentation: safety devices

13.4.1 *The ship shall be provided with a chlorine absorbing plant with a connection to the cargo piping system and the cargo tanks. The absorbing plant shall be capable of neutralizing at least 2% of the total cargo capacity at a reasonable absorption rate.*

13.4.2 *During the gas-freeing of cargo tanks, vapours shall not be discharged to the atmosphere.*

13.4.3 *A gas detecting system shall be provided that is capable of monitoring chlorine concentrations of at least 1 ppm by volume. Sample points shall be located:*

- *near the bottom of the hold spaces*
- *in the pipes from the safety relief valves*
- *at the outlet from the gas absorbing plant*
- *at the inlet to the ventilation systems for the accommodation, service and machinery spaces and control stations, and*
- *on deck - at the forward end, midships and the after end of the cargo area. This is only required to be used during cargo handling and gas-freeing operations.*

The gas detection system shall be provided with an audible and visual alarm with a set point of 5 ppm.

The gas detection system is to be permanently installed.

13.4.4 *Each cargo tank shall be fitted with a high-pressure alarm giving an audible alarm at a pressure equal to 1,05 MPa gauge.*

13.5 Personnel protection

13.5.1 *The enclosed space required by [5.1.5] shall meet the following requirements:*

- *the space shall be easily and quickly accessible from the weather decks and from accommodation spaces by means of air locks, and shall be capable of being rapidly closed gastight*
- *one of the decontamination showers required by Ch 9, Sec 14, [1.4.3] shall be located near the weather deck airlock to the space*
- *the space shall be designed to accommodate the entire crew of the ship and be provided with a source of uncontaminated air for a period of not less than 4 h, and*
- *one set of oxygen therapy equipment shall be carried in the space.*

In addition to the source of uncontaminated air, two complete and independent air breathing apparatuses, not employing oxygen supplies, each having a capacity of at least 1200 litres of non-compressed air and two sets of protective equipment, complete with gas-tight boots, gloves and eye protection, are to be provided. The above-mentioned equipment and clothing are to be kept in the space indicated above and are additional to those required in other parts of this Chapter.

13.6 Filling limits for cargo tanks

13.6.1 *The requirements of Ch 9, Sec 15, [1.1.3], item b) do not apply when it is intended to carry chlorine.*

13.6.2 When determining the filling limits of the cargo tanks for the transport of chlorine, the effect of the refrigeration plant is not to be considered.

13.6.3 *The chlorine content of the gas in the vapour space of the cargo tank after loading shall be greater than 80% by volume.*

14 Ethylene oxide

14.1 General

14.1.1 *For the carriage of ethylene oxide, the requirements of [18] shall apply, with the additions and modifications as given in this sub-article.*

14.1.2 *Deck tanks shall not be used for the carriage of ethylene oxide.*

14.1.3 *Stainless steels types 416 and 442, as well as cast iron, shall not be used in ethylene oxide cargo containment and piping systems.*

14.1.4 *Before loading, tanks shall be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been ethylene oxide, propylene oxide or mixtures of these products. Particular care shall be taken in the case of ammonia in tanks made of steel other than stainless steel.*

14.1.5 *Ethylene oxide shall be discharged only by deepwell pumps or inert gas displacement. The arrangement of pumps shall comply with [18.1.15].*

14.1.6 *Ethylene oxide shall be carried refrigerated only and maintained at temperatures of less than 30°C.*

14.1.7 *PRVs shall be set at a pressure of not less than 0,55 MPa gauge. The maximum set pressure shall be specially approved by* the Society.

14.1.8 *The protective padding of nitrogen gas, as required by [18.1.27], shall be such that the nitrogen concentration in the vapour space of the cargo tank will, at no time, be less than 45% by volume.*

14.1.9 *Before loading, and at all times when the cargo tank contains ethylene oxide liquid or vapour, the cargo tank shall be inerted with nitrogen.*

14.1.10 *The water-spray system required by [18.1.29] and that required by Ch 9, Sec 11, [1.3] shall operate automatically in a fire involving the cargo containment system.*

14.1.11 *A jettisoning arrangement shall be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.*

15 Separate piping systems

15.1 General

15.1.1 *Separate piping systems, as defined in Ch 9, Sec 1, [4.1.45], shall be provided.*

16 Methyl acetylene-propadiene mixtures

16.1 General

16.1.1 *Methyl acetylene-propadiene mixtures shall be suitably stabilized for transport. Additionally, upper limits of temperatures and pressure during the refrigeration shall be specified for the mixtures.*

16.1.2 *Examples of acceptable stabilized compositions are:*

- *Composition 1:*
  - *maximum methyl acetylene to propadiene molar ratio of 3 to 1*
  - *maximum combined concentration of methyl acetylene and propadiene of 65 mol%*
  - *minimum combined concentration of propane, butane, and isobutane of 24 mol%, of which at least one third (on a molar basis) shall be butanes and one third propane,*
  - *maximum combined concentration of propylene and butadiene of 10 mol%.*
- *Composition 2:*
  - *maximum methylacetylene and propadiene combined concentration of 30 mol%*
  - *maximum methyl acetylene concentration of 20 mol%*
  - *maximum propadiene concentration of 20 mol%*
  - *maximum propylene concentration of 45 mol%*
  - *maximum butadiene and butylenes combined concentration of 2 mol%*
  - *minimum saturated C4 hydrocarbon concentration of 4 mol%, and*
  - *minimum propane concentration of 25 mol%.*

16.1.3 *Other compositions may be accepted, provided the stability of the mixture is demonstrated to the satisfaction of* the Society.

16.1.4 *If a ship has a direct vapour compression refrigeration system, this shall comply with the following requirements, subject to pressure and temperature limitations depending on the composition. For the example compositions given in [16.1.2], the following features shall be provided:*

a) Vapour compressor that does not raise the temperature and pressure of the vapour above 60°C and 1,75 MPa gauge during its operation, and that does not allow vapour to stagnate in the compressor while it continues to run

b) Discharge piping from each compressor stage or each cylinder in the same stage of a reciprocating compressor shall have:

1) two temperature-actuated shutdown switches set to operate at 60°C or less

2) a pressure-actuated shutdown switch set to operate at 1,75 MPa gauge or less, and

3) a safety relief valve set to relieve at 1,8 MPa gauge or less;

c) The relief valve required by [16.1.4], item b), 3). shall vent to a mast meeting the requirements of Ch 9, Sec 8, [2.1.10], Ch 9, Sec 8, [2.1.14] and Ch 9, Sec 8, [2.1.18] and shall not relieve into the compressor suction line, and

d) An alarm that sounds in the cargo control position and in the navigation bridge when a high-pressure switch, or a high-temperature switch, operates.

16.1.5 *The piping system, including the cargo refrigeration system, for tanks to be loaded with methyl acetylene-propadiene mixtures shall be either independent (as defined in Ch 9, Sec 1, [4.1.28]) or separate (as defined in Ch 9, Sec 1, [4.1.45]) from piping and refrigeration systems for other tanks. This segregation shall apply to all liquid and vapour vent lines and any other possible connections, such as common inert gas supply lines.*

17 Nitrogen

17.1 General

17.1.1 *Materials of construction and ancillary equipment such as insulation shall be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system. Due consideration shall be given to ventilation in areas where condensation might occur, to avoid the stratification of oxygen-enriched atmosphere.*

18 Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide content of not more than 30% by weight

18.1 General

18.1.1 *Products transported under the provisions of this sub-article shall be acetylene-free.*

18.1.2 *Unless cargo tanks are properly cleaned, these products shall not be carried in tanks that have contained as one of the three previous cargoes any product known to catalyse polymerization, such as:*

- *anhydrous ammonia and ammonia solutions*
- *amines and amine solutions, and*
- *oxidizing substances (e.g. chlorine).*

18.1.3 *Before loading, tanks shall be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been propylene oxide or ethylene oxide-propylene oxide mixtures. Particular care shall be taken in the case of ammonia in tanks made of steel other than stainless steel.*

18.1.4 *In all cases, the effectiveness of cleaning procedures for tanks and associated pipework shall be checked, by suitable testing or inspection, to ascertain that no traces of acidic or alkaline materials remain that might create a hazardous situation in the presence of these products.*

18.1.5 *Tanks shall be entered and inspected prior to each initial loading of these products to ensure freedom from contamination, heavy rust deposits and any visible structural defects. When cargo tanks are in continuous service for these products, such inspections shall be performed at intervals of not more than two years.*

18.1.6 *Tanks for the carriage of these products shall be of steel or stainless steel construction.*

18.1.7 *Tanks that have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.*

18.1.8 *All valves, flanges, fittings and accessory equipment shall be of a type suitable for use with these products and shall be constructed of steel or stainless steel in accordance with recognized standards. Disc or disc faces, seats and other wearing parts of valves shall be made of stainless steel containing not less than 11% chromium.*

18.1.9 *Gaskets shall be constructed of materials which do not react with, dissolve in, or lower the auto-ignition temperature of, these products and which are fire-resistant and possess adequate mechanical behaviour. The surface presented to the cargo shall be polytetrafluoroethylene (PTFE) or materials giving a similar degree of safety by their inertness. Spirally-wound stainless steel with a filler of PTFE or similar fluorinated polymer may be accepted, if approved by* the Society.

18.1.10 *Insulation and packing, if used, shall be of a material which does not react with, dissolve in, or lower the auto-ignition temperature of, these products.*

18.1.11 *The following materials are generally found unsatisfactory for use in gaskets, packing and similar uses in containment systems for these products and would require testing before being approved:*

- *neoprene or natural rubber, if it comes into contact with the products*
- *asbestos or binders used with asbestos, and*
- *materials containing oxides of magnesium, such as mineral wools.*

18.1.12 *Filling and discharge piping shall extend to within 100 mm of the bottom of the tank or any sump.*

18.1.13 *The products shall be loaded and discharged in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product shall be independent of all other containment systems.*

18.1.14 *During discharging operations, the pressure in the cargo tank shall be maintained above 0,007 MPa gauge.*

18.1.15 *The cargo shall be discharged only by deepwell pumps, hydraulically operated submerged pumps or inert gas displacement. Each cargo pump shall be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.*

18.1.16 *Tanks carrying these products shall be vented independently of tanks carrying other products. Facilities shall be provided for sampling the tank contents without opening the tank to atmosphere.*

18.1.17 *Cargo hoses used for transfer of these products shall be marked "FOR ALKYLENE OXIDE TRANSFER ONLY".*

18.1.18 *Hold spaces shall be monitored for these products. Hold spaces surrounding type A and type B independent tanks shall also be inerted and monitored for oxygen. The oxygen content of these spaces shall be maintained below 2% by volume. Portable sampling equipment is satisfactory.*

18.1.19 *Prior to disconnecting shore lines, the pressure in liquid and vapour lines shall be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines shall not be discharged to atmosphere.*

18.1.20 *Tanks shall be designed for the maximum pressure expected to be encountered during loading, carriage or unloading of cargo.*

18.1.21 *Tanks for the carriage of propylene oxide with a design vapour pressure of less than 0.06 MPa, and tanks for the carriage of ethylene oxide-propylene oxide mixtures with a design vapour pressure of less than 0.12 MPa, shall have a cooling system to maintain the cargo below the reference temperature. The reference temperatures are referred to in Ch 9, Sec 15, [1.1.3].*

18.1.22 *Pressure relief valve settings shall not be less than 0,02 MPa gauge; and for type C independent tanks not greater than 0,7 MPa gauge for the carriage of propylene oxide and not greater than 0,53 MPa gauge for the carriage of ethylene oxide-propylene oxide mixtures.*

18.1.23 *The piping system for tanks to be loaded with these products shall be completely separate from piping systems for all other tanks, including empty tanks, and from all cargo compressors. If the piping system for the tanks to be loaded with these products is not independent, as defined in Ch 9, Sec 1, [4.1.28], the required piping separation shall be accomplished by the removal of spool pieces, valves, or other pipe sections and the installation of blank flanges at these locations. The required separation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connections such as common inert gas supply lines.*

18.1.24 *The products shall be transported only in accordance with cargo handling plans approved by* the Society. *Each intended loading arrangement shall be shown on a separate cargo handling plan. Cargo handling plans shall show the entire cargo piping system and the locations for installation of the blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan shall be kept on board the ship. The International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk shall be endorsed to include references to the approved cargo handling plans.*

18.1.25 *Before each initial loading of these products, and before every subsequent return to such service, certification verifying that the required piping separation has been achieved shall be obtained from a responsible person acceptable to the port Administration and carried on board the ship. Each connection between a blank flange and pipeline flange shall be fitted with a wire and seal by the responsible person to ensure that inadvertent removal of the blank flange is impossible.*

18.1.26 *The maximum allowable loading limits for each tank shall be indicated for each loading temperature that may be applied, in accordance with Ch 9, Sec 15, [1.5].*

18.1.27 *The cargo shall be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system shall be installed to prevent the tank pressure falling below 0,007 MPa gauge in the event of product temperature fall due to ambient conditions or malfunctioning of refrigeration system. Sufficient nitrogen shall be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99.9% by volume) shall be used for padding. A battery of nitrogen bottles, connected to the cargo tanks through a pressure reduction valve, satisfies the intention of the expression "automatic" in this context.*

18.1.28 *The cargo tank vapour space shall be tested prior to and after loading to ensure that the oxygen content is 2% by volume or less.*

18.1.29 *A water-spray system of sufficient capacity shall be provided to blanket effectively the area surrounding the loading manifold, the exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles shall be such as to give a uniform distribution rate of 10 litre/m^2/min. The arrangement shall ensure that any spilled cargo is washed away.*

18.1.30 *The water-spray system shall be capable of local and remote manual operation in case of a fire involving the cargo containment system. Remote manual operation shall be arranged such that the remote starting of pumps supplying the water-spray system and remote operation of any normally closed valves in the system can be carried out from a suitable location outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.*

18.1.31 *When ambient temperatures permit, a pressurized water hose ready for immediate use shall be available during loading and unloading operations, in addition to the above water-spray requirements.*

19 Vinyl chloride

19.1 General

19.1.1 *In cases where polymerization of vinyl chloride is prevented by addition of an inhibitor, Article [8] is applicable. In cases where no inhibitor has been added, or the inhibitor concentration is insufficient, any inert gas used for the purposes of Article [6] shall contain no more oxygen than 0,1% by volume. Before loading is started, inert gas samples from the tanks and piping shall be analysed. When vinyl chloride is carried, a positive pressure shall always be maintained in the tanks and during ballast voyages between successive carriages.*

20 Mixed C4 cargoes

20.1 General

20.1.1 *Cargoes that may be carried individually under the requirements of this Code, notably butane, butylenes and butadiene, may be carried as mixtures subject to the provisions of this section. These cargoes may variously be referred to as "Crude C4", "Crude butadiene", "Crude steam-cracked C4", "Spent steam-cracked C4", "C4 stream", "C4 raffinate", or may be shipped under a different description. In all cases, the material safety data sheets (MSDS) shall be consulted as the butadiene content of the mixture is of prime concern as it is potentially toxic and reactive. While it is recognized that butadiene has a relatively low vapour pressure, if such mixtures contain butadiene they shall be regarded as toxic and the appropriate precautions applied.*

20.1.2 *If the mixed C4 cargo shipped under the terms of this section contains more than 50% (mole) of butadiene, the inhibitor precautions in [8] shall apply.*

20.1.3 *Unless specific data on liquid expansion coefficients is given for the specific mixture loaded, the filling limit restrictions of Ch 9, Sec 15 shall be calculated as if the cargo contained 100% concentration of the component with the highest expansion ratio.*

21 Carbon dioxide: high purity

21.1 General

21.1.1 Interpretation and application for ships carrying liquefied carbon dioxide in bulk are given in Tab 2.

21.1.2 *Uncontrolled pressure loss from the cargo can cause "sublimation" and the cargo will change from the liquid to the solid state. The precise "triple point" temperature of a particular carbon dioxide cargo shall be supplied before loading the cargo, and will depend on the purity of that cargo, and this shall be taken into account when cargo instrumentation is adjusted. The set pressure for the alarms and automatic actions described in this section shall be set to at least 0,05 MPa above the triple point for the specific cargo being carried. The "triple point" for pure carbon dioxide occurs at 0,5 MPa gauge and – 54.4°C.*

21.1.3 *There is a potential for the cargo to solidify in the event that a cargo tank relief valve, fitted in accordance with Ch 9, Sec 8, [2], fails in the open position. To avoid this, a means of isolating the cargo tank safety valves shall be provided and the requirements of Ch 9, Sec 8, [2.1.11], item b) do not apply when carrying this carbon dioxide. Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of Ch 9, Sec 8, [2.1.18] do not apply.*

21.1.4 *Discharge piping from safety relief valves are not required to comply with Ch 9, Sec 8, [2.1.12], but shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of Ch 9, Sec 8, [2.1.18] do not apply.*

21.1.5 *Cargo tanks shall be continuously monitored for low pressure when a carbon dioxide cargo is carried. An audible and visual alarm shall be given at the cargo control position and on the bridge. If the cargo tank pressure continues to fall to within 0.05 MPa of the "triple point" for the particular cargo, the monitoring system shall automatically close all cargo manifold liquid and vapour valves and stop all cargo compressors and cargo pumps. The emergency shutdown system required by Ch 9, Sec 18, [3] may be used for this purpose.*

21.1.6 *All materials used in cargo tanks and cargo piping system shall be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the carbon dioxide cargo at the set pressure of the automatic safety system described in [21.1.2].*

21.1.7 *Cargo hold spaces, cargo compressor rooms and other enclosed spaces where carbon dioxide could accumulate shall be fitted with continuous monitoring for carbon dioxide build-up. This fixed gas detection system replaces the requirements of Ch 9, Sec 13, [6], and hold spaces shall be monitored permanently even if the ship has type C cargo containment.*

22 Carbon dioxide: reclaimed quality

22.1 General

22.1.1 Specific relaxations may apply for ships carrying liquefied carbon dioxide (reclaimed quality) in bulk, as detailed in Tab 2.

22.1.2 *The requirements of [21] also apply to this cargo. In addition, the materials of construction used in the cargo system shall also take account of the possibility of corrosion, in case the reclaimed quality carbon dioxide cargo contains impurities such as water, sulphur dioxide, etc., which can cause acidic corrosion or other problems.*

Table 2 : Possible relaxations for ships carrying liquefied carbon dioxide in bulk

Reference	Relaxations
Ch 9, Sec 3, [1.1.3]	A single A-0 bulkhead is sufficient.
Ch 9, Sec 5, [7.4]	Electrical bonding of piping and tanks is not required.
Ch 9, Sec 10	Certified safe electrical equipment is not required.
Ch 9, Sec 11	This entire Section is not applicable.
Ch 9, Sec 12, [1.2.12]	Safe placing and safe construction of electrical fan motors is not required.
Ch 9, Sec 12, [1.2.15]	Protection screens in vent ducts are not required.
Ch 9, Sec 13, [6]	Only Ch 9, Sec 13, [6.1.13] and Ch 9, Sec 13, [6.1.14] are applicable.
Ch 9, Sec 18, [3.3]	Fusible elements in the emergency shutdown system are not required.

Section 18 Operating Requirements

1 General

1.1

1.1.1 This Section contains only the provisions of IGC Code article 18.10, as the other provisions of Chapter 18 of the IGC Code are operating requirements which are not within the scope of classification.

2 Cargo operating manual

2.1 General

2.1.1 *The ship shall be provided with copies of suitably detailed cargo system operation manuals approved by the Society such that trained personnel can safely operate the ship with due regard to the hazards and properties of the cargoes that are permitted to be carried.*

Note 1: As required in Ch 9, Sec 1, [5], the cargo operating manual is to be submitted for approval in order to check that all documents listed in [2.1.2] are included in the cargo operating manual.

2.1.2 *The content of the manuals shall include, but not be limited to:*

- *overall operation of the ship from dry-dock to dry-dock, including procedures for cargo tank cooldown and warm-up, transfer (including ship-to-ship transfer), cargo sampling, gas-freeing, ballasting, tank cleaning and changing cargoes;*
- *cargo temperature and pressure control systems;*
- *cargo system limitations, including minimum temperatures (cargo system and inner hull), maximum pressures, transfer rates, filling limits and sloshing limitations;*
- *nitrogen and inert gas systems;*
- *firefighting procedures: operation and maintenance of firefighting systems and use of extinguishing agents;*
- *special equipment needed for the safe handling of the particular cargo;*
- *fixed and portable gas detection;*
- *control, alarm and safety systems;*
- *emergency shutdown systems;*
- *procedures to change cargo tank pressure relief valve set pressures in accordance with Ch 9, Sec 8, [2.1.10] and Ch 9, Sec 4, [3.3.2]; and*
- *emergency procedures, including cargo tank relief valve isolation, single tank gas-freeing and entry and emergency ship-to-ship transfer operations.*

3 Cargo emergency shutdown (ESD) system

3.1 General

3.1.1 *A cargo emergency shutdown system shall be fitted to stop cargo flow in the event of an emergency, either internally within the ship, or during cargo transfer to ship or shore. The design of the ESD system shall avoid the potential generation of surge pressures within cargo transfer pipe work (see [3.2.1]).*

3.1.2 *Auxiliary systems for conditioning the cargo that use toxic or flammable liquids or vapours shall be treated as cargo systems for the purposes of ESD. Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.*

3.1.3 *The ESD system shall be activated by the manual and automatic initiations listed in Tab 1. Any additional initiations shall only be included in the ESD system if it can be shown that their inclusion does not reduce the integrity and reliability of the system overall.*

3.1.4 *Ship's ESD systems shall incorporate a ship-shore link in accordance with recognized standards.*

Note 1: ISO 28460:2010 Petroleum and natural gas industries - Installation and equipment for liquefied natural gas - Ship-to-shore interface and port operations.

3.1.5 *A functional flow chart of the ESD system and related systems shall be provided in the cargo control station and on the navigation bridge.*

Table 1 : ESD functional arrangements

Initiation	Shutdown action							
	Pumps		Compressor systems				Valves	Link
	Cargo pumps and cargo booster pumps	Spray / stripping pumps	Vapour return compressors	Fuel gas compressors	Reliquefaction plant **(3)**, including condensate return pumps, if fitted	Gas combustion unit	ESD valves	Signal to ship / shore link **(4)**
Emergency push buttons (see [3.3.1])	F	F	F	see **(6)**	F	F	F	F
Fire detection on deck or in compressor house **(1)** (see [3.3.2])	F	F	F	F	F	F	F	F
High level in cargo tank **(12)**	F	F	F	see **(5)** see **(6)**	see **(5)** see **(7)**	see **(5)**	see **(10)**	F
Signal from ship / shore link (see [3.1.4])	F	F	F	see **(6)**	see **(7)**	NA	F	NA
Loss of motive power to ESD valves **(2)**	F	F	F	see **(6)**	see **(7)**	NA	F	F
Main electric power failure ("blackout")	see **(11)**	see **(11)**	see **(11)**	see **(11)**	see **(11)**	see **(11)**	F	F
Level alarm override **(13)**	see **(8)**	see **(8)** see **(9)**	F	see **(5)**	see **(5)**	see **(5)**	F	F

(1) Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck.

(2) Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators.

(3) Indirect refrigeration systems which form part of the reliquefaction plant do not need to be included in the ESD function if they employ an inert medium such as nitrogen in the refrigeration cycle.

(4) Signal need not indicate the event initiating ESD.

(5) These items of equipment can be omitted from these specific automatic shutdown initiators, provided the equipment inlets are protected against cargo liquid ingress.

(6) If the fuel gas compressor is used to return cargo vapour to shore, it shall be included in the ESD system when operating in this mode.

(7) If the reliquefaction plant compressors are used for vapour return/shore line clearing, they shall be included in the ESD system when operating in that mode.

(8) The override system permitted by Ch 9, Sec 13, [3.1.8] may be used at sea to prevent false alarms or shutdowns. When level alarms are overridden, operation of cargo pumps and the opening of manifold ESD valves shall be inhibited except when high-level alarm testing is carried out in accordance with Ch 9, Sec 13, [3.1.6] (see [3.3.4]).

(9) Cargo spray or stripping pumps used to supply forcing vaporizer may be excluded from the ESD system only when operating in that mode.

(10) The sensors referred to in Ch 9, Sec 13, [3.1.3] may be used to close automatically the tank filling valve for the individual tank where the sensors are installed, as an alternative to closing the ESD valve as referred to in [3.2.3]. If this option is adopted, activation of the full ESD system shall be initiated when the high-level sensors in all the tanks to be loaded have been activated.

(11) These items of equipment shall be designed not to restart upon recovery of main electric power and without confirmation of safe conditions.

(12) see Ch 9, Sec 13, [3.1.3] and Ch 9, Sec 13, [3.1.4]

(13) see Ch 9, Sec 13, [3.1.8]

Note 1: F = Functional requirement; NA = Not applicable.

Note 2: In applying the second sentence of (8), a hardware system such as an electric or mechanical interlocking device is to be provided to prevent inadvertent operation of cargo pumps and inadvertent opening of manifold ESD valves.

3.2 ESD valve requirements

3.2.1 General

a) The term ESD valve means any valve operated by the ESD system.

b) ESD valves shall be remotely operated, be of the fail-closed type (closed on loss of actuating power), be capable of local manual closure and have positive indication of the actual valve position. As an alternative to the local manual closing of the ESD valve, a manually operated shut-off valve in series with the ESD valve shall be permitted. The manual valve shall be located adjacent to the ESD valve. Provisions shall be made to handle trapped liquid should the ESD valve close while the manual valve is also closed.

The cargo stations in way of which the fusible elements are to be fitted are to be intended as the loading and unloading manifolds.

c) ESD valves in liquid piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

d) The closing time of the valve, in second, referred to in Ch 9, Sec 13, [3.1.1] to Ch 9, Sec 13, [3.1.4] (i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than 3600 U / LR, where

U : Ullage volume at operating signal level, in m^3

LR : Maximum loading rate agreed between ship and shore facility, in m^3/h.

The loading rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm, the ship and the shore piping systems, where relevant.

3.2.2 ESD valves of fail-closed type

When ESD valve is actuated by hydraulic or pneumatic system, the following is to be complied with:

a) Audible and visible alarm is to be given in the event of loss of pressure that causes activation of fail-closed action. The alarm is to be provided in a normally manned control station (e.g. Cargo Control Room and/or the navigation bridge, etc.).

b) The following conditions are also to be complied with to ensure the fail-closed action:

- Failure of hydraulic or pneumatic system is not to lead to loss of fail-closed functionality (i.e. activated by spring or weight); or
- Hydraulic or pneumatic system for fail-closed action is to be arranged with stored power and separated from normal valve operation.

3.2.3 Ship-shore and ship-ship manifold connections

One ESD valve shall be provided at each manifold connection. Cargo manifold connections not being used for transfer operations shall be blanked with blank flanges rated for the design pressure of the pipeline system.

3.2.4 Cargo system valves

If cargo system valves as defined in Ch 9, Sec 5, [5] are also ESD valves within the meaning of [3], then the requirements of [3] shall apply.

3.3 ESD system controls

3.3.1 *As a minimum, the ESD system shall be capable of manual operation by a single control on the bridge and either in the control position required by Ch 9, Sec 13, [1.1.4] or the cargo control room, if installed, and no less than two locations in the cargo area.*

3.3.2 *The ESD system shall be automatically activated on detection of a fire on the weather decks of the cargo area and/or cargo machinery spaces. As a minimum, the method of detection used on the weather decks shall cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly. Detection may be by means of fusible elements designed to melt at temperatures between 98°C and 104°C, or by area fire detection methods.*

3.3.3 *Cargo machinery that is running shall be stopped by activation of the ESD system in accordance with the cause and effect matrix in Tab 1.*

3.3.4 *The ESD control system shall be configured so as to enable the high-level testing required in Ch 9, Sec 13, [3.1.6] to be carried out in a safe and controlled manner. For the purpose of the testing, cargo pumps may be operated while the overflow control system is overridden. Procedures for level alarm testing and re-setting of the ESD system after completion of the high-level alarm testing shall be included in the operation manual.*

3.4 Additional shutdowns

3.4.1 *The requirements of Ch 9, Sec 8, [3.1.1], item a), to protect the cargo tank from external differential pressure may be fulfilled by using an independent low pressure trip to activate the ESD system, or, as minimum, to stop any cargo pumps or compressors.*

3.4.2 *An input to the ESD system from the overflow control system required by Ch 9, Sec 13, [3] may be provided to stop any cargo pumps or compressors' running at the time a high level is detected, as this alarm may be due to inadvertent internal transfer of cargo from tank to tank.*

3.5 Pre-operations testing

3.5.1 *Cargo emergency shutdown and alarm systems involved in cargo transfer shall be checked and tested before cargo handling operations begin.*

3.6 Testing

3.6.1 Ship operators should periodically verify that the ESD valves onboard their vessels function correctly. The test results are to be recorded.

Also, as part of the check on the integrity of the cargo containment system, the ESD valves are to be pressure tested and internally inspected. Pressure testing at the same pressure as working pressure is recommended to be conducted every 5 years.

Note 1: The instruction manual produced by the ESD valve manufacturer providing information on installing, servicing and reassembly of the valves should be retained onboard the ship.

Section 19 Summary of Minimum Requirements

1 General

1.1 Explanatory notes to the summary of minimum requirements

1.1.1 Product name

The product name shall be used in the shipping document for any cargo offered for bulk shipments. Any additional name may be included in brackets after the product name. In some cases, the product names are not identical with the names given in previous issues of the Code.

1.1.2 Ship type

- *Ship type 1G (see Ch 9, Sec 2, [1.1.2], item a))*
- *Ship type 2G (see Ch 9, Sec 2, [1.1.2], item b))*
- *Ship type 2PG (see Ch 9, Sec 2, [1.1.2], item c))*
- *Ship type 3G (see Ch 9, Sec 2, [1.1.2], item d)).*

1.1.3 Independent tank type C required

Type C independent tank (see Ch 9, Sec 4, [10]).

1.1.4 Tank environmental control

Inert : Inerting (see Ch 9, Sec 9, [1.4])

Dry : Drying (see Ch 9, Sec 17, [7])

– : No special requirements under the Code.

1.1.5 Vapour detection

F : Flammable vapour detection

T : Toxic vapour detection

F + T : Flammable and toxic vapour detection

A : Asphixiant.

1.1.6 Gauging

I : Indirect or closed (see Ch 9, Sec 13, [2.1.4], item a) and Ch 9, Sec 13, [2.1.4], item b))

R : Indirect, closed or restricted (from Ch 9, Sec 13, [2.1.4], item a) to Ch 9, Sec 13, [2.1.4], item d))

C : Indirect or closed (from Ch 9, Sec 13, [2.1.4], item a) to Ch 9, Sec 13, [2.1.4], item c))).

1.1.7 Special requirements

When specific reference is made to Ch 9, Sec 14 and/or to Ch 9, Sec 17, these requirements shall be additional to the requirements in any other column.

1.1.8 Refrigerant gases

Non-toxic and non-flammable gases.

1.1.9

Unless otherwise specified, gas mixtures containing less than 5% total acetylenes may be transported with no further requirements than those provided for the major components.

2 Additional information on products

2.1

2.1.1 Tab 2 lists some additional information for those products which are listed in Tab 1.

The list shown in Tab 2 gives properties for pure products. The specific gravity to be taken into account for the design of a ship might be altered considering the actual properties of the commercial product.

Information on temperature classes and explosion groups for electrical equipment in connection with the products to be carried is indicated in Ch 9, Sec 10, Tab 1.

Table 1 : Summary of minimum requirements

Product name	Ship type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging	Special requirements
Acetaldehyde	2G/2PG	–	Inert	F + T	C	Ch 9, Sec 14, [1.4.3], Ch 9, Sec 14, [1.3.3], item a), Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [6.1.1], item a)
Ammonia, anhydrous	2G/2PG	–	–	T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item a), Ch 9, Sec 17, [12]
Butadiene (all isomers)	2G/2PG	–	–	F + T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item b), Ch 9, Sec 17, [4.1.2], Ch 9, Sec 17, [4.1.3], Ch 9, Sec 17, [6], Ch 9, Sec 17, [8]
Butane (all isomers)	2G/2PG	–	–	F	R	
Butane-propane mixture	2G/2PG	–	–	F	R	
Butylenes (all isomers)	2G/2PG	–	–	F	R	
Carbon Dioxide (high purity)	3G	–	–	A	R	Ch 9, Sec 17, [21]
Carbon Dioxide (Reclaimed quality)	3G	–	–	A	R	Ch 9, Sec 17, [22]
Chlorine	1G	Yes	Dry	T	I	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [3.1.2], Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [5], Ch 9, Sec 17, [7], Ch 9, Sec 17, [9], Ch 9, Sec 17, [13]
Diethyl ether **(1)**	2G/2PG	–	Inert	F + T	C	Ch 9, Sec 14, [1.4.2], Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [2.1.1], item f), Ch 9, Sec 17, [3.1.1], Ch 9, Sec 17, [6.1.1], item a), Ch 9, Sec 17, [9], Ch 9, Sec 17, [10], Ch 9, Sec 17, [11.1.2], Ch 9, Sec 17, [11.1.3]
Dimethylamine	2G/2PG	–	–	F + T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item a)
Dimethyl Ether	2G/2PG	–	–	F + T	C	
Ethane		–	–	F	R	
Ethyl Chloride	2G/2PG	–	–	F + T	C	
Ethylene	2G	–	–	F	R	
Ethylene oxide	1G	Yes	Inert	F + T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item b), Ch 9, Sec 17, [3.1.2], Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [5], Ch 9, Sec 17, [6.1.1], item a), Ch 9, Sec 17, [14]
Ethylene oxide- propylene oxide mixtures with ethylene oxide content of not more than 30% by weight **(1)**	2G/2PG	–	Inert	F + T	C	Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [3.1.1], Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [6.1.1], item a), Ch 9, Sec 17, [9], Ch 9, Sec 17, [10], Ch 9, Sec 17, [18]
Hydrogen	2G	–	–	F	C	Ch 9, Sec 21
Isoprene **(1)** (all isomers)	2G/2PG	–	–	F	R	Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [8], Ch 9, Sec 17, [9], Ch 9, Sec 17, [11.1.1]
Isoprene (part refined) **(1)**	2G/2PG	–	–	F	R	Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [8], Ch 9, Sec 17, [9], Ch 9, Sec 17, [11.1.1]
Isopropylamine **(1)**	2G/2PG	–	–	F + T	C	Ch 9, Sec 14, [1.4.2], Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [2.1.1], item d), Ch 9, Sec 17, [9], Ch 9, Sec 17, [10], Ch 9, Sec 17, [11.1.1], Ch 9, Sec 17, [15]
(1) This cargo is also covered by the IBC Code.						

Product name	Ship type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging	Special requirements
Methane (LNG)	2G	–	–	F	C	
Methyl acetylene-propadiene mixtures	2G/2PG	–	–	F	R	Ch 9, Sec 17, [16]
Methyl bromide	1G	Yes	–	F + T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item c), Ch 9, Sec 17, [3.1.2], Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [5]
Methyl chloride	2G/2PG	–	–	F + T	C	Ch 9, Sec 17, [2.1.1], item c)
Mixed C4 Cargoes	2G/2PG	–	–	F + T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item b), Ch 9, Sec 17, [4.1.2], Ch 9, Sec 17, [4.1.3], Ch 9, Sec 17, [6], Ch 9, Sec 17, [20]
Monoethylamine **(1)**	2G/2PG	–	–	F + T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [2.1.1], item a), Ch 9, Sec 17, [3.1.1], Ch 9, Sec 17, [9], Ch 9, Sec 17, [10], Ch 9, Sec 17, [11.1.1], Ch 9, Sec 17, [15]
Nitrogen	3G	–	–	A	C	Ch 9, Sec 17, [17]
Pentane (all isomers) **(1)**	2G/2PG	–	–	F	R	Ch 9, Sec 17, [9], Ch 9, Sec 17, [11]
Pentene (all isomers) **(1)**	2G/2PG	–	–	F	R	Ch 9, Sec 17, [9], Ch 9, Sec 17, [11]
Propane	2G/2PG	–	–	F	R	
Propylene	2G/2PG	–	–	F	R	
Propylene oxide **(1)**	2G/2PG	–	Inert	F + T	C	Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [3.1.1], Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [6.1.1], item a), Ch 9, Sec 17, [9], Ch 9, Sec 17, [10], Ch 9, Sec 17, [18]
Refrigerant gases	3G	–	–	-	R	
Sulphur dioxide	1G	Yes	Dry	T	C	Ch 9, Sec 14, [1.4], Ch 9, Sec 17, [3.1.2], Ch 9, Sec 17, [4.1.1], Ch 9, Sec 17, [5], Ch 9, Sec 17, [17]
Vinyl chloride	2G/2PG	–	–	F + T	C	Ch 9, Sec 14, [1.4.2], Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [2.1.1], item b), Ch 9, Sec 17, [2.1.1], item c), Ch 9, Sec 17, [3.1.1], Ch 9, Sec 17, [6], Ch 9, Sec 17, [19]
Vinyl ethyl ether **(1)**	2G/2PG	–	Inert	F + T	C	Ch 9, Sec 14, [1.4.2], Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [2.1.1], item b), Ch 9, Sec 17, [3.1.1], Ch 9, Sec 17, [6.1.1], item a), Ch 9, Sec 17, [8], Ch 9, Sec 17, [9], Ch 9, Sec 17, [10], Ch 9, Sec 17, [11.1.2], Ch 9, Sec 17, [11.1.3]
Vinylidene chloride **(1)**	2G/2PG	–	Inert	F + T	C	Ch 9, Sec 14, [1.4.2], Ch 9, Sec 14, [1.4.3], Ch 9, Sec 17, [2.1.1], item e), Ch 9, Sec 17, [6.1.1], item a), Ch 9, Sec 17, [8], Ch 9, Sec 17, [9], Ch 9, Sec 17, [10]
(1) This cargo is also covered by the IBC Code.						

Table 2 : Additional information on products

Product name	Boiling temperature (°C)	Specific gravity at boiling point (kg/m³)	Ratio vapour/air density
Acetaldehyde	21	780	1,52
Ammonia, anhhydrous	–33	682	0,60
Butiadene	–5	650	1,88
N-Butane / ISO-butane	–0,5 / –12	601	2,00
Butylenes	–6,3 / –7	625	1,94
Carbon dioxide	– 79,0	1180	1,50
Chlorine	–34,5	1562	2,49
Diethyl ether	34	640	2,55
Dimethylamine	7	671	1,55
Dimethyl ether	– 24,4	735	1,62
Ethane	–89	544	1,05
Ethyl chloride	12	920	2,20
Ethylene	–104	568	0,97
Ethylene oxide	11	870	1,52
Isoprene	34	680	2,40
Isopropylamine	32	700	2,03
Methane (LNG)	–161	422	0,55
Methyl acetylene/propadiene mixture	–38 / –20	–	1,48
Methyl bromide	4	1721	3,30
Methyl chloride	–24	1004	1,79
Mixed C4	–	–	–
Monoethylamine	16,6	690	1,56
Nitrogen	–196	806	0,97
Pentanes (all isomers)	27 / 36	610	2,50
Pentene (all isomers)	30 / 36	610	2,40
Propane	–42	581	1,55
Propylene	–47	610	1,48
Propylene oxides	34	860	2,00
Refrigerant gases			
Dichlorodifluoromethane (R12)	–30	1487	4,26
Dichloromonofluoroethane (R21)	8,86	1405	3,90
Dichlorotetrafluoroethane (R114)	3,59	1518	6.1
Monochlorodifluoromethane (R22)	–41	1409	3.21
Monochlorotetrafluoroethane (R124)	–	–	4,70
Monochlorotrifluoromethane (R13)	–81,48	1521	3,60
Sulphur dioxide	–10	1461	2,30
Vinyl chloride	–14	970	2,15
Vinyl ethyl ether	36	754	2,50
Vinylidene chloride	32	1250	3,45

Section 20 Hull Scantling

1 General

1.1 Application

1.1.1 The requirements in this Section apply to the hull structure, with the exception of the independent tank structure and tank supports, which are to be in compliance with Ch 9, Sec 4.

2 Flooding for ships with independent tanks

2.1 General

2.1.1 The net scantling of structural elements subject to flooding pressure is to be checked using the formula given in Pt B, Ch 7, Sec 4, Pt B, Ch 7, Sec 5 and Pt B, Ch 7, Sec 6, considering a still water bending moment of 0,5 $M_{sw\text{-}max}$ and a draught corresponding to the deepest equilibrium waterline in damage condition for transverse bulkhead.

At early stage of design, when damage stability calculations are not available, calculation with draft corresponding to 0,8 D without heel may be considered.

3 Finite element model

3.1 General

3.1.1 For the checking of the scantlings of primary supporting members, a three-dimensional finite element model is required.

The check is to be made in accordance with Part B, Chapter 8, taking into account the structural modeling principles given in [3.2].

3.2 Structural modeling

3.2.1 Modeling principles

The following primary supporting members are to be modeled:

- outer shell, inner bottom, main deck, trunk deck, longitudinal and transverse bulkhead plating
- double-bottom longitudinal girders
- double-side horizontal stringers
- deck longitudinal girders
- transverse web frames with main frames if relevant
- primary supporting members of transverse bulkheads.

3.2.2 Model extension for units with independent tanks

For units with independent tanks, the structural model is to include the primary supporting members of the hull (see a)) and the tanks with their supporting members and key systems.

The cargo tank model is to include the following primary members:

- shell plating
- bulkhead plating, including wash bulkheads if any
- bottom plating
- top plating
- transverse web frames
- horizontal stringers
- girders.

3.2.3 Modeling of supports and keys

The cargo tanks are linked to the hold by the following supports and keys, acting in one direction:

- vertical supports (Z direction)
- antipitching keys (X direction), used also as anticollision keys
- antirolling keys (Y direction)
- antiflotation keys (Z direction).

They can be modeled by either linear elements (bar, flexible mounts, springs), or non-linear elements (gap elements).

When linear elements are used to model keys and supports not allowing tension loads, they are to be deleted when in tension.

Stiffness of these linear and/or non-linear elements is to be representative of the actual stiffness of the supports and keys.

3.2.4 Stiffness of supports and keys for independent tanks

The axial stiffness of elements used for the modeling of supports and keys of independent tanks is to be calculated taking into account the stiffness of:

- the support in way of tank
- the spacer
- the support in way of hull.

The stiffness of the pad located between the lower and upper parts of the support may be calculated as follows:

$K = E S / h$

where:

K : Stiffness of the pad, in N/mm

E : Young modulus of the pad, in N/mm^2

S : Sectional area of the pad, in mm^2

h : Height of the pad, in mm.

The stiffness of the gap or spring element is to be taken as: $K_{element} = K / N_{elements}$

with:

$N_{elements}$: Number of elements used in the pad modeling.

3.2.5 Size of the elements

The mesh size should be equal to the spacing of the longitudinal ordinary stiffeners. Each of these longitudinal stiffeners is to be modeled. The aspect ratio of the elements should be as close to 1,0 as possible.

3.3 Load combinations for direct strength analysis

3.3.1 The loading conditions and associated draughts, SWBM and dynamic load cases to be applied on the finite element model are described in Tab 1.

Additional loading conditions defined in the loading manual may be considered when deemed necessary.

3.4 Yielding strength criteria

3.4.1 Yielding strength criteria for primary supporting members are defined in Pt B, Ch 7, Sec 6.

Yielding strength criteria for supporting members and keys systems are defined in Ch 9, Sec 4, [7.4] and Ch 9, Sec 4, [7.6].

3.5 Buckling check

3.5.1 Buckling strength criteria for primary supporting members are defined in Pt B, Ch 9, Sec 1.

Table 1 : Loading conditions and associated draughts and SWBM for FEM model

Loading conditions	Type A, B and C independent tanks			Membrane tanks		
	Draught	SWBM	Dynamic load cases	Draught	SWBM	Dynamic load cases
Homogeneous	T_{SC}	M_{SW-S}	All	T_{SC}	M_{SW-S}	HVM1, FVM1, BR1, BR2, BP1, OHM1, OHS1, OVA2
Ballast	T_{BAL}	M_{SW-H}	All	T_{BAL}	M_{SW-H}	HVM2, FVM2, BR1, BP1, OHM2
Alternate: Full / Empty / Full	$0,9T_{SC}$	$0,7M_{SW-H}$	All	$0,9T_{SC}$	$0,9M_{SW-H}$	HVM2, FVM2, BR1, BR2, BP1, BP2, OHM1, OVA2
Alternate: Empty / Full / Empty	$0,8T_{SC}$	$0,7M_{SW-S}$	All	$0,75T_{SC}$	$0,9M_{SW-S}$	HVM1, FVM1, BR1, BR2, BP1, BP2, OHM1, OHM2, OHS2, OVA2

Note 1:
M_{SW-S} : Design SWBM in sagging conditions
M_{SW-H} : Design SWBM in hogging conditions.

4 Membrane tanks

4.1 General

4.1.1 The net scantlings of plating and ordinary stiffeners of membrane tanks are to be not less than those obtained from Part B, Chapter 7, where the hull girder loads and internal pressure to be considered are to be calculated according to Part B, Chapter 5.

Specific allowable hull girder stresses and/or deflections, indicated by the cargo containment Designer, are to be taken into account for the determination of the hull scantlings.

4.1.2 The net scantlings of primary supporting members of membrane tanks are to be not less than those obtained from Part B, Chapter 7, where the hull girder loads and the internal pressure are to be calculated according to Part B, Chapter 5.

4.2 Sloshing loads

4.2.1 The net thicknesses of plating subject to sloshing pressure are to be checked using the formula given in Pt B, Ch 7, Sec 4, [4] with P_{sl} to be taken equal to P_{sl} given in Ch 9, App 1, [2.2].

No buckling check is required.

Areas to be checked for sloshing pressure are defined in Ch 9, App 1, [2.2].

4.2.2 The net section modulus of ordinary stiffeners subject to sloshing pressure, including longitudinals, are to be checked using the formulae given in Pt B, Ch 7, Sec 5, [1.3] with P_{sl} to be taken equal to P_{sl} given Ch 9, App 1, [2.2].

Areas to be checked for sloshing pressure are defined in Ch 9, App 1, [2.2].

No buckling check is required.

4.3 Collision loads

4.3.1 The structure of the tank is to be checked for collision loads using the pressure defined in Ch 9, App 1, [4.1.1] and the general scantling criteria associated to the AC-3 acceptance criteria, as defined in:

- Part B, Chapter 7 for plating, stiffeners and primary supporting members
- Part B, Chapter 8 for direct strength analysis.

5 Structural details

5.1 General

5.1.1 The specific requirements in Pt B, Ch 13, Sec 5, [2] for ships with the service notation **liquefied gas carrier** are to be complied with.

5.2 Connections of inner bottom with transverse cofferdam bulkheads

5.2.1 The thickness and material properties of the supporting floors are to be at least equal to those of the cofferdam bulkhead plating, unless finite element analysis and thermal calculations are submitted to the Society for case-by-case agreement

5.2.2 Vertical webs fitted within the cofferdam bulkhead are to be aligned with the double bottom girders.

5.2.3 Manholes in double bottom floors aligned with the cofferdam bulkhead plating are to be located as low as practicable and at mid-distance between two adjacent longitudinal girders.

Section 21 Additional Requirements for Ship carrying Liquefied Hydrogen in Bulk

1 General

1.1 Application

1.1.1 This Section applies to liquefied hydrogen carrier as defined in [1.3.1].

1.1.2 The requirements of this Section complement the general requirements given elsewhere in Part D, Chapter 9.

1.1.3 In accordance with Ch 9, Sec 1, [1.2.3], liquefied gas carriers complying with the requirements on this Section are eligible for the assignment of the service notation **liquefied gas carrier**, as defined in Ch 9, Sec 1, completed by the additional service features defined in Pt A, Ch 1, Sec 2, [4.4.5] where the cargo type will be indicated as **LH2**.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation defined Ch 9, Sec 1, [5], the documents and drawings to be submitted for liquefied hydrogen carriers are listed in Tab 1.

Table 1 : Documents to be submitted

No.	A/I	Documents
1	I	Risk analysis as per [2] and follow-up report of the recommendations
2	A	Leakage scenario
3	A	Hydrogen dispersion analysis
4	A	Insulation performance of the insulation system, as applicable
5	I	Atmosphere handling procedures for the insulation spaces, as applicable
Note 1: A = to be submitted for approval; I = to be submitted for information		

1.3 Definitions

1.3.1 Liquefied hydrogen carrier

A liquefied hydrogen carrier is a ship designed for the carriage of liquefied hydrogen in bulk.

1.3.2 Permeation

Permeation is flow of a fluid through another material by diffusion without a defect or opening of the latter.

1.3.3 Inner shell

The inner shell is the inner element of cargo containment systems with two boundaries, which is regarded as a primary barrier. See Fig 1.

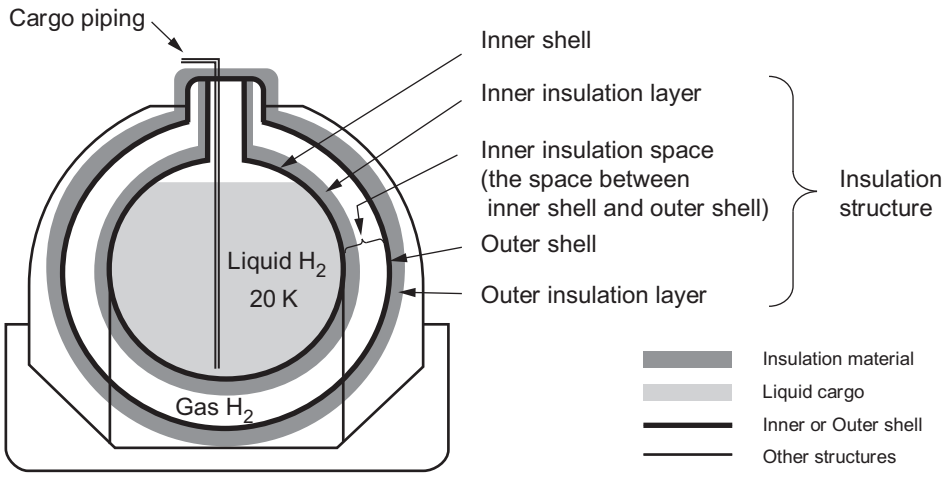
1.3.4 Outer shell

The outer shell is the outer element of cargo containment systems with two boundaries, which is regarded as a secondary barrier or a part of insulation system in relation to the tank types. See Fig 1.

1.3.5 Inner insulation space

The inner insulation space is the space between an inner and an outer shell. See Fig 1.

Figure 1 : Illustration of cargo containment system



2 Safety assessment

2.1 Hazard identification and risk analysis

2.1.1 A risk assessment is to be conducted in order to ensure that any risks arising from the use of hydrogen likely to affect people on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration is to be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure. As a minimum, the risk assessment is to include the studies detailed in [2.1.4] to [2.1.5] and may be required to be completed to the satisfaction of the Society.

2.1.2 Hazards are to be identified using acceptable and recognised hazard identification techniques. The following hazards are to be considered, as a minimum: loss of function, component damage, operational and environment-related influences, electrical faults, unwanted chemical reactions, auto-ignition of fuels, fire, explosion, short-term power failure (blackout). The effects of the following are to be considered:

- the ship's operational profile
- the ship's operational status
- modes of operation
- environmental conditions
- dependencies - power, fuel, air, cooling, heating, data, human input
- environmental impact and failures - human error, supply failure, system, machinery
- equipment and component failure, random, systematic, common cause.

2.1.3 The risks are to be analysed using acceptable and recognised risk analysis techniques. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. If mitigation solutions are operational, details of risks, and the means by which they are mitigated, are to be included in the cargo operating manual.

2.1.4 An HAZID study is to be carried out. The study is to cover at least the following spaces, zones and systems, where relevant:

- cargo area
- cargo machinery spaces containing hydrogen consumers
- zones where vent lines and safety valve discharge lines are led, except where ventilation inlets to accommodation and machinery spaces are provided with gas detection arrangements
- containment systems and adjacent structure.

Operational procedures may not be the primary mitigation of risks identified by the HAZID study.

Gas dispersion analysis is required to better assess the risk associated with gas venting or pressure relief. The dispersion of hydrogen from vent outlets is to be analysed in order to minimize risk of ingress of flammable gas into accommodation spaces, service spaces, machinery spaces and control stations. Extension of hazardous areas is to be determined based on the results of the analysis.

2.1.5 For liquefied hydrogen tanks and associated insulated pipings, the risk analysis is to include the risks:

- arising from the deterioration of insulation capability by single damage and determine the safety measures to be adopted in such situation
- associated to cryogenic leakages
- associated to oxygen enrichment of the atmosphere.

2.1.6 For any risk assessment carried out in the scope of the present Rules, a detailed follow-up report of actions and mitigation measures taken in response to any analysis findings is to be submitted to the Society.

This report is to include especially the monitoring and control options.

3 Cargo containment

3.1 General

3.1.1 The suitability of the cargo containment system and the overall effectiveness of the design are to be evaluated as a part of the risk assessment in [2].

3.1.2 The cargo containment system is to be resistant to hydrogen embrittlement at the design temperatures and pressures.

3.1.3 When deterioration of insulation capability by single damage is possible, appropriate safety measures are to be adopted taking into account the deterioration.

3.1.4 Appropriate safety measures are to be taken to prevent formation of explosive mixture in the case of a leakage and permeation of hydrogen, including installation of hydrogen detectors in order to detect a possible ground-level travel of low temperature hydrogen gas, and at high points in spaces where warm hydrogen gas can be trapped.

3.1.5 Helium or a mixture of 5% hydrogen and 95% nitrogen are to be used as the tightness test medium for cargo tank and cargo piping.

3.2 Independent tanks using vaccum insulation

3.2.1 The insulation performance of vacuum insulation of cargo containment system is to be evaluated to the satisfaction of the Society based on experiments, as necessary.

3.2.2 Notwithstanding [4.1.4], liquid and gas hydrogen pipes may pass through spaces constituting a part of a cargo containment system using vacuum insulation where the degree of vacuum is monitored.

3.2.3 When selecting the most onerous scenario stipulated in [6.1.1], the evaluation is to include fire or loss of vacuum from the overall insulation system and is also to consider the resulting magnitude of the heat flux in case of a single failure on the cargo containment system in each case.

3.3 Independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces

3.3.1 The outer shell of the cargo containment system is to be located at the distance from the ship's outer shell required in Ch 9, Sec 2 for cargo tanks of type 2G ship.

3.3.2 Strength of the outer shell is to be determined by analyses and tests considering safety principles, all applicable design conditions, materials used, and construction processes in reference to Ch 9, Sec 4, and is to be approved by the Society.

3.3.3 The following requirements are to be applied to the outer shell:

- All joints of the outer shell are to be welded and of full penetration type. All joints of the outer shell are to be of in-plane butt weld, as far as practicable. Tee welds of full penetration type may be used, depending on the results of the test carried out at the approval of the welding procedure, where the in-plane butt weld is not practicable due to the construction process and structure of the outer shell.
- If a manhole is sealed by welding using backing rings, backing rings may be left after welding without removal, provided that they do not cause any significant harmful effects.

3.3.4 The outer shell is to be subjected to pneumatic pressure testing to check its strength.

3.3.5 Appropriate thermal insulation is to be provided to keep the temperature of the outer shell and outer insulation layer above the boiling point of oxygen. The insulation performance is to be evaluated to the satisfaction of the Society based on experiments, as necessary. When applying Ch 9, Sec 4, [5.2.5], the degradation of insulation performance caused by hydrogen atmosphere is to be considered. Means are to be provided for monitoring the condition of the insulation for detection of failures.

3.3.6 Requirements for type C independent tank are to be applied to the inner shell.

3.3.7 The pressure of the inner insulation space is to be monitored taking into account the requirement for a cargo tank in Ch 9, Sec 13, [4].

3.3.8 Under normal conditions, appropriate measures are to be taken to maintain the pressure of the inner insulation space within the design limits.

3.3.9 Pressure and vacuum relief valves are to be provided for inner insulation spaces which may be subject to pressures beyond their design capabilities, taking into account the requirements for pressure relief systems of cargo tanks in Ch 9, Sec 8, [2] and Ch 9, Sec 8, [3]. The appropriate capacity of vacuum relief valves should be provided taking into account the expected rate of pressure drop in the inner insulation space of the cargo tanks of the ship under normal cargo operations, which replaces the requirements Ch 9, Sec 8, [3.1.1], item b). When applying Ch 9, Sec 8, [3.1.2], the vacuum relief valves are not to admit air to the inner insulation space. In the event that the pressure relief valve for the inner insulation space is activated, the hydrogen gas release is to be vented to a safe location.

3.3.10 The requirements in Ch 9, Sec 5 other than Ch 9, Sec 5, [3] and Ch 9, Sec 5, [10], i.e. the requirements for cargo piping outside the cargo areas, are to be applied for piping handling hydrogen for the inner insulation space.

3.3.11 Appropriate measures are to be taken for atmosphere control of the inner insulation space (e.g. inerting, gas freeing, aerating and purging, etc.).

3.3.12 A tightness test is to be performed on the outer shell as per [3.1.5]

3.3.13 Requirement [4.1.3] need not be applied to piping handling hydrogen for the inner insulation space, other than piping penetrating the inner shell, located inside the inner insulation space.

3.3.14 Notwithstanding [4.1.4], piping handling hydrogen for an inner insulation space may pass through other inner insulation spaces.

3.3.15 Manholes for access from or to the inner insulation space through the inner shell are not permitted.

3.3.16 Cargo piping connected to the inside of the inner shell are to be led directly from the weather deck. No pipe is to penetrate the inner shell from or to the inner insulation space.

3.4 Membrane tanks keeping insulation spaces under vacuum

3.4.1 Structural integrity is to be verified for all the structural components of the cargo containment systems and the inner hull structure considering the vacuum environment of the insulation spaces.

3.4.2 Both the primary and secondary barriers are to be made of metallic materials and be liquid-tight and gas-tight.

3.4.3 Tightness test is to be conducted for both the primary and secondary insulation spaces using either helium or a mixture of 5% hydrogen and 95% nitrogen.

3.4.4 Pressure relief systems are to be provided for the insulation spaces which may be subject to pressures beyond their design capabilities. The designer is to demonstrate adequate sizing of the PRV's for the spaces to the satisfaction of the Society.

3.4.5 The insulation system is to be capable of maintaining the hydrogen in the tank in liquid state under the anticipated operational conditions and taking into account the degree of vacuum in the insulation spaces and the designed tolerance levels in the insulation spaces. This is to be evaluated based on experiments as necessary.

3.4.6 The required degree of vacuum in the insulation spaces is to be determined so as to prevent any damage to the system components due to the condensation and/or solidification of the remaining gas components.

3.4.7 The degree of vacuum in the insulation spaces is to be monitored and kept within the designed level during normal operation. The vacuum system is to be redundant to the satisfaction of the Society.

3.4.8 Atmosphere handling procedures for the insulation spaces are to be established. It is to be verified through testing that the insulation components do not prevent the effective atmosphere control operation for the spaces, including but not limited to gas displacement, evacuation and removal of leaked hydrogen.

3.4.9 Indicating and detecting instruments are to be provided for the detection and identification of emergency cases such as hydrogen leakage into the inter barrier space and loss of vacuum due to air ingress into the insulation spaces. They are to be sufficiently redundant to the satisfaction of the Society.

3.4.10 Pressure control systems in the primary insulation space such as pressure relief or vacuum pumping systems are to be certified safe-type equipment according to the hazardous area classification and be able to discharge cryogenic hydrogen to a safe location. Pressure control systems in the primary or secondary insulation spaces are also to be designed and arranged to prevent blockage due to the frozen air.

3.4.11 Hydrogen-compatibility of the insulation materials is to be verified by test. It is to be ensured that the insulation performance of the insulation materials in contact with the leaked hydrogen remains acceptable after restoring.

3.4.12 Hydrogen gas detectors are to be installed along the primary and secondary spaces vacuum pump lines in order to detect potential cargo leakage into the insulation space.

3.4.13 One vacuum pump is to be provided for each tank and for each interbarrier space. Vacuum pumping systems are to be sized to maintain vacuum in each space. In addition, a back-up pump is to be provided, able to maintain vacuum in the largest space under vacuum.

3.4.14 Vacuum pumps are to be considered as an essential auxiliary and at least one of them is to be supplied from the emergency source of electrical power.

3.4.15 Oxygen detection is to be implemented for secondary spaces for air ingress detection.

3.4.16 Regarding the relief valve sizing for the cargo tank, the evaluation is to include the scenarios of vacuum loss in any one of the insulation spaces in addition to [6.1.1].

4 Process pressure vessels and liquid, vapour and pressure piping systems

4.1 General

4.1.1 Hydrogen piping components are to be designed in accordance with ASME B31.12-2019-Part IP (Industrial Piping standard) or other recognized standard accepted by the Society.

4.1.2 All hydrogen pipes are to be:

- butt-welded unless demonstrated not feasible
- arranged to minimize the number of connections

Gaskets are to be protected against blow-out.

4.1.3 Double-walled pipe, or fixed hydrogen detectors capable of detecting a hydrogen leak, are to be provided for confined places where leakage of hydrogen may occur. Sources of hydrogen leakage include, but are not limited to, cargo valves, flanges and seals.

4.1.4 Liquid and gas hydrogen pipes are not to pass through enclosed spaces in addition to those referred to in Ch 9, Sec 5, [2.2.1], unless:

- the spaces are equipped with gas detection systems which activate the alarm at not more than 20% LEL and shut down the isolation valves, as appropriate, at not more than 40% LEL and the spaces are adequately ventilated; or
- the spaces are maintained in an inert condition.

This requirement is not applicable to spaces constituting a part of a cargo containment system using vacuum insulation where the degree of vacuum is monitored.

4.1.5 For pipes containing liquefied hydrogen and cold hydrogen vapour, measures are to be taken to prevent the exposed surfaces from reaching –183°C. For places where preventive measures against low temperature are not sufficiently effective, such as manifolds, other appropriate measures such as ventilation which avoids the formation of highly enriched oxygen and the installation of trays recovering liquid air may be permitted in lieu of the preventive measures.

4.1.6 Means to remove impure substances condensed at low temperature e.g. filtering, are to be provided in hydrogen fuel piping systems.

4.1.7 Due consideration is to be given to static electricity associated with rotating or reciprocating machinery including the installation of conductive machinery belts and precautionary measures incorporated in operating and maintenance procedures, in addition to the bonding of tanks, piping and equipment required by requirement Ch 9, Sec 5, [7.4.1]. Anti-static clothing and footwear, and a portable hydrogen detector is to be provided for each crew member working in the cargo area.

4.2 Design pressure

4.2.1 For high-pressure hydrogen piping the design pressure of the ducting is to be taken as the higher of the following:

- the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space
- local instantaneous peak pressure in way of the rupture: This pressure is to be taken as the critical pressure given in Ch 9, Sec 5, [4.1.5] with k = 1,41

5 Materials

5.1 General

5.1.1 All equipment and components are to be made of materials, including filler materials for welding, that are suitable for the range of process fluids and conditions expected.

5.1.2 Materials for containment and piping systems are to be in accordance with the requirements of NR216 Materials and Welding unless otherwise specified.

5.1.3 Components in contact with hydrogen are to be made of materials compatible with hydrogen use, in particular with respect to embrittlement and hydrogen attack phenomena. 304/304L and 316/316L austenitic stainless steel may be used. Other materials may be approved upon special consideration. The demonstration of the suitability of materials is to be performed by tests according to a recognized standard accepted by the Society (e.g. ISO 11114-1:2017 or ISO 11114-4:2017).

5.1.4 Requirements for materials intended to be used in applications with design temperature lower than -165°C are to be agreed with the Society. Where minimum design temperature is lower than -196°C, materials are to meet the toughness requirements of ISO 21028-1: 2016 and testing for insulation materials is to be carried out with the appropriate medium, over a range of temperatures expected in service.

5.1.5 Material of construction and ancillary equipment such as insulation is to be resistant to the effect of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cryogenic hydrogen containment system. Suitability of material is to be demonstrated in accordance with a recognized standard accepted by the Society such as EN 1797:2001.

This requirement is applied to all locations where contact with condensed oxygen is anticipated under normal conditions and foreseeable single failure scenarios.

5.1.6 Insulation on liquid hydrogen piping systems exposing to air are to be of non-combustible material and are to be designed to have a seal in the outer covering to prevent the condensation of air and subsequent oxygen enrichment within the insulation.

5.1.7 At places where contact with hydrogen is anticipated, suitable materials are to be used to prevent any structural deterioration owing to hydrogen embrittlement and degradation of strength and fatigue properties due to continual exposure to hydrogen, as necessary.

6 Vent systems for cargo containment

6.1 General

6.1.1 Relief valves are to be sized for the most onerous scenario. The evaluation is to include the fire scenario and is to consider the resulting magnitude of the heat flux on the cargo containment system in each case.

6.1.2 Pressure relief systems are to be designed and constructed to prevent blockage due to formation of water or ice.

6.1.3 Measures are to be taken to prevent vents from becoming blocked by accumulations of ice formed from moisture in the air.

7 Cargo containment system atmosphere control

7.1 Inert gas production on board

7.1.1 The equipment is to be capable of producing inert gas so that the space is inerted with an oxygen content lower than 3% by volume.

A continuous-reading oxygen content meter is to be fitted to the inert gas supply from the equipment and is to be provided with an alarm set at a maximum of 1% oxygen content by volume.

8 Electrical installations

8.1 Temperature class and explosion group

8.1.1 The explosion group and temperature class of electrical equipment of a certified safe type for use in hydrogen/air mixtures are to be at least IIC and T1.

9 Fire protection and extinction

9.1 Enclosed spaces containing cargo handling equipment

9.1.1 If a carbon dioxide fixed fire-extinguishing system is provided for compliance with Ch 9, Sec 11, [1.5.2], the amount of carbon dioxide is to be sufficient to provide a quantity of free gas equal to 75% or more of the gross volume of the protected space. Alternatively, a fixed dry chemical powder fixed fire extinguishing system complying with IMO MSC.1/Circ.1315 may be considered.

9.2 Fire detection

9.2.1 Fire detectors for detecting hydrogen fire is to be selected, taking into account the features of hydrogen fire, to the satisfaction of the Society.

10 Artificial ventilation in the cargo area

10.1 Spaces required to be entered during normal cargo handling operations

10.1.1 The ventilation rate is to be sufficient to dilute the average gas/vapour concentration below 20% of the LEL in all maximum probable leakage scenarios due to technical failures.

11 Instrumentation and automation systems

11.1 Gas detection

11.1.1 Gas/vapour detection equipment is to be designed, installed and tested in accordance with a recognized standard accepted by the Society (e.g. ISO 26142:2010 for hydrogen detectors). The gas detection equipment is to be of a type approved by the Society and suitable for all expected ambient conditions including air flow velocities.

11.1.2 At gas or vapour concentration of 20% LEL inside the gas detection cabinet, the gas detection equipment is to be automatically shut down.

11.1.3 Gas/vapour detection above a gas or vapour concentration of 20% LEL is to trigger an alarm.

11.1.4 Gas/vapour detection above a gas or vapour concentration of 40% LEL is to activate the safety systems.

12 Filling limits for cargo tanks

12.1 Default filling limit

12.1.1 A filling limit exceeding 98% at reference temperature is not permitted.

13 Survey at work and certification

13.1 General

13.1.1 The manufacture, testing, and survey is to be in accordance with the applicable Rules for Classification, recognized standards accepted by the Society and the specific requirements given in this Section.

13.2 Valves

13.2.1 Type approval

Each type of valve is to be type tested. The scope of tests is to include at least the tests specified in Tab 2.

13.2.2 Production testing

Each valve is to be tested in the presence of the Surveyor unless an alternative survey scheme (BV Mode I according to NR320) has been agreed. Testing is to include hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure for all valves, seat and stem leakage test at a pressure equal to 1,1 times the design pressure for valves other than pressure relief valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below –55°C. The setting pressure of safety valves is to be tested at ambient temperature.

For valves used for isolation of instrumentation in piping not greater than 25mm, unit production testing need not to be witnessed by the Surveyor. Records of testing are to be available for review.

Table 2 : Valve type approval tests

No.	Test	Applicable testing standard
1	Hydraulic pressure test	
2	Burst test	
3	Pneumatic leak test (internal and external, including permeability measuring)	
4	Insulation test **(1)**	
6	Material compatibility test	ISO 11114-4:2017
7	Fire resistance test **(2)**	ISO 19921:2005 ISO 19922:2005
(1) Applicable to automatic valves **(2)** For emergency shutdown valves, with materials having melting temperatures lower than 925°C.		

Appendix 1 Guidance for Calculation of Pressures and Accelerations

1 Guidance to detailed calculation of internal pressure for static design purpose

1.1 Calculation of dynamic liquid pressure

1.1.1 *This Appendix provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of static design calculations. This pressure may be used for determining the internal pressure referred to in Ch 9, Sec 4, [3.3.2], item e), where:*

- $(P_{gd})_{max}$ *, in MPa, is the associated liquid pressure determined using the maximum design accelerations.*
- $(P_{gd}site)_{max}$ *, in MPa, is the associated liquid pressure determined using site specific accelerations.*
- P_{eq} *, in MPa, should be the greater of* P_{eq1} *and* P_{eq2} *calculated as follows:*

  $P_{eq1} = P_o + (P_{gd})_{max}$

  $P_{eq2} = P_h + (P_{gd}site)_{max}$

1.1.2 *The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship referred to in Ch 9, Sec 4, [3.4.2]. The value of internal liquid pressure* P_{gd} *, in MPa, resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:*

$$P_{gd} = a_\beta Z_\beta \frac{\rho}{1{,}02 \times 10^5}$$

where:

a_β : *Dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction* β *(see Fig 1).*

For large tanks, an acceleration ellipsoid taking account of transverse vertical and longitudinal accelerations, should be used.

Methods for the calculation of acceleration in upright ship conditions and inclined ship conditions are given in [1.2]

Z_β : *Largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the* β *direction (see Fig 2).*

The liquid heights Z_β are to be calculated in accordance with Fig 4 at each calculation point of the tank.

At each calculation point, the maximum internal pressure $(P_{gd})_{max}$ is to be obtained for the β direction which gives the maximum value of P_{gd} (see Fig 3).

Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining Z_β *, unless the total volume of tank domes* V_d *does not exceed the following value:*

$$V_d = V_t \frac{100 - FL}{FL}$$

with:

V_t : *Tank volume without any domes*

FL : *Filling limit according to Ch 9, Sec 15.*

ρ : *Maximum cargo density, in kg/m³, at the design temperature.*

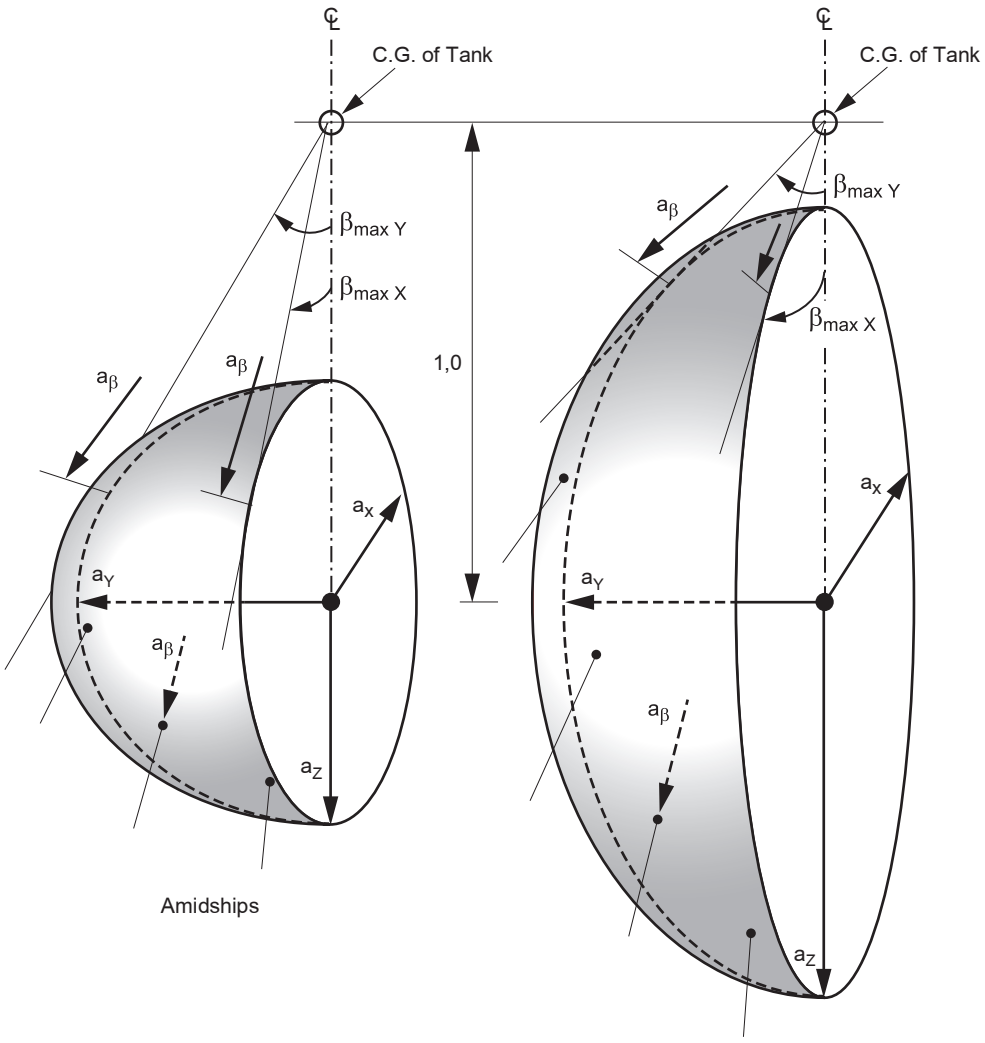
Where the maximum mass density of the liquid carried is not given, the following values are to be considered:

- ρ_L = 0,50 t/m³ = 500 kg/m³ for methane
- ρ_L according to Ch 9, Sec 19, Tab 2 for other products.

The direction that gives the maximum value $(P_{gd})max$ *or* $(P_{gd}site)_{max}$ *should be considered. The above formula applies only to full tanks.*

Equivalent calculation procedures may be applied.

Figure 1 : Acceleration ellipsoid



a_β resulting acceleration (static and dynamic) in arbitrary direction β
a_X longitudinal component of acceleration
a_Y transverse component of acceleration
a_Z vertical component of acceleration

Figure 2 : Determination of internal pressure heads

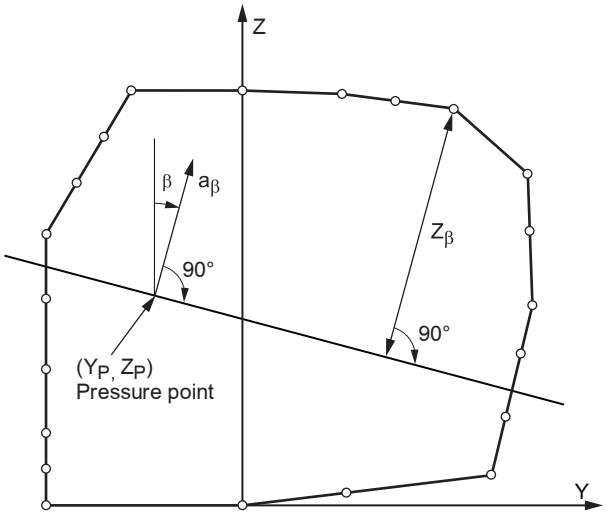


Figure 3 : Determination of internal pressure for pressure points 1, 2 and 3

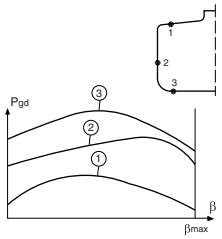
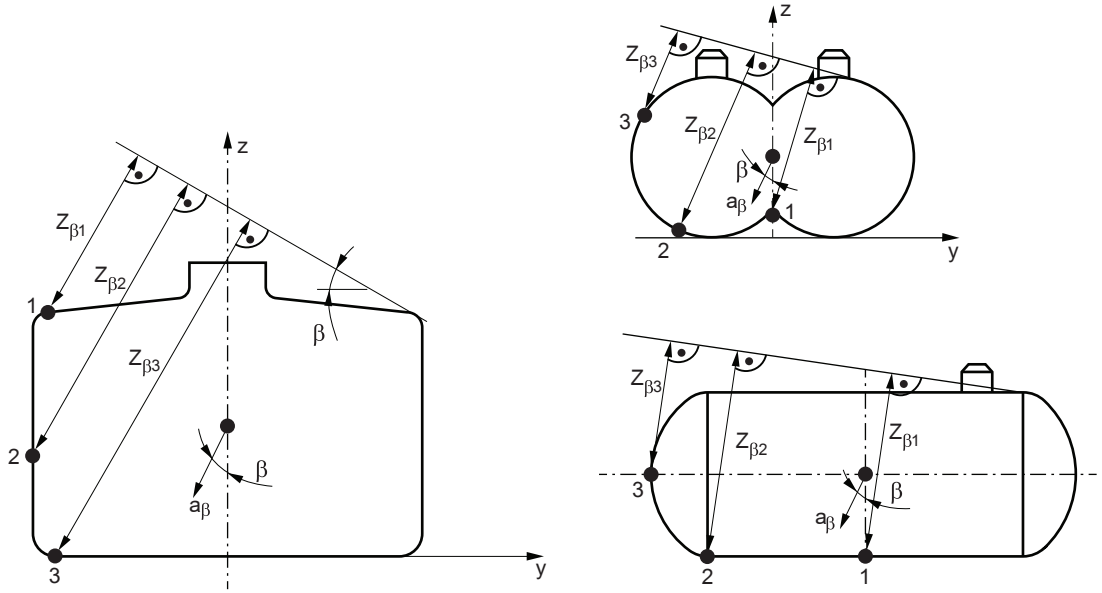


Figure 4 : Determination of liquid height Z_β for pressure points 1, 2 and 3



1.2 Calculation of acceleration components

1.2.1 Guidance formulae for acceleration components

The following formulae are given as guidance for the components of acceleration due to ship's motions corresponding to a probability level of 10^{-8} in the North Atlantic and apply to ships with a length exceeding 50 m and at or near their service speed:

- *vertical acceleration, as defined in Ch 9, Sec 4, [3.4.2]:*

$$a_z = \pm a_0 \sqrt{1 + \left(5{,}3 - \frac{45}{L_0}\right)^2 \left(\frac{x}{L_0} + 0{,}05\right)^2 \left(\frac{0{,}6}{C_B}\right)^{1{,}5} + \left(\frac{0{,}6\, y K^{1{,}5}}{B}\right)^2}$$

- *transverse acceleration, as defined in Ch 9, Sec 4, [3.4.2]:*

$$a_y = \pm a_0 \sqrt{0{,}6 + 2{,}5\left(\frac{x}{L_0} + 0{,}05\right)^2 + K\left(1 + 0{,}6\, K \frac{z}{B}\right)^2}$$

- *longitudinal acceleration, as defined in Ch 9, Sec 4, [3.4.2]:*

$$a_x = \pm a_0 \sqrt{0{,}06 + A^2 - 0{,}25\, A}$$

where:

$$a_0 = 0{,}2\, \frac{V}{\sqrt{L_0}} + \frac{34 - \frac{600}{L_0}}{L_0}$$

L_0 : *Length of the ship for determination of scantlings as defined in recognized standards, in m*

C_B : *Block coefficient*

B : *Greatest moulded breadth of the ship, in m*

x : *Longitudinal distance, in m, from amidships to the centre of gravity of the tank with contents; x is positive forward of amidships, negative aft of amidships*

y : *Transverse distance, in m, from centreline to the centre of gravity of the tank with contents*

z : *Vertical distance, in m, from the ship's actual waterline to the centre of gravity of tank with contents; z is positive above and negative below the waterline*

K : *K = 1 in general.*

For particular loading conditions and hull forms, determination of K according to the following formula may be necessary:

K = 13 GM / B

where:

K ≥ 1

GM : *metacentric height, in m*

$$A = \left(0,7 - \frac{L_0}{1200} + 5\frac{z}{L_0}\right)\left(\frac{0,6}{C_B}\right)$$

V : *Service speed, in knots*

a_x, a_y, a_z : *Maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions. They are considered as acting separately for calculation purposes, and a_z does not include the component due to the static weight, ay includes the component due to the static weight in the transverse direction due to rolling and ax includes the component due to the static weight in the longitudinal direction due to pitching. The accelerations derived from the above formulae are applicable only to ships at or near their service speed, not while at anchor or otherwise near stationary in exposed locations.*

1.2.2 Accelerations for type C tanks

The inertial internal liquid pressure is to be calculated considering the ship in the following mutually exclusive conditions:

a) Upright ship conditions

In these conditions, the ship encounters waves which produce ship motions in the X-Z plane, i.e. surge, heave and pitch.

The dimensionless acceleration a_β is to be obtained, for an arbitrary direction β, in accordance with Fig 5, in which the wave longitudinal and vertical accelerations a_X and a_Z, respectively, are calculated from the formula in [1.2.1].

b) Inclined ship conditions

In these conditions, the ship encounters waves which produce ship motions in the X-Y and Y-Z planes, i.e. sway, heave, roll and yaw.

The dimensionless acceleration a_β is to be obtained, for an arbitrary direction β, in accordance with Fig 6, in which the wave transverse and vertical accelerations a_Y and a_Z, respectively, are calculated from the formula in [1.2.1].

Figure 5 : Dimensionless acceleration in upright ship condition

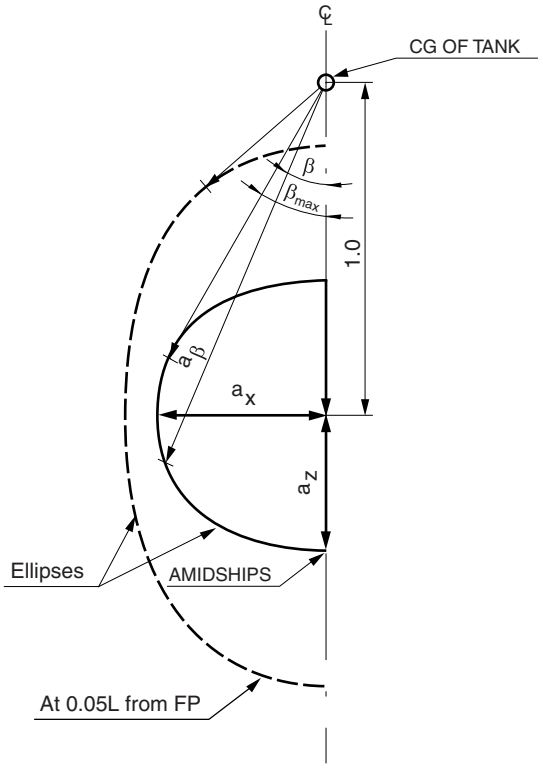
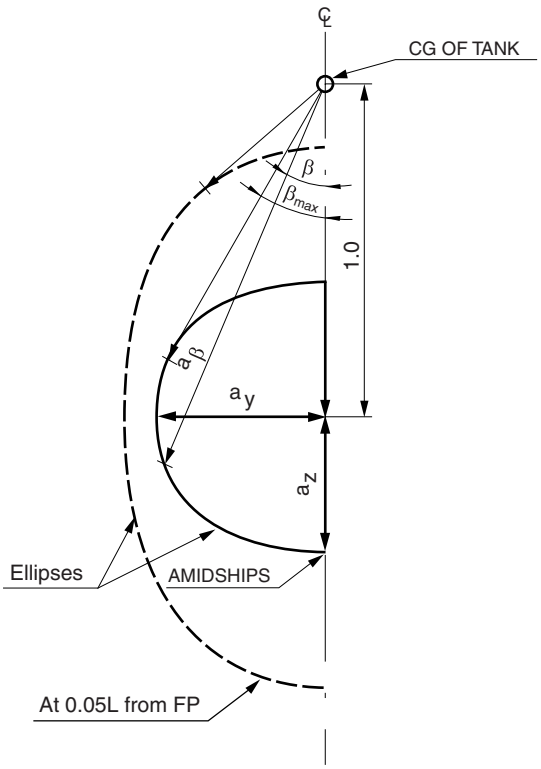


Figure 6 : Dimensionless acceleration in inclined ship condition



1.2.3 Accelerations for type A tanks

The inertial liquid pressure is to be calculated considering ship accelerations in the three directions.

The dimensionless acceleration a_β is to be obtained, for an arbitrary direction (β_X, β_Y), in accordance with Fig 1, in which the wave longitudinal, transverse and vertical accelerations a_X, a_Y and a_Z, respectively, are calculated from the formula in [1.2.1].

Note 1: For analysis based on three-dimensional models, several load cases are to be considered. For each load case, the pressures are to be calculated for each finite element of the tank boundary with a given direction (β_X, β_Y).

The choice and number of load cases considered is to be to the satisfaction of the Society with respect to maximising the inertial liquid pressure on each element of the tank boundary.

2 Internal pressure for membrane tanks

2.1 General

2.1.1 The inertial internal liquid pressure is to be calculated according to Pt B, Ch 5, Sec 6.

2.2 Sloshing pressure and tank areas to be checked

2.2.1 The sloshing pressure is to be considered with regards to the number and size of membrane tanks.

The sloshing pressure in membrane tanks of ships having a total capacity over 180 000 m^3 is to be specially considered by the Society.

The ship structural members, i.e. plating, stiffeners and primary supporting members, supporting the membrane tanks are to be checked against the sloshing pressure defined in [2.2.2] for the tanks areas defined in [2.2.3].

2.2.2 The standard filling levels for membrane tanks of ships having a capacity less than 180 000 m^3 are to be taken as follows:

- Full load condition:

  The liquid height in the cargo tank is comprised between 70% of the cargo tank height to 98% of the cargo tank volume.
- Ballast condition:

  The liquid height in the cargo tank is comprised between 0% and 10% of the cargo tank height. In case of specific arrangement and tank dimensions, the value of 10% may be adapted on case by case basis.

For the standard filling levels, the sloshing pressure P_{sl}, in kN/m^2, is to be obtained from the following formula:

$P_{sl} = P_{wi} + P_{pv}$

where:

P_{wi} : Quasi static pressure, in kN/m², taken equal to 240 kN/m²

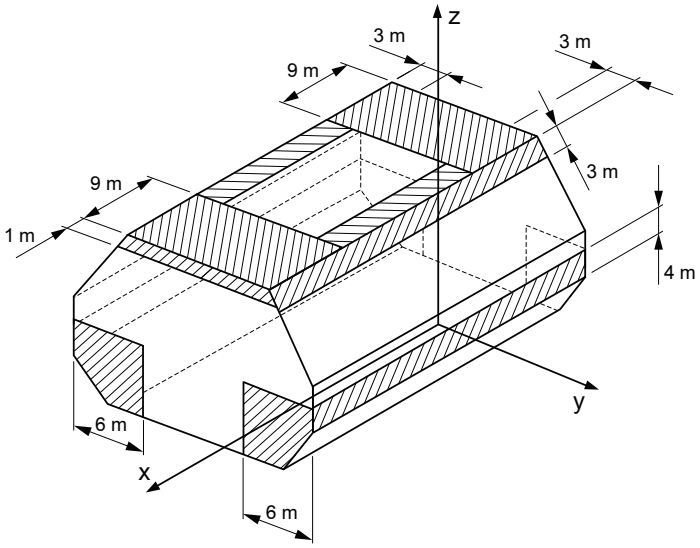
If duly justified (for example by numerical analysis and/or model tests), another value of P_{wi} can be considered by the Society

P_{pv} : Design vapour pressure, in kN/m², not taken less than 25 kN/m²

2.2.3 The areas of the tanks to be checked for sloshing are described in Fig 7.

For small tanks, the dimensions of those areas may be adapted on a case-by-case basis.

Figure 7 : Areas to be checked for sloshing



3 Guidance for calculation of pressures for a static heel angle of 30°

3.1 Internal pressure calculation

3.1.1 Accelerations

The components of transverse and vertical accelerations to be used for this calculation are as follows:

- Positive roll angle case:

$$a_y = g\sin\frac{\pi}{6}$$

$$a_z = (-g)\cos\frac{\pi}{6}$$

- Negative roll angle case:

$$a_y = (-g)\sin\frac{\pi}{6}$$

$$a_z = (-g)\cos\frac{\pi}{6}$$

3.1.2 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector whose absolute values of Y and Z components are the transverse and vertical accelerations defined in [3.1.1] is the point of the tank boundary whose projection on the direction forming a 30° angle with the vertical direction is located at the greatest distance from the tank's centre of gravity.

3.1.3 Calculation of internal pressure

The internal pressure is calculated as follows:

$$P_{gd} = \rho[a_Y(y - y_H) + a_Z(z - z_H)]$$

where y_H and z_H are the coordinates of the highest point defined in [3.1.2].

3.2 Sea pressure calculation

3.2.1 The sea pressure is calculated as follows:

- Positive roll angle:

$$P_s = \rho g\left[y\sin\frac{\pi}{6} + (T - z)\cos\frac{\pi}{6}\right]$$

- Negative roll angle:

$$P_s = \rho g\left[(-y)\sin\frac{\pi}{6} + (T - z)\cos\frac{\pi}{6}\right]$$

4 Calculation of dynamic pressure for collision loads

4.1 General

4.1.1 The dynamic pressure resulting from collision loads defined in Ch 9, Sec 4, [3.5.2] is the following:

$P_w = \rho_l a_x |x - x_B|$

where:

ρ_l : Maximum cargo density, in kg/m^3, at the design temperature

x : X co-ordinate, in m, at the point considered

- for the case of forward acceleration:

  a_x : Longitudinal acceleration, in m/s^2, equal to: $a_x = 0.5$ g

  x_B : X co-ordinate, in m, of aft bulkhead of the tank.

- for the case of aftward acceleration:

  a_x : Longitudinal acceleration, in m/s^2, equal to: $a_x = 0.25$ g

  x_B : X co-ordinate, in m, of fore bulkhead of the tank.

Appendix 2 Correspondances between Pt D, Chapter 9 and IMO Circular MSC.1/Circ.1679

1 General

1.1

1.1.1 Tab 1 provides correspondances between the provisions of the IMO Circular MSC.1/Circ.1679 "Interim guidelines for use of liquified petroleum gas (LPG) cargo as fuel" and those of the present Chapter.

Table 1 : Equivalences between Part D, Chapter 9, Section 16 and IMO Circular MSC.1/Circ.1679

Ref. in IMO Circular MSC.1/Circ. 1679	Ref. in Part D, Chapter 9, sec 16
1.1	–
1.2	–
1.3	–
1.4	–
2.1.1	Ch 9, Sec 16, [1.1.2]
2.1.2	Ch 9, Sec 16, [9.2.2], item a)
2.1.3	Ch 9, Sec 16, [9.2.2]
2.2	–
2.3.1	Ch 9, Sec 16, [9.2.3]a)
2.3.2	Ch 9, Sec 16, [9.2.3], item b)
2.3.3	–
2.3.4	Ch 9, Sec 16, [9.2.3], item c)
2.3.5	Ch 9, Sec 16, [9.2.3], item d)

Ref. in IMO Circular MSC.1/ Circ. 1679	Ref. in Part D, Chapter 9, sec 16
2.4.1	Ch 9, Sec 16, [9.2.4], item a)
2.4.2	Ch 9, Sec 16, [9.2.4], item b)
2.4.3	–
2.4.4	Ch 9, Sec 16, [9.2.4], item c)
2.4.5	Ch 9, Sec 16, [9.2.4], item d)
2.4.6	Ch 9, Sec 16, [9.2.4], item e)
2.4.7	Ch 9, Sec 16, [9.2.4], item f)
2.4.8	Ch 9, Sec 16, [9.2.4], item g)
2.5.1	Ch 9, Sec 16, [9.2.5], item a)
2.5.2	Ch 9, Sec 16, [9.2.5], item b)
2.5.3	Ch 9, Sec 16, [9.2.5], item c)
2.5.4	Ch 9, Sec 16, [9.2.5], item d)
2.5.5	Ch 9, Sec 16, [9.2.5], item e)

Appendix 3 Correspondances between Part D, Chapter 9 and the IGC Code

1 General

1.1

1.1.1 Tab 1 to Tab 18 provide correspondances between the provisions of the IGC Code and those of the present Chapter.

Table 1 : Equivalences between Part D, Chapter 9 and Chapter 1 of the IGC Code

Ref. in IGC Code, Chapter 1	Ref. in Part D, Chapter 9
1.1.1	–
1.1.2.1	–
1.1.2.2	–
1.1.2.3	–
1.1.3	–
1.1.4.1	Ch 9, Sec 1, [2.1.1]
1.1.4.2	Ch 9, Sec 1, [2.1.2]
1.1.4.3	Ch 9, Sec 1, [2.1.3]
1.1.4.4	Ch 9, Sec 1, [2.1.4]
1.1.5	Ch 9, Sec 1, [2.1.5]
1.1.6.1	–
1.1.6.2	–
1.1.6.3	–
1.1.6.4	–
1.1.7.1	Ch 9, Sec 1, [2.1.6]
1.1.7.2	Ch 9, Sec 1, [2.1.7]
1.1.8	Ch 9, Sec 1, [2.1.8]
1.1.9	Ch 9, Sec 1, [2.1.9]
1.1.10	Ch 9, Sec 1, [2.1.10]
1.1.11	Ch 9, Sec 1, [2.1.11]
1.1.12	Ch 9, Sec 1, [2.1.12]
1.2	Ch 9, Sec 1, [4]
1.3.1	–
1.3.2	–
1.4.1.1	–
1.4.1.2	–
1.4.1.3	–
1.4.1.4	–
1.4.1.5	–
1.4.2	–
1.4.3.1	–
1.4.3.2	–
1.4.3.3	–
1.4.4.1	–
1.4.4.2	–
1.4.4.3	–
1.4.4.4	–
1.4.5.1	–
1.4.6.1	–
1.4.6.2.1	–
1.4.6.2.2	–
1.4.6.2.3	–
1.4.6.3	–
1.4.6.4	–
1.4.6.5	–
1.4.6.6	–
1.4.6.7	–
1.4.6.8	–
1.4.6.9	–

Table 2 : Equivalences between Part D, Chapter 9 and Chapter 2 of the IGC Code

Ref. in IGC Code, Chapter 2	Ref. in Part D, Chapter 9
2.1.1	Ch 9, Sec 2, [1.1.1]
2.1.2	Ch 9, Sec 2, [1.1.2]
2.1.3	Ch 9, Sec 2, [1.1.3]
2.1.4	Ch 9, Sec 2, [1.1.4]
2.1.5	Ch 9, Sec 2, [1.1.5]
2.2.1	Ch 9, Sec 2, [2.1.1]
2.2.2	Ch 9, Sec 2, [2.1.2]
2.2.3	Ch 9, Sec 2, [2.1.4]
2.2.4	Ch 9, Sec 2, [2.1.6]
2.2.5	Ch 9, Sec 2, [2.1.7]
2.2.6	Ch 9, Sec 2, [2.1.9]
2.2.7	Ch 9, Sec 2, [2.1.10]
2.2.8	Ch 9, Sec 2, [2.1.11]
2.3	Ch 9, Sec 2, [3.1.1]
2.3.2.1	Ch 9, Sec 2, [3.2.1]
2.3.2.2	Ch 9, Sec 2, [3.2.2]
2.4.1	Ch 9, Sec 2, [4.1.1]
2.4.2	Ch 9, Sec 2, [4.1.3]
2.4.3	Ch 9, Sec 2, [4.1.4]
2.4.4	Ch 9, Sec 2, [4.1.5]
2.5.1	Ch 9, Sec 2, [5.1.1]
2.5.2	Ch 9, Sec 2, [5.1.2]
2.5.3	Ch 9, Sec 2, [5.1.3]
2.5.4	Ch 9, Sec 2, [5.1.4]
2.5.5	Ch 9, Sec 2, [5.1.5]
2.5.6	Ch 9, Sec 2, [5.1.6]
2.5.7	Ch 9, Sec 2, [5.1.7]
2.5.8	Ch 9, Sec 2, [5.1.9]
2.6.1	Ch 9, Sec 2, [6.1.2]
2.6.2	Ch 9, Sec 2, [6.1.3]
2.7	Ch 9, Sec 2, [7.1.1]
2.7.1	Ch 9, Sec 2, [7.1.3]
2.7.2	Ch 9, Sec 2, [7.1.4]

Table 3 : Equivalences between Part D, Chapter 9 and Chapter 3 of the IGC Code

Ref. in IGC Code, Chapter 3	Ref. in Part D, Chapter 9
3.1.1	Ch 9, Sec 3, [1.1.1]
3.1.2	Ch 9, Sec 3, [1.1.3]
3.1.3	Ch 9, Sec 3, [1.1.4]
3.1.4	Ch 9, Sec 3, [1.1.6]
3.1.5	Ch 9, Sec 3, [1.1.7]
3.1.6	Ch 9, Sec 3, [1.1.8]
3.1.7	Ch 9, Sec 3, [1.1.9]
3.2.1	Ch 9, Sec 3, [1.2.1]
3.2.2	Ch 9, Sec 3, [1.2.3]
3.2.3	Ch 9, Sec 3, [1.2.4]
3.2.4.1	Ch 9, Sec 3, [1.2.5]
3.2.4.2	Ch 9, Sec 3, [1.2.8]
3.2.4.3	Ch 9, Sec 3, [1.2.9]
3.2.4.4	Ch 9, Sec 3, [1.2.10]
3.2.5	Ch 9, Sec 3, [1.2.11]
3.2.6	Ch 9, Sec 3, [1.2.12]
3.2.7	Ch 9, Sec 3, [1.2.13]
3.3.1	Ch 9, Sec 3, [1.3.2]
3.3.2	Ch 9, Sec 3, [1.3.3]
3.3.3	Ch 9, Sec 3, [1.3.4]
3.3.4	Ch 9, Sec 3, [1.3.5]
3.3.5	Ch 9, Sec 3, [1.3.6]
3.3.6	Ch 9, Sec 3, [1.3.7]
3.3.7	Ch 9, Sec 3, [1.3.8]
3.4.1	Ch 9, Sec 3, [1.4.1]
3.4.2	Ch 9, Sec 3, [1.4.2]
3.4.3	Ch 9, Sec 3, [1.4.3]
3.5.1	Ch 9, Sec 3, [1.5.4]
3.5.2	Ch 9, Sec 3, [1.5.5]
3.5.3.1	Ch 9, Sec 3, [1.5.6], a)
3.5.3.2	Ch 9, Sec 3, [1.5.6], b)
3.5.3.3	Ch 9, Sec 3, [1.5.6], c)
3.5.3.4	Ch 9, Sec 3, [1.5.6], d)
3.5.3.5	Ch 9, Sec 3, [1.5.6], e)
3.5.4	Ch 9, Sec 3, [1.5.7]
3.5.5	Ch 9, Sec 3, [1.5.8]
3.5.6	Ch 9, Sec 3, [1.5.9]
3.6.1	Ch 9, Sec 3, [1.6.1]
3.6.2	Ch 9, Sec 3, [1.6.4]
3.6.3	Ch 9, Sec 3, [1.6.5]
3.6.4	Ch 9, Sec 3, [1.6.6]
3.6.5	Ch 9, Sec 3, [1.6.8]
3.6.6	Ch 9, Sec 3, [1.6.9]
3.6.7	Ch 9, Sec 3, [1.6.10]
3.7.1	Ch 9, Sec 3, [1.7.5]
3.7.2	Ch 9, Sec 3, [1.7.6]
3.7.3	Ch 9, Sec 3, [1.7.7]
3.7.4	Ch 9, Sec 3, [1.7.8]
3.7.5	Ch 9, Sec 3, [1.7.9]
3.8.1	Ch 9, Sec 3, [1.8.1]
3.8.2	Ch 9, Sec 3, [1.8.2]
3.8.3	Ch 9, Sec 3, [1.8.3]
3.8.4.1	Ch 9, Sec 3, [1.8.4], a)
3.8.4.2	Ch 9, Sec 3, [1.8.4], b)
3.8.4.3	Ch 9, Sec 3, [1.8.4], c)
3.8.4.4	Ch 9, Sec 3, [1.8.4], d)
3.8.5	Ch 9, Sec 3, [1.8.5]
3.8.6	Ch 9, Sec 3, [1.8.6]
3.8.7	Ch 9, Sec 3, [1.8.8]

Table 4 : Equivalences between Part D, Chapter 9 and Chapter 4 of the IGC Code

Ref. in IGC Code, Chapter 4	Ref. in Part D, Chapter 9
4.1.1	Ch 9, Sec 4, [1.2.1]
4.1.2	Ch 9, Sec 4, [1.2.2]
4.1.3	Ch 9, Sec 4, [1.2.3]
4.1.4	Ch 9, Sec 4, [1.2.4]
4.1.5	Ch 9, Sec 4, [1.2.8]
4.1.6	Ch 9, Sec 4, [1.2.5]
4.1.7	Ch 9, Sec 4, [1.2.6]
4.1.8	Ch 9, Sec 4, [1.2.7]
4.2	Ch 9, Sec 4, [1.3.1]
4.3.1	Ch 9, Sec 4, [2.1.1]
4.3.2	Ch 9, Sec 4, [2.1.2]
4.3.3	Ch 9, Sec 4, [2.1.3]
4.3.4	Ch 9, Sec 4, [2.1.4]
4.3.5	Ch 9, Sec 4, [2.1.5]
4.3.6	Ch 9, Sec 4, [2.1.6]
4.4.1	Ch 9, Sec 4, [2.2.1]
4.4.2	Ch 9, Sec 4, [2.2.2]
4.4.3	Ch 9, Sec 4, [2.2.3]
4.4.4	Ch 9, Sec 4, [2.2.4]
4.4.5	Ch 9, Sec 4, [2.2.5]
4.5	Ch 9, Sec 4, [2.3.1]
4.6.1	Ch 9, Sec 4, [2.4.2]
4.6.2	Ch 9, Sec 4, [2.4.3]
4.7.1	Ch 9, Sec 4, [2.5.1]
4.18.1.6	Ch 9, Sec 4, [4.5.1], f)
4.18.2.1	Ch 9, Sec 4, [4.6.1]
4.18.2.2	Ch 9, Sec 4, [4.6.2]
4.18.2.3	Ch 9, Sec 4, [4.6.3]
4.18.2.4.1	Ch 9, Sec 4, [4.6.4], a)
4.18.2.4.2	Ch 9, Sec 4, [4.6.4], b)
4.18.2.5	Ch 9, Sec 4, [4.6.5]
4.18.2.6.1	Ch 9, Sec 4, [4.6.6], a)
4.18.2.6.2	Ch 9, Sec 4, [4.6.6], b)
4.18.2.6.3	Ch 9, Sec 4, [4.6.6], c)
4.18.2.6.4	Ch 9, Sec 4, [4.6.6], d)
4.18.2.7	Ch 9, Sec 4, [4.6.7]
4.18.2.8	Ch 9, Sec 4, [4.6.8]
4.18.2.9	Ch 9, Sec 4, [4.6.9]
4.18.3.1	Ch 9, Sec 4, [4.7.1]
4.18.3.2	Ch 9, Sec 4, [4.7.2]
4.18.3.3	Ch 9, Sec 4, [4.7.3]
4.19	Ch 9, Sec 4, [5.1.1]
4.19.1.1	Ch 9, Sec 4, [5.2.1]
4.19.1.2	Ch 9, Sec 4, [5.2.2]
4.19.1.4	Ch 9, Sec 4, [5.2.3]
4.19.1.5	Ch 9, Sec 4, [5.2.5]
4.19.1.6	Ch 9, Sec 4, [5.2.6]
4.19.2.1	Ch 9, Sec 4, [5.3.1]
4.22.6	Ch 9, Sec 4, [9.6.1]
4.22.7	Ch 9, Sec 4, [9.7.1]
4.23.1.1	Ch 9, Sec 4, [10.1.1]
4.23.1.2	Ch 9, Sec 4, [10.2.1]
4.23.1.3	Ch 9, Sec 4, [10.1.3]
4.23.2.1.1	Ch 9, Sec 4, [10.2.1], a)
4.23.2.1.2	Ch 9, Sec 4, [10.2.1], b)
4.23.2.1.3	Ch 9, Sec 4, [10.2.1], c)
4.23.2.2	Ch 9, Sec 4, [10.2.2]
4.23.2.3	Ch 9, Sec 4, [10.2.3]
4.23.2.4	Ch 9, Sec 4, [10.2.4]
4.23.2.5	Ch 9, Sec 4, [10.2.5]
4.23.3.1	Ch 9, Sec 4, [10.3.2]
4.23.3.2	Ch 9, Sec 4, [10.3.3]
4.23.4	Ch 9, Sec 4, [10.4.1]
4.23.5.1	Ch 9, Sec 4, [10.5.1]
4.23.5.2	Ch 9, Sec 4, [10.5.2]
4.23.6.1	Ch 9, Sec 4, [10.6.1]
4.23.6.2	Ch 9, Sec 4, [10.6.2]
4.23.6.3	Ch 9, Sec 4, [10.6.3]
4.23.6.4	Ch 9, Sec 4, [10.6.4]
4.23.6.5	Ch 9, Sec 4, [10.6.5]
4.23.6.6	Ch 9, Sec 4, [10.6.6]
4.23.6.7	Ch 9, Sec 4, [10.6.7]

Ref. in IGC Code, Chapter 4	Ref. in Part D, Chapter 9
4.7.2	Ch 9, Sec 4, [2.5.2]
4.7.3	Ch 9, Sec 4, [2.5.3]
4.8.1	Ch 9, Sec 4, [7.1.1]
4.8.2	Ch 9, Sec 4, [7.4.8], a)
4.8.3	Ch 9, Sec 4, [7.1.2]
4.9	Ch 9, Sec 4, [2.7.1]
4.10.1	Ch 9, Sec 4, [2.8.1]
4.10.2	Ch 9, Sec 4, [2.8.2]
4.11	Ch 9, Sec 4, [3.1.1]
4.12.1	Ch 9, Sec 4, [3.2.1]
4.12.2	Ch 9, Sec 4, [3.2.2]
4.13.1	Ch 9, Sec 4, [3.3.1]
4.13.2	Ch 9, Sec 4, [3.3.2]
4.13.3	Ch 9, Sec 4, [3.3.3]
4.13.4	Ch 9, Sec 4, [3.3.4]
4.13.5	Ch 9, Sec 4, [3.3.5]
4.13.6	Ch 9, Sec 4, [3.3.6]
4.13.7	Ch 9, Sec 4, [3.3.7]
4.13.8	Ch 9, Sec 4, [3.3.8]
4.13.9	Ch 9, Sec 4, [3.3.9]
4.13.10	Ch 9, Sec 4, [3.3.10]
4.14	Ch 9, Sec 4, [3.4.1]
4.14.1.1	Ch 9, Sec 4, [3.4.2], a)
4.14.1.2	Ch 9, Sec 4, [3.4.2], b)
4.14.1.3	Ch 9, Sec 4, [3.4.2], c)
4.14.1.4	Ch 9, Sec 4, [3.4.2], d)
4.14.1.5	Ch 9, Sec 4, [3.4.2], e)
4.14.2	Ch 9, Sec 4, [3.4.3]
4.14.3	Ch 9, Sec 4, [3.4.4]
4.14.4	Ch 9, Sec 4, [3.4.6]
4.14.5	Ch 9, Sec 4, [3.4.7]
4.15	Ch 9, Sec 4, [3.5.1]
4.15.1	Ch 9, Sec 4, [3.5.2]
4.15.2	Ch 9, Sec 4, [3.5.3]
4.16.1	Ch 9, Sec 4, [4.1.1]
4.16.2	Ch 9, Sec 4, [4.1.2]
4.16.3	Ch 9, Sec 4, [4.1.3]
4.17.1.1	Ch 9, Sec 4, [4.2.1], a)
4.17.1.2	Ch 9, Sec 4, [4.2.1], b)
4.17.1.3	Ch 9, Sec 4, [4.2.1], c)
4.17.2.1	Ch 9, Sec 4, [4.2.2], a)
4.17.2.2	Ch 9, Sec 4, [4.2.2], b)
4.17.3	Ch 9, Sec 4, [4.2.3]
4.18	Ch 9, Sec 4, [4.4.1]
4.18.1	Ch 9, Sec 4, [4.5.1]
4.18.1.1	Ch 9, Sec 4, [4.5.1], a)
4.18.1.2	Ch 9, Sec 4, [4.5.1], b)
4.18.1.3	Ch 9, Sec 4, [4.5.1], c)
4.18.1.4	Ch 9, Sec 4, [4.5.1], d)
4.18.1.5	Ch 9, Sec 4, [4.5.1], e)

Ref. in IGC Code, Chapter 4	Ref. in Part D, Chapter 9
4.19.2.2	Ch 9, Sec 4, [5.3.2]
4.19.2.3	Ch 9, Sec 4, [5.3.3]
4.19.2.4	Ch 9, Sec 4, [5.3.4]
4.19.2.5.1	Ch 9, Sec 4, [5.3.5]
4.19.2.5.2	Ch 9, Sec 4, [5.3.6]
4.19.2.6	Ch 9, Sec 4, [5.3.7]
4.19.3.1	Ch 9, Sec 4, [5.4.1]
4.19.3.2	Ch 9, Sec 4, [5.4.2]
4.19.3.3	Ch 9, Sec 4, [5.4.3]
4.19.3.4	Ch 9, Sec 4, [5.4.4]
4.19.3.5	Ch 9, Sec 4, [5.4.5]
4.19.3.6	Ch 9, Sec 4, [5.4.6]
4.19.3.7	Ch 9, Sec 4, [5.4.7]
4.20	Ch 9, Sec 4, [6.1.1]
4.20.1.1	Ch 9, Sec 4, [6.2.1]
4.20.1.2	Ch 9, Sec 4, [6.2.2]
4.20.1.3	Ch 9, Sec 4, [6.2.3]
4.20.2	Ch 9, Sec 4, [6.3.1]
4.20.3.1	Ch 9, Sec 4, [6.4.1]
4.20.3.2	Ch 9, Sec 4, [6.4.2]
4.20.3.3	Ch 9, Sec 4, [6.4.3]
4.20.3.4	Ch 9, Sec 4, [6.4.5]
4.20.3.5	Ch 9, Sec 4, [6.4.6]
4.20.3.6	Ch 9, Sec 4, [6.4.7]
4.20.3.7	Ch 9, Sec 4, [6.4.8]
4.21.1.1	Ch 9, Sec 4, [8.1.1]
4.21.1.2	Ch 9, Sec 4, [8.1.2]
4.21.2.1	Ch 9, Sec 4, [8.2.1]
4.21.2.2	Ch 9, Sec 4, [7.4.1]
4.21.2.3	Ch 9, Sec 4, [7.4.2]
4.21.3.1	Ch 9, Sec 4, [8.3.1]
4.21.3.2	Ch 9, Sec 4, [8.3.2]
4.21.3.3	Ch 9, Sec 4, [8.3.6]
4.21.4.1	Ch 9, Sec 4, [8.4.1]
4.21.4.2	Ch 9, Sec 4, [8.4.2]
4.21.5	Ch 9, Sec 4, [8.5.1]
4.22.1.1	Ch 9, Sec 4, [9.1.1]
4.22.1.2	Ch 9, Sec 4, [9.1.2]
4.22.2.1	Ch 9, Sec 4, [9.2.1]
4.22.2.2	Ch 9, Sec 4, [9.2.2]
4.22.2.3	Ch 9, Sec 4, [9.2.5]
4.22.3.1.1	Ch 9, Sec 4, [9.3.2], a)
4.22.3.1.2	Ch 9, Sec 4, [9.3.2], b)
4.22.3.1.3	Ch 9, Sec 4, [9.3.1]
4.22.3.2	Ch 9, Sec 4, [9.3.3]
4.22.4.1	Ch 9, Sec 4, [9.4.1]
4.22.4.2	Ch 9, Sec 4, [9.4.2]
4.22.4.3	Ch 9, Sec 4, [9.4.3]
4.22.5.1	Ch 9, Sec 4, [9.5.1]
4.22.5.2	Ch 9, Sec 4, [9.5.2]

Ref. in IGC Code, Chapter 4	Ref. in Part D, Chapter 9
4.23.7	Ch 9, Sec 4, [10.7.1]
4.24.1.1	Ch 9, Sec 4, [11.1.1]
4.24.1.2	Ch 9, Sec 4, [11.1.2]
4.24.1.3	Ch 9, Sec 4, [11.1.3]
4.24.1.4	Ch 9, Sec 4, [11.1.4]
4.24.1.5	Ch 9, Sec 4, [11.1.5]
4.24.1.6	Ch 9, Sec 4, [11.1.6]
4.24.1.7	Ch 9, Sec 4, [11.1.7]
4.24.2.1	Ch 9, Sec 4, [11.2.1]
4.24.2.2	Ch 9, Sec 4, [11.2.2]
4.24.3	Ch 9, Sec 4, [11.3.1]
4.24.4.1	Ch 9, Sec 4, [11.4.1]
4.24.4.2	Ch 9, Sec 4, [11.4.2]
4.24.4.3	Ch 9, Sec 4, [11.4.3]
4.24.5.1	Ch 9, Sec 4, [11.6.1]
4.24.5.2	Ch 9, Sec 4, [11.6.2]
4.24.5.3	Ch 9, Sec 4, [11.6.3]
4.24.6.1	Ch 9, Sec 4, [11.7.1]
4.24.6.2	Ch 9, Sec 4, [11.7.2]
4.24.6.3	Ch 9, Sec 4, [11.7.3]
4.24.6.4	Ch 9, Sec 4, [11.7.4]
4.24.6.5	Ch 9, Sec 4, [11.7.5]
4.24.7.1	Ch 9, Sec 4, [11.8.1]
4.24.7.2	Ch 9, Sec 4, [11.8.2]
4.24.8.1	Ch 9, Sec 4, [11.9.1]
4.24.8.2	Ch 9, Sec 4, [11.9.2]
4.24.9.1	Ch 9, Sec 4, [11.10.1]
4.24.9.2	Ch 9, Sec 4, [11.10.2]
4.24.9.3	Ch 9, Sec 4, [11.10.3]
4.25.1	Ch 9, Sec 4, [12.1.1]
4.25.2	Ch 9, Sec 4, [12.2.1]
4.25.3.1	Ch 9, Sec 4, [12.3.1]
4.25.3.2	Ch 9, Sec 4, [12.3.2]
4.25.4.1	Ch 9, Sec 4, [12.4.1]
4.25.4.2	Ch 9, Sec 4, [12.4.2]
4.25.5	Ch 9, Sec 4, [12.5.1]
4.26.1.1	Ch 9, Sec 4, [13.1.1]
4.26.1.2	Ch 9, Sec 4, [13.1.2]
4.26.1.3	Ch 9, Sec 4, [13.1.3]
4.26.1.4	Ch 9, Sec 4, [13.1.4]
4.27.1	Ch 9, Sec 4, [14.1.1]
4.27.2	Ch 9, Sec 4, [14.1.2]
4.27.3	Ch 9, Sec 4, [14.1.3]
4.27.4	Ch 9, Sec 4, [14.1.4]
4.28.1.1	Ch 9, App 1, [1.1.1]
4.28.1.2	Ch 9, App 1, [1.1.2]
4.28.1.3	Ch 9, App 1, [1.1.2]
4.28.2.1	Ch 9, App 1, [1.2.1]
4.28.3	Ch 9, Sec 4, [4.3.1]

Table 5 : Equivalences between Part D, Chapter 9 and Chapter 5 of the IGC Code

Ref. in IGC Code, Chapter 5	Ref. in Part D, Chapter 9
5.1.1	Ch 9, Sec 5, [1.1.1]
5.1.2	Ch 9, Sec 5, [1.1.3]
5.1.3	Ch 9, Sec 5, [1.1.4]
5.2.1	Ch 9, Sec 5, [2.1.3]
5.2.2.1	Ch 9, Sec 5, [2.2.1]
5.2.2.2	Ch 9, Sec 5, [2.2.2]
5.2.2.3	Ch 9, Sec 5, [2.2.3]
5.2.2.4	Ch 9, Sec 5, [2.2.4]
5.3.1	Ch 9, Sec 5, [3.1.1]
5.3.2.1	Ch 9, Sec 5, [3.2.1]
5.3.2.2	Ch 9, Sec 5, [3.2.2]
5.3.3	Ch 9, Sec 5, [3.3.1]
5.3.4	Ch 9, Sec 5, [3.4.1]
5.4.1	Ch 9, Sec 5, [4.1.1]
5.4.2	Ch 9, Sec 5, [4.1.2]
5.4.3	Ch 9, Sec 5, [4.1.3]
5.4.4	Ch 9, Sec 5, [4.1.4]
5.5.1.1	Ch 9, Sec 5, [5.1.1]
5.5.1.2	Ch 9, Sec 5, [5.1.1]
5.5.2.1	Ch 9, Sec 5, [5.1.2]
5.5.2.2	Ch 9, Sec 5, [5.1.2]
5.5.3.1	Ch 9, Sec 5, [5.2.1]
5.5.3.2	Ch 9, Sec 5, [5.2.2]
5.5.4	Ch 9, Sec 5, [5.3.1]
5.5.5	Ch 9, Sec 5, [5.3.2]
5.5.6	Ch 9, Sec 5, [5.3.3]
5.5.7	Ch 9, Sec 5, [5.3.4]
5.6.1	Ch 9, Sec 5, [6.1.2]
5.6.2	Ch 9, Sec 5, [6.1.3]
5.6.3	Ch 9, Sec 5, [6.2.1]
5.6.4	Ch 9, Sec 5, [6.3.1]
5.6.5.1	Ch 9, Sec 5, [6.4.1]
5.6.5.2	Ch 9, Sec 5, [6.4.2]
5.6.5.3	Ch 9, Sec 5, [6.4.3]
5.6.5.4	Ch 9, Sec 5, [6.4.4]
5.6.5.5	Ch 9, Sec 5, [6.4.5]
5.6.5.6	Ch 9, Sec 5, [6.4.6]
5.6.6	Ch 9, Sec 5, [6.5.1]
5.7.1	Ch 9, Sec 5, [7.1.1]
5.7.2	Ch 9, Sec 5, [7.2.1]
5.7.3	Ch 9, Sec 5, [7.3.1]
5.7.4	Ch 9, Sec 5, [7.4.1]
5.8.1	Ch 9, Sec 5, [8.1.1]
5.8.2	Ch 9, Sec 5, [8.2.1]
5.8.3.1	Ch 9, Sec 5, [8.3.1]
5.8.3.2	Ch 9, Sec 5, [8.3.2]
5.8.4	Ch 9, Sec 5, [8.4.1]
5.8.5	Ch 9, Sec 5, [8.5.1]
5.9.1	Ch 9, Sec 5, [9.1.1]
5.9.2	Ch 9, Sec 5, [9.2.1]
5.9.3	Ch 9, Sec 5, [9.3.1]
5.10.1	Ch 9, Sec 5, [10.1.1]
5.10.2	Ch 9, Sec 5, [10.2.1]
5.10.3	Ch 9, Sec 5, [10.3.1]
5.11.1	Ch 9, Sec 5, [11.1.1]
5.11.2.1	Ch 9, Sec 5, [11.2.1]
5.11.2.2	Ch 9, Sec 5, [11.2.2]
5.11.2.3	Ch 9, Sec 5, [11.2.4]
5.11.2.4	Ch 9, Sec 5, [11.2.5]
5.11.3	Ch 9, Sec 5, [11.3.1]
5.11.4	Ch 9, Sec 5, [11.4.1]
5.11.5	Ch 9, Sec 5, [11.5.1]
5.11.6.1	Ch 9, Sec 5, [11.6.1]
5.11.6.2	Ch 9, Sec 5, [11.6.2]
5.11.6.3	Ch 9, Sec 5, [11.6.4]
5.11.6.4	Ch 9, Sec 5, [11.6.5]
5.11.7.1	Ch 9, Sec 5, [11.7.3]
5.11.7.2	Ch 9, Sec 5, [11.7.4]
5.11.7.3	Ch 9, Sec 5, [11.7.5]
5.12.1	Ch 9, Sec 5, [12.1.1]
5.12.2	Ch 9, Sec 5, [12.1.2]
5.12.3.1	Ch 9, Sec 5, [12.1.4]
5.12.3.2	Ch 9, Sec 5, [12.1.4]
5.12.4	Ch 9, Sec 5, [12.1.5]
5.13.1.1	Ch 9, Sec 5, [13.3.1]
5.13.1.2	Ch 9, Sec 5, [13.4.1]
5.13.2.1	Ch 9, Sec 5, [13.5.1]
5.13.2.2	Ch 9, Sec 5, [13.5.2]
5.13.2.3	Ch 9, Sec 5, [13.5.3]
5.13.2.4	Ch 9, Sec 5, [13.5.4]
5.13.2.5	Ch 9, Sec 5, [13.5.5]
5.13.3	Ch 9, Sec 5, [13.6.1]

Table 6 : Equivalences between Part D, Chapter 9 and Chapter 6 of the IGC Code

Ref. in IGC Code, Chapter 6	Ref. in Part D, Chapter 9
6.1.1	Ch 9, Sec 6, [1.1.1]
6.1.2	Ch 9, Sec 6, [1.1.2]
6.1.3	Ch 9, Sec 6, [1.1.3]
6.1.4	Ch 9, Sec 6, [1.1.4]
6.1.5	Ch 9, Sec 6, [1.1.5]
6.1.6	Ch 9, Sec 6, [1.1.6]
6.2.1	Ch 9, Sec 6, [2.1.1]
6.2.2	Ch 9, Sec 6, [2.1.2]
6.2.3	Ch 9, Sec 6, [2.1.3]
6.3.1.1	Ch 9, Sec 6, [3.1.1]
6.3.1.2	Ch 9, Sec 6, [3.1.2]
6.3.2.1	Ch 9, Sec 6, [3.2.1]
6.3.2.2	Ch 9, Sec 6, [3.2.2]
6.3.2.3	Ch 9, Sec 6, [3.2.3]
6.3.2.4	Ch 9, Sec 6, [3.2.4]
6.3.3.1	Ch 9, Sec 6, [3.3.1]
6.3.3.2	Ch 9, Sec 6, [3.3.2]
6.3.4	Ch 9, Sec 6, [3.4.1]
6.4.1.1	Ch 9, Sec 6, [4.1.4]
6.5.1.1	Ch 9, Sec 6, [5.1.1]
6.5.2.1	Ch 9, Sec 6, [5.2.1]
6.5.3.1	Ch 9, Sec 6, [5.3.1]
6.5.3.2	Ch 9, Sec 6, [5.3.2]
6.5.3.3	Ch 9, Sec 6, [5.3.3]
6.5.3.4	Ch 9, Sec 6, [5.3.4]
6.5.3.5	Ch 9, Sec 6, [5.3.5]
6.5.3.6	Ch 9, Sec 6, [5.3.6]
6.5.4	Ch 9, Sec 6, [5.4.1]
6.5.5.1	Ch 9, Sec 6, [5.5.1]
6.5.5.2	Ch 9, Sec 6, [5.5.2]
6.5.5.3	Ch 9, Sec 6, [5.5.3]
6.5.5.4	Ch 9, Sec 6, [5.5.4]
6.5.5.5	Ch 9, Sec 6, [5.5.5]
6.5.6.1	Ch 9, Sec 6, [5.6.3]
6.5.6.2	Ch 9, Sec 6, [5.6.4]
6.5.6.3	Ch 9, Sec 6, [5.6.5]
6.5.6.4	Ch 9, Sec 6, [5.6.6]
6.5.6.5	Ch 9, Sec 6, [5.6.7]
6.5.6.6	Ch 9, Sec 6, [5.6.8]
6.5.6.7	Ch 9, Sec 6, [5.6.9]
6.5.6.8	Ch 9, Sec 6, [5.6.10]
6.6.1.1	Ch 9, Sec 6, [6.1.1]
6.6.2.1	Ch 9, Sec 6, [6.2.1]
6.6.2.2	Ch 9, Sec 6, [6.2.2]
6.6.2.3	Ch 9, Sec 6, [6.2.3]
6.6.3	Ch 9, Sec 6, [6.3.1]
6.6.4	Ch 9, Sec 6, [6.4.1]
6.6.5	Ch 9, Sec 6, [6.5.1]
6.7.1	Ch 9, Sec 6, [7.1.1]

Table 7 : Equivalences between Part D, Chapter 9 and Chapter 7 of the IGC Code

Ref. in IGC Code, Chapter 7	Ref. in Part D, Chapter 9
7.1.1	Ch 9, Sec 7, [1.1.1]
7.1.2	Ch 9, Sec 7, [1.1.2]
7.1.3	Ch 9, Sec 7, [1.1.3]
7.2	Ch 9, Sec 7, [2.1.1]
7.3.1	Ch 9, Sec 7, [3.1.3]
7.3.2	Ch 9, Sec 7, [3.1.4]
7.4.1	Ch 9, Sec 7, [4.1.2]
7.4.2	Ch 9, Sec 7, [4.2.1]
7.4.3	Ch 9, Sec 7, [4.3.1]
7.4.4.1	Ch 9, Sec 7, [4.4.1]
7.4.4.2	Ch 9, Sec 7, [4.4.2]
7.4.4.3	Ch 9, Sec 7, [4.4.3]
7.4.4.4	Ch 9, Sec 7, [4.4.4]
7.4.4.5	Ch 9, Sec 7, [4.4.5]
7.5	Ch 9, Sec 7, [5.1.1]
7.6	Ch 9, Sec 7, [6.1.1]
7.7	Ch 9, Sec 7, [7.1.1]
7.8.1	Ch 9, Sec 7, [8.1.1], a)
7.8.2	Ch 9, Sec 7, [8.1.1], b)
7.8.3	Ch 9, Sec 7, [8.1.1], c)
7.8.4	Ch 9, Sec 7, [8.1.1], d)

Table 8 : Equivalences between Part D, Chapter 9 and Chapter 8 of the IGC Code

Ref. in IGC Code, Chapter 8	Ref. in Part D, Chapter 9
8.1	Ch 9, Sec 8, [1.1.1]
8.2.1	Ch 9, Sec 8, [2.1.1]
8.2.2	Ch 9, Sec 8, [2.1.2]
8.2.3	Ch 9, Sec 8, [2.1.5]
8.2.4	Ch 9, Sec 8, [2.1.6]
8.2.5.1	Ch 9, Sec 8, [2.1.7], a)
8.2.5.2	Ch 9, Sec 8, [2.1.7], b)
8.2.6	Ch 9, Sec 8, [2.1.8]
8.2.7	Ch 9, Sec 8, [2.1.9]
8.2.8	Ch 9, Sec 8, [2.1.10]
8.2.9	Ch 9, Sec 8, [2.1.11]
8.2.10	Ch 9, Sec 8, [2.1.12]
8.2.11.1	Ch 9, Sec 8, [2.1.14]
8.2.11.2	Ch 9, Sec 8, [2.1.14]
8.2.12	Ch 9, Sec 8, [2.1.15]
8.2.13	Ch 9, Sec 8, [2.1.6]
8.2.14	Ch 9, Sec 8, [2.1.17]
8.2.15	Ch 9, Sec 8, [2.1.18]
8.2.16	Ch 9, Sec 8, [2.1.19]
8.2.17	Ch 9, Sec 8, [2.1.20]
8.2.18	Ch 9, Sec 8, [2.1.21]
8.3.1	Ch 9, Sec 8, [3.1.1]
8.3.2	Ch 9, Sec 8, [3.1.2]
8.3.3	Ch 9, Sec 8, [3.1.3]
8.4.1	Ch 9, Sec 8, [4.1.1]
8.4.1.1	Ch 9, Sec 8, [4.1.1], a)
8.4.1.2	Ch 9, Sec 8, [4.1.1], b)
8.4.1.3	Ch 9, Sec 8, [4.1.1], b)
8.4.2	Ch 9, Sec 8, [4.2.1]
8.4.3.1	Ch 9, Sec 8, [4.3.1]
8.4.3.2	Ch 9, Sec 8, [4.3.2]
8.4.3.3	Ch 9, Sec 8, [4.3.3]
8.4.4.1	Ch 9, Sec 8, [4.4.1]
8.4.4.2	Ch 9, Sec 8, [4.4.2]
8.4.5	Ch 9, Sec 8, [4.5.1]

Table 9 : Equivalences between Part D, Chapter 9 and Chapter 9 of the IGC Code

Ref. in IGC Code, Chapter 9	Ref. in Part D, Chapter 9
9.1.1	Ch 9, Sec 9, [1.1.1]
9.1.2	Ch 9, Sec 9, [1.1.2]
9.1.3	Ch 9, Sec 9, [1.1.3]
9.1.4	Ch 9, Sec 9, [1.1.4]
9.1.5	Ch 9, Sec 9, [1.1.5]
9.2.1	Ch 9, Sec 9, [1.2.1]
9.2.2	Ch 9, Sec 9, [1.2.2]
9.2.3	Ch 9, Sec 9, [1.2.3]
9.3	Ch 9, Sec 9, [1.3.1]
9.4.1	Ch 9, Sec 9, [1.4.1]
9.4.2	Ch 9, Sec 9, [1.4.3]
9.4.3	Ch 9, Sec 9, [1.4.4]
9.4.4	Ch 9, Sec 9, [1.4.5]
9.4.5	Ch 9, Sec 9, [1.4.6]
9.4.6	Ch 9, Sec 9, [1.4.7]
9.5.1	Ch 9, Sec 9, [1.5.3]
9.5.2	Ch 9, Sec 9, [1.5.4]
9.5.3	Ch 9, Sec 9, [1.5.5]
9.5.4	Ch 9, Sec 9, [1.5.6]

Table 10 : Equivalences between Part D, Chapter 9 and Chapter 10 of the IGC Code

Ref. in IGC Code, Chapter 10	Ref. in Part D, Chapter 9
10.1	Ch 9, Sec 10, [1.3.1]
10.1.1	Ch 9, Sec 10, [1.3.2]
10.1.1.1	Ch 9, Sec 10, [1.3.3]
10.1.1.2	Ch 9, Sec 10, [1.3.4]
10.1.1.3	Ch 9, Sec 10, [1.3.5]
10.1.2	Ch 9, Sec 10, [1.3.6]
10.2.1	Ch 9, Sec 10, [1.4.1]
10.2.2	Ch 9, Sec 10, [1.4.3]
10.2.3	Ch 9, Sec 10, [1.4.4]
10.2.4	Ch 9, Sec 10, [1.4.5]
10.2.5	Ch 9, Sec 10, [1.4.6]
10.2.6	Ch 9, Sec 10, [1.4.7]
10.2.7	Ch 9, Sec 10, [1.4.8]
10.2.8	Ch 9, Sec 10, [1.4.9]
10.2.9	Ch 9, Sec 10, [1.4.10]

Table 11 : Equivalences between Part D, Chapter 9 and Chapter 11 of the IGC Code

Ref. in IGC Code, Chapter 11	Ref. in Part D, Chapter 9
11.1.1	Ch 9, Sec 11, [1.1.1]
11.1.2	Ch 9, Sec 11, [1.1.2]
11.1.3	Ch 9, Sec 11, [1.1.4]
11.1.4	Ch 9, Sec 11, [1.1.5]
11.2.1	Ch 9, Sec 11, [1.2.1]
11.2.2	Ch 9, Sec 11, [1.2.2]
11.2.3	Ch 9, Sec 11, [1.2.3]
11.2.4	Ch 9, Sec 11, [1.2.4]
11.2.5	Ch 9, Sec 11, [1.2.5]
11.3.1	Ch 9, Sec 11, [1.3.2]
11.3.2.1	Ch 9, Sec 11, [1.3.3]
11.3.2.2	Ch 9, Sec 11, [1.3.4]
11.3.3	Ch 9, Sec 11, [1.3.5]
11.3.4	Ch 9, Sec 11, [1.3.6]
11.3.5	Ch 9, Sec 11, [1.3.7]
11.3.6	Ch 9, Sec 11, [1.3.8]
11.3.7	Ch 9, Sec 11, [1.3.9]
11.3.8	Ch 9, Sec 11, [1.3.10]
11.4.1	Ch 9, Sec 11, [1.4.1]
11.4.2	Ch 9, Sec 11, [1.4.2]
11.4.3	Ch 9, Sec 11, [1.4.3]
11.4.4	Ch 9, Sec 11, [1.4.5]
11.4.5	Ch 9, Sec 11, [1.4.6]
11.4.6	Ch 9, Sec 11, [1.4.7]
11.4.7	Ch 9, Sec 11, [1.4.8]
11.4.8	Ch 9, Sec 11, [1.4.9]
11.5.1	Ch 9, Sec 11, [1.5.2]
11.5.2	Ch 9, Sec 11, [1.5.4]
11.5.3	Ch 9, Sec 11, [1.5.5]
11.6.1	Ch 9, Sec 11, [1.6.1]
11.6.2	Ch 9, Sec 11, [1.6.2]
11.6.3	Ch 9, Sec 11, [1.6.3]

Table 12 : Equivalences between Part D, Chapter 9 and Chapter 12 of the IGC Code

Ref. in IGC Code, Chapter 12	Ref. in Part D, Chapter 9
Scope	Ch 9, Sec 12, [1.1.1]
12.1.1	Ch 9, Sec 12, [1.2.1]
12.1.2	Ch 9, Sec 12, [1.2.2]
12.1.3	Ch 9, Sec 12, [1.2.3]
12.1.4	Ch 9, Sec 12, [1.2.4]
12.1.5	Ch 9, Sec 12, [1.2.5]
12.1.6	Ch 9, Sec 12, [1.2.11]
12.1.7	Ch 9, Sec 12, [1.2.12]
12.1.8	Ch 9, Sec 12, [1.2.14]
12.1.9	Ch 9, Sec 12, [1.2.15]
12.1.10	Ch 9, Sec 12, [1.2.16]
12.2.1	Ch 9, Sec 12, [1.3.2]
12.2.2	Ch 9, Sec 12, [1.3.3]
12.2.3	Ch 9, Sec 12, [1.3.4]

Table 13 : Equivalences between Part D, Chapter 9 and Chapter 13 of the IGC Code

Ref. in IGC Code, Chapter 13	Ref. in Part D, Chapter 9
13.1.1	Ch 9, Sec 13, [1.1.3]
13.1.2	Ch 9, Sec 13, [1.1.4]
13.1.3	Ch 9, Sec 13, [1.1.6]
13.2.1	Ch 9, Sec 13, [2.1.1]
13.2.2	Ch 9, Sec 13, [2.1.2]
13.2.3	Ch 9, Sec 13, [2.1.4]
13.3.1	Ch 9, Sec 13, [3.1.1]
13.3.2	Ch 9, Sec 13, [3.1.3]
13.3.3	Ch 9, Sec 13, [3.1.4]
13.3.4	Ch 9, Sec 13, [3.1.5]
13.3.5	Ch 9, Sec 13, [3.1.6]
13.3.6	Ch 9, Sec 13, [3.1.7]
13.3.7	Ch 9, Sec 13, [3.1.8]
13.4.1	Ch 9, Sec 13, [4.1.1]
13.4.2	Ch 9, Sec 13, [4.1.2]
13.4.3	Ch 9, Sec 13, [4.1.3]
13.4.4	Ch 9, Sec 13, [4.1.4]
13.4.5	Ch 9, Sec 13, [4.1.5]
13.4.6	Ch 9, Sec 13, [4.1.6]
13.4.7	Ch 9, Sec 13, [4.1.7]
13.5.1	Ch 9, Sec 13, [5.1.1]
13.5.2	Ch 9, Sec 13, [5.1.2]
13.5.3	Ch 9, Sec 13, [5.1.3]
13.6.1	Ch 9, Sec 13, [6.1.1]
13.6.2	Ch 9, Sec 13, [6.1.2]
13.6.3	Ch 9, Sec 13, [6.1.3]
13.6.4	Ch 9, Sec 13, [6.1.4]
13.6.5	Ch 9, Sec 13, [6.1.5]
13.6.6	Ch 9, Sec 13, [6.1.6]
13.6.7	Ch 9, Sec 13, [6.1.7]
13.6.8	Ch 9, Sec 13, [6.1.8]
13.6.9	Ch 9, Sec 13, [6.1.9]
13.6.10	Ch 9, Sec 13, [6.1.10]
13.6.11	Ch 9, Sec 13, [6.1.11]
13.6.12	Ch 9, Sec 13, [6.1.12]
13.6.13	Ch 9, Sec 13, [6.1.13]
13.6.14	Ch 9, Sec 13, [6.1.14]
13.6.15	Ch 9, Sec 13, [6.1.15]
13.6.16	Ch 9, Sec 13, [6.1.16]
13.6.17	Ch 9, Sec 13, [6.1.17]
13.6.18	Ch 9, Sec 13, [6.1.18]
13.6.19	Ch 9, Sec 13, [6.1.19]
13.6.20	Ch 9, Sec 13, [6.1.20]
13.7.1	Ch 9, Sec 13, [7.1.1]
13.7.2.1	Ch 9, Sec 13, [7.2.1]
13.7.2.2	Ch 9, Sec 13, [7.2.2]
13.7.2.3	Ch 9, Sec 13, [7.2.4]
13.7.2.4	Ch 9, Sec 13, [7.2.5]
13.8.1	Ch 9, Sec 13, [8.1.1]
13.8.2	Ch 9, Sec 13, [8.1.2]
13.8.3	Ch 9, Sec 13, [8.1.3]
13.8.4	Ch 9, Sec 13, [8.1.4]
13.8.5	Ch 9, Sec 13, [8.1.5]
13.8.6	Ch 9, Sec 13, [8.1.6]
13.8.7	Ch 9, Sec 13, [8.1.7]
13.8.8	Ch 9, Sec 13, [8.1.8]
13.8.9	Ch 9, Sec 13, [8.1.9]
13.8.10	Ch 9, Sec 13, [8.1.10]
13.9.1	Ch 9, Sec 13, [9.1.1]
13.9.2	Ch 9, Sec 13, [9.1.2]
13.9.3	Ch 9, Sec 13, [9.1.3]
13.9.4	Ch 9, Sec 13, [9.1.4]
13.9.5	Ch 9, Sec 13, [9.1.5]
13.9.6	Ch 9, Sec 13, [9.1.6]
13.9.7	Ch 9, Sec 13, [9.1.7]

Table 14 : Equivalences between Part D, Chapter 9 and Chapter 14 of the IGC Code

Ref. in IGC Code, Chapter 14	Ref. in Part D, Chapter 9
14.1.1	Ch 9, Sec 14, [1.1.1]
14.1.2	Ch 9, Sec 14, [1.1.2]
14.1.3	Ch 9, Sec 14, [1.1.3]
14.2.1	Ch 9, Sec 14, [1.2.1]
14.2.2	Ch 9, Sec 14, [1.2.2]
14.3.1	Ch 9, Sec 14, [1.3.1]
14.3.2	Ch 9, Sec 14, [1.3.2]
14.3.3	Ch 9, Sec 14, [1.3.3]
14.4.1	Ch 9, Sec 14, [1.4.1]
14.4.2	Ch 9, Sec 14, [1.4.2]
14.4.3	Ch 9, Sec 14, [1.4.3]
14.4.4	Ch 9, Sec 14, [1.4.5]

Table 15 : Equivalences between Part D, Chapter 9 and Chapter 15 of the IGC Code

Ref. in IGC Code, Chapter 15	Ref. in Part D, Chapter 9
15.1.1	Ch 9, Sec 15, [1.1.1]
15.1.2	Ch 9, Sec 15, [1.1.2]
15.1.3	Ch 9, Sec 15, [1.1.3]
15.1.4	Ch 9, Sec 15, [1.1.4]
15.2	Ch 9, Sec 15, [1.2.1]
15.3	Ch 9, Sec 15, [1.3.1]
15.4.1	Ch 9, Sec 15, [1.4.1]
15.4.2	Ch 9, Sec 15, [1.4.2]
15.5.1	Ch 9, Sec 15, [1.5.1]
15.5.2	Ch 9, Sec 15, [1.5.2]
15.6.1	Ch 9, Sec 15, [1.6.1]
15.6.2	Ch 9, Sec 15, [1.6.2]
15.6.3	Ch 9, Sec 15, [1.6.3]

Table 16 : Equivalences between Part D, Chapter 9 and Chapter 16 of the IGC Code

Ref. in IGC Code, Chapter 16	Ref. in Part D, Chapter 9
16.1	Ch 9, Sec 16, [1.1.1]
16.2	Ch 9, Sec 16, [2.1.1]
16.2.1	Ch 9, Sec 16, [2.1.2]
16.2.2	Ch 9, Sec 16, [2.1.3]
16.3.1	Ch 9, Sec 16, [3.1.1]
16.3.2	Ch 9, Sec 16, [3.1.2]
16.3.3	Ch 9, Sec 16, [3.1.3]
16.3.4	Ch 9, Sec 16, [3.1.4]
16.4.1.1	Ch 9, Sec 16, [4.1.1]
16.4.1.2	Ch 9, Sec 16, [4.1.5]
16.4.2	Ch 9, Sec 16, [4.2.1]
16.4.3	Ch 9, Sec 16, [4.3.1]
16.4.4.1	Ch 9, Sec 16, [4.4.1]
16.4.4.2	Ch 9, Sec 16, [4.4.2]
16.4.5	Ch 9, Sec 16, [4.5.1]
16.4.6.1	Ch 9, Sec 16, [4.6.1]
16.4.6.2	Ch 9, Sec 16, [4.6.2]
16.4.6.3	Ch 9, Sec 16, [4.6.3]
16.4.7	Ch 9, Sec 16, [4.7.1]
16.4.8	Ch 9, Sec 16, [4.8.1]
16.5.1	Ch 9, Sec 16, [5.1.1]
16.5.2.1	Ch 9, Sec 16, [5.2.1]
16.5.2.2	Ch 9, Sec 16, [5.2.2]
16.5.3	Ch 9, Sec 16, [5.4.1]
16.5.4	Ch 9, Sec 16, [5.5.1]
16.6.1.1	Ch 9, Sec 16, [6.1.1]
16.6.1.2	Ch 9, Sec 16, [6.1.2]
16.6.1.3	Ch 9, Sec 16, [6.1.4]
16.6.2.1	Ch 9, Sec 16, [6.2.1]
16.6.2.2	Ch 9, Sec 16, [6.2.2]
16.6.2.3	Ch 9, Sec 16, [6.2.3]
16.6.2.4	Ch 9, Sec 16, [6.2.4]
16.6.3.1	Ch 9, Sec 16, [6.3.1]
16.6.3.2	Ch 9, Sec 16, [6.3.2]
16.6.3.3	Ch 9, Sec 16, [6.3.3]
16.6.3.4	Ch 9, Sec 16, [6.3.5]
16.6.3.5	Ch 9, Sec 16, [6.3.6]
16.6.3.6	Ch 9, Sec 16, [6.3.7]
16.7	Ch 9, Sec 16, [7.1.1]
16.7.1.1	Ch 9, Sec 16, [7.6.1]
16.7.1.2	Ch 9, Sec 16, [7.6.2]
16.7.1.3	Ch 9, Sec 16, [7.6.3]
16.7.1.4	Ch 9, Sec 16, [7.6.4]
16.7.1.5	Ch 9, Sec 16, [7.6.5]
16.7.2.1	Ch 9, Sec 16, [7.7.1]
16.7.2.2	Ch 9, Sec 16, [7.7.2]
16.7.2.3	Ch 9, Sec 16, [7.7.3]
16.7.2.4	Ch 9, Sec 16, [7.7.4]
16.7.3.1	Ch 9, Sec 16, [7.8.1]
16.7.3.2	Ch 9, Sec 16, [7.8.2]
16.7.3.3	Ch 9, Sec 16, [7.8.3]
16.7.3.4	Ch 9, Sec 16, [7.8.4]
16.7.3.5	Ch 9, Sec 16, [7.8.5]
16.8.1.1	Ch 9, Sec 16, [8.1.1]
16.8.1.2	Ch 9, Sec 16, [8.1.2]
16.8.1.3	Ch 9, Sec 16, [8.1.3]
16.8.2	Ch 9, Sec 16, [8.2.1]
16.8.3.1	Ch 9, Sec 16, [8.3.1]
16.8.3.2	Ch 9, Sec 16, [8.3.2]
16.9.1	Ch 9, Sec 16, [9.1.1]
16.9.2	Ch 9, Sec 16, [9.1.2]
16.9.3	Ch 9, Sec 16, [9.1.3]
16.9.4	Ch 9, Sec 16, [9.1.4]
16.9.5	Ch 9, Sec 16, [9.1.5]

Table 17 : Equivalences between Part D, Chapter 9 and Chapter 17 of the IGC Code

Ref. in IGC Code, Chapter 17	Ref. in Part D, Chapter 9
17.1	Ch 9, Sec 17, [1.1.1]
17.2	Ch 9, Sec 17, [2.1.1]
17.3.1	Ch 9, Sec 17, [3.1.1]
17.3.2	Ch 9, Sec 17, [3.1.2]
17.4.1	Ch 9, Sec 17, [4.1.1]
17.4.2	Ch 9, Sec 17, [4.1.2]
17.4.3	Ch 9, Sec 17, [4.1.3]
17.5.1	Ch 9, Sec 17, [5.1.1]
17.5.2	Ch 9, Sec 17, [5.1.2]
17.5.3	Ch 9, Sec 17, [5.1.3]
17.5.4	Ch 9, Sec 17, [5.1.4]
17.5.5	Ch 9, Sec 17, [5.1.5]
17.5.6	Ch 9, Sec 17, [5.1.6]
17.5.7	Ch 9, Sec 17, [5.1.7]
17.6	Ch 9, Sec 17, [6.1.1]
17.7	Ch 9, Sec 17, [7.1.1]
17.8	Ch 9, Sec 17, [8.1.1]
17.9	Ch 9, Sec 17, [9.1.1]
17.10	Ch 9, Sec 17, [10.1.1]
17.11.1	Ch 9, Sec 17, [11.1.2]
17.11.2	Ch 9, Sec 17, [11.1.2]
17.11.3	Ch 9, Sec 17, [11.1.3]
17.12.1	Ch 9, Sec 17, [12.1.1]
17.12.2	Ch 9, Sec 17, [12.1.2]
17.12.3	Ch 9, Sec 17, [12.1.3]
17.12.4	Ch 9, Sec 17, [12.1.4]
17.12.5	Ch 9, Sec 17, [12.1.5]
17.12.6	Ch 9, Sec 17, [12.1.6]
17.12.7	Ch 9, Sec 17, [12.1.7]
17.12.8	Ch 9, Sec 17, [12.1.8]
17.13.1.1	Ch 9, Sec 17, [13.1.1]
17.13.1.2	Ch 9, Sec 17, [13.1.2]
17.13.1.3	Ch 9, Sec 17, [13.1.3]
17.13.1.4	Ch 9, Sec 17, [13.1.4]
17.13.1.5	Ch 9, Sec 17, [13.1.5]
17.13.1.6	Ch 9, Sec 17, [13.1.6]
17.13.2.1	Ch 9, Sec 17, [13.2.1]
17.13.2.2	Ch 9, Sec 17, [13.2.2]
17.13.2.3	Ch 9, Sec 17, [13.2.4]
17.13.3.1	Ch 9, Sec 17, [13.3.1]
17.13.3.2	Ch 9, Sec 17, [13.3.2]
17.13.4.1	Ch 9, Sec 17, [13.4.1]
17.13.4.2	Ch 9, Sec 17, [13.4.2]
17.13.4.3	Ch 9, Sec 17, [13.4.3]
17.13.4.4	Ch 9, Sec 17, [13.4.4]
17.13.5	Ch 9, Sec 17, [13.5.1]
17.13.6.1	Ch 9, Sec 17, [13.6.1]
17.13.6.2	Ch 9, Sec 17, [13.6.3]
17.14.1	Ch 9, Sec 17, [14.1.1]
17.14.2	Ch 9, Sec 17, [14.1.2]
17.14.3	Ch 9, Sec 17, [14.1.3]
17.14.4	Ch 9, Sec 17, [14.1.4]
17.14.5	Ch 9, Sec 17, [14.1.5]
17.14.6	Ch 9, Sec 17, [14.1.6]
17.14.7	Ch 9, Sec 17, [14.1.7]
17.14.8	Ch 9, Sec 17, [14.1.8]
17.14.9	Ch 9, Sec 17, [14.1.9]
17.14.10	Ch 9, Sec 17, [14.1.10]
17.14.11	Ch 9, Sec 17, [14.1.11]
17.15	Ch 9, Sec 17, [15.1.1]
17.16.1	Ch 9, Sec 17, [16.1.1]
17.16.2	Ch 9, Sec 17, [16.1.2]
17.16.3	Ch 9, Sec 17, [16.1.3]
17.16.4	Ch 9, Sec 17, [16.1.4]
17.16.5	Ch 9, Sec 17, [16.1.5]
17.17	Ch 9, Sec 17, [17.1.1]
17.18.1	Ch 9, Sec 17, [18.1.1]
17.18.2	Ch 9, Sec 17, [18.1.2]
17.18.3	Ch 9, Sec 17, [18.1.3]
17.18.4	Ch 9, Sec 17, [18.1.4]
17.18.5	Ch 9, Sec 17, [18.1.5]
17.18.6	Ch 9, Sec 17, [18.1.6]
17.18.7	Ch 9, Sec 17, [18.1.7]
17.18.8	Ch 9, Sec 17, [18.1.8]
17.18.9	Ch 9, Sec 17, [18.1.9]
17.18.10	Ch 9, Sec 17, [18.1.10]
17.18.11	Ch 9, Sec 17, [18.1.11]
17.18.12	Ch 9, Sec 17, [18.1.12]
17.18.13	Ch 9, Sec 17, [18.1.13]
17.18.14	Ch 9, Sec 17, [18.1.14]
17.18.15	Ch 9, Sec 17, [18.1.15]
17.18.16	Ch 9, Sec 17, [18.1.16]
17.18.17	Ch 9, Sec 17, [18.1.17]
17.18.18	Ch 9, Sec 17, [18.1.18]
17.18.19	Ch 9, Sec 17, [18.1.19]
17.18.20	Ch 9, Sec 17, [18.1.20]
17.18.21	Ch 9, Sec 17, [18.1.21]
17.18.22	Ch 9, Sec 17, [18.1.22]
17.18.23	Ch 9, Sec 17, [18.1.23]
17.18.24	Ch 9, Sec 17, [18.1.24]
17.18.25	Ch 9, Sec 17, [18.1.25]
17.18.26	Ch 9, Sec 17, [18.1.26]
17.18.27	Ch 9, Sec 17, [18.1.27]
17.18.28	Ch 9, Sec 17, [18.1.28]
17.18.29	Ch 9, Sec 17, [18.1.29]
17.18.30	Ch 9, Sec 17, [18.1.30]
17.18.31	Ch 9, Sec 17, [18.1.31]
17.19	Ch 9, Sec 17, [19.1.1]
17.20.1	Ch 9, Sec 17, [20.1.1]
17.20.2	Ch 9, Sec 17, [20.1.2]
17.20.3	Ch 9, Sec 17, [20.1.3]
17.21.1	Ch 9, Sec 17, [21.1.2]
17.21.2	Ch 9, Sec 17, [21.1.3]
17.21.3	Ch 9, Sec 17, [21.1.4]
17.21.4	Ch 9, Sec 17, [21.1.5]
17.21.5	Ch 9, Sec 17, [21.1.6]
17.21.6	Ch 9, Sec 17, [21.1.7]
17.22.1	Ch 9, Sec 17, [22.1.2]

Table 18 : Equivalences between Part D, Chapter 9 and Chapter 18 of the IGC Code

Ref. in IGC Code, Chapter 18	Ref. in Part D, Chapter 9
18.1	–
18.2	Ch 9, Sec 18, [2]
18.3	–
18.4	–
18.5	–
18.6	–
18.7	–
18.8	–
18.9	–
18.10.1.1	Ch 9, Sec 18, [3.1.1]
18.10.1.2	Ch 9, Sec 18, [3.1.2]
18.10.1.3	Ch 9, Sec 18, [3.1.3]
18.10.1.4	Ch 9, Sec 18, [3.1.4]
18.10.1.5	Ch 9, Sec 18, [3.1.5]
18.10.2.1.1	Ch 9, Sec 18, [3.2.1], a)
18.10.2.1.2	Ch 9, Sec 18, [3.2.1], b)
18.10.2.1.3	Ch 9, Sec 18, [3.2.1], c)
18.10.2.1.4	Ch 9, Sec 18, [3.2.1], d)
18.10.2.2	Ch 9, Sec 18, [3.2.3]
18.10.2.3	Ch 9, Sec 18, [3.2.4]
18.10.3.1	Ch 9, Sec 18, [3.3.1]
18.10.3.2	Ch 9, Sec 18, [3.3.2]
18.10.3.3	Ch 9, Sec 18, [3.3.3]
18.10.3.4	Ch 9, Sec 18, [3.3.4]
18.10.4.1	Ch 9, Sec 18, [3.4.1]
18.10.4.2	Ch 9, Sec 18, [3.4.2]
18.10.5	Ch 9, Sec 18, [3.5.1]
18.11	–
18.12	–

CHAPTER 10
TANKERS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Cargo Systems

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **tanker**, as defined in Pt A, Ch 1, Sec 2, [4.4.7].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.3 The liquid cargoes which are allowed to be carried by ships having the service notation **tanker** are specified in Ch 7, App 4.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• Part B • Ch 10, Sec 2	• NR566 • Ch 10, Sec 2
	L < 65 m	• NR600	• NR566 • Ch 10, Sec 2
Hull	L ≥ 65 m	• Part B • Ch 10, Sec 2	• Part B • Ch 10, Sec 2
	L < 65 m	• NR600	• NR600
Stability		• Part B • Ch 10, Sec 2	• NR566 • Ch 10, Sec 2
Machinery and cargo systems		• Part C • Ch 10, Sec 3	• NR566 • Ch 10, Sec 3
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT. NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.			

Section 2 Hull and Stability

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the following information are to be submitted:

- indication of the type of cargoes, including cargo temperatures and densities.

2 General arrangement

2.1 Compartment arrangement

2.1.1 General

Tankers may be built with independent or integral cargo tanks.

2.1.2 Integral tanks

Cofferdams are to be fitted between cargo tanks and compartments intended for liquids likely to alter edible liquids carried.

Tanks are to be separated from any compartment containing heat sources by cofferdams or duly heat-insulated bulkheads.

2.1.3 Arrangement of tanks

In general, each tank is to be fitted with:

- a graduated metal gauge rod or any other equivalent sounding device
- an inspection door of adequate size fitted with a watertight metal cover secured by wing bolts or any other device offering equivalent safety
- an expansion system intended to avoid any excessive pressure and any risk of overflow due to a rise in temperature or occasional fermentation; the expansion capacity is to be about 0,5% of the tank cubic capacity
- a drain well that may be suppressed where precautions are taken to improve the running of liquids towards the suction pipes.

3 Stability

3.1 Intact stability

3.1.1 General

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.3] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2.

In general, a representative sample of loading conditions intended to be used for the ship is also to be submitted. The additional loading conditions are also to be in compliance with the requirements of Pt B, Ch 3, Sec 2.

4 Design loads

4.1 Loading conditions for longitudinal strength assessment

4.1.1 In addition to the requirements in Pt B, Ch 5, Sec 8, still water loads are to be calculated for the following loading conditions:

- partial loading conditions
- light and heavy ballast conditions
- mid-voyage conditions relating to tank cleaning or other operations where, at the Society's discretion, these differ significantly from the ballast conditions.

4.2 Load combinations for direct strength analysis

4.2.1 Applicable general load combinations

The load combinations defined in Ch 7, Sec 3, [4.3] are to be considered.

5 Hull scantlings

5.1 Strength check with respect to stresses due to the temperature gradient

5.1.1 Direct calculations of stresses induced in the hull structures by the temperature gradient are to be performed for ships intended to carry cargoes at temperatures exceeding 90°C. In these calculations, the water temperature is to be assumed equal to 0°C.

The calculations are to be submitted to the Society for review.

5.1.2 The stresses induced in the hull structures by the temperature gradient are to comply with the checking criteria in Part B, Chapter 7.

6 Scantlings of independent tank structures

6.1 General

6.1.1 Ships designed with independent cargo tanks are to comply with the applicable provisions of Part D, Chapter 7.

7 Supports of independent tanks

7.1 General

7.1.1 Ships designed with independent cargo tanks are to comply with the applicable provisions of Part D, Chapter 7.

8 Other structures

8.1 Machinery space

8.1.1 Extension of the hull structures within the machinery space

Longitudinal bulkheads carried through cofferdams are to be extended within the machinery space and be used preferably as longitudinal bulkheads for liquid cargo tanks. In any case, such extension is to be compatible with the shape of the structures of the double bottom, deck and platforms of the machinery space.

9 Construction and testing

9.1 Special structural details

9.1.1 The specific requirements in Pt B, Ch 13, Sec 5, [2] for ships with the service notation **tanker** are to be complied with.

Section 3 Machinery and Cargo Systems

1 General

1.1 Documents to be submitted

1.1.1 The documents listed in Tab 1 are to be submitted for approval.

2 Piping systems

2.1 General

2.1.1 Materials

a) Materials used for piping systems are to comply with the provisions of Pt C, Ch 1, Sec 10, [2.1].

b) Attention is drawn to any national standards or regulations which might restrict the use of materials in contact with edible substances.

2.1.2 Independence of piping systems

a) The cargo piping system is to be entirely separated from other piping systems serving the ship.

b) In the case of carriage of edible substances, arrangements are to be made to avoid any inadvertent contamination of the cargo. In particular, the filling and discharge connections serving the cargo tanks are to be located remote from those serving the machinery piping systems.

2.1.3 Passage of pipes through tanks

Cargo tanks containing edible substances are not to be passed through by pipes conveying other liquids.

2.2 Cargo piping and pumping

2.2.1 Cargo pumps

At least two cargo pumps are to be provided for transferring the cargo.

2.2.2 Level gauging systems

Level gauging systems of tanks containing edible substances are to be so designed as to avoid any contamination of the cargo.

2.3 Air pipes

2.3.1

a) Air pipes of cargo tanks are to be fitted with automatic closing appliances. Refer to Pt C, Ch 1, Sec 10, [9.1].

b) Air pipes of tanks containing edible substances are to be led as far as practicable from:

- air pipes of sewage or flammable oil tanks
- machinery ventilation outlets.

2.4 Refrigerating installations

2.4.1

a) Where the cargo needs to be kept refrigerated for conservation purposes, the refrigerating installation is to comply with the applicable provisions of Part F, Chapter 7.

b) Provisions are to be made to avoid any contamination of the cargo by the refrigeration fluid.

2.5 Cargo tank cleaning systems

2.5.1 Adequate means are to be provided for cleaning the cargo tanks.

2.6 Additional requirements for ships carrying category Z substances

2.6.1 Tankers carrying category Z substances are to comply with the provisions of Ch 7, Sec 4, [9.2.2].

Table 1 : Documents to be submitted

No.	Description of the document **(1)**
1	Diagram of the cargo piping system
2	Diagram of the cargo tank venting system
3	Diagram of the cargo tank level gauging system
4	Diagram of the cargo tank cleaning system
5	Diagram of the bilge and ballast systems serving the cargo spaces
6	Diagram of the cargo heating and refrigerating systems

(1) Diagrams are also to include, where applicable:

- the (local and remote) control and monitoring systems and automation systems
- the instructions for the operation and maintenance of the piping system concerned (for information).

Part D
Service Notations

CHAPTER 11
PASSENGER SHIPS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 4 Machinery and Cargo System

Section 5 Electrical Installations

Appendix 1 Calculation Method for Cross-Flooding Arrangements

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **passenger ship**, as defined in Pt A, Ch 1, Sec 2, [4.5.2].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.3 For ships having to comply with the provisions of SOLAS Ch II-1 reg 8-1 and SOLAS Ch II-2 reg 21 and 22, the service notation **passenger ship** is to be completed by the additional service feature **SRTP** according to requirements of NR598 Implementation of Safe Return to Port and Orderly Evacuation.

1.1.4 Additional guidance for arrangement and structural assessment is provided in NI 640 Structural Assessment of Passenger Ships.

Table 1 : Applicable requirements

Item		Ships having the navigation notation **unrestricted navigation**	Ships having a navigation notation other than **unrestricted navigation**	
			Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 90 m	• Part B • Ch 11, Sec 2	• Part B • Ch 11, Sec 2	• NR566
	L < 90 m	• NR600	• NR600	• NR566
Hull	L ≥ 90 m	• Part B • Ch 11, Sec 3	• Part B • Ch 11, Sec 3	• Part B • Ch 11, Sec 3
	L < 90 m	• NR600	• NR600	• NR600
Stability		• Part B • Ch 11, Sec 3	• Part B • Ch 11, Sec 3	• NR566
Machinery and cargo systems		• Part C • Ch 11, Sec 4	• Part C • Ch 11, Sec 4	• NR566
Electrical installations		• Part C • Ch 11, Sec 5	• Part C • Ch 11, Sec 5	• NR566
Automation		• Part C	• Part C	• NR566
Fire protection, detection and extinction		• Part C	• Part C	• NR566

Note 1:
NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT
NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Ship Arrangement

1 General

1.1 Definitions

1.1.1 Deepest subdivision load line

Deepest subdivision load line *is the waterline which corresponds to the summer load line of the ship.*

1.1.2 Passenger spaces

Passenger spaces are those spaces which are provided for the accommodation and use of passengers, excluding baggage, store, provision and mail rooms.

In all cases volumes and areas are to be calculated to moulded lines.

2 General arrangement design

2.1 Openings in watertight boundaries below the bulkhead deck

2.1.1 General

The number of openings in watertight boundaries is to be reduced to the minimum compatible with the design and proper working of the ship.

Where pipes, scuppers, electric cables, etc., are carried through watertight boundaries, arrangements are to be made to ensure the watertight integrity of the boundaries.

Valves not forming part of a piping system are not permitted in watertight boundaries.

Lead or other heat sensitive materials are not to be used in systems which penetrate watertight boundaries, where deterioration of such systems in the event of fire would impair the watertight integrity of the boundaries.

2.1.2 Openings in machinery spaces

Not more than one door apart from the doors to shaft tunnels may be fitted in each watertight bulkhead within spaces containing the main and auxiliary propulsion machinery including boilers serving the needs of propulsion. Where two or more shafts are fitted the tunnels are to be connected by an inter-communicating passage. Only one door is to be provided between the machinery space and the tunnel spaces where two shafts are fitted and only two doors where there are more than two shafts. All these doors are to be of the sliding type and are to be so located as to have their sills as high as practicable. The hand gear for operating these doors from above the bulkhead deck is to be situated outside the spaces containing the machinery.

Portable plates on bulkheads are not permitted except in machinery spaces. The Society may permit not more than one power-operated sliding watertight door larger than 1,20 m to be substituted for these portable plates in each watertight bulkhead, provided these doors are intended to remain closed during navigation except in the case of urgent necessity at the discretion of the master. These doors need not meet the requirements of [2.3.4] e) regarding complete closure by hand-operated gear in 90 seconds.

2.1.3 Openings in cargo spaces

a) Watertight doors complying with the requirements of [2.3.1] may be fitted in watertight bulkheads dividing cargo spaces on 'tween decks. Such doors may be hinged, rolling or sliding doors but are not to be remotely controlled. They are to be fitted at the highest level and as far from the shell plating as practicable, but in no case are the outboard vertical edges to be situated at a distance from the shell plating which is less than one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision load line.

b) The doors accessible during the voyage are to be fitted with a device which prevents unauthorised opening. When it is proposed to fit such doors, the number and arrangements are to receive the special consideration of the Society.

2.1.4 Openings in passenger ships carrying goods vehicles and accompanying personnel

This requirement applies to passenger ships designed or adapted for the carriage of goods vehicles and accompanying personnel where the total number of persons on board, other than passengers as defined in Pt A, Ch 1, Sec 2, [4.5.2], exceeds 12.

If in such a ship the total number of passengers which include personnel accompanying vehicles does not exceed:

$$N = 12 + \frac{A}{25}$$

where:

N : *Maximum number of passengers for which the ship is certified*

A : *Total deck area, in m^2, of spaces available for the stowage of goods vehicles,*

and where the clear height at the stowage position and at the entrance to such spaces is not less than 4 m, the provisions of [2.1.3] in respect of watertight doors apply except that the doors may be fitted at any level in watertight bulkheads dividing cargo spaces.

Additionally, indicators are required on the navigation bridge to show automatically when each door is closed and all door fastenings are secured.

2.1.5 Trunks and tunnels

Where trunkways or tunnels for access from crew accommodation to the stokehold, for piping, or for any other purpose are carried through watertight bulkheads, they are to be watertight and in accordance with the requirements of Pt B, Ch 4, Sec 5, [10.5]. The access to at least one end of each such tunnel or trunkway, if used as a passage at sea, is to be through a trunk extending watertight to a height sufficient to permit access above the bulkhead deck. The access to the other end of the trunkway or tunnel may be through a watertight door. Such trunkways or tunnels are not to extend through the first subdivision bulkhead abaft the collision bulkhead.

Where trunkways in connection with refrigerated cargo and ventilation or forced draught trunks are carried through more than one watertight bulkhead, the means of closure at such openings are to be operated by power and be capable of being closed from a central position situated above the bulkhead deck.

Where a ventilation trunk passing through a structure penetrates a watertight area of the bulkhead deck, the trunk is to be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heel angle during flooding, in accordance with Ch 12, Sec 3, [2.3.5].

2.1.6 Additional requirements

In addition to [2.1.2], [2.1.3], [2.1.4], and [2.1.5], the requirements reported in [2.3.4] are to be complied with.

2.2 Openings in bulkheads above the bulkhead deck

2.2.1 General

The internal watertight subdivision arrangements to limit the entry and spread of water above the bulkhead deck is to be in accordance with the design arrangements necessary for compliance with the stability requirements in Part B, Chapter 3. Where pipes, scuppers, electric cables, etc. are carried through internal watertight boundaries that are immersed at any intermediate or final stage of flooding in damage cases that contribute to the attained subdivision index A, arrangements are to be made to ensure their watertight integrity.

Doors in internal watertight subdivision arrangements above the bulkhead deck, and also above the worst intermediate or final stage of flooding waterlines, are to be capable of preventing the passage of water when immersed in the required range of positive stability for any damage cases contributing to the attained subdivision index A. These doors may remain open provided they can be remotely closed from the navigation bridge. They are to be always ready to be immediately closed.

The coamings of all openings in the exposed weather deck are to be of ample height and strength and are to be provided with efficient means for expeditiously closing them weathertight. Freeing ports, open rails and scuppers are to be fitted as necessary for rapidly cleaning the weather deck of water under all weather conditions.

Sidescuttles, gangway, cargo and fuelling ports and other means for closing openings in the shell plating above the bulkhead deck are to be of efficient design and construction and of sufficient strength (see Pt B, Ch 11, Sec 12) having regard to the spaces in which they are fitted and their positions relative to the deepest subdivision load line.

Efficient inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be provided for all sidescuttles to spaces below the first deck above the bulkhead deck.

2.2.2 Open end of air pipes

Air pipes terminating within a superstructure which are not fitted with watertight means of closure are to be considered as unprotected openings when applying Pt B, Ch 3, App 3, [1.6.11].

2.2.3 Additional requirements

In addition to [2.2.1] and [2.2.2], the requirements reported in [2.3.5] are to be complied with.

2.3 Doors

2.3.1 Requirements for doors

The requirements relevant to the operating systems for doors complying with the prescriptions in [2.3.2] and [2.3.4] are specified in Tab 1 for doors of internal watertight bulkheads and Tab 2 for doors of external watertight boundaries below equilibrium or intermediate waterplane.

2.3.2 Construction of watertight doors

The design, materials and construction of all watertight doors are to be to the satisfaction of the Society.

Such doors are to be suitably marked to ensure that they may be properly used to provide maximum safety.

The frames of vertical watertight doors are to have no groove at the bottom in which dirt might lodge and prevent the door closing properly.

2.3.3 Category of watertight doors

a) Category B

A watertight door that may be opened during navigation when work in the immediate vicinity of the door necessitates it being opened, according to SOLAS regulation II-1/22.3. The door must be immediately closed when the task which necessitated it being open is finished.

b) Category C

A watertight door that may be opened during navigation to permit the passage of passengers or crew, according to SOLAS regulation II-1/22.3. The door must be immediately closed when transit through the door is complete.

c) Category D

A watertight door that is to be closed before the voyage commences and is to be kept closed during navigation:

- A watertight door of a width of more than 1,2 m in machinery spaces as permitted by SOLAS regulation II-1/13.9. The door is to remain closed during navigation except in case of urgent necessity at the discretion of the master according to SOLAS regulation II-1/22.4.
- Additionally, watertight doors fitted in watertight bulkheads dividing cargo between deck spaces in accordance with SOLAS regulation II-1/13.8.1 or dividing cargo spaces in accordance with SOLAS regulation II-1/14.2, are to be closed before the voyage commences and are to be closed during navigation according to SOLAS regulation II-1/22.5.

Table 1 : Doors in internal watertight bulkheads of passenger ships

Position relative to bulkhead deck	Category	Type **(1)**	Remote closure	Remote indication	Audible or visual alarm	Notice
Below bulkhead deck	B, C **(2)**	POS	X	X	X (local)	
	D	S, H				X
	D	POS	X	X	X (local)	
	D	S, H		X		X
At or above bulkhead deck and below the worst intermediate or final equilibrium waterline	B, C **(2) (3)**	POS	X	X	X (local)	
At or above bulkhead deck, and above the worst intermediate and final equilibrium waterlines, but immersed in the required range of positive stability	Not applicable **(4) (5)**	POS, POH	X	X	X (local)	
	Not applicable **(4) (6)**	S, H		X		X

(1) POS : Power operated, sliding or rolling
POH : Power operated, hinged
S : Sliding or rolling
H : Hinged
(2) See IMO MSC.1/Circ.1564
(3) See explanatory Note to Regulation 17.2 of Res.MSC.429(98)/Rev.2
(4) See explanatory Note to Regulation 17.2 of Res.MSC.429(98)/Rev.2
(5) May remain open, but is always to be ready to be immediately closed
(6) Normally closed. If hinged, this door is to be of hinged action type.

Table 2 : Doors in external watertight boundaries below equilibrium or intermediate waterplane

Position relative to bulkhead deck	Frequency of use while at sea	Type **(1)**	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Permanently closed	S, H		X		X
At or above	Normally closed /permanently closed **(2)**	S, H		X		X

(1) S : Sliding or rolling
H : Hinged
(2) If hinged, normally closed door is to be of single action type.

2.3.4 Doors in watertight bulkheads below the bulkhead deck

a) Watertight doors, except as provided in [2.1.3] item a) and [2.1.4], are to be power operated sliding doors complying with the requirements of items e) to l).

b) The means of operation whether by power or by hand of any power-operated sliding watertight door are to be capable of closing the door with the ship listed to 15° either way. Consideration is to also be given to the forces which may act on either side of the door as may be experienced when water is flowing through the opening applying a static head equivalent to a water height of at least 1 m above the sill on the centreline of the door.

c) *Watertight door controls, including hydraulic piping and electrical cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted, in order to minimise the likelihood of them being involved in any damage which the ship may sustain. The positioning of watertight doors and their controls are to be such that if the ship sustains damage within one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision load line, the operation of the watertight doors clear of the damaged portion of the ship is not impaired.*

d) *Each power-operated sliding watertight door:*

- *is to move vertically or horizontally;*
- *is to be normally limited to a maximum clear opening width of 1,20 m. The Society may permit larger doors only to the extent considered necessary for the effective operation of the ship provided that other safety measures, including the following, are taken into consideration:*
  - *special consideration is to be given to the strength of the door and its closing appliances in order to prevent leakages;*
  - *the door is to be located outside the damage zone B/5.*
- *is to be fitted with the necessary equipment to open and close the door using electrical power, hydraulic power, or any other form of power that is acceptable to the Society;*
- *is to be provided with an individual hand-operated mechanism. It is to be possible to open and close the door by hand at the door itself from either side and, in addition, close the door from an accessible position above the bulkhead deck with an all round crank motion or some other movement providing the same degree of safety acceptable to the Society. Direction of rotation or other movement is to be clearly indicated at all operating positions. The time necessary for the complete closure of the door, when operating by hand gear, may not exceed 90 s with the ship in the upright position. Visual indicators to show whether the door is open or closed are to be provided at the accessible position above the bulkhead deck.*
- *is to be provided with controls for opening and closing the door by power from both sides of the door and also for closing the door by power from the central operating console required in item n);*
- *is to be provided with an audible alarm, distinct from any other alarm in the area, which is to sound whenever the door is closed remotely by power and which is to sound for at least 5 s but no more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In the case of remote hand operation it is sufficient for the audible alarm to sound only when the door is moving. Additionally, in passenger areas and areas of high ambient noise, the Society may require the audible alarm to be supplemented by an intermittent visual signal at the door;*
- *is to have an approximately uniform rate of closure under power. The closure time, from the time the door begins to move to the time it reaches the completely closed position, is to in no case be less than 20 s or more than 40 s with the ship in the upright position.*

e) *The electrical power required for power-operated sliding watertight doors is to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and be capable of being automatically supplied by a transitional source of emergency electrical power in the event of failure of either the main or emergency source of electrical power.*

The transitional source of emergency electrical power is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically, in the event of failure of either the main or emergency source of electrical power, to control, indication and alarm circuits at least for half an hour.

f) *Power-operated sliding watertight doors are to have either:*

- *a centralised hydraulic system with two independent power sources each consisting of a motor and pump capable of simultaneously closing all doors. In addition, there are to be for the whole installation hydraulic accumulators of sufficient capacity to operate all the doors at least three times, i.e. closed-open-closed, against an adverse list of 15°. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. The power operating system is to be designed to minimise the possibility of having a single failure in the hydraulic piping adversely affect the operation of more than one door. The hydraulic system is to be provided with a low-level alarm for hydraulic fluid reservoirs serving the power-operated system and a low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators. These alarms are to be audible and visual and are to be situated on the central operating console at the navigation bridge; or*
- *an independent hydraulic system for each door with each power source consisting of a motor or pump capable of opening and closing the door. In addition, there is to be a hydraulic accumulator of sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of 15°. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. A low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators is to be provided at the central operating console required in item m). Loss of stored energy indication at each local operating position is to also be provided; or*

- *an independent electrical system and motor for each door with each power source consisting of a motor capable of opening and closing the door. The power source is to be capable of being automatically supplied by the transitional source of emergency electrical power in the event of failure of either the main or emergency source of electrical power and with sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of 15°.*

  The transitional source of emergency electrical power is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically, in the event of failure of either the main or emergency source of electrical power, to watertight doors, but not necessarily all of them simultaneously, unless an independent source of stored energy is provided.

For the systems specified above, provision is to be made as follows:

Power systems for power-operated watertight sliding doors are to be separate from any other power system. A single failure in the electrical or hydraulic power-operated systems excluding the hydraulic actuator is not to prevent the hand operation of any door.

g) Control handles are to be provided at each side of the bulkhead at a minimum height of 1,6 m above the floor and are to be so arranged as to enable persons passing through the doorway to hold both handles in the open position without being able to set the power closing mechanism in operation accidentally. The direction of movement of the handles in opening and closing the door is to be in the direction of door movement and is to be clearly indicated.

h) As far as practicable, electrical equipment and components for watertight doors are to be situated above the bulkhead deck and outside hazardous areas and spaces.

i) The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water.

j) Electric power, control, indication and alarm circuits are to be protected against faults in such a way that a failure in one door circuit is not to cause a failure in any other door circuit. Short-circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck is not to cause the door to open.

k) A single electrical failure in the power operating or control system of a power-operated sliding watertight door is not to result in a closed door opening. Availability of the power supply is to be continuously monitored at a point in the electric circuit as near as practicable to each of the motors required in g). Loss of any such power supply is to activate an audible and visual alarm at the central operating console required in item m).

l) Failure of the normal power supply of the required alarms are to be indicated by an audible and visual alarm at the central operating console required in item m).

m) A central operating console for all power-operated sliding watertight doors is to be located in the safety centre in accordance with Pt C, Ch 4, Sec 14. If the safety centre is located in a separate space adjacent to the navigation bridge, a central operating console is also to be located on the navigation bridge.

The central operating console is to have a "master mode" switch with two modes of control:

- *a "local control" mode which is to allow any door to be locally opened and locally closed after use without automatic closure, and*
- *a "doors closed" mode which is to automatically close any door that is open in not more than 60 s with the ship in an upright position. The "doors closed" mode is to permit doors to be opened locally and is to automatically reclose the doors upon release of the local control mechanism.*

The "master mode" switch is to normally be in the "local control" mode. The "doors closed" mode is to only be used in an emergency or for testing purposes.

n) The central operating console is to be provided with a diagram showing the location of each power-operated sliding watertight door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light is to indicate a door is fully closed. When the door is closed remotely the red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door. Indication is also to be provided to the onboard stability computer, if installed.

o) It is not to be possible to remotely open any door from the central operating console.

p) All watertight doors are to be kept closed during navigation. Certain watertight doors may be permitted to remain open during navigation only if considered absolutely necessary; that is, being open is determined essential to the safe and effective operation of the ship's machinery or to permit passengers normally unrestricted access throughout the passenger area. Such determination is to be made by the Society only after careful consideration of the impact on ship operations and survivability. A watertight door permitted to remain thus open is to be clearly indicated in the ship's stability information and the damage control documentation *and is always to be ready for immediate closure.*

q) All watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or an independent hydraulic unit for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located on the central operating console required in item n).

r) Signboard/instructions are to be placed in way of the door advising how to act when the door closed.

2.3.5 Doors in bulkheads above the bulkhead deck

a) General

Doors are to be capable of being opened and closed by hand locally from both sides of the doors with the ship listed to 15° to either side.

Position indicators are to be provided on the bridge to show that the doors are open or closed and that the dogs are fully and properly engaged.

Where the doors also serve as fire doors they are to be provided with position indicators at the fire control station and audible alarms as required for fire doors, as well as for weathertight doors. Where two doors are fitted they must be capable of independent operation remotely and from both sides of each door.

b) Doors normally closed at sea

In addition to a), doors not required for frequent access while at sea are to be kept normally closed and may be of either hinged or sliding type.

Doors kept normally closed are to have local operation from both sides of the doors and are to be labelled on both sides: "to be kept closed at sea".

c) Doors normally open at sea

Where fitted in public spaces for the passage of passengers and crew, the doors may be kept normally open at sea and may be either hinged or sliding type.

In addition to a), doors kept normally open at sea are to have local power operation from both sides of the door and remote closing from the bridge. Operation of these doors is to be similar to that specified in Pt C, Ch 4, Sec 5 where, using a "master mode" switch on the bridge, local control can override the remote closing feature after which the door is automatically remotely reclosed upon release of the local control mechanism.

Doors kept normally open at sea are to have audible alarms, distinct from any other alarm in the area, which sound whenever the doors are closed remotely. The alarms are to sound for at least 5 s but not more than 10 s before the doors begins to move and continue sounding until the doors are completely closed. In passenger areas and areas of high ambient noise, the audible alarms are to be supplemented by visual signals at both sides of the doors.

d) Failure of the normal power supply of the required alarms are to be indicated by an audible and visual alarm.

e) All watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or an independent hydraulic unit for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located on the central operating console required in item n).

f) Signboard/instructions are to be placed in way of the door advising how to act when the door closed.

2.4 Ballast compartment arrangement

2.4.1 *Water ballast is not to be, in general, carried in tanks intended for fuel oil. In ships in which it is not practicable to avoid putting water in fuel oil tanks, oily-water separating equipment to the satisfaction of the Society is to be fitted, or other alternative means, such as discharge to shore facilities, acceptable to the Society is to be provided for disposing of the oily-water ballast (see Pt C, Ch 1, Sec 10, [7]).*

2.5 Machinery compartment arrangement

2.5.1 When longitudinal bulkheads are fitted in the machinery space, adequate self-operating arrangements are to be provided in order to avoid excessive heel after damage.

Where such arrangements are cross-flooding systems, their area is to be calculated in accordance with the requirements in Ch 11, App 1 In addition, such systems are to comply with the criteria for the maximum time necessary to cross flood according to Ch 11, Sec 3, [2.3.5], item a).

Section 3 Hull and Stability

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Pt B, Ch 1, Sec 4, the following documents are to be submitted:

- Stability documentation as specified in Article [2]
- Plan of design loads on deck as specified in [4.1].

2 Stability

2.1 Definitions

2.1.1 Deepest subdivision draught

The deepest subdivision draught (d_S) is the waterline which corresponds to the summer load line draught of the ship.

2.1.2 Light service draught

Light service draught (d_L) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

2.1.3 Partial subdivision draught

The partial subdivision draught (d_P) is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

2.1.4 Subdivision length L_s

The subdivision length L_s is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

2.1.5 Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, the Society may define the limits of the machinery spaces.

2.1.6 Other definitions

Mid-length is the mid point of the subdivision length of the ship.

Aft terminal is the aft limit of the subdivision length.

Forward terminal is the forward limit of the subdivision length.

Breadth B is the greatest moulded breadth, in m, of the ship at or below the deepest subdivision draught.

Draught d is the vertical distance, in m, from the moulded baseline at mid-length to the waterline in question.

Permeability μ of a space is the proportion of the immersed volume of that space which can be occupied by water.

2.2 Intact stability

2.2.1 General

Every passenger ship regardless of size is to be inclined upon its completion. The lightship displacement and the longitudinal, transverse and vertical position of its centre of gravity shall be determined. The Master is to be supplied with such information satisfactory to the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information is to be furnished to the Society.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

2.2.2 Periodical lightweight check

At periodical intervals not exceeding five years, a lightweight survey is to be carried out on all passenger ships to verify any changes in lightship displacement and longitudinal centre of gravity. The ship is to be re-inclined whenever, in comparison with the approved stability information, a deviation from the lightship displacement exceeding 2% or a deviation of the longitudinal centre of gravity exceeding 1% of L_{LL} is found, or anticipated.

2.2.3 Standard requirements

In addition to Pt B, Ch 3, Sec 2, [2], the requirements in [2.2.4] to [2.2.6] are to be complied with for the loading conditions defined in Pt B, Ch 3, App 2, [1.2.1] and Pt B, Ch 3, App 2, [1.2.9].

2.2.4 Crowding of passengers

The angle of heel on account of crowding of passengers to one side as defined below may not exceed 10°:

- *a minimum weight of 75 kg is to be assumed for each passenger except that this value may be increased subject to the approval of the Society. In addition, the mass and distribution of the luggage is to be approved by the Society;*
- *the height of the centre of gravity for passengers is to be assumed equal to:*
  - *1,0 m above deck level for passengers standing upright. Account may be taken, if necessary, of camber and sheer of deck; and*
  - *0,3 m above the seat in respect of seated passengers.*
- *passengers and luggage are to be considered to be in the spaces normally at their disposal;*
- *passengers without luggage are to be considered as distributed to produce the most unfavourable combination of passenger heeling moment and/or initial metacentric height, which may be obtained in practice. In this connection, a value higher than four persons per square metre is not necessary.*

2.2.5 Maximum turning angle

The angle of heel on account of turning may not exceed 10° when calculated using the following formula:

$$M_R = 0,02 \frac{V_0^2}{L_S} \Delta \left(KG - \frac{T_1}{2} \right)$$

where:

M_R : *Heeling moment, in t.m*

V_0 : *Service speed, in m/s*

T_1 : *Mean draught, in m*

KG : *Height of centre of gravity above keel, in m.*

2.2.6 *Where anti-rolling devices are installed in a ship, the Society is to be satisfied that the above criteria can be maintained when the devices are in operation.*

2.3 Damage stability for ships where SDS notation has been required

2.3.1 General

The requirements of this Section are to be applied to passenger ships in conjunction with the exploratory notes as set out by the IMO Resolution MSC 429(98).

2.3.2 Required subdivision index R

The required subdivision index R of a passenger ship according to the total number of persons on board is defined in Tab 1.

These regulations are intended to provide ships with a minimum standard of subdivision. In addition to these requirements, the requirements of [2.3.12] are to be complied with.

Table 1 : Required subdivision index R

Total number of persons on board N	R
N < 400	0,722
400 ≤ N ≤ 1350	N / 7580 + 0,66923
1350 < N ≤ 6000	0,0369 Ln (N + 89,048) + 0,579
N > 6000	1 – (852,5 + 0,03875 N) / (N + 5000)

2.3.3 Attained subdivision index A

The attained subdivision index A is to be calculated in accordance with Pt B, Ch 3, App 3, [1.4].

The attained subdivision index A is not to be less than the required subdivision index R. In addition, the partial indices A_s, A_p and A_L are not to be less than 0,9 R.

2.3.4 Calculation of the factor p_i

The factor pi is to be calculated in accordance with Pt B, Ch 3, App 3, [1.5].

2.3.5 Calculation of the factor s_i

The factor s_i is to be determined for each case of assumed flooding, involving a compartment or group of compartments, in accordance with the following notations and the provisions in this regulation.

θ_e : *The equilibrium heel angle in any stage of flooding, in degrees*

θ_v : *The angle, in any stage of flooding, where the righting lever becomes negative, or the angle at which an opening incapable of being closed weathertight becomes submerged*

In applying this criterion, openings which are incapable of being closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship.

GZ_{max} : *The maximum positive righting lever, in metres, up to the angle* θ_v

Range : *The Range of positive righting levers, in degrees, measured from the angle* θ_e. *The positive range is to be taken up to the angle* θ_v

Flooding stage is any discrete step during the flooding process, including the stage before equalization (if any) until final equilibrium has been reached.

The factor s_i, *for any damage case at any initial loading condition,* d_i, *shall be obtained from the formula:*

$$s_i = \min[s_{intermediate,i}, (s_{final,i} \cdot s_{mom,i})]$$

where:

$s_{intermediate,i}$: *The probability to survive all intermediate flooding stages until the final equilibrium stage, and is calculated in accordance with item a)*

$s_{final,i}$: *The probability to survive in the final equilibrium stage of flooding. It is calculated in accordance with item b)*

$s_{mom,i}$: *The probability to- survive heeling moments, and is calculated in accordance with item c)*

a) *Calculation of* $s_{intermediate}$:

The factor $s_{intermediate,i}$ *is to be taken as the least of the s-factors obtained from all flooding stages including the stage before equalization, if any, and is to be calculated as follows:*

$$s_{intermediate,\,i} = \left[\frac{GZ_{max}}{0{,}05} \cdot \frac{Range}{7}\right]^{-\frac{1}{4}}$$

where GZ_{max} *is not to be taken as more than 0,05 m and Range as not more than 7°.*

$s_{intermediate,i} = 0$, *if the intermediate heel angle exceeds 15°.*

Where cross-flooding fittings are required, the time for equalization is not to exceed 10 min. The time for equalization is to be calculated in accordance with Ch 11, App 1

b) *Calculation of* s_{final}:

The factor $s_{final,i}$ *is to be obtained from the formula:*

$$s_{final,\,i} = K\left[\frac{GZ_{max}}{TGZ_{max}} \cdot \frac{Range}{TRange}\right]^{-\frac{1}{4}}$$

where:

GZ_{max} *is not to be taken as more than* TGZ_{max}

Range is not to be taken as more than T_{Range}

TGZ_{max} *is taken equal to:*

- $TGZ_{max} = 0{,}20$ *m for ro-ro passenger ships each damage case that involves a ro-ro space*
- $TGZ_{max} = 0{,}12$ *m otherwise*

T_{Range} *is taken equal to:*

- $T_{Range} = 20°$ *for ro-ro passenger ships each damage case that involves a ro-ro space,*
- $T_{Range} = 16°$ *otherwise*

K is taken equal to:

- $K = 1$ if $\theta_e \le \theta_{min}$
- $K = 0$ if $\theta_e \ge \theta_{max}$
- $K = \sqrt{\dfrac{\theta_{max} - \theta_e}{\theta_{max} - \theta_{min}}}$ otherwise

where:

θ_{min} *is equal to 7°*

θ_{max} *is equal to 15°.*

c) *Calculation of* s_{mom}:

The factor $s_{mom,i}$ *is to be calculated at the final equilibrium from the formula:*

$$s_{mom,\,i} = \frac{(GZ_{max} - 0{,}04)\,Displacement}{M_{heel}}$$

where:

$s_{mom,i} \le 1$

Displacement is the intact displacement at the respective draught (d_s, d_p, d_l)

M_{heel} is the maximum assumed heeling moment as calculated as follows:

$M_{heel} = \max[M_{passenger}, M_{wind}, M_{Survivalcraft}]$

where heeling moments $M_{passenger}$, M_{wind} and $M_{Survivalcraft}$ are calculated in [2.3.11].

2.3.6 Equalization arrangements

Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted shall, where practicable, be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the bulkhead deck. These fittings together with their controls are to be acceptable to the Society. Suitable information concerning the use of equalization devices are to be supplied to the master of the ship.

Tanks and compartments taking part in such equalization are to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

2.3.7 Cases where s_i is to be equal to zero

The factor s_i is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:

- *the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor s_i. Such openings are to include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, but the openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, side scuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.*
- *any part of the bulkhead deck considered a horizontal evacuation route.*

The factor s_i is to be taken as zero if, taking into account sinkage, heel and trim, any of the following occur in any intermediate stage or in the final stage of flooding:

- *immersion of any vertical escape hatch in the bulkhead deck intended for compliance with the applicable requirements of Pt C, Ch 4, Sec 8*
- *any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the bulkhead deck become inaccessible or inoperable*
- *immersion of any part of piping or ventilation ducts located within the assumed extent of damage and carried through a watertight boundary if this can lead to the progressive flooding of compartment not assumed as flooded.*

2.3.8 Calculation of the factor v_i

Where horizontal watertight boundaries are fitted above the waterline under consideration the s-value calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in [2.3.5] by the reduction factor v_m defined below, which represents the probability that the spaces above the horizontal subdivision will not be flooded.

The factor v_i is to be calculated in accordance with Pt B, Ch 3, App 3, [1.6.10] and Pt B, Ch 3, App 3, [1.6.11].

2.3.9 Contribution dA to the index A

The contribution dA to the index A is to be calculated in accordance with Pt B, Ch 3, App 3, [1.6.12].

2.3.10 Permeability

For the purpose of the subdivision and damage stability calculations of the regulations, the permeability of each general compartment or part of a compartment is to be according to Tab 2.

Other figures for permeability may be used if substantiated by calculations.

Table 2 : Values of permeability

Spaces	Permeability
Appropriated to stores	0,60
Occupied by accommodation or voids	0,95
Occupied by machinery	0,85
Intended for liquids	0 or 0,95 **(1)**
(1) whichever results in the more severe requirements.	

2.3.11 Inclining moments

The following inclining moments are to be taken into account:

a) *Moment due to the crowding of passengers:*

$M_{passenger}$ is the maximum assumed heeling moment resulting from movement of passengers, and is to be obtained as follows:

$M_{passenger} = (0{,}075\ N_p)\ (0{,}45\ B)$ (tm)

where:

N_p : *Maximum number of passengers permitted to be on board in the service condition corresponding to the deepest subdivision draught under consideration; and*

B : *Breadth of the ship.*

Alternatively, the heeling moment may be calculated assuming the passengers are distributed with 4 persons per square metre on available deck areas towards one side of the ship on the decks where muster stations are located and in such a way that they produce the most adverse heeling moment. In doing so, a weight of 75 kg per passenger is to be assumed.

b) *Moment due to launching of all fully loaded davit-launched survival craft on one side:*

$M_{Survivalcraft}$ is the maximum assumed heeling moment due to the launching of all fully loaded davit-launched survival craft on one side of the ship. It shall be calculated using the following assumptions:

- *all lifeboats and rescue boats fitted on the side to which the ship has heeled after having sustained damage are to be assumed to be swung out fully loaded and ready for lowering.*
- *for lifeboats which are arranged to be launched fully loaded from the stowed position, the maximum heeling moment during launching is to be taken.*
- *a fully loaded davit-launched liferaft attached to each davit on the side to which the ship has heeled after having sustained damage is to be assumed to be swung out ready for lowering.*
- *persons not in the life-saving appliances which are swung out are not to provide either additional heeling or righting moment.*
- *life-saving appliances on the side of the ship opposite to the side to which the ship has heeled are to be assumed to be in a stowed position.*

c) *Moment due to wind pressure:*

M_{wind} is the maximum assumed wind force acting in a damage situation:

$M_{wind} = (P\ A\ Z) / 9{,}806 \cdot 10^3$ (tm)

P : *Wind pressure*

$P = 120\ N/m^2$

A : *Projected lateral area above waterline*

z : *Distance from centre of lateral projected area above waterline to T/2; and*

T : *Ship's draught, d_i.*

2.3.12 Special requirements concerning stability

A passenger ship intended to carry 400 or more persons is to have watertight subdivision abaft the collision bulkhead so that $s_i = 1$ for a damage involving all the compartments with 0.08L measured from the forward perpendicular for the three loading conditions used to calculate the attained subdivision index A. If the attained subdivision index A is calculated for different trims, this requirement shall also be satisfied for those loading conditions.

A passenger ship intended to carry 36 or more persons is to be capable of withstanding damage along the side shell to an extent specified below. Compliance with this regulation is to be achieved by demonstrating that s_i, as defined in [2.3.5], is not less than 0,9 for the three loading conditions used to calculate the attained subdivision index A. If the attained subdivision index A is calculated for different trims, this requirement is also to be satisfied for those loading conditions.

The damage extent to be assumed when demonstrating compliance with the above paragraph, is to be dependent on the total number of persons carried, and L, such that:

- *the vertical extent of damage is to extend from the ships moulded baseline to a position up to 12,5 m above the position of the deepest subdivision draught as defined in [2.1], unless a lesser vertical extent of damage were to give a lower value of s_i in which case this reduced extent is to be used.*
- *where 400 or more persons are to be carried, a damage length of 0,03 L but not less than 3 m is to be assumed at any position along the side shell, in conjunction with a penetration inboard of 0,1 B but not less than 0,75 m measured inboard from the ship side, at right angles to the centreline at the level of the deepest subdivision draught.*
- *where less than 400 persons are carried, damage length is to be assumed at any position along the shell side between transverse watertight bulkheads provided that the distance between two adjacent transverse watertight bulkheads is not less than the assumed damage length. If the distance between adjacent transverse watertight bulkheads is less than the assumed damage length, only one of these bulkheads is to be considered effective for the purpose of demonstrating compliance with the criteria $s_i \geq 0{,}9$.*
- *where 36 persons are carried, a damage length of 0,015 L but not less than 3 m is to be assumed, in conjunction with a penetration inboard of 0,05 B but not less than 0,75 m.*
- *where more than 36, but fewer than 400 persons are carried the values of damage length and penetration inboard, used in the determination of the assumed extent of damage, are to be obtained by linear interpolation between the values of damage length and penetration which apply for ships carrying 36 persons and 400 persons.*

2.3.13 Documents to be supplied

The master is to be supplied with such information to the satisfaction of the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information shall be furnished to the Society.

The information should include:

- *curves or tables of minimum operational metacentric height (GM) and maximum permissible trim versus draught which assures compliance with the intact and damage stability requirements where applicable, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity (KG) and maximum permissible trim versus draught, or with the equivalents of either of these curves or tables.*
- *instructions concerning the operation of cross-flooding arrangements*
- *all other data and aids which might be necessary to maintain the required intact stability and stability after damage.*

The intact and damage stability information specified above are to be presented as consolidated data and encompass the full operating range of draught and trim. Applied trim values shall coincide in all stability information intended for use on board. Information not required for determination of stability and trim limits should be excluded from this information.

If the damage stability is calculated in accordance with the present sub-article, a stability limit curve is to be determined using linear interpolation between the minimum required GM assumed for each of the three draughts d_s, d_p and d_l. When additional subdivision indices are calculated for different trims, a single envelope curve based on the minimum values from this calculations is to be presented. When it is intended to develop curves of maximum permissible KG, it is to be ensured that the resulting maximum KG curves correspond with a linear variation of GM.

As an alternative to a single envelope curve, the calculations for additional trims may be carried out with one common GM for all of the trims assumed at each subdivision draught. The lowest values of each partial index A_s, A_p and A_l across these trims shall then be used in the summation of the attained subdivision index A according to [2.3.3]. This will result in one GM limit curve based on the GM used at each draught. A trim limit diagram showing the assumed trim range shall be developed.

When curves or tables of minimum operational metacentric height (GM) or maximum allowable KG versus draught are not provided, the master is to ensure that the operating condition does not deviate from approved loading conditions, or verify by calculation that the stability requirement are satisfied for this loading condition.

2.3.14 Damage control documentation

Plans showing clearly for each deck and hold the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding are to be permanently exhibited for the guidance of the officer in charge of the ship. In addition, booklets containing the aforementioned information are to be made available to the officers of the ship.

Detailed description of the information to be included in the damage control documentation is reported in Pt B, Ch 3, Sec 3, [4].

3 Structure design principles

3.1 Hull structure

3.1.1 Framing

In general, the strength deck and the bottom of passenger ships of more than 100 m in length are to be longitudinally framed.

Where a transverse framing system is adopted for such ships, it is to be considered by the Society on a case-by-case basis.

4 Design loads

4.1 Loads on deck

4.1.1 Plan of design loads on deck

A plan of design static loads on deck, including fork lift areas, axle loads and tyre print areas of wheeled loads, is to be provided for information.

All values displayed on this plan are to be at least equivalent to the values given by the present Rules for each kind of load.

4.2 Sea pressures

4.2.1 Bow impact pressure

The bow impact pressure p_{FI}, in kN/m^2, is to be taken as obtained in Pt B, Ch 5, Sec 5, [4.3.1] considering the coefficient C_Z calculated from the following formulae:

- for $z \geq 21,5\ H + T_{LC} - 11$:

$$C_Z = [10,75H - 0,5(z - T_{LC})]\left[0,82 - 0,09\left(\frac{z - T_{LC}}{T_{LC}}\right)\right]$$

- for $z < 21,5\ H + T_{LC} - 11$:

$$C_Z = \left[4,5 - 0,5\left(\frac{z - T_{LC}}{T_{LC}}\right)\right]$$

where:

H : Wave parameter defined in Pt B, Ch 5, Sec 3, for a reference length calculated with:

$\alpha = 0,65\ C_{W\text{-}LC}^{-1,3}$

$f_\alpha = 1,0$

z : z co-ordinate, in m, of the calculation point, with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 3, [2.6]

Other values of bow impact pressure may be considered by the Society on a case-by-case basis, provided that they are documented through model tests or full scale measurements.

5 Hull girder strength

5.1 Basic criteria

5.1.1 Strength deck

In addition to the requirements in Pt B, Ch 6, Sec 1, [1.3], the contribution of the hull structures up to the strength deck to the longitudinal strength is to be assessed through a finite element analysis of the whole ship in the following cases:

- when the size of openings in the side shell and/or longitudinal bulkheads located below the deck assumed by the Designer as the strength deck decrease significantly the capability of the plating to transmit shear forces to the strength deck.
- when the ends of superstructures which are required to contribute to longitudinal strength may be considered not effectively connected to the hull structures in way.

5.2 Global transverse strength

5.2.1 The behaviour of the ship primary structural members under racking effects due to transverse forces induced by transverse accelerations is to be investigated according to Pt B, Ch 7, App 1, or by means of a complete ship model under transverse accelerations load case according to NI640.

6 Hull scantlings

6.1 Balcony doors

6.1.1 General

Glazed sliding doors fitted on sides of superstructures are to comply with the following requirements:

- Pt B, Ch 11, Sec 12, [3.3] for the assessment of glass panes
- [6.1.2] for the structural testing of supporting frames.

6.1.2 Supporting frame structural testing

Strength test of balcony doors supporting frames is to be carried out according to the following procedure:

- the structural testing is to be carried out at twice the design pressure defined in Pt B, Ch 5, Sec 5, [5]
- the door assembly, its supporting frame and supporting structure are to be same as, or deemed representative of the ship actual arrangement
- the pressure is to be applied uniformly on the door entire external area
- the glass panel may be alternatively replaced by a steel plate, of reduced thickness in order to represent equivalent flexural stiffness of the glass
- the pressure is to be maintained for not less than 5 minutes
- visual inspection is to be carried out after testing, without damage nor deformation.

Section 4 Machinery and Cargo System

1 Bilge system

1.1 General

1.1.1

a) The bilge pumping system required in Pt C, Ch 1, Sec 10, [6] shall be capable of operation under all practicable conditions after a casualty, whether the ship is upright or listed. For this purpose, wing suctions shall generally be fitted except in narrow compartments at the end of the ship where one suction may be sufficient. In compartments of unusual form, additional suctions may be required.

b) Arrangements shall be made whereby water in the compartment may find its way to the suction pipes.

c) Where, for particular compartments, the Society is satisfied that the provisions of drainage may be undesirable, it may allow such provision to be dispensed with if damage stability calculations carried out in accordance with Ch 11, Sec 3, [2] *show that the survival capability of the ship will not be impaired.*

1.2 Bilge pumps

1.2.1 Number and capacity of bilge pumps

a) a) At least three power pumps shall be fitted connected to the bilge main, one of which may be driven by the propulsion machinery. Where the bilge pump numeral is 30 or more, one additional independent power pump shall be provided.

The bilge pump numeral shall be calculated as follows:

- *when P_1 is greater than P:*

  bilge pump numeral =

  $$72\left[\frac{M + 2P_1}{V + P_1 - P}\right]$$

- *in other cases:*

  bilge pump numeral =

  $$72\left[\frac{M + 2P}{V}\right]$$

  where:

  L : *Length of the ship (metres), as defined in Pt B, Ch 1, Sec 3, [2.1.1]*

  M : *Volume of the machinery space (cubic metres), as defined in Ch 11, Sec 3, [2.1.5], that is below the bulkhead deck; with the addition thereto of the volume of any permanent oil fuel bunkers which may be situated above the inner bottom and forward of, or abaft, the machinery space*

  P : *Whole volume of the passenger and crew spaces below the bulkhead deck (cubic metres), which are provided for the accommodation and use of passengers and crew, excluding baggage, store and provision rooms*

  V : *Whole volume of the ship below the bulkhead deck (cubic metres).*

  $P_1 = K \cdot N$

  where:

  N : *Number of passengers for which the ship is to be certified*

  $K = 0{,}056\ L$

  However, where the value of K·N is greater than the sum of P and the whole volume of the actual passenger spaces above the bulkhead deck, the figure to be taken as P_1 is that sum or two-thirds K·N, whichever is the greater.

b) Each of the above pumps is to have a capacity not less than that required in Pt C, Ch 1, Sec 10, [6.7.4].

c) For use of ejectors in lieu of bilge pumps, see Pt C, Ch 1, Sec 10, [6.7.2].

1.2.2 Location of bilge pumps

Where practicable, the power bilge pumps shall be placed in separate watertight compartments and so arranged or situated that these compartments will not be flooded by the same damage. If the main propulsion machinery, auxiliary machinery and boilers are in two or more watertight compartments, the pumps available for bilge service shall be distributed as far as is possible throughout these compartments.

1.2.3 Availability of pumps

On a ship of 91,5 m in length and upwards or having a criterion numeral of 30 or more, as stated in Ch 11, Sec 3, [2.3.6]*, the arrangements shall be such that at least one power bilge pump will be available for use in all flooding conditions which the ship is required to withstand, and in all flooding conditions derived from consideration of minor damages as specified in Ch 11, Sec 3, [2.3.12], as follows:*

a) one of the required bilge pumps shall be an emergency pump of a reliable submersible type having a source of power situated above the bulkhead deck, or

b) the bilge pumps and their sources of power shall be so distributed throughout the length of the ship that at least one pump in an undamaged compartment will be available.

1.2.4 Draining capability

With the exception of additional pumps which may be provided for peak compartments only, each required bilge pump shall be so arranged as to draw water from any space required to be drained.

1.3 Direct bilge suction

1.3.1

a) In passenger ships subject to subdivision regulations*, independent power bilge pumps situated in machinery and/or boiler spaces shall have direct suctions from these spaces, except that not more than two such suctions shall be required in any one space.*

b) Where two or more such suctions are provided in one compartment, there shall be at least one on each side of the ship.

c) The Society may require independent power bilge pumps situated in other spaces to have separate direct suctions.

1.4 Control location

1.4.1

a) The spindles of the sea inlet and direct suction valves shall extend well above the engine room platform.

b) Where the circulating pumps are driven by electric motors, their starting equipment shall be located at, or above, the level of the motors.

1.5 Provision against bilge system damage

1.5.1 Damage to the bilge system

Provision shall be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than one fifth of the breadth of the ship (measured at right angles to the centreline at the level of the deepest subdivision load line), or is in a duct keel, a non-return valve shall be fitted to the pipe in the compartment containing the open end. The deepest subdivision load line shall be taken as the deepest subdivision draught.

1.5.2 Operation in the case of flooding

a) Distribution boxes, cocks and valves in connection with the bilge pumping system shall be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment; in addition, damage to a pump or its pipe connecting to the bilge main outboard of a line drawn at one fifth of the breadth of the ship shall not put the bilge system out of action.

b) If there is only one system of pipes common to all the pumps, the necessary valves for controlling the bilge suctions must be capable of being operated from above the bulkhead deck.

c) Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it shall be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding condition; in that case only the valves necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

1.5.3 Valve controls

All cocks and valves referred in [1.5.2] which can be operated from above the bulkhead deck shall have their controls at their place of operation clearly marked and shall be provided with means to indicate whether they are open or closed.

1.6 Drainage and pumping arrangements for vehicle, special category and ro-ro spaces protected by fixed pressure water-spraying systems

1.6.1 *When fixed pressure water-spraying fire-extinguishing systems are fitted, in view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks during the operation of the fixed pressure water-spraying system, the following arrangements shall be provided:*

a) In the spaces above the bulkhead deck, scuppers shall be fitted so as to ensure that such water is rapidly discharged directly overboard, taking into account IMO Circular MSC.1/Circ.1320

b)

1) in ro-ro passenger ships, discharge valves for scuppers, fitted with positive means of closing operable from a position above the bulkhead deck in accordance with the requirements of the International Convention on Load Lines in force, shall be kept open while the ships are at sea

2) any operation of valves referred to in 1) shall be recorded in the log-book

c) In the spaces below the bulkhead deck, the Society may require pumping and drainage facilities to be provided additional to the requirements above and to those of Pt C, Ch 1, Sec 10. In such case, the drainage system shall be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

2 Ballast system

2.1

2.1.1 *Water ballast should not in general be carried in tanks intended for fuel oil. In ships in which it is not practicable to avoid putting water in fuel oil tanks, oily-water separating equipment to the satisfaction of the Society shall be fitted, or other alternative means, such as discharge to shore facilities shall be provided for disposing of the oily-water ballast.*

3 Miscellaneous requirements

3.1 Steering gear

3.1.1 For steering gear arrangements without auxiliary means for steering, see Ch 15, Sec 4, [24.3.2].

3.2 Oil-level gauges

3.2.1 For oil-level gauges, see Pt C, Ch 1, Sec 10, [11.6.7].

3.3 Watertight doors

3.3.1 For watertight doors, see Ch 11, Sec 2.

Section 5 Electrical Installations

1 General

1.1 Documentation to be submitted

1.1.1 The documentation dealing with the electrical system for watertight door and fire door systems as requested in Pt C, Ch 2, Sec 1, Tab 1, Pt B, Ch 1, Sec 4, Tab 1 and Pt C, Ch 4, Sec 1, Tab 1 is to be submitted for approval.

1.2 Electrical distribution and protection

1.2.1 *In a passenger ship, distribution systems shall be so arranged that fire in any main vertical zone as defined in* Part C, Chapter 4 *will not interfere with services essential for safety in any other such zone.*

This requirement will be met if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

1.2.2 For generators arranged to operate in parallel and for individually operating generators, arrangements are to be made to disconnect automatically the excess load when the generators are overloaded in such a way as to prevent a sustained loss of speed. The operation of such device is to activate a visual and audible alarm.

1.3 Flooding detection systems for passenger ships carrying 36 or more persons

1.3.1 *A flooding detection system for watertight spaces below the bulkhead deck is to be provided based on IMO MSC.1/Circ.1291.*

2 Emergency source of electrical power and emergency installations

2.1 General

2.1.1 *A self-contained emergency source of electrical power shall be provided.*

2.1.2 *Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.*

Exceptionally, whilst the vessel is at sea, is understood to mean conditions such as:

a) Blackout situation

b) Dead ship situation

c) Routine use for testing

d) Short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless instructed otherwise by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of Pt C, Ch 2, Sec 3, [2.4] are complied with.

2.1.3 *The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.*

2.1.4 *The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in* [2.2.3] *for the period specified, if they depend upon an electrical source for their operation.*

2.1.5 *The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services stated in* [2.2.7] *for the periods specified therein, if they depend upon an electrical source for their operation.*

2.1.6 *An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power referred to in* Pt C, Ch 2, Sec 3, [2.3.15] *and* Pt C, Ch 2, Sec 3, [2.3.16] *are being discharged.*

2.1.7 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor converters, means are to be provided for supplying such services also in the event of failure of the converter (e.g. providing a bypass feeder or a duplication of converter).

2.1.8 *Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.*

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries is to be assumed available. It is assumed that means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator stored starting energy is not to be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

For steam ships, the 30 minute time limit given in SOLAS can be interpreted as the time from blackout/dead ship condition defined above to light-off of the first boiler.

2.1.9 *Provision shall be made for the periodical testing of the complete emergency system and shall include the testing of automatic starting arrangements.*

2.1.10 For starting arrangements of emergency generating sets, see Pt C, Ch 1, Sec 2, [3.1].

2.1.11 *The emergency source of electrical power may be either a generator or an accumulator battery, which shall comply with the provisions of* [2.1.12] *or* [2.1.13]*, respectively.*

2.1.12 *Where the emergency source of electrical power is a generator, it shall be:*

a) Driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed cup test) of not less than 43°C

b) Started automatically upon failure of the electrical supply to the emergency switchboard *from the main source of electrical power and shall be automatically connected to the emergency switchboard; those services referred to in* [2.2.7] *shall then be transferred automatically to the emergency generating set. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s, and*

c) Provided with a transitional source of emergency electrical power according to [2.1.14].

2.1.13 *Where the emergency source of electrical power is an accumulator battery, it shall be capable of:*

a) Carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage

b) Automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power, and

c) Immediately supplying at least those services specified in [2.2.7].

2.1.14 *The transitional source of emergency electrical power required by* [2.1.12] (c) *shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the services in* [2.2.7] *if they depend upon an electrical source for their operation.*

2.1.15 Where the emergency and/or transitional source of power is an uninterruptible power system (UPS), it is to comply with the requirements of Pt C, Ch 2, Sec 6, [3].

2.2 Distribution of electrical power

2.2.1 *The emergency switch board shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.*

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

2.2.2 *In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.*

2.2.3 *The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:*

a) For a period of 36 hours, emergency lighting:

1) at every muster and embarkation station and over the sides

2) in alleyways, stairways and exits giving access to the muster and embarkation stations

3) in all service and accommodation alleyways, stairways and exits, personnel lift cars

4) in the machinery spaces and main generating stations including their control positions

5) in all control stations, machinery control rooms, and at each main and emergency switchboard

6) at all stowage positions for firemen's outfits

7) at the steering gear, and

8) at the fire pump, the sprinkler pump and the emergency bilge pump referred to in (d) below and at the starting position of their motors

b) For a period of 36 hours:

1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force, and

2) the VHF radio installation required by Regulation IV/7.1.1 and IV/7.1.2 of SOLAS 1974 as amended, and, if applicable:

- *the MF radio installation required by Regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3*
- *the ship earth station required by Regulation IV/10.1.1, and*
- *the MF/HF radio installation required by Regulations IV/11.1.1 and IV/11.1.2*

c) For a period of 36 hours:

1) all internal communication equipment required in an emergency (see [2.2.4]

2) the shipborne navigational equipment as required by Regulation V/12; where such provision is unreasonable or impracticable the Society may waive this requirement for ships of less than 5,000 gross tonnage

3) the fire detection and fire alarm system, the fire door holding and release system, and

4) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals (see [2.2.5]) *that are required in an emergency, unless such services have an independent supply for the period of 36 hours from an accumulator battery suitably located for use in an emergency*

d) For a period of 36 hours:

1) one of the fire pumps required by the relevant provisions of Part C, Chapter 4

2) the automatic sprinkler pump, if any, and

3) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves

e) For the period of time required in Pt C, Ch 1, Sec 14, [2]*, the steering gear if required to be so supplied*

f) For a period of half an hour:

1) any watertight doors required by Regulation II-1/13 to be power operated together with their indicators and warning signals

2) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

2.2.4 Internal communication equipment required in an emergency generally includes:

a) The means of communication between the navigation bridge and the steering gear compartment

b) The means of communication between the navigation bridge and the position in the machinery space or control room from which the engines are normally controlled

c) The means of communication which is provided between the officer of the watch and the person responsible for closing any watertight door which is not capable of being closed from a central control station

d) The public address system or other effective means of communication throughout the accommodation, public and service spaces

e) The means of communication between the navigation bridge and the main fire control station.

2.2.5 Internal signals required in an emergency generally include:

a) General alarm

b) Watertight door indication

c) Fire door indication.

2.2.6 In a ship engaged regularly in voyages of short duration, i.e. voyages where the route is no greater than 20 nautical miles offshore or where the vessel has a class notation "Coastal Service", the Society if satisfied that an adequate standard of safety would be attained may accept a lesser period than the 36-hour period specified in [2.2.3] (b) to (e) but not less than 12 hours.

2.2.7 *The transitional source of emergency electrical power required is to supply at least the following services if they depend upon an electrical source for their operation:*

a) For half an hour:

1) the lighting required by [2.2.3] (b1) *and* Pt C, Ch 2, Sec 3, [3.6.7] (a)

2) all services required by [2.2.3] (c1, 3 and 4) *unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency*

b) It is also to supply power to close the watertight doors as required by Regulation II-1/13.7.3.3, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided. Power to the control, indication and alarm circuits as required by Regulation II-1/13.7.2, for half an hour.

2.3 Low-location lighting

2.3.1 Passenger ships are to be provided with a low-location lighting (LLL) system in accordance with Pt C, Ch 4, Sec 8, [2.2.3].

Where LLL is satisfied by electric illumination, it is to comply with the following requirements.

2.3.2 The LLL system is to be connected to the emergency switchboard and is to be capable of being powered either by the main source of electrical power, or by the emergency source of electrical power for a minimum period of 60 minutes after energising in an emergency.

2.3.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with IEC Publication 60331: Fire characteristics of electrical cables, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes.

2.3.4 Single lights and lighting assemblies are to be designed or arranged so that any single fault or failure in a light or lighting assembly, other than a short-circuit, will not result in a break in visible delineation exceeding 1 metre.

2.3.5 Light and lighting assemblies are to be flame-retardant as a minimum, to have an ingress protection of at least IP55 and to meet the type test requirements as specified in Pt C, Ch 3, Sec 6, Tab 1.

2.3.6 The LLL system is to be capable of being manually activated by a single action from the continuously manned central control station. It may, additionally, be continuously operating or be switched on automatically, e.g. by the presence of smoke within the space(s) being served.

2.3.7 When powered, the systems are to achieve the following minimum luminance:

- for any planar source: 10 cd/m^2 from the active parts in a continuous line of 15 mm minimum width
- for any point source: 35 mcd in the typical track directions of approach and viewing which is to be considered:
  - for sources which are required to be viewed from a horizontal position, i.e. deck mounted or horizontally bulkhead mounted fittings, within a 60° cone having its centre located 30° from the horizontal mounting surface of the point source and in line with the track direction, see Fig 1
  - for sources which are required to be viewed vertically, i.e. the vertical LLL marking up to the door handles, within a 60° cone having its centre located perpendicular to the mounting service of the point source, see Fig 2.

Spacing between sources is not to exceed 300 mm.

2.3.8 The lights or lighting assemblies are to be continuous except as interrupted by constructional constraints, such as corridors or cabin doors etc., are to provide a visible delineation along the escape route and, where applicable, are to lead to the exit door handles. Interruption of the LLL system due to constructional constraints is not to exceed 2 metres.

2.3.9 The lighting is to be provided on at least one side of the corridor or stairway. In corridors and stairways in excess of 2 metres width, lighting is to be provided on both sides.

2.3.10 In corridors the lighting is to be installed either on the bulkhead within 300 mm of the deck or, alternatively, on the deck within 150 mm of the bulkhead.

2.3.11 In stairways the lighting is to be installed within 300 mm above the steps such that each step may be readily identified from either above or below that step. The top and bottom steps are to be further identified to show that there are no further steps.

Figure 1 :

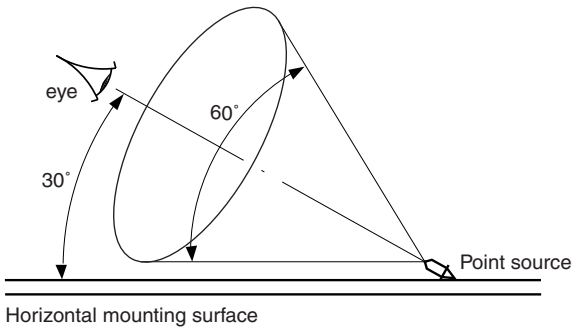
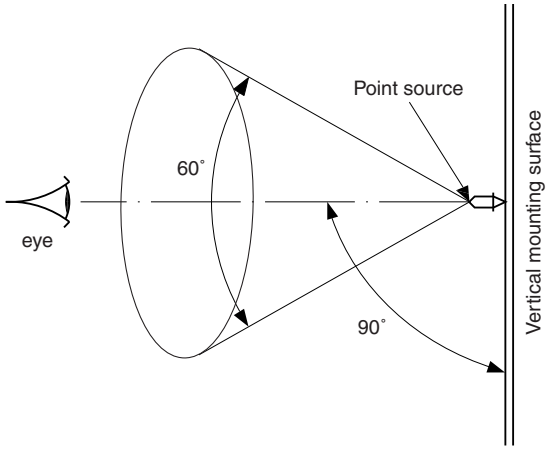


Figure 2 :



3 General emergency alarm and public address systems

3.1 General emergency alarm system

3.1.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren for sounding the general emergency alarm signal is to comply with the following requirements.

3.1.2 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in [3.2] or other suitable means of communication.

3.1.3 The entertainment sound system is to be automatically turned off when the general alarm system is activated.

3.1.4 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of the normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

3.1.5 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by [2.1] and [2.2].

3.1.6 The system is to be capable of operation from the navigation bridge and, except for the ship’s whistle, also from other strategic points.

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station is normally to be regarded as strategic points.

3.1.7 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

3.1.8 The alarm system is to be audible throughout all the accommodation and normal crew working spaces and on all open decks.

3.1.9 The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB (A) and at least 10 dB (A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather.

3.1.10 In cabins without a loudspeaker installation, an electronic alarm transducer, e.g. a buzzer or similar, is to be installed.

3.1.11 The sound pressure level at the sleeping position in cabins and in cabin bathrooms is to be at least 75 dB (A) and at least 10 dB (A) above ambient noise levels.

3.1.12 For cables used for the general emergency alarm system, see Pt C, Ch 2, Sec 3, [9.6.1], Pt C, Ch 2, Sec 11, [5.2.1] and Pt C, Ch 2, Sec 11, [5.2.5].

3.1.13 Electrical cables and apparatus for the general emergency alarm system and their power supply are to be arranged so that the loss of the system in any one area due to localised fire is minimised.

3.1.14 Where the fire alarm to summon the crew operated from the navigation bridge or fire control station is part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm in the passenger spaces.

3.2 Public address system

3.2.1 The public address system is to be one complete system consisting of a loudspeaker installation which enables simultaneous broadcast of messages from the navigation bridge, and at least one other location on board for use when the navigation bridge has been rendered unavailable due to the emergency, to all spaces where crew members or passengers, or both, are normally present (accommodation and service spaces and control stations and open decks), and to assembly stations (i.e. muster stations).

In spaces such as under deck passageways, bosun's locker, hospital and pump room, the public address system may not be required.

3.2.2 The public address system is to be arranged to operate on the main source of electrical power, the emergency source of electrical power and transitional sources of electrical power as required by Pt C, Ch 2, Sec 3, [2.3] and Pt C, Ch 2, Sec 3, [3.6].

3.2.3 The controls of the system on the navigation bridge are to be capable of interrupting any broadcast on the system from any other location on board.

3.2.4 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigation bridge, is to be in place.

3.2.5 The system is not to require any action by the addressee.

3.2.6 It is to be possible to address crew accommodation and work spaces separately from passenger spaces.

3.2.7 In addition to any function provided for routine use aboard the ship, the system is to have an emergency function control at each control station which:

a) Is clearly indicated as the emergency function

b) Is protected against unauthorised use

c) Automatically overrides any other input system or program, and

d) Automatically overrides all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces.

3.2.8 The system is to be installed with regard to acoustically marginal conditions, so that emergency announcements are clearly audible above ambient noise in all spaces where crew members or passengers, or both, are normally present (accommodation and service spaces and control stations and open decks), and at assembly stations (i.e. muster stations).

3.2.9 With the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

a) In interior spaces 75 dB (A) and at least 20 dB (A) above the speech interference level, and

b) In exterior spaces 80 dB (A) and at least 15 dB (A) above the speech interference level.

Evidence of this level is to be shown with test result in open sea or equivalent quay measurement with appropriate correction factor.

3.2.10 The system is to be arranged to prevent feed-back or other interference.

3.2.11 The system is to be arranged to minimise the effect of a single failure so that the emergency messages are still audible (above ambient noise levels) also in the event of failure of any one circuit or component.

3.2.12 Each loudspeaker is to be individually protected against short-circuits.

3.2.13 For cables used for the public address system, see Pt C, Ch 2, Sec 3, [9.6.1], Pt C, Ch 2, Sec 11, [5.2.1] and Pt C, Ch 2, Sec 11, [5.2.5].

3.2.14 All areas of each fire zone are to be served by at least two dedicated loops of flame-retardant cables which are to be sufficiently separated throughout their length and supplied by two separate and independent amplifiers.

3.2.15 A temperature alarm is to be provided in the public address cabinets in case of forced air cooling.

3.3 Combined general emergency alarm - public address system

3.3.1 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [3.1] and [3.2], the following are to be satisfied:

- the system automatically overrides any other input system when an emergency alarm is required.
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required.
- the system is arranged to minimise the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the event of failure of any one circuit or component, by means of the use of more than one device for generating an electronic sound signal.

4 Installation

4.1 Section and distribution boards

4.1.1 Cubicles and cupboards in areas which are accessible to any passenger are to be lockable.

5 Type approved components

5.1

5.1.1 Components for Low-Location Lighting systems (LLL) in passenger ship escape routes are to be type approved or in accordance with [5.1.2].

5.1.2 Case-by-case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

Appendix 1 Calculation Method for Cross-Flooding Arrangements

1 Calculation method for cross-flooding arrangements

1.1 Definitions

1.1.1 Definitions

Σk : *Sum of friction coefficients in the considered cross-flooding arrangement*

S : *Cross-section area, in m², of the cross-flooding pipe or duct. If the cross-section area is not circular, then:*

$$S_{equiv} = \frac{\pi D_{equiv}^2}{4}$$

where:

$$D_{equiv} = \frac{4A}{p}$$

A : *actual cross-section area*

p : *actual cross-section perimeter*

θ_0 : *Angle, in degree, before commencement of cross-flooding. This assumes that the cross-flooding device is fully flooded but that no water has entered into the equalizing compartment on the opposite side of the damage*

θ_f : *Heel angle, in degree, at final equilibrium*
$\theta_f \leq \theta$

θ : *Any angle of heel between the commencement of cross-flooding and the final equilibrium at a given time*

W_f : *Volume, in m³, of water which is used to bring the ship from commencement of cross-flooding θ_0 to final equilibrium θ_f*

W_θ : *Volume, in m³, of water which is used to bring the ship from any angle of heel θ to the final equilibrium θ_f*

H_0 : *Head of water, in m, before commencement of cross-flooding, with the same assumption as for θ_0*

H_θ : *Head of water, in m, when any angle of heel θ is achieved*

h_f : *Final head of water, in m, after cross-flooding*
($h_f = 0$, when the level inside the equalizing compartment is equal to the free level of the sea).

1.2 Cross-flooding area

1.2.1 Cross-flooding area calculation

The cross-flooding area S, in m², can be calculated from the following formula:

$$S = \frac{2W_f}{T_f F} \cdot \frac{\left(1 - \sqrt{\frac{h_f}{H_0}}\right)}{\sqrt{2gH_0}} \cdot \frac{1}{\left(1 - \frac{h_f}{H_0}\right)}$$

1.2.2 Calculation of time

T_f : *Time required from commencement of cross flooding θ_o to the final equilibrium θ_f*

T_θ : *Time required to bring the ship from any angle of heel θ to the final equilibrium θ_f*

$$T_\theta = \frac{2W_\theta}{S \cdot F} \cdot \frac{\left(1 - \sqrt{\frac{h_f}{H_\theta}}\right)}{\sqrt{2gH_\theta}} \cdot \frac{1}{\left(1 - \frac{h_f}{H_\theta}\right)}$$

T : *Time required from commencement of cross flooding θ_o until any angle of heel θ is achieved:*
$T = T_f - T_\theta$

1.2.3 Dimensionless factor F

The dimensionless factor of reduction of speed through an equalization device, being a function of bends, valves, etc., in the cross-flooding system is to be calculated as follows:

$$F = \frac{1}{\sqrt{\sum k}}$$

where F is not to be taken as more than 1.

Values for k can be obtained from [1.2.4] or other appropriate sources.

1.2.4 Factor of reduction k

The factor of reduction is to be calculated depending on the following cases:

- Case 1: 90° circular bend
- Case 2: radius bend R/D = 2
- Case 3: mitre bend
- Case 4: 90° double mitre bend
- Case 5: pipe inlet
- Case 6: pipe outlet
- Case 7: non-return valve
- Case 8: pipe friction losses
- Case 9: gate valve
- Case 10: butterfly valve
- Case 11: disc valve.

Case 1: 90° CIRCULAR BEND (see Fig 1)

The factor k is defined in Tab 1.

Figure 1 : 90°CIRCULAR BEND

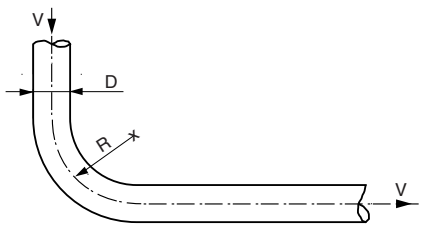


Table 1 : Values of factor k

R/D	2	3	4	5	6	7
k	.30	.26	.23	.20	.18	.17

Case 2: RADIUS BEND R/D = 2 (see Fig 2)

The factor k is defined in Tab 2.

Figure 2 : RADIUS BEND R/D = 2

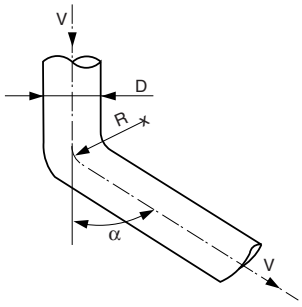


Table 2 : Values of factor k

α°	15	30	45	60	75	90
k	.06	.12	.18	.24	.27	.30

Case 3: MITRE BEND (see Fig 3)

The factor k is defined in Tab 3.

Figure 3 : MITRE BEND

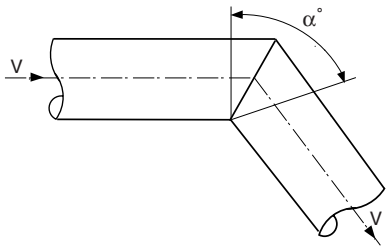


Table 3 : Values of factor k

α°	5	15	30	45	60	90
k	.02	.06	.17	.32	.68	1.26

Case 4: 90°DOUBLE MITRE BEND (see Fig 4)
The factor k is defined in Tab 4.

Figure 4 : 90° DOUBLE MITRE BEND

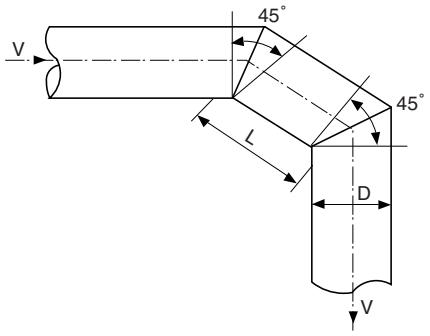


Table 4 : Values of factor k

L/D	1	2	3	4	5	6
k	.41	.40	.43	.46	.46	.44

Case 5: PIPE INLET (see Fig 5)
The factor k is defined in Tab 5.

Figure 5 : PIPE INLET

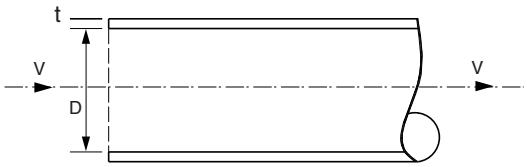
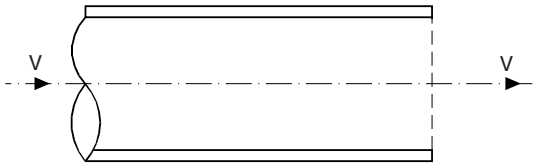


Table 5 : Values of factor k

t/D	.01	.02	.03	.04	.05	≥ .05
k	.83	.68	.53	.46	.44	.43

Case 6: PIPE OUTLET (see Fig 6)
k = 1.0

Figure 6 : PIPE OUTLET

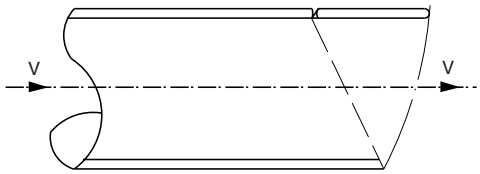


Case 7: NON-RETURN VALVE (see Fig 7)

k = 0.5

The value of k actually increases with decrease in Froude number, particularly below speeds of 2m/sec.

Figure 7 : NON-RETURN VALVE



Case 8: PIPE FRICTION LOSSES

The coefficient above is a mean value and does in fact vary as Reynold's number (i.e. varies with V for constant D and v) as well as with relative roughness.

k = 0.02/D per unit length

Case 9: GATE VALVE (see Fig 8)

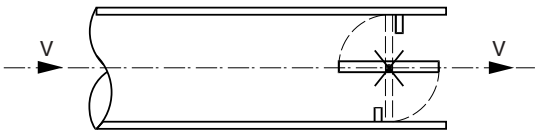
k = 0.3

Figure 8 : GATE VALVE

Case 10: BUTTERFLY VALVE (see Fig 9)

k = 0.8

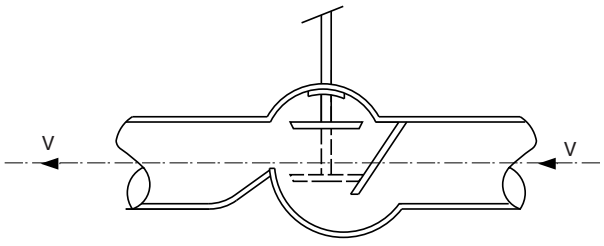
Figure 9 : BUTTERFLY VALVE



Case 11: DISC VALVE (see Fig 10)

k = 6.0

Figure 10 : DISC VALVE



1.2.5 Cross-flooding through successive devices

If the same flow crosses successive flooding devices of cross-section S_1, S_2, S_3,... having corresponding friction coefficients k_1, k_2, k_3,..., then the total k coefficient referred to S_1 is:

$$\sum k = k_1 + k_2 \frac{S_1^2}{S_2^2} + k_3 \frac{S_1^2}{S_3^2} \ldots$$

1.2.6 Different flooding devices not crossed by the same volume

If different flooding devices are not crossed by the same volume, each k coefficient is to be multiplied by the square of the ratio of the volume crossing the device and the volume crossing the reference section (which will be used for the time calculation):

$$\sum k = k_1 + k_2 \frac{S_1^2}{S_2^2} \cdot \frac{W_2^2}{W_1^2} + k_3 \frac{S_1^2}{S_3^2} \cdot \frac{W_3^2}{W_1^2} \ldots$$

1.2.7 Cross flooding through devices in parallel

For cross-flooding through devices in parallel that lead to the same space, equalisation time is to be calculated assuming that:

$$SF = S_1F_1 + S_2F_2 + \ldots$$

with:

$$F = \frac{1}{\sqrt{\sum k}}$$

for each device of cross section S_i.

1.2.8 Air pipe venting criteria

In arrangements where the total air pipe sectional area is 10% or more of the cross-flooding sectional area, the restrictive effect of any air back pressure may be neglected in the cross-flooding calculations. The air pipe sectional area is to be taken as the minimum or the net sectional area of any automatic closing devices, if that is less.

In arrangements where the total air pipe sectional area is less than 10% of the cross-flooding sectional area, the restrictive effect of air back pressure is to be considered in the cross-flooding calculations. The following method may be used for this purpose:

The k coefficient used in the calculation of cross-flooding time is to take into account the drop of head in the air pipe. This can be done using an equivalent coefficient k_e, which is calculated according to the following formula:

$$k_e = k_w + k_a \frac{\rho_a}{\rho_w} \cdot \left(\frac{S_w}{S_a}\right)^2$$

where:

k_w : *k coefficient for the cross-flooding arrangement (water)*

k_a : *k coefficient for the air pipe*

ρ_a : *Air density*

ρ_w : *Water density*

S_w : *Cross-section area of the cross-flooding device (water)*

S_a : *Cross-section of air pipe*

1.2.9 Alternatives

As an alternative to the provisions above, and for arrangements other than those shown in [1.2.4], direct calculation using computational fluid dynamics (CFD), time-domain simulations or model testing may also be used.

1.2.10 Examples

- *Cross-flooding through a series of structural ducts with 1 manhole (see Fig 11 and Fig 12)*
  - *if $0 < L_i < 1$:*

    $k = 0,2748\ L_i + 0,0313$
  - *if $1 \leq L_i \leq 4$:*

    $k = -0,0986\ L_i^3 + 0,6873\ L_i^2 - 1,0212\ L_i + 0,7386$
  - *if $L_i > 4$:*

    $k = 1,34$
- *Cross-flooding through a series of structural ducts with 2 manholes (see Fig 13)*
  - *if $0 < L_i < 1$:*

    $k = 0,4045\ L_i + 0,0627$
  - *if $1 \leq L_i \leq 4$:*

    $k = 0,0424\ L_i^3 + 0,3593\ L_i^2 - 1,1401\ L_i - 0,356$
  - *if $L_i > 4$:*

    $k = 1,17$

Note 1: k is the friction coefficient related to each space between two adjacent girders. k is evaluated with effective cross-section area therefore in calculations use the real cross-section area A and not S_{equiv}. The pressure loss for entrance in the first manhole is already computed in the calculation, and k = 1 has to be added to take into account the outlet losses.

Figure 11 : Structural duct with 1 manhole

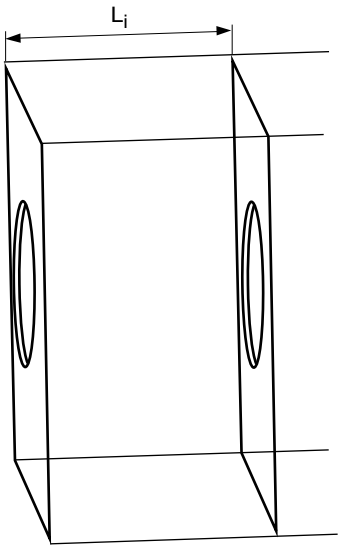


Figure 12 : Series of structural ducts with 1 manhole

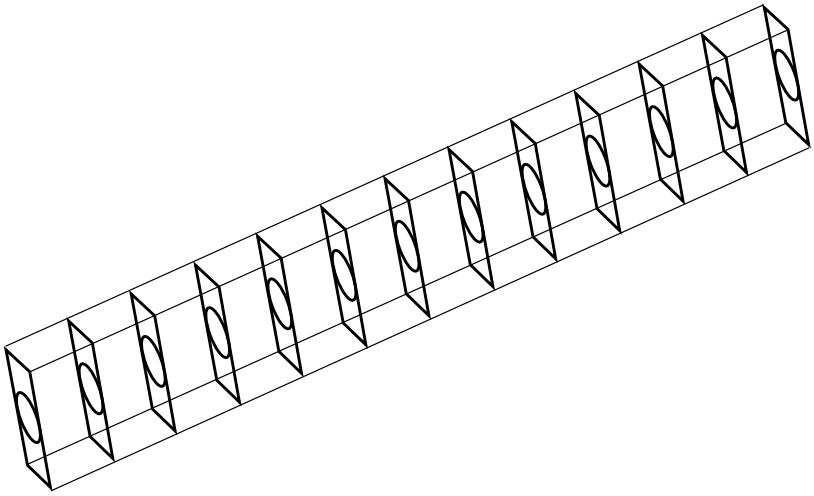
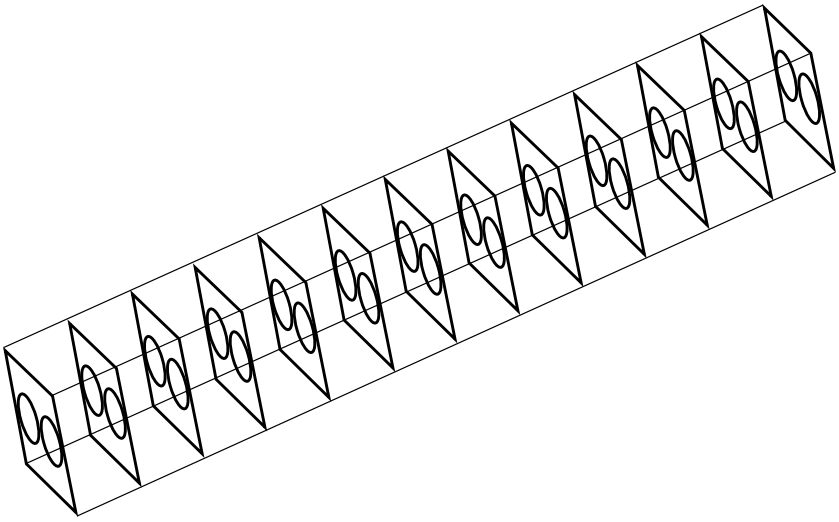


Figure 13 : Series of structural ducts with 2 manholes



CHAPTER 12
RO-RO PASSENGER SHIPS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 4 Electrical Installations

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **ro-ro passenger ship**, as defined in Pt A, Ch 1, Sec 2, [4.5.3].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.3 For ships having to comply with the provisions of SOLAS Ch II-1 reg 8-1 and SOLAS Ch II-2 reg 21 and 22, the service notation **ro-ro passenger ship** is to be completed by the additional service feature **SRTP** according to requirements of NR598 Implementation of Safe Return to Port and Orderly Evacuation.

1.1.4 Additional guidance for arrangement and structural assessment is provided in NI640 Structural Assessment of Passenger Ships.

Table 1 : Applicable requirements

Item		Ships having the navigation notation **unrestricted navigation**	Ships having a navigation notation other than **unrestricted navigation**	
			Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B • Ch 12, Sec 2	• Part B • Ch 12, Sec 2	• NR566
	L < 65 or 90 m **(1)**	• NR600	• NR600	• NR566
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 12, Sec 3	• Part B • Ch 12, Sec 3	• Part B • Ch 12, Sec 3
	L < 65 or 90 m **(1)**	• NR600	• NR600	• NR600
Stability		• Part B • Ch 12, Sec 3	• Part B • Ch 12, Sec 3	• NR566
Machinery and cargo systems		• Part C • Ch 1, Sec 3 • Ch 11, Sec 4	• Part C • Ch 1, Sec 3 • Ch 11, Sec 4	• NR566
Electrical installations		• Part C • Ch 12, Sec 4	• Part C • Ch 12, Sec 4	• NR566
Automation		• Part C	• Part C	• NR566
Fire protection, detection and extinction		• Part C	• Part C	• NR566

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Ship Arrangement

1 General

1.1 Definitions

1.1.1 Deepest subdivision load line

Deepest subdivision load line *is the waterline which corresponds to the summer load line of the ship.*

1.1.2 Ro-ro cargo spaces

Ro-ro cargo spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles, including road or rail tankers, trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

1.1.3 Special category spaces

Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

2 General arrangement design

2.1 Number and disposition of transverse watertight bulkheads

2.1.1 Where there are less transverse bulkheads than those specified in Pt B, Ch 2, Sec 1, [2.1] or where the distance between them is considered excessive by the Society, ships are to be fitted with a system of partial bulkheads, side transverse frames and deck transverses such as to provide equivalent transverse strength.

2.2 Openings in watertight boundaries below the bulkhead deck

2.2.1 General

The number of openings in watertight boundaries is to be reduced to the minimum compatible with the design and proper working of the ship.

Where pipes, scuppers, electric cables, etc., are carried through watertight boundaries, arrangements are to be made to ensure the watertight integrity of the boundaries.

Valves not forming part of a piping system are not permitted in watertight boundaries.

Lead or other heat sensitive materials are not to be used in systems which penetrate watertight boundaries, where deterioration of such systems in the event of fire would impair the watertight integrity of the boundaries.

2.2.2 Openings in machinery spaces

Not more than one door apart from the doors to shaft tunnels may be fitted in each watertight bulkhead within spaces containing the main and auxiliary propulsion machinery including boilers serving the needs of propulsion. Where two or more shafts are fitted the tunnels are to be connected by an inter-communicating passage. Only one door is to be provided between the machinery space and the tunnel spaces where two shafts are fitted and only two doors where there are more than two shafts. All these doors are to be of the sliding type and are to be so located as to have their sills as high as practicable. The hand gear for operating these doors from above the bulkhead deck is to be situated outside the spaces containing the machinery.

Portable plates on bulkheads are not permitted except in machinery spaces. The Society may permit not more than one power-operated sliding watertight door larger than 1,20 m to be substituted for these portable plates in each watertight bulkhead, provided these doors are intended to remain closed during navigation except in the case of urgent necessity at the discretion of the master. These doors need not meet the requirements of [2.3.4] e) regarding complete closure by hand-operated gear in 90 seconds.

2.2.3 Openings in cargo spaces

Watertight doors complying with the requirements of [2.3.1] may be fitted in watertight bulkheads dividing cargo spaces on 'tween decks. Such doors may be hinged, rolling or sliding doors but are not to be remotely controlled. They are to be fitted at the highest level and as far from the shell plating as practicable, but in no case are the outboard vertical edges to be situated at a distance from the shell plating which is less than one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision load line.

The doors accessible during the voyage are to be fitted with a device which prevents unauthorised opening. When it is proposed to fit such doors, the number and arrangements are to receive the special consideration of the Society.

2.2.4 Openings in ships carrying goods vehicles and accompanying personnel

This requirement applies to passenger ships designed or adapted for the carriage of goods vehicles and accompanying personnel where the total number of persons on board, other than passengers as defined in Pt A, Ch 1, Sec 2, [4.5.2], exceeds 12.

If in such a ship the total number of passengers which include personnel accompanying vehicles does not exceed:

$$N = 12 + \frac{A}{25}$$

where:

N : The maximum number of passengers for which the ship is certified

A : The total deck area, in m^2, of spaces available for the stowage of goods vehicles,

and where the clear height at the stowage position and at the entrance to such spaces is not less than 4 m, the provisions of [2.2.3] in respect of watertight doors apply except that the doors may be fitted at any level in watertight bulkheads dividing cargo spaces.

Additionally, indicators are required on the navigation bridge to show automatically when each door is closed and all door fastenings are secured.

2.2.5 Trunks and tunnels

Where trunkways or tunnels for access from crew accommodation to the machinery space, for piping, or for any other purpose are carried through watertight bulkheads, they are to be watertight and in accordance with the requirements of Pt B, Ch 4, Sec 5, [10.5]. The access to at least one end of each such tunnel or trunkway, if used as a passage at sea, is to be through a trunk extending watertight to a height sufficient to permit access above the bulkhead deck. The access to the other end of the trunkway or tunnel may be through a watertight door. Such trunkways or tunnels are not to extend through the first subdivision bulkhead abaft the collision bulkhead.

Where trunkways in connection with refrigerated cargo and ventilation or forced draught trunks are carried through more than one watertight bulkhead, the means of closure at such openings are to be operated by power and be capable of being closed from a central position situated above the bulkhead deck.

Where a ventilation trunk passing through a structure penetrates a watertight area of the bulkhead deck, the trunk is to be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heel angle during flooding, in accordance with Ch 12, Sec 3, [2.3.5].

2.2.6 Additional requirements

In addition to [2.2.2], [2.2.3], [2.2.4], and [2.2.5], the requirements reported in [2.3.4] are to be complied with.

2.3 Doors

2.3.1 Requirements for doors

The requirements relevant to the operating systems for doors complying with the prescriptions in [2.3.2] and [2.3.4] are specified in Tab 1 for doors of internal watertight bulkheads and Tab 2 for doors of external watertight boundaries below equilibrium or intermediate waterplane.

2.3.2 Construction of watertight doors

The design, materials and construction of all watertight doors are to be to the satisfaction of the Society.

Such doors are to be suitably marked to ensure that they may be properly used to provide maximum safety.

The frames of vertical watertight doors are to have no groove at the bottom in which dirt might lodge and prevent the door closing properly.

2.3.3 Category of watertight door

a) Category B

A watertight door that may be opened during navigation when work in the immediate vicinity of the door necessitates it being opened, according to SOLAS regulation II-1/22.3. The door must be immediately closed when the task which necessitated it being open is finished.

b) Category C

A watertight door that may be opened during navigation to permit the passage of passengers or crew, according to SOLAS regulation II-1/22.3. The door must be immediately closed when transit through the door is complete.

c) Category D

A watertight door that is to be closed before the voyage commences and is to be kept closed during navigation:

- A watertight door of a width of more than 1,2 m in machinery spaces as permitted by SOLAS regulation II-1/13.9. The door is to remain closed during navigation except in case of urgent necessity at the discretion of the master according to SOLAS regulation II-1/22.4.
- Additionally, watertight doors fitted in watertight bulkheads dividing cargo between deck spaces in accordance with SOLAS regulation II-1/13.8.1 or dividing cargo spaces in accordance with SOLAS regulation II-1/14.2, are to be closed before the voyage commences and are to be closed during navigation according to SOLAS regulation II-1/22.5.

Table 1 : Doors in internal watertight bulkheads of ro-ro passenger ships

Position relative to bulkhead deck	Category	Type (1)	Remote closure	Remote indication	Audible or visual alarm	Notice
Below bulkhead deck	B, C (2)	POS	X	X	X (local)	
	D	S, H				X
	D	POS	X	X	X (local)	
	D	S, H		X		X
At or above bulkhead deck and below the worst intermediate or final equilibrium waterline	B, C (2) (3)	POS	X	X	X (local)	
At or above bulkhead deck, and above the worst intermediate and final equilibrium waterlines, but immersed in the required range of positive stability	Not applicable (4) (5)	POS, POH	X	X	X (local)	
	Not applicable (4) (6)	S, H		X		X
At or above bulkhead deck on ro-ro passenger ships	Not applicable (7)	S, H		X	X (local)	X

(1) POS : Power operated, sliding or rolling
POH : Power operated, hinged
S : Sliding or rolling
H : Hinged
(2) See IMO MSC.1/Circ.1564
(3) See explanatory Note to Regulation 17.2 of Res.MSC.429(98)/Rev.2
(4) See explanatory Note to Regulation 17.2 of Res.MSC.429(98)/Rev.2
(5) May remain open, but is always to be ready to be immediately closed
(6) Normally closed. If hinged, this door is to be of hinged action type
(7) Permanently closed. The Administration may permit some access to be opened in accordance with Reg. II-1/23.6 and 23.8

Table 2 : Doors in external watertight boundaries below equilibrium or intermediate waterplane

Position relative to bulkhead deck	Frequency of use while at sea	Type (1)	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Permanently closed	S, H		X		X
At or above	Normally closed /permanently closed (2)	S, H		X		X
	Normally closed /permanently closed (3)	S, H		X	X (remote / local)	X

(1) S : Sliding or rolling
H : Hinged
(2) If hinged, normally closed door is to be of single action type.
(3) Doors giving access to below ro-ro deck.

2.3.4 Doors in watertight bulkheads below the bulkhead deck

a) Watertight doors, except as provided in [2.2.3] paragraph 1 and [2.2.4], are to be power operated sliding doors complying with the requirements of items e) to l)

b) The means of operation whether by power or by hand of any power-operated sliding watertight door are to be capable of closing the door with the ship listed to 15° either way. Consideration is to also be given to the forces which may act on either side of the door as may be experienced when water is flowing through the opening applying a static head equivalent to a water height of at least 1 m above the sill on the centreline of the door.

c) Watertight door controls, including hydraulic piping and electrical cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted, in order to minimise the likelihood of them being involved in any damage which the ship may sustain. The positioning of watertight doors and their controls are to be such that if the ship sustains damage within one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision load line, the operation of the watertight doors clear of the damaged portion of the ship is not impaired.

d) Each power-operated sliding watertight door:

- *is to move vertically or horizontally;*
- *is to be normally limited to a maximum clear opening width of 1,20 m. The Society may permit larger doors only to the extent considered necessary for the effective operation of the ship provided that other safety measures, including the following, are taken into consideration:*
  - *special consideration is to be given to the strength of the door and its closing appliances in order to prevent leakages;*
  - *the door is to be located outside the damage zone B/5;*
- *is to be fitted with the necessary equipment to open and close the door using electrical power, hydraulic power, or any other form of power that is acceptable to the Society;*

- *is to be provided with an individual hand-operated mechanism. It is to be possible to open and close the door by hand at the door itself from either side and, in addition, close the door from an accessible position above the bulkhead deck with an all round crank motion or some other movement providing the same degree of safety acceptable to the Society. Direction of rotation or other movement is to be clearly indicated at all operating positions. The time necessary for the complete closure of the door, when operating by hand gear, may not exceed 90 s with the ship in the upright position. Visual indicators to show whether the door is open or closed are to be provided at the accessible position above the bulkhead deck.*
- *is to be provided with controls for opening and closing the door by power from both sides of the door and also for closing the door by power from the central operating console required in item m);*
- *is to be provided with an audible alarm, distinct from any other alarm in the area, which is to sound whenever the door is closed remotely by power and which is to sound for at least 5 s but no more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In the case of remote hand operation it is sufficient for the audible alarm to sound only when the door is moving. Additionally, in passenger areas and areas of high ambient noise, the Society may require the audible alarm to be supplemented by an intermittent visual signal at the door;*
- *is to have an approximately uniform rate of closure under power. The closure time, from the time the door begins to move to the time it reaches the completely closed position, is to in no case be less than 20 s or more than 40 s with the ship in the upright position.*

e) *The electrical power required for power-operated sliding watertight doors is to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and be capable of being automatically supplied by a transitional source of emergency electrical power in the event of failure of either the main or emergency source of electrical power.*

The transitional source of emergency electrical power is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically, in the event of failure of either the main or emergency source of electrical power, to control, indication and alarm circuits at least for half an hour.

f) *Power-operated sliding watertight doors are to have either:*

- *a centralised hydraulic system with two independent power sources each consisting of a motor and pump capable of simultaneously closing all doors. In addition, there are to be for the whole installation hydraulic accumulators of sufficient capacity to operate all the doors at least three times, i.e. closed-open-closed, against an adverse list of 15°. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. The power operating system is to be designed to minimise the possibility of having a single failure in the hydraulic piping adversely affect the operation of more than one door. The hydraulic system is to be provided with a low-level alarm for hydraulic fluid reservoirs serving the power-operated system and a low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators. These alarms are to be audible and visual and are to be situated on the central operating console at the navigation bridge; or*
- *an independent hydraulic system for each door with each power source consisting of a motor or pump capable of opening and closing the door. In addition, there is to be a hydraulic accumulator of sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of 15°. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. A low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators is to be provided at the central operating console required in item n). Loss of stored energy indication at each local operating position is to also be provided; or*
- *an independent electrical system and motor for each door with each power source consisting of a motor capable of opening and closing the door. The power source is to be capable of being automatically supplied by the transitional source of emergency electrical power in the event of failure of either the main or emergency source of electrical power and with sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of 15°.*

  The transitional source of emergency electrical power is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically, in the event of failure of either the main or emergency source of electrical power, to watertight doors, but not necessarily all of them simultaneously, unless an independent source of stored energy is provided.

For the systems specified above, provision is to be made as follows:

Power systems for power-operated watertight sliding doors are to be separate from any other power system. A single failure in the electrical or hydraulic power-operated systems excluding the hydraulic actuator is not to prevent the hand operation of any door.

g) *Control handles are to be provided at each side of the bulkhead at a minimum height of 1,6 m above the floor and are to be so arranged as to enable persons passing through the doorway to hold both handles in the open position without being able to set the power closing mechanism in operation accidentally. The direction of movement of the handles in opening and closing the door is to be in the direction of door movement and is to be clearly indicated.*

h) *As far as practicable, electrical equipment and components for watertight doors are to be situated above the bulkhead deck and outside hazardous areas and spaces.*

i) *The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water.*

j) *Electric power, control, indication and alarm circuits are to be protected against faults in such a way that a failure in one door circuit is not to cause a failure in any other door circuit. Short-circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck is not to cause the door to open.*

k) *A single electrical failure in the power operating or control system of a power-operated sliding watertight door is not to result in a closed door opening. Availability of the power supply is to be continuously monitored at a point in the electric circuit as near as practicable to each of the motors required in g). Loss of any such power supply is to activate an audible and visual alarm at the central operating console required in item m).*

l) *Failure of the normal power supply of the required alarms are to be indicated by an audible and visual alarm at the central operating console required in item m).*

m) *A central operating console for all power-operated sliding watertight doors is to be located in the safety centre in accordance with Pt C, Ch 4, Sec 14. If the safety centre is located in a separate space adjacent to the navigation bridge, a central operating console is also to be located on the navigation bridge.*

The central operating console is to have a "master mode" switch with two modes of control:

- *a "local control" mode which is to allow any door to be locally opened and locally closed after use without automatic closure, and*
- *a "doors closed" mode which is to automatically close any door that is open in not more than 60 s with the ship in an upright position. The "doors closed" mode is to permit doors to be opened locally and is to automatically reclose the doors upon release of the local control mechanism.*

The "master mode" switch is to normally be in the "local control" mode. The "doors closed" mode is to only be used in an emergency or for testing purposes.

n) *The central operating console is to be provided with a diagram showing the location of each power-operated sliding watertight door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light is to indicate a door is fully closed. When the door is closed remotely the red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door. Indication is also to be provided to the onboard stability computer, if installed.*

o) *It is not to be possible to remotely open any door from the central operating console.*

p) *All watertight doors are to be kept closed during navigation. Certain watertight doors may be permitted to remain open during navigation only if considered absolutely necessary; that is, being open is determined essential to the safe and effective operation of the ship's machinery or to permit passengers normally unrestricted access throughout the passenger area. Such determination is to be made by the Society only after careful consideration of the impact on ship operations and survivability. A watertight door permitted to remain thus open is to be clearly indicated in the ship's stability information* and the damage control documentation *and is always to be ready for immediate closure.*

q) *All watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or an independent hydraulic unit for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located on the central operating console required in item n).*

r) *Signboard/instructions are to be placed in way of the door advising how to act when the door closed.*

2.3.5 Doors in bulkheads above the bulkhead deck

a) *General*

Doors are to be capable of being opened and closed by hand locally from both sides of the doors with the ship listed to 15° to either side.

Position indicators are to be provided on the bridge to show that the doors are open or closed and that the dogs are fully and properly engaged.

Where the doors also serve as fire doors they are to be provided with position indicators at the fire control station and audible alarms as required for fire doors, as well as for weathertight doors. Where two doors are fitted they must be capable of independent operation remotely and from both sides of each door.

b) Doors normally closed at sea

In addition to a), doors not required for frequent access while at sea are to be kept normally closed and may be of either hinged or sliding type.

Doors kept normally closed are to have local operation from both sides of the doors and are to be labelled on both sides: "to be kept closed at sea".

c) Doors normally open at sea

Where fitted in public space for the passage of passengers and crew, the doors may be kept normally open at sea and may be either hinged or sliding type.

In addition to a), doors kept normally open at sea are to have local power operation from both sides of the door and remote closing from the bridge. Operation of these doors is to be similar to that specified in Pt C, Ch 4, Sec 5 where, using a "master mode" switch on the bridge, local control can override the remote closing feature after which the door is automatically remotely reclosed upon release of the local control mechanism.

Doors kept normally open at sea are to have audible alarms, distinct from any other alarm in the area, which sound whenever the doors are closed remotely. The alarms are to sound for at least 5 s but not more than 10 s before the doors begins to move and continue sounding until the doors are completely closed. In passenger areas and areas of high ambient noise, the audible alarms are to be supplemented by visual signals at both sides of the doors.

d) Failure of the normal power supply of the required alarms are to be indicated by an audible and visual alarm.

e) The following doors, located above the bulkhead deck, are to be provided with adequate means of closure and locking devices according to a) and b) above and the requirements of Pt B, Ch 11, Sec 8, [4]:

- *cargo loading doors in the shell or the boundaries of enclosed superstructures,*
- *bow visors fitted in the shell or the boundaries of enclosed superstructures,*
- *cargo loading doors in the collision bulkhead,*
- *weathertight ramps forming an alternative closure to those previously defined.*

f) All watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or an independent hydraulic unit for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located on the central operating console required in item n).

g) Signboard/instructions are to be placed in way of the door advising how to act when the door closed.

2.3.6 Watertight doors above the freeboard deck

The scantlings of the watertight doors above the freeboard deck in ro-ro spaces are to be checked in accordance with the structural requirements of Part B, Chapter 7 for watertight structure in flooded conditions.

2.4 Openings in bulkheads above the bulkhead deck

2.4.1 General

The internal watertight subdivision arrangements to limit the entry and spread of water above the bulkhead deck is to be in accordance with the design arrangements necessary for compliance with the stability requirements in Part B, Chapter 3. Where pipes, scuppers, electric cables, etc. are carried through internal watertight boundaries that are immersed at any intermediate or final stage of flooding in damage cases that contribute to the attained subdivision index A, arrangements are to be made to ensure their watertight integrity.

Doors in internal watertight subdivision arrangements above the bulkhead deck, and also above the worst intermediate or final stage of flooding waterlines, are to be capable of preventing the passage of water when immersed in the required range of positive stability for any damage cases contributing to the attained subdivision index A. These doors may remain open provided they can be remotely closed from the navigation bridge. They are to be always ready to be immediately closed.

The coamings of all openings in the exposed weather deck are to be of ample height and strength and are to be provided with efficient means for expeditiously closing them weathertight. Freeing ports, open rails and scuppers are to be fitted as necessary for rapidly cleaning the weather deck of water under all weather conditions.

Sidescuttles, gangway, cargo and fuelling ports and other means for closing openings in the shell plating above the bulkhead deck are to be of efficient design and construction and of sufficient strength (see Pt B, Ch 11, Sec 12) having regard to the spaces in which they are fitted and their positions relative to the deepest subdivision load line.

Efficient inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be provided for all sidescuttles to spaces below the first deck above the bulkhead deck.

2.4.2 Watertight integrity from the ro-ro deck (bulkhead deck) to spaces below

All access from the ro-ro deck that leads to spaces below the bulkhead deck are to have a lowest point which is not less than 2.5 m above the bulkhead deck, unless the access is covered by the provisions of [2.4.3].

2.4.3 Vehicle ramps and other accesses

Where vehicle ramps are installed to give access to spaces below the bulkhead deck, their openings are to be closed weathertight to prevent ingress of water below, and fitted with alarms and open/close indicators on the navigation bridge. The means of closure are to be watertight if the deck is intended as a watertight horizontal boundary for compliance with stability requirements.

The Society may permit the fitting of particular accesses to spaces below the bulkhead deck provided they are necessary for the essential working of the ship, e.g. the movement of machinery and stores, subject to such accesses being made watertight, fitted with alarms and open/close indicators on the navigation bridge.

2.4.4 Open end of air pipes

Air pipes terminating within a superstructure which are not fitted with watertight means of closure are to be considered as unprotected openings when applying Pt B, Ch 3, App 3, [1.6.11].

2.4.5 Additional requirements

In addition to [2.4.1], [2.4.2], [2.4.3] and [2.4.4], the requirements in [2.3.5] are to be complied with.

2.5 Integrity of the hull and superstructure, damage prevention and control

2.5.1 *Indicators are to be provided on the navigation bridge for all shell doors, loading doors and other closing appliances which, if left open or not properly secured, could, in the opinion of the Society, lead to flooding of a special category space or ro-ro cargo space. The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed or if any of the securing arrangements are not in place and fully locked and by audible alarms if such door or closing appliances become open or the securing arrangements become unsecured. The indicator panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage" so arranged that an audible alarm is given on the navigation bridge if the ship leaves harbour with the bow doors, inner doors, stern ramp or any other side shell doors not closed or any closing device not in the correct position. The power supply for the indicator system is to be independent of the power supply for operating and securing the doors.*

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

2.5.2 *Television surveillance and a water leakage detection system are to be arranged to provide an indication to the navigation bridge and to the engine control station of any leakage through inner and outer bow doors, stern doors or any other shell doors which could lead to flooding of special category spaces or ro-ro cargo spaces.*

2.5.3 *Special category spaces and ro-ro cargo spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions and unauthorised access by passengers thereto can be detected during navigation.*

2.5.4 *Documented operating procedures for closing and securing all shell doors, loading doors and other closing appliances which, if left open or not properly secured, could, in the opinion of the Society, lead to flooding of a special category space or ro-ro cargo space, are to be kept on board and posted at an appropriate place.* The operating procedures may be included in the stability information or in the damage control booklet.

2.5.5 A closing indicator is to be fitted for the inner bow doors which constitute a prolongation of the collision bulkhead above the bulkhead deck as requested in [2.5.1].

2.6 Ballast compartment arrangement

2.6.1 *Water ballast is not to, in general, be carried in tanks intended for fuel oil. In ships in which it is not practicable to avoid putting water in fuel oil fuel, oily-water separating equipment to the satisfaction of the Society is to be fitted, or other alternative means, such as discharge to shore facilities, acceptable to the Society is to be provided for disposing of the oily-water ballast (see Pt C, Ch 1, Sec 10, [7].*

2.7 Machinery compartment arrangement

2.7.1 When longitudinal bulkheads are fitted in the machinery space, adequate self-operating arrangements are to be provided in order to avoid excessive heel after damage.

Where such arrangements are cross-flooding systems, their area is to be calculated in accordance with the requirements in Ch 11, App 1. In addition, such systems are to comply with the criteria for the maximum time necessary to cross flood according to Ch 12, Sec 3, [2.3.5], item a).

2.8 Passenger spaces in ro-ro ships

2.8.1 No passenger spaces are permitted within the enclosed ro-ro decks.

Section 3 Hull and Stability

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the following documents are to be submitted:

- operating and maintenance manual (see Pt B, Ch 11, Sec 6 and Pt B, Ch 11, Sec 7) of bow and stern doors and ramps
- plan of design loads on deck as specified in [4.1.1]
- plan of arrangement of motor vehicles, railway cars and/or other types of vehicles which are intended to be carried and indicating securing and load bearing arrangements
- characteristics of motor vehicles, railways cars and/or other types of vehicles which are intended to be carried: (as applicable) axle load, axle spacing, number of wheels per axle, wheel spacing, size of tyre print

2 Stability

2.1 Definitions

2.1.1 Deepest subdivision draught

The deepest subdivision draught (d_S) is the waterline which corresponds to the summer load line draught of the ship.

2.1.2 Light service draught

Light service draught (d_L) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

2.1.3 Partial subdivision draught

The partial subdivision draught (d_P) is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

2.1.4 Subdivision length L_s

The subdivision length L_s is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

2.1.5 Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, the Society may define the limits of the machinery spaces.

2.1.6 Other definitions

Mid-length is the mid point of the subdivision length of the ship.

Aft terminal is the aft limit of the subdivision length.

Forward terminal is the forward limit of the subdivision length.

Breadth B is the greatest moulded breadth, in m, of the ship at or below the deepest subdivision draught.

Draught d is the vertical distance, in m, from the moulded baseline at mid-length to the waterline in question.

Permeability μ of a space is the proportion of the immersed volume of that space which can be occupied by water.

2.2 Intact stability

2.2.1 General

Every passenger ship regardless of size is to be inclined upon its completion. The lightship displacement and the longitudinal, transverse and vertical position of its centre of gravity shall be determined. The Master is to be supplied with such information satisfactory to the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information is to be furnished to the Society.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

2.2.2 Periodical lightweight check

At periodical intervals not exceeding five years, a lightweight survey is to be carried out on all passenger ships to verify any changes in lightship displacement and longitudinal centre of gravity. The ship is to be re-inclined whenever, in comparison with the approved stability information, a deviation from the lightship displacement exceeding 2% or a deviation of the longitudinal centre of gravity exceeding 1% of L is found, or anticipated.

2.2.3 Standard requirements

In addition to Pt B, Ch 3, Sec 2, [2], the requirements in [2.2.4] to [2.2.6] are to be complied with for the loading conditions defined in Pt B, Ch 3, App 2, [1.2.1] and Pt B, Ch 3, App 2, [1.2.9].

2.2.4 Crowding of passengers

The angle of heel on account of crowding of passengers to one side as defined below may not exceed 10°:

- *a minimum weight of 75 kg is to be assumed for each passenger except that this value may be increased subject to the approval of the Society. In addition, the mass and distribution of the luggage is to be approved by the Society;*
- *the height of the centre of gravity for passengers is to be assumed equal to:*
  - *1,0 m above deck level for passengers standing upright. Account may be taken, if necessary, of camber and sheer of deck; and*
  - *0,3 m above the seat in respect of seated passengers.*
- *passengers and luggage are to be considered to be in the spaces normally at their disposal;*
- *passengers without luggage are to be considered as distributed to produce the most unfavourable combination of passenger heeling moment and/or initial metacentric height, which may be obtained in practice. In this connection, a value higher than four persons per square metre is not necessary.*

2.2.5 Maximum turning angle

The angle of heel on account of turning may not exceed 10° when calculated using the following formula:

$$M_R = 0,02 \frac{V_0^2}{L_S} \Delta \left(KG - \frac{T_1}{2} \right)$$

where:

M_R : *Heeling moment, in t.m*

V_0 : *Service speed, in m/s*

T_1 : *Mean draught, in m*

KG : *Height of centre of gravity above keel, in m.*

2.2.6 *Where anti-rolling devices are installed in a ship, the Society is to be satisfied that the above criteria can be maintained when the devices are in operation.*

2.2.7 Stability booklet for ro-ro ships

The stability booklet of ro-ro ships is to contain information concerning the importance of securing and maintaining all closure watertight integrity, due to the rapid loss of stability which may result when water enters the vehicle deck and the fact capsize can rapidly occur.

2.3 Damage stability for ships where SDS notation has been required

2.3.1 General

The requirements of this Section are to be applied to passenger ships in conjunction with the exploratory notes as set out by the IMO Resolution MSC 429(98).

2.3.2 Required subdivision index R

The required subdivision index R of a passenger ship according to the total number of persons on board is defined in Tab 1.

These regulations are intended to provide ships with a minimum standard of subdivision. In addition to these requirements, the requirements of [2.3.12] are to be complied with.

Table 1 : Required subdivision index R

Total number of persons on board N	R
N < 400	0,722
400 ≤ N ≤ 1350	N / 7580 + 0,66923
1350 < N ≤ 6000	0,0369 Ln (N + 89,048) + 0,579
N > 6000	1 – (852,5 + 0,03875 N) / (N + 5000)

2.3.3 Attained subdivision index A

The attained subdivision index A is to be calculated in accordance with Pt B, Ch 3, App 3, [1.4].

The partial indices A_s, A_p and A_L are not to be less than 0,9 R.

2.3.4 Calculation of the factor p_i

The factor pi is to be calculated in accordance with Pt B, Ch 3, App 3, [1.5].

2.3.5 Calculation of the factor s_i

The factor s_i is to be determined for each case of assumed flooding, involving a compartment or group of compartments, in accordance with the following notations and the provisions in this regulation.

θ_e : *The equilibrium heel angle in any stage of flooding, in degrees*

θ_v : *The angle, in any stage of flooding, where the righting lever becomes negative, or the angle at which an opening incapable of being closed weathertight becomes submerged*

In applying this criterion, openings which are incapable of being closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship.

GZ_{max} : *The maximum positive righting lever, in metres, up to the angle θ_v*

Range : *The Range of positive righting levers, in degrees, measured from the angle θ_e. The positive range is to be taken up to the angle θ_v*

Flooding stage is any discrete step during the flooding process, including the stage before equalization (if any) until final equilibrium has been reached.

The factor s_i, for any damage case at any initial loading condition, d_i, shall be obtained from the formula:

$$s_i = \min[s_{intermediate,i}, (s_{final,i} \cdot s_{mom,i})]$$

where:

$s_{intermediate,i}$: *The probability to survive all intermediate flooding stages until the final equilibrium stage, and is calculated in accordance with item a)*

$s_{final,i}$: *The probability to survive in the final equilibrium stage of flooding. It is calculated in accordance with item b)*

$s_{mom,i}$: *The probability to- survive heeling moments, and is calculated in accordance with item c)*

a) Calculation of $s_{intermediate}$:

The factor $s_{intermediate,i}$ is to be taken as the least of the s-factors obtained from all flooding stages including the stage before equalization, if any, and is to be calculated as follows:

$$s_{intermediate,\,i} = \left[\frac{GZ_{max}}{0{,}05} \cdot \frac{Range}{7}\right]^{\frac{1}{4}}$$

where GZ_{max} is not to be taken as more than 0,05 m and Range as not more than 7°.

$s_{intermediate}$ = 0, if the intermediate heel angle exceeds 15°.

Where cross-flooding fittings are required, the time for equalization is not to exceed 10 min. The time for equalization is to be calculated in accordance with Ch 11, App 1

b) Calculation of s_{final}:

The factor $s_{final,i}$ is to be obtained from the formula:

$$s_{final,\,i} = K\left[\frac{GZ_{max}}{TGZ_{max}} \cdot \frac{Range}{TRange}\right]^{\frac{1}{4}}$$

where:

GZ_{max} is not to be taken as more than TGZ_{max}

Range is not to be taken as more than T_{Range}

TGZ_{max} is taken equal to:

- *TGZ_{max} = 0,20 m for ro-ro passenger ships each damage case that involves a ro-ro space*
- *TGZ_{max} = 0,12 m otherwise*

T_{Range} is taken equal to:

- *T_{Range} = 20° for ro-ro passenger ships each damage case that involves a ro-ro space,*
- *T_{Range} = 16° otherwise*

K is taken equal to:

- $K = 1$ if $\theta_e \le \theta_{min}$
- $K = 0$ if $\theta_e \ge \theta_{max}$
- $K = \sqrt{\frac{\theta_{max} - \theta_e}{\theta_{max} - \theta_{min}}}$ otherwise

where:

θ_{min} *is equal to 7°*

θ_{max} *is equal to 15°.*

c) *Calculation of* s_{mom}*:*

The factor $s_{mom,i}$ *is to be calculated at the final equilibrium from the formula:*

$$s_{mom,i} = \frac{(GZ_{max} - 0{,}04)\,Displacement}{M_{heel}}$$

where:

$s_{mom,i} \leq 1$

Displacement is the intact displacement at the respective draught (d_s ,d_p ,d_l)

M_{heel} *is the maximum assumed heeling moment as calculated as follows:*

$$M_{heel} = \max[M_{passenger}, M_{wind}, M_{Survivalcraft}]$$

where heeling moments $M_{passenger}$, M_{wind} *and* $M_{Survivalcraft}$ *are calculated in [2.3.11].*

2.3.6 Equalization arrangements

Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted shall, where practicable, be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the bulkhead deck. These fittings together with their controls are to be acceptable to the Society. Suitable information concerning the use of equalization devices are to be supplied to the master of the ship.

Tanks and compartments taking part in such equalization are to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

2.3.7 Cases where s_i is to be equal to zero

The factor s_i *is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:*

- *the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor* s_i*. Such openings are to include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, but the openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, side scuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.*
- *any part of the bulkhead deck considered a horizontal evacuation route.*

The factor s_i *is to be taken as zero if, taking into account sinkage, heel and trim, any of the following occur in any intermediate stage or in the final stage of flooding:*

- *immersion of any vertical escape hatch in the bulkhead deck intended for compliance with the applicable requirements of Pt C, Ch 4, Sec 8*
- *any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the bulkhead deck become inaccessible or inoperable*
- *immersion of any part of piping or ventilation ducts located within the assumed extent of damage and carried through a watertight boundary if this can lead to the progressive flooding of compartment not assumed as flooded.*

2.3.8 Calculation of the factor v_i

Where horizontal watertight boundaries are fitted above the waterline under consideration the s-value calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in [2.3.5] by the reduction factor v_m *defined below, which represents the probability that the spaces above the horizontal subdivision will not be flooded.*

The factor v_i is to be calculated in accordance with Pt B, Ch 3, App 3, [1.6.10] and Pt B, Ch 3, App 3, [1.6.11].

2.3.9 Contribution dA to the index A

The contribution dA to the index A is to be calculated in accordance with Pt B, Ch 3, App 3, [1.6.12].

2.3.10 Permeability

For the purpose of the subdivision and damage stability calculations of the regulations, the permeability of each general compartment or part of a compartment is to be according to Tab 2.

Other figures for permeability may be used if substantiated by calculations.

The permeability of the Ro-Ro spaces is to be as per Tab 3.

Table 2 : Values of permeability

Spaces	Permeability
Appropriated to stores	0,60
Occupied by accommodation or voids	0,95
Occupied by machinery	0,85
Intended for liquids	0 or 0,95 **(1)**
(1) whichever results in the more severe requirements.	

Table 3 : Permeability of Ro-Ro spaces

Permeability at draught:		
d_S	d_P	d_L
0,90	0,90	0,95

2.3.11 Inclining moments

The following inclining moments are to be taken into account:

a) *Moment due to the crowding of passengers:*

$M_{passenger}$ is the maximum assumed heeling moment resulting from movement of passengers, and is to be obtained as follows:

$M_{passenger} = (0,075\ N_p)\ (0,45\ B)$ (tm)

where:

N_p : *Maximum number of passengers permitted to be on board in the service condition corresponding to the deepest subdivision draught under consideration; and*

B : *Breadth of the ship.*

Alternatively, the heeling moment may be calculated assuming the passengers are distributed with 4 persons per square metre on available deck areas towards one side of the ship on the decks where muster stations are located and in such a way that they produce the most adverse heeling moment. In doing so, a weight of 75 kg per passenger is to be assumed.

b) *Moment due to launching of all fully loaded davit-launched survival craft on one side:*

$M_{Survivalcraft}$ is the maximum assumed heeling moment due to the launching of all fully loaded davit-launched survival craft on one side of the ship. It shall be calculated using the following assumptions:

- *all lifeboats and rescue boats fitted on the side to which the ship has heeled after having sustained damage are to be assumed to be swung out fully loaded and ready for lowering*
- *for lifeboats which are arranged to be launched fully loaded from the stowed position, the maximum heeling moment during launching is to be taken*
- *a fully loaded davit-launched liferaft attached to each davit on the side to which the ship has heeled after having sustained damage is to be assumed to be swung out ready for lowering*
- *persons not in the life-saving appliances which are swung out are not to provide either additional heeling or righting moment*
- *life-saving appliances on the side of the ship opposite to the side to which the ship has heeled are to be assumed to be in a stowed position.*

c) *Moment due to wind pressure:*

M_{wind} is the maximum assumed wind force acting in a damage situation:

$M_{wind} = (P\ A\ Z) / 9,806 \cdot 10^3$ (tm)

P : *Wind pressure*

$P = 120\ N/m^2$

A : *Projected lateral area above waterline*

z : *Distance from centre of lateral projected area above waterline to T/2; and*

T : *Ship's draught, d_i.*

2.3.12 Special requirements concerning stability

A passenger ship intended to carry 400 or more persons is to have watertight subdivision abaft the collision bulkhead so that $s_i = 1$ *for a damage involving all the compartments with 0.08L measured from the forward perpendicular for the three loading conditions used to calculate the attained subdivision index A. If the attained subdivision index A is calculated for different trims, this requirement shall also be satisfied for those loading conditions.*

A passenger ship intended to carry 36 or more persons is to be capable of withstanding damage along the side shell to an extent specified below. Compliance with this regulation is to be achieved by demonstrating that s_i, as defined in [2.3.5], is not less than 0,9 for the three loading conditions used to calculate the attained subdivision index A. If the attained subdivision index A is calculated for different trims, this requirement is also to be satisfied for those loading conditions.

The damage extent to be assumed when demonstrating compliance with the above paragraph, is to be dependent on the total number of persons carried, and L, such that:

- *the vertical extent of damage is to extend from the ships moulded baseline to a position up to 12,5 m above the position of the deepest subdivision draught as defined in Ch 11, Sec 3, [2.1], unless a lesser vertical extent of damage were to give a lower value of s_i in which case this reduced extent is to be used.*
- *where 400 or more persons are to be carried, a damage length of 0,03 L_s but not less than 3 m is to be assumed at any position along the side shell, in conjunction with a penetration inboard of 0,1 B but not less than 0,75 m measured inboard from the ship side, at right angles to the centreline at the level of the deepest subdivision draught.*
- *where less than 400 persons are carried, damage length is to be assumed at any position along the shell side between transverse watertight bulkheads provided that the distance between two adjacent transverse watertight bulkheads is not less than the assumed damage length. If the distance between adjacent transverse watertight bulkheads is less than the assumed damage length, only one of these bulkheads is to be considered effective for the purpose of demonstrating compliance with the criteria $s_i \geq 0,9$.*
- *where 36 persons are carried, a damage length of 0,015 L_s but not less than 3 m is to be assumed, in conjunction with a penetration inboard of 0,05 B but not less than 0,75 m.*
- *where more than 36, but fewer than 400 persons are carried the values of damage length and penetration inboard, used in the determination of the assumed extent of damage, are to be obtained by linear interpolation between the values of damage length and penetration which apply for ships carrying 36 persons and 400 persons.*

2.3.13 Documents to be supplied

The master is to be supplied with such information to the satisfaction of the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information shall be furnished to the Society.

The information should include:

- *curves or tables of minimum operational metacentric height (GM) and minimum permissible trim versus draught which assures compliance with the intact and damage stability requirements where applicable, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity (KG) and maximum permissible trim versus draught, or with the equivalents of either of these curves or tables.*
- *instructions concerning the operation of cross-flooding arrangements*
- *all other data and aids which might be necessary to maintain the required intact stability and stability after damage.*

The intact and damage stability information specified above are to be presented as consolidated data and encompass the full operating range of draught and trim. Applied trim values shall coincide in all stability information intended for use on board. Information not required for determination of stability and trim limits should be excluded from this information.

If the damage stability is calculated in accordance with the present sub-article, a stability limit curve is to be determined using linear interpolation between the minimum required GM assumed for each of the three draughts d_s, d_p and d_l. When additional subdivision indices are calculated for different trims, a single envelope curve based on the minimum values from this calculations is to be presented. When it is intended to develop curves of maximum permissible KG, it is to be ensured that the resulting maximum KG curves correspond with a linear variation of GM.

As an alternative to a single envelope curve, the calculations for additional trims may be carried out with one common GM for all of the trims assumed at each subdivision draught. The lowest values of each partial index A_s, A_p and A_l across these trims shall then be used in the summation of the attained subdivision index A according to [2.3.3]. This will result in one GM limit curve based on the GM used at each draught. A trim limit diagram showing the assumed trim range shall be developed.

When curves or tables of minimum operational metacentric height (GM) or maximum allowable KG versus draught are not provided, the master is to ensure that the operating condition does not deviate from approved loading conditions, or verify by calculation that the stability requirement are satisfied for this loading condition.

2.3.14 Damage control documentation

Plans showing clearly for each deck and hold the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding are to be permanently exhibited for the guidance of the officer in charge of the ship. In addition, booklets containing the aforementioned information are to be made available to the officers of the ship.

Detailed description of the information to be included in the damage control documentation is reported in Pt B, Ch 3, Sec 3, [4].

3 Structure design principles

3.1 General

3.1.1 Wood sheathing is recommended for caterpillar trucks and unusual vehicles.

It is recommended that a piece of wood of suitable thickness should be fitted under each crutch in order to distribute the mass over the plate and the nearest stiffeners.

3.2 Hull structure

3.2.1 Framing

In general, the strength deck and the bottom are to be longitudinally framed.

Where a transverse framing system is adopted for such ships, it is to be considered by the Society on a case by case basis.

3.2.2 Side structures

Where decks are fitted with ramp openings adjacent to the ship's side, special consideration is to be given to the supports for the side framing.

4 Design loads

4.1 Loads on deck

4.1.1 Plan of design loads on deck

A plan of design static loads on deck, including fork lift areas, axle loads and any tyre print areas of wheeled loads, is to be provided for information.

All values displayed on this plan are to be at least equivalent to the values given by the present Rules for each kind of load.

4.2 Lowest 0,5 m of bulkheads forming vertical division along escape routes

4.2.1 The still water and inertial pressures transmitted to the structures *belonging to lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes* are to be obtained, in kN/m^2, as specified in Pt B, Ch 5, Sec 6, [6.1], where the value $p_{dl\text{-}s}$ is to be taken not less than 1,5 kN/m^2 *to allow them to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.*

5 Hull girder strength

5.1 Basic criteria

5.1.1 Strength deck

In addition to the requirements in Pt B, Ch 6, Sec 1, [1.3], the contribution of the hull structures up to the strength deck to the longitudinal strength is to be assessed through a finite element analysis of the whole ship in the following cases:

- when the size of openings in the side shell and/or longitudinal bulkheads located below the deck assumed by the Designer as the strength deck decrease significantly the capability of the plating to transmit shear forces to the strength deck
- when the ends of superstructures which are required to contribute to longitudinal strength may be considered not effectively connected to the hull structures in way.

5.2 Global transverse strength

5.2.1 The behaviour of the ship primary structural members under racking effects due to transverse forces induced by transverse accelerations is to be investigated according to Pt B, Ch 7, App 1, or by means of a complete ship model according to NI640 considering the loading conditions and load cases defined in Pt B, Ch 7, App 1, [4.1.2].

6 Hull scantlings

6.1 Plating

6.1.1 Lowest 0,5 m of bulkheads forming vertical division along escape routes

The net thickness of plating belonging to the lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes is to be obtained according to Pt B, Ch 7, Sec 4, where the loads are defined in [4.2.1].

6.2 Ordinary stiffeners

6.2.1 Lowest 0,5 m of bulkheads forming vertical division along escape routes

The net scantlings of ordinary stiffeners belonging to the lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes are to be obtained according to Pt B, Ch 7, Sec 5, where the loads are defined in [4.2.1].

6.3 Primary supporting members

6.3.1 Double bottom structures

In ships where pillars are widely spaced and transmit very high loads to the double bottom, the net scantlings of double bottom structures are to be considered by the Society on a case-by-case basis, taking into account the results of direct calculations.

Where deemed necessary, on the basis of the above results, additional floors and bottom girders may be required.

6.3.2 Lowest 0,5 m of bulkheads forming vertical division along escape routes

The net scantlings of primary supporting members belonging to the lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes are to be obtained according to Pt B, Ch 7, Sec 6, where the loads are defined in [4.2.1].

7 Other structures

7.1 Superstructures and deckhouses

7.1.1 *Where a ventilation trunk passing through a structure penetrates the bulkhead deck, the trunk is to be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heeling angle allowable during intermediate stages of flooding, in accordance with* the criteria in [2.3.5].

7.1.2 *Where all or part of the penetration of the bulkhead deck is on the main ro-ro deck, the trunk is to be capable of withstanding impact pressure due to internal water motions (sloshing) of water trapped in the ro-ro deck,* to be calculated according to the applicable formulae in Pt B, Ch 5, Sec 6, [2].

8 Construction and testing

8.1 Special structural details

8.1.1 The specific requirements in Pt B, Ch 13, Sec 5, [2] for ships with the service notation **ro-ro passenger ship** are to be complied with.

Section 4 Electrical Installations

1 General

1.1 Applicable requirements

1.1.1 In addition to the relevant requirements of Part C, Chapter 2 and Ch 11, Sec 5 and those contained in this Section, electrical installations in spaces intended for the carriage of motor vehicles with fuel in their tanks for their propulsion are to comply with those of Part C, Chapter 4.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, Tab 1, the following are to be submitted for approval:

a) Plan of hazardous areas

b) Document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas

c) Diagrams of indicator systems for shell doors, loading doors and similar appliances, television surveillance or water leakage detection systems

d) Diagrams of the supplies to the supplementary emergency lighting systems.

1.3 Safety characteristics

1.3.1 The explosion group and temperature class of electrical equipment of a certified safe type for use with explosive petrol-air mixtures are to be at least IIA and T3.

1.4 Flooding detection systems for passenger ships carrying 36 or more persons

1.4.1 *A flooding detection system for watertight spaces below the bulkhead deck is to be provided based on IMO MSC.1/Circ.1291.*

2 Supplementary emergency lighting

2.1

2.1.1 *In addition to the emergency lighting required in* Ch 11, Sec 5, [2.2]*, on every passenger ship with ro-ro cargo spaces or special category spaces:*

a) All passenger public spaces and alleyways shall be provided with supplementary electric lighting that can operate for at least three hours when all other sources of electrical power have failed and under any condition of heel. The illumination provided shall be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting shall consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, any other means of lighting which is at least as effective may be accepted by the Society. The supplementary lighting shall be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided shall be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service;

b) A portable rechargeable battery operated lamp shall be provided in every crew space alleyway and recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required in (a), is provided.

3 Installation

3.1 Installations in special category spaces situated above the bulkhead deck

3.1.1 On any deck or platform, if fitted, on which vehicles are carried and on which explosive vapours might be expected to accumulate, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment and cables are to be installed at least 450 mm above the deck or platform.

Electrical equipment is to be as stated in Pt C, Ch 2, Sec 3, [10.2.7] and electrical cables as stated in Pt C, Ch 2, Sec 3, [10.5.3].

3.1.2 Where the installation of electrical equipment and cables at less than 450 mm above the deck or platform is deemed necessary for the safe operation of the ship, the electrical equipment is to be of a certified safe type as stated in Pt C, Ch 2, Sec 3, [10.2.6] and the electrical cables are to be as stated in Pt C, Ch 2, Sec 3, [10.5.2].

3.1.3 Electrical equipment and cables in exhaust ventilation ducts are to be as stated in [3.1.2].

3.1.4 The requirements in this item are summarised in Tab 1.

3.2 Installations in special category spaces situated below the bulkhead deck

3.2.1 Any electrical equipment installed is to be as stated in Pt C, Ch 2, Sec 3, [10.2.6] and electrical cables are to be as stated in Pt C, Ch 2, Sec 3, [10.5.2].

3.2.2 Electrical equipment and cables in exhaust ventilation ducts are to be as stated in [3.2.1].

3.2.3 The requirements in this item are summarised in Tab 2.

3.3 Installations in cargo spaces other than special category spaces intended for the carriage of motor vehicles

3.3.1 The requirements for installations in special category spaces situated below the bulkhead deck, as stated in [3.2], apply.

3.3.2 All electric circuits terminating in cargo holds are to be provided with multipole linked isolating switches located outside the holds. Provision is to be made for locking in the off position.

This requirement does not apply to safety installations such as fire, smoke or gas detection systems.

3.4 Protection of socket outlets in vehicle spaces

3.4.1 The provisions of [3.4.2] to [3.4.7] are applicable to socket outlets with a rated current not exceeding 63A in AC installations and 16A in DC installations. Socket outlets with higher rated current will be subject to special consideration by the Society.

Table 1 : Electrical equipment permitted in special category spaces above the bulkhead deck

No.	Description of spaces	Electrical equipment	Hazardous area
1	Areas at less than 450 mm above the deck or platforms for vehicles, if fitted, without openings of sufficient size permitting penetration of petrol gases downward	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 0 b) certified intrinsically safe apparatus Ex(ib) c) simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ib" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and acceptable to the appropriate authority d) certified flameproof Ex(d) e) certified pressurised Ex(p) f) certified increased safety Ex(e) g) certified encapsulated Ex(m) h) certified sand filled Ex(q) i) certified specially Ex(s) j) cables sheathed with at least one of the following: • a non-metallic impervious sheath in combination with braiding or other metallic covering • copper or stainless steel sheath (for mineral insulated cables only)	Zone 1
2	Exhaust ventilation ducts	As stated under item 1.	Zone 1
3	• areas above a height of 450 mm from the deck • areas above a height of 450 mm from each platform for vehicles, if fitted, without openings of sufficient size permitting penetration of petrol gases downward • areas above platforms for vehicles, if fitted, with openings of sufficient size permitting penetration of petrol gases downward	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 1 b) tested specially for zone 2 (e.g. type "n" protection) c) pressurised, and acceptable to the appropriate authority d) encapsulated, and acceptable to the appropriate authority e) the type which ensures the absence of sparks and arcs and of "hot spots" during its normal operation. For installation, in compliance with Pt C, Ch 4, Sec 13, [2.2.2], a minimum class of protection IP55 is acceptable as an alternative f) cables sheathed with at least a non-metallic external impervious sheath	Zone 2

Table 2 : Electrical equipment permitted in special category spaces below the bulkhead deck

No	Description of spaces	Electrical equipment	Hazardous area
1	Special category spaces	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 0 b) certified intrinsically safe apparatus Ex(ib) c) simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category "ib" not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and acceptable to the appropriate authority d) certified flameproof Ex(d) e) certified pressurised Ex(p) f) certified increased safety Ex(e) g) certified encapsulated Ex(m) h) certified sand filled Ex(q) i) certified specially Ex(s) j) cables sheathed with at least one of the following: • a non-metallic impervious sheath in combination with braiding or other metallic covering • copper or stainless steel sheath (for mineral insulated cables only)	Zone 1
2	Exhaust ventilation ducts	As stated under item 1	Zone 1

3.4.2 A separate final sub-circuit is to be provided for each socket outlet. Each final sub-circuit is to be automatically disconnected in case of overcurrent, overload and earth fault (e.g. with an earth fault breaker).

3.4.3 Socket outlets with a current rating above 16A are to be provided with a switch. The switch is to be so interlocked that the plug can only be inserted or withdrawn when the switch is in "off" position.

3.4.4 The temperature rise on the live parts of socket outlets and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

3.4.5 The minimum required degree of protection for socket outlets installed in vehicle spaces is IP56.

3.4.6 Socket-outlets and plugs with a specified degree of protection shall be provided with effective means to maintain the same degree of protection after the plug is removed from the socket-outlet.

Where a loose cover is used for this purpose, it shall be anchored to its socket-outlet, for example by means of a chain.

3.4.7 Suitable means for phase inversion are to be available for 3-phase sockets.

4 Type approved components

4.1

4.1.1 Accumulator lamps for the supplementary electric lighting, alarm systems for closing devices of openings and water leakage detection systems if of electronic type, and television surveillance systems are to be type approved or in accordance with [4.1.2].

4.1.2 Case-by-case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

Part D
Service Notations

CHAPTER 13
SHIPS FOR DREDGING ACTIVITY

Section 1	General
Section 2	Hull and Stability
Section 3	Machinery and Dredging Systems
Appendix 1	Guidance on Calculation of Transverse Strength Hopper Well Structure

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of one of the following service notations:

- **dredger**
- **hopper dredger**
- **hopper unit**
- **split hopper dredger**
- **split hopper unit**

as defined in Pt A, Ch 1, Sec 2, [4.13].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.3 The additional service feature **EOC** may be assigned in accordance with Pt A, Ch 1, Sec 2, [4.13.1] only to:

- ships greater than 90m in length assigned the service notation **dredger**
- ships greater than 65m in length assigned the service notation **hopper dredger**, **hopper unit**, **split hopper dredger** or **split hopper unit**.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement		• Part B	• NR566
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 13, Sec 2	• Part B • Ch 13, Sec 2
	L < 65 or 90 m **(1)**	• NR600 • Ch 13, Sec 2	• NR600 • Ch 13, Sec 2
Stability		• Part B • Ch 13, Sec 2	• NR566 • Ch 13, Sec 2
Machinery and cargo systems		• Part C • Ch 13, Sec 3	• NR566 • Ch 13, Sec 3
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566

(1) 90 m for ships assigned with the service notation **dredger** and 65 m for ships assigned with the service notation **hopper dredger**, **hopper unit**, **split hopper dredger** and **split hopper unit**.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

1.2 Definitions

1.2.1 Gantry

Any means of lowering or hoisting dredging equipment from resting positions to operational positions and vice versa.

1.2.2 Hopper well

Cargo space intended to carry spoil.

1.2.3 Jet water system

Piping system for water intended to liquefy the spoil for unloading purpose by means of jet nozzles.

1.2.4 Overflow

Any means of draining off process water.

1.2.5 Spoil

Mixture of soil, sand, clay or gravel particles and water.

1.2.6 Suction tube inlet

Part of the side shell structure where external suction tube dredge piping and internal dredge piping are connected.

1.3 Documentation to be submitted

1.3.1 The documentation listed in Tab 2 is to be submitted, as applicable.

Table 2 : Documents to be submitted

No.	I/A **(1)**	Description of the document
1	A	Stability booklet including conditions at dredging draught(s)
2	A	Loading manual including conditions at dredging draught(s)
3	I	Fatigue calculation report **(2)**
4	A	General arrangement of the dredging equipment
5	A	Arrangement of suction tube inlet section
6	A	Construction of suction tube inlet
7	A	Gantry foundations
8	A	Bottom door and cylinder integrations
9	A	Integration of bow or stern coupling
10	A	Overflow integration, if applicable
11	A	Hinges, chocks and cylinder integrations
12	I	Calculation of clearances
13	A	Integration of spud carrier and other spud related equipment
14	A	Integration of cutter ladder
15	A	Integration of anchor booms
16	A	Integration of winches
17	A	Foundation excavator
18	A	Couplings
19	A	Transverse sections through hoppers, wells, pump rooms and dredging machinery spaces
20	A	Connection of other dredging machinery with the hull structure
21	A	Closing arrangements: dredge piping valves
22	A	Hydraulic piping diagram including dredging equipment
23	A	Dredge piping diagram
24	A	Jet water piping diagram
25	I	Calculation of SWBM and shear forces in sailing and working conditions
26	I	Design loads on all components of the dredging equipment
27	I	Specification of the dredging equipment operation test
28	I	Calculation of overflow size
29	A	Superstructure hinges and connections to the ship's structure, including mass and location of the superstructure centre of gravity **(3)**
30	A	Structure of hydraulic jack spaces **(3)**
31	A	Deck hinges, including location of centre of buoyancy and of centre of gravity of each half-hull, mass of equipped half-hull, half mass of spoil or water, supplies for each half-hull and mass of superstructures supported by each half-hull **(3)**
32	A	Hydraulic jacks and connections to ship's structure including operating pressure and maximum pressure of the hydraulic jacks (cylinder and rod sides) and corresponding forces **(3)**
33	A	Longitudinal chocks of bottom and deck **(3)**
34	A	Transverse chocks **(3)**
35	A	Hydraulic installation of jacks, with explanatory note **(3)**

(1) A: to be submitted for approval; I: to be submitted for information.
(2) Applicable to ships assigned the additional service feature **EOC** and for ships greater than 150m in length.
(3) Applicable to ships assigned the service notation **split hopper dredger** and **split hopper unit**.

Section 2 Hull and Stability

Symbols

a : Distance from the bottom to the sealing joint located at the lower part of the hopper well, in m

b_p : Maximum breadth, in m, of the hopper well

C : Wave coefficient, defined in Pt B, Ch 5, Sec 4

d : Vertical distance, in m, from the calculation point to the filling level of the considered navigation or dredging situation (see [3.1.1])

g : Gravity acceleration, in m/s^2 taken equal to 9,81 m/s^2

H_{Di} : Wave parameter corresponding to the dredging situation i (see [3.1.1])

h_{Di} : Distance, in m, from spoil level to base line (see Fig 7) when working in the dredging situation i (see [3.1.1])

k : Material factor for steel, defined in Pt B, Ch 4, Sec 1, [2.2]

ℓ_p : Maximum length, in m, of the hopper well

n : Navigation coefficients, defined in Pt B, Ch 5, Sec 3, [1.1.2]

n_{Di} : Navigation coefficient for the dredging situation i (see [3.1.1])

P_{Di} : Mass, in t, of the spoil contained in the hopper well for the dredging situation i (see [3.1.1])

R_{eH} : Minimum yield stress, in N/mm^2, of the material

R_m : Minimum ultimate tensile strength, in N/mm^2, of the material.

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified

T_{Di} : Design draught, in m, corresponding to the dredging situation i (see [3.1.1])

T_{IF} : Navigation draught, in m, corresponding to the international freeboard

V_{Di} : Volume of spoil contained in the hopper well for the dredging situation i (see [3.1.1]), in m^3 (vertically limited to the lowest overflow level)

δ : Specific gravity of the mixture of sea water and spoil for the navigation situation, taken equal to 1,025

δ_i : Specific gravity of the mixture of sea water and spoil for the dredging situation i (see [3.1.1]), taken equal to:

$$\delta_i = \frac{P_{Di}}{V_{Di}}$$

1 Stability

1.1 Intact stability

1.1.1 General

The intact stability of the ship is to be sufficient to comply with the criteria indicated in [1.1.3] for the operational loading conditions of Pt B, Ch 3, App 2, [1.2.10] and the calculation method described in [1.1.2].

1.1.2 Calculation method

The calculation of the righting lever curves is to take into account:

- the change of trim due to heel
- the inflow of seawater or outflow of liquid cargo at the upper edge of the hopper coaming in the case of an open hopper
- the inflow of water at the lower edge of the overflow, located at cargo level or at the lowest possible position above cargo level, or at the lower edge of the lowest overflow ports or spillways.

1.1.3 Intact stability criteria

The area under the righting lever curve is not to be less than

- 0,07 m.rad up to an angle of 15° when the maximum righting lever GZ_{max} occurs at 15°
- 0,055 m.rad up to an angle of 30° when the maximum righting lever GZ_{max} occurs at 30° or above.

Where the maximum righting lever GZ_{max} occurs at angles of between 15° and 30°, the corresponding area under the righting lever curve is to be equal to or greater than A, where A is to be obtained, in m·rad by the following formula:

$A = 0,055 + 0,001\ (30° - \theta_{max})$

where

θ_{max} : angle of heel in degrees at which the righting lever curve reaches its maximum.

The area under the righting lever curve between:

- the angles of heel of 30° and 40°, or
- the angle of heel of 30° and the down-flooding angle θ_f, if this angle is less than 40°,

is to be not less than 0,03 m.rad.

The righting lever GZ is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

The maximum righting lever GZ_{max} should occur at an angle of heel not less than 15°.

The initial metacentric height GM_0 as corrected for the free surface effect of the tanks and the hopper(s) containing liquids is not to be less than 0,15 m.

1.1.4 Weather criterion at the international freeboard

At the international freeboard, the dredger is to comply with the requirements of Pt B, Ch 3, Sec 2, [3.2] considering:

- the state of the cargo as a liquid
- 10% stores and fuel
- and the hopper(s) loaded with a homogeneous cargo up to the upper edge of the hopper coaming if the density of the cargo is not less than 1000 kg/m^3; otherwise the hopper is considered to be partially loaded with a cargo of density equal to 1000 kg/m^3.

1.1.5 Weather criterion at the dredging freeboard

At the dredging freeboard, the dredger is to comply with the requirements of Pt B, Ch 3, Sec 2, [3.2] considering a reduced wind pressure equal to 270 N/m^2 for the most severe of the loading conditions in Pt B, Ch 3, App 2, [1.2.10]. The most severe loading condition is defined as the loading condition where the area under the righting lever curve between 0° and 40° is the least.

1.1.6 Dredgers with open hopper(s)

When the height of the hopper coaming overflow edge above the dredging draught is less than the minimum bow height as specified in the International Load Line Convention 1966, the loading conditions in Pt B, Ch 3, App 2, [1.2.10] at the dredging draught are to take into account a layer of seawater on top of the cargo up to the overflow edge of the hopper coaming. However, if overflow ports or spillways of a size sufficient to enable a fast freeing of the water in the hopper on top of the cargo are fitted in the hopper coaming above the freeboard deck, the layer of sea water may be reduced up to the lower edge of the overflow ports or spillways.

The area of the overflow ports or spillways is to be at least equivalent to the area required by Regulation 24(1) of the International Convention on Load Lines, 1966.

1.1.7 Dredgers with bottom doors

Dredgers with bottom doors or similar means of discharging cargo by gravity at port side and at starboard side are to comply with the following criteria considering an asymmetric discharging:

- the angle of equilibrium is not to exceed 25°
- the righting lever GZ within the 30° range beyond the angle of equilibrium is to be at least 0,10 m
- the range of stability is not to be less than 30°.

The dredger is assumed loaded up to the dredging draught with solid cargo of a density equal to 1900 kg/m^3, when discharging, 20% of the total hopper load is assumed to be discharged only at one side of the longitudinal centreline of the hopper, horizontally equally distributed at the discharging side.

1.2 Damage stability where the additional class notation SDS has been requested

1.2.1 Reduced freeboard

Dredgers which have been assigned reduced freeboard as permitted by Regulation 27 of the International Convention on Load Lines, 1966 are to be assigned the additional class notation **SDS**.

1.2.2 General

Dredgers assigned the additional class notation **SDS** are is to comply with the requirements of Pt B, Ch 3, App 3, [1], modified by [1.2.3], [1.2.4] and [1.2.6].

1.2.3 Calculation method of the righting lever curves

The calculation of the righting lever curves is to take into account:

- the change of trim due to heel
- the inflow of seawater or outflow of cargo at the upper edge of the hopper coaming in the case of an open hopper
- the inflow of water at the lower edge of the overflow, located at the highest possible position or at the lower edge of the lowest overflow ports or spillways
- the sliding of the cargo in the hopper, in transverse and longitudinal direction, according to the following shifting law:
  - for $\rho \leq 1400$ (liquid cargo):

    $\theta_r = \theta_g$

- for $1400 < \rho < 2000$ (sliding cargo):
  $\theta_r = \theta_g (2000 - \rho) / 600$
- for $\rho \geq 2000$ (solid cargo):
  $\theta_r = 0$

where:

ρ : Cargo density, in kg/m^3

θ_r : Angle of heel or angle of trim, in degrees

θ_g : Shifting angle of the cargo, in degrees.

1.2.4 Progressive flooding

Internal and external progressive floodings are to be considered in accordance with the requirements of Pt B, Ch 3, Sec 3, [3.3].

1.2.5 The attained subdivision index A_U

The attained subdivision index A_U is to be calculated for the draught d_U and the corresponding initial trim assuming the dredger in the unloaded condition, i.e. loaded with 50% fuel and stores, no cargo in the hopper(s) and the hopper(s) in direct communication with the sea.

1.2.6 The attained subdivision index A_L

The attained subdivision index A_L is to be calculated assuming the dredger loaded at the dredging draught d_l with 50% fuel and stores, for each of the densities ρ_d and ρ_i defined by:

- The design density ρ_d corresponding to the dredging draught and obtained from the following formula:
  $\rho_d = M_2 / V_2$
  where:
  M_2 : Mass of cargo in the hopper when the dredger is loaded at the dredging draught with 50% fuel and stores
  V_2 : Volume of the hopper at the highest overflow position.
- Each density ρ_i greater than ρ_d, obtained from the following formula:
  $\rho_i = 2200 - 200\ i$
  where i is equal to 0; 1; 2; 3; etc.

The damage stability calculations are to be performed taking into account the initial trim of the dredging draught, an assumed permeability of the cargo in the hopper equal to 0% and a permeability of the space above the cargo equal to 100%.

1.2.7 Damage stability criteria

The dredger is to comply with the following criteria:

$A \geq R$

$A_U \geq 0,7\ R$

$A_L \geq 0,7\ R$

where:

R : Required index as defined in Pt B, Ch 3, App 3, [1.3]

A_U : Attained subdivision index at the unloaded draught d_U, as defined in [1.2.5]

A_L : Attained subdivision index at the loaded draught d_l and for the cargo densities defined in [1.2.6].

2 Structure design principles

2.1 General

2.1.1 The attention of Designers is drawn to the fact that structural arrangement of ships for dredging activities involves discontinuities and that particular care is to be taken to avoid cracks or fractures.

2.1.2 Where dredgers are likely to work in association with hopper barges, the sheerstrake is to be protected, slightly below the deck, by a fender efficiently secured to the shell plating and extending over at least two thirds of the ship's length. Compensation is to be provided in way of the gangway port in raised deck, if fitted.

2.1.3 Where dredgers are likely to work in association with hopper barges, the shell plating is to be protected by a fender extending from the load waterline to the lowest waterline.

Additional structural reinforcements are to be provided in way of fenders and submitted to the Society for approval.

2.1.4 On bucket dredgers, in order to prevent dangerous flooding in the event of damage to the shell plating by metal debris (e.g. anchors), a watertight compartment is to be provided at the lower part of the caissons on either side of the bucket well in the area of the buckets. The compartment is to be of adequate size to allow surveys to be carried out.

2.1.5 Reinforcements are to be provided at locations where the hull is heavily stressed, such as:

- beneath the suction pipe gantries
- in way of the gantry frame on bucket dredgers
- points where tow ropes are secured
- connections of piles, etc.

2.1.6 Flat bottom areas, other than flat bottom area forward, where dynamic pressures due to the bottom impact might occur are to be examined by the Society on a case by case basis.

2.1.7 When overflows are provided in the hopper spaces, their sectional area is to be large enough, taking into account the density of the spoil to be drained off.

The arrangment of the overflows is to be such that:

- they prevent the maximum authorised draught from being exceeded during loading
- trim and stability are always in accordance with the reviewed loading conditions
- draining off is made without any overflowing on the exposed deck, so as to maintain a safe passage from aft to fore.

2.1.8 The corners of the cut-outs in the bottom plating are to be rounded and the radius is to be as large as possible, especially near the bottom doors.

The shape and the radius of cut-out corners are to be in accordance with Pt B, Ch 4, Sec 5 or NR600, Ch 2, Sec 1, as applicable.

2.1.9 Where hopper barges and suction dredgers are intended for unrestricted navigation, it is recommended, as far as possible, that sidescuttles are not be fitted in the shell plating.

2.1.10 The brackets are generally to be of a swept shape. A flange is to be fitted on the free edge if the length of this edge exceeds 60 times the web thickness.

2.1.11 For ships with one of the service notations **split hopper dredger** or **split hopper unit**, where panting beams are provided as stated in Pt B, Ch 11, Sec 1, [2.3.5], stringers and web frames are to be fitted on the centreline bulkheads of the two half-hulls to take up the reactions.

2.2 Longitudinal members in the area of the hopper well

2.2.1 The scantlings of the midship region are generally to be kept over the full length of the hopper well.

2.2.2 Attention is to be paid to the structural continuity of longitudinal members, especially coaming and hopper well bulkheads.

2.2.3 The upper deck stringer plate is to extend to the longitudinal bulkhead over the full length of the hopper well.

2.2.4 The fore and aft ends of longitudinal bulkheads of hopper spaces are to be extended by webs and brackets, with a size not less than one frame spacing (see Fig 1).

Openings in primary members in way of the transition are to be avoided.

A longitudinal effective coaming is to be extended via large brackets, the length of the bracket is to be equal to the height of the coaming. A suitable overlap between the coaming stay and bracket is to be provided. The bracket is to be full penetration welded to the deck.

2.2.5 The fore and aft ends of the centreline cellular keel are to be extended by means of brackets and webs. The sloped plating of the cellular keel is to be extended behind the hopper end bulkheads for at least one frame spacing.

In areas where a double bottom is provided, the brackets may be arranged in accordance with Fig 2.

2.2.6 The vertical sides of the trunks are to be extended beyond the end of the hopper spaces over a distance of at least 1,5 times their height.

2.2.7 The Society may, on a case-by-case basis, require that longitudinal members of the double bottom structure are extended, by means of brackets, inside the side compartments bounding the hopper spaces.

2.2.8 Arrangements other than those described in [2.2.4] to [2.2.7] are to be considered by the Society on a case-by-case basis.

Figure 1 : Longitudinal bulkhead extension outside of hopper wells

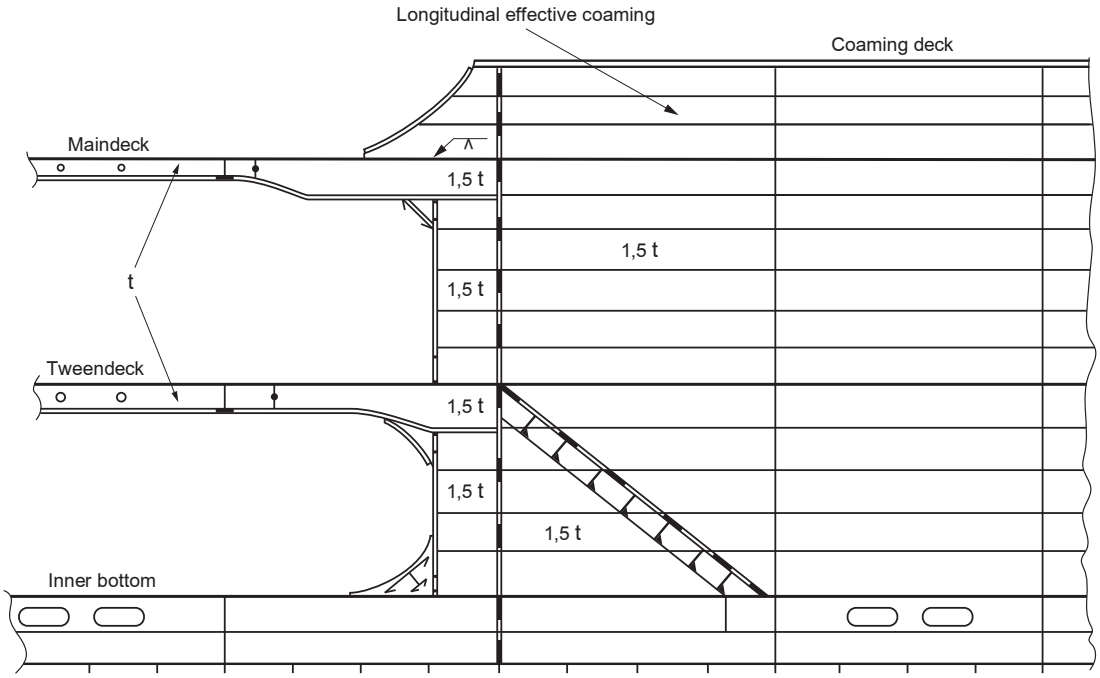
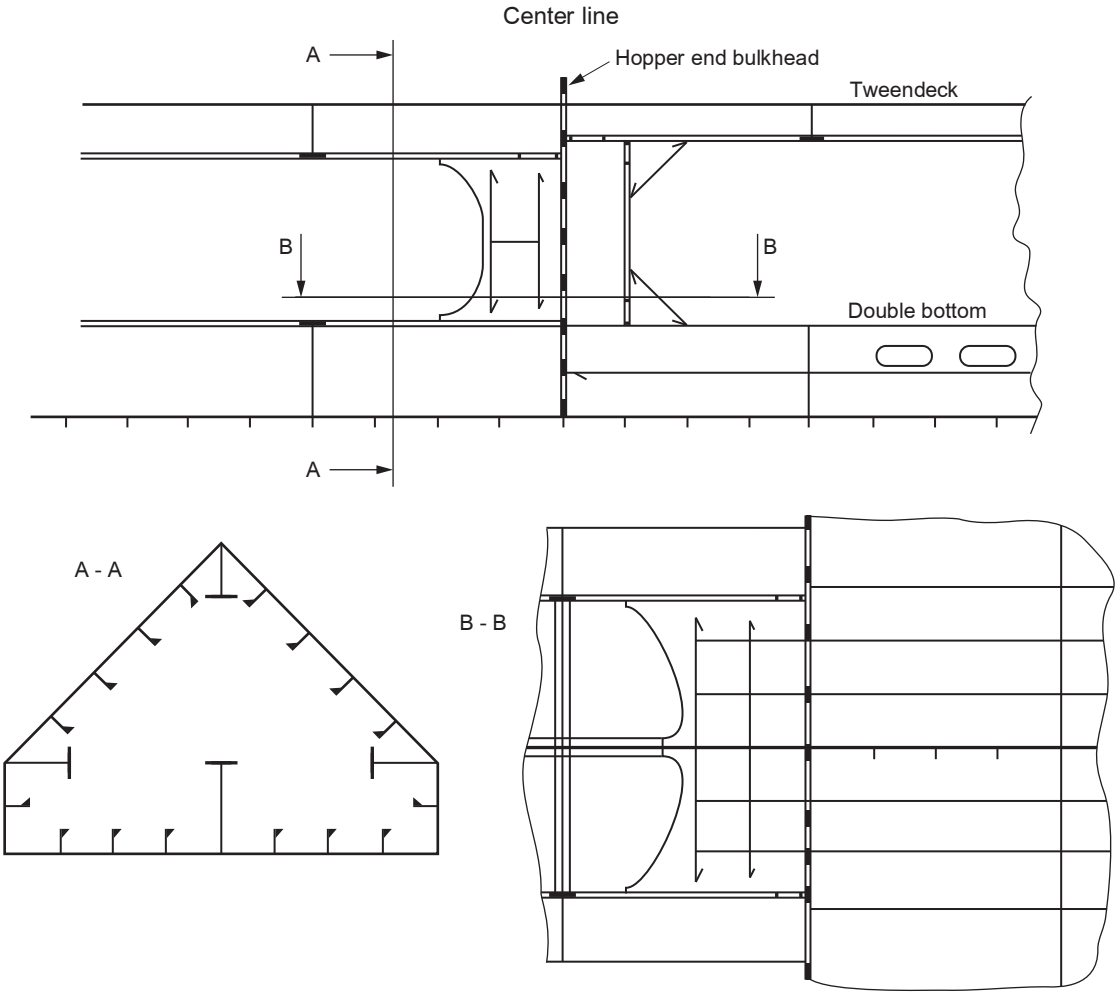


Figure 2 : Integration of cellular keels



2.3 Transverse members in the area of the hopper well

2.3.1 Transverse primary supporting rings

Within the hopper well area, transverse primary supporting rings are to be provided and are to involve:

- deep floors inside hopper spaces
- side vertical primary supporting members
- hopper well vertical primary supporting members
- strong beams inside hopper spaces, at deck or trunk level
- where necessary, cross-ties connecting either the side vertical primary supporting members to the hopper well vertical primary supporting members or the floor to the hopper well vertical primary supporting members.

The spacing of the transverse rings is generally to be taken not greater than five frame spaces.

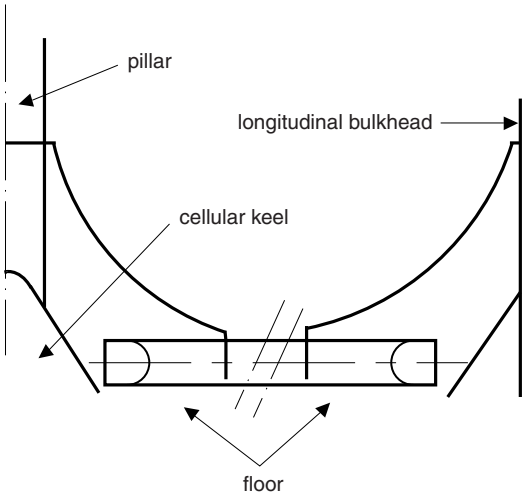
2.3.2 The cellular keel is to be rigidly connected to the transverse rings required in [2.3.1].

2.3.3 The upper part of the cellular keel may be connected to the deck or trunk structure by means of axial or inclined pillars in association with strong beams, or by a centerline wash bulkhead.

2.3.4 The connection of hopper well floors with the longitudinal bulkheads and the cellular keel is to be arranged such that the continuity of the strength is ensured.

Where the floor is made of a box with sloping sides, particular attention is to be paid to the continuity of the lower flange. Fig 3 shows an example of possible connection.

Figure 3 : Example of connection with floor made of box with sloping sides



2.3.5 The connection between the flanges of the strong beams and the adjacent structure is generally to be made by means of brackets having the thickness of these flanges and extending inside the adjacent structure.

2.3.6 In general the sloped hopper well plating is to be supported by a deck or a stringer at the connection to the longitudinal vertical bulkhead. The welding at this location is to be full or partial penetration in the hopper well. Outside of the hopper well the welding may be fillet welding. Tensile stress in the fillet welds is to be less than 0,5 R_y.

2.4 Arrangements relating to suction pipes

2.4.1 Where a cut-out is necessary in the side shell plating to fit the suction pipe guides, continuity of members is to be restored, for example by means of knuckled plates as thick as the side shell plating and with a knuckle angle as small as possible.

The knuckles are to be stiffened by reinforced vertical primary supporting members and intercostal girders of the same web height (see Fig 4 and Fig 5)

The fillet welding between the web of vertical primary supporting members and the knuckled plates is not to be made onto the knuckles, but about 50 mm apart.

Figure 4 : Suction pipe guide arrangement for transversally stiffened vessel

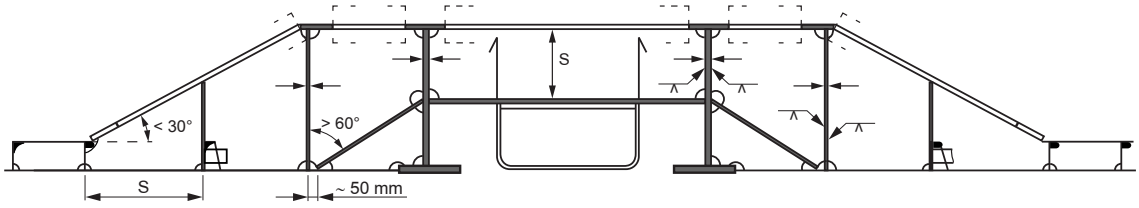
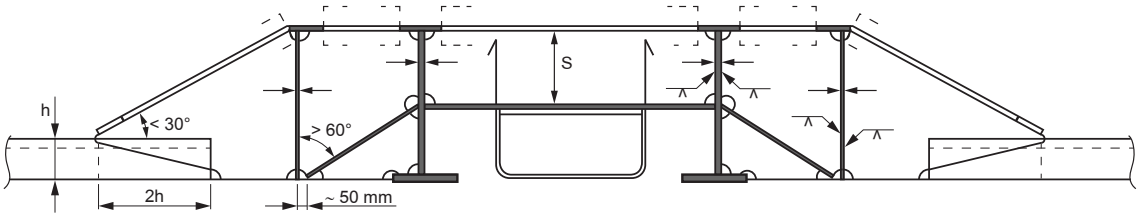


Figure 5 : Suction pipe guide arrangement for longitudinally stiffened



2.4.2 The suction pipe guides are to be fitted as far as possible from the hopper well ends or from any cut-out in the bottom or deck plating.

Deck plating is generally to be reinforced in way of suction pipe guides. Alternatively, strength of deck plating is to be justified by direct calculations for a knuckle angle greater than 30° on a case by case basis.

2.4.3 In areas where, during suction pipe operations, the drag head and the joint may run against the hull, one or several of the following arrangements are generally to be provided:

- thickness plating in excess of thickness obtained according to Pt B, Ch 7, Sec 4 or NR600, Ch 4, Sec 3, as applicable, for bilge and side shell
- reinforcement of the structure by means of vertical primary supporting members, girders, intermediate frames or longitudinals, depending on the construction type
- fenders to be provided outside the hull; these fenders together with the bilge shape are not to impede the suction pipe operation
- cofferdam to be provided to limit the possible flooding of side compartments.

2.4.4 The suction pipes are generally to be fitted with:

- auxiliary devices able to lift the suction pipe, in addition to the suction pipe gantries
- a sufficient number of attachment points on the suction pipe itself, to facilitate handling
- a load limiting device to avoid any overload, if the suction pipe is equipped with cutting teeth
- accessories fitted onto the suction pipe built in several parts to facilitate partial replacements in case of damage.

2.5 Areas subject to heavy wear

2.5.1 Some parts of the structure subjected to heavy wear, such as longitudinal bulkheads of hopper wells, may be protected or reinforced to avoid frequent replacement.

2.5.2 If protection is provided by means of removable plates, called wear plates, attention is to be paid to avoid corrosion between the facing sides of these plates and the hopper well plating.

2.5.3 If reinforcement is made by increasing the thickness, the section moduli may be determined taking into account the extra thickness, provided it is not considered as a voluntary addition t_{vol_add} when applying requirements in Pt B, Ch 4, Sec 2.

If this extra thickness is disregarded in the section moduli calculation, it is to be considered as a voluntary addition t_{vol_add} when applying requirements in Pt B, Ch 4, Sec 2 and is to be clearly indicated on the midship section drawing.

2.6 Reinforcements for grounding

2.6.1 If grounding is considered for normal operation of the ship, the bottom plating and the bottom structure are to be reinforced as indicated in [2.6.2] to [2.6.5].

2.6.2 Along the full length of the ship, in the area of flat bottoms, the bottom net thickness obtained according to Pt B, Ch 7, Sec 4 or NR600, Ch 4, Sec 3, as applicable, is to be increased by 2,5 mm.

2.6.3 Where the ship has a transversely framed double bottom, floors are to be fitted at each frame space and associated with intercostal longitudinal girders, the mean spacing of which is to be not greater than 2,10 m.

Moreover, intercostal longitudinal ordinary stiffeners located at mid-spacing of bottom girders are to be provided.

2.6.4 Where the ship has a longitudinally framed double bottom, the floor spacing may not exceed three frame spaces and the bottom girder spacing may not exceed three longitudinal ordinary stiffener spaces.

Intercostal transverse stiffeners are to be provided at mid-span of longitudinal ordinary stiffeners.

Floors are to be stiffened by vertical stiffeners having the same spacing as the longitudinal ordinary stiffeners.

2.6.5 Where the ship is built with open hopper spaces (bottom doors provided on the bottom), reinforcements as required in [2.6.3] or [2.6.4] are to be provided within the side compartments, the cellular keel and, in general, within the limits of the flat bottom area.

2.7 Bolted structures

2.7.1 Where the dredger is made of several independent members connected by bolting, the connection is to be examined by the Society on a case-by-case basis.

3 Design loads

3.1 General

3.1.1 Design loads are to be determined for the various load cases in the following situations:

- navigation situation
- each dredging situation i, with i choosen between 1 to x, where x is the number of operating area notations which are assigned to the ship according to Pt A, Ch 1, Sec 2, [5.3.2].

The navigation situation is associated with the following design parameters:

- Navigation draught T_{IF} , in m, corresponding to the international freeboard
- block coefficient at the considered loading condition $C_{B\text{-}LC}$
- waterplane coefficient at the considered loading condition $C_{W\text{-}LC}$
- wave parameter H
- navigation coefficient n
- roll radius k_r and metacentric height GM as per full load condition
- the hopper well(s) filled with water up to the load line

Each dredging situation i is associated with the following design parameters:

- design draughts T_{Di}, in m

  For ships assigned the service notation **split hopper dredger** or **split hopper unit**, the following design draughts have to be included, as a minimum, among the different design dredging draughts:

  T_{IF} : Draught when dredging at the international freeboard

  T_{WL} : Draught when dredging with well filled up to waterline

  T_{OL} : Draught when dredging with well filled with water up to the lowest overflow level
- still water bending moments and shear forces
- block coefficient at the considered loading condition $C_{B\text{-}LC}$
- waterplane coefficient at the considered loading condition $C_{W\text{-}LC}$
- wave parameter H_{Di} , calculated using the coefficients given in:
  - Tab 1 for ships assigned the operating are notation **unrestricted dredging area (T= x m)**,
  - Tab 2 for ships assigned the operating area notations defined in Pt A, Ch 1, Sec 2, Tab 3,
  - Tab 3 for ships assigned the additional service feature **EOC**, and granted with the operating area notations defined in Pt A, Ch 1, Sec 2, Tab 4

  instead of the coefficients given for H, as defined in Pt B, Ch 5, Sec 3, [1.1.1]
- navigation coefficient n_{Di}, calculated using H_{Di} instead of H, as defined in Pt B, Ch 5, Sec 3, [1.1.2],
- Roll radius k_r and metacentric height GM as per full load condition
- spoil density δ_i and hopper well filling level h_{Di}.

  For ships assigned the additional class notation **split hopper dredger** or **split hopper unit**, the following values of h_{Di} have to be included, as a minimum:

  h_{IF} : Distance, in m, from spoil level to base line when dredging at the international freeboard (see Fig 7)

  h_{WL} : Distance, in m, from spoil level to base line when dredging with well filled up to waterline (see Fig 7)

  h_{OL} : Distance, in m, from the lowest overflow level to base line when dredging with well filled with water up to the lowest overflow level.

3.1.2 For dredgers made of bolted structure, the Society may require the hull girder loads calculated with the maximum length of the unit when mounted to be applied to each individual element.

Table 1 : Wave parameter H_{Di} coefficients for ships assigned the operating area notation unrestricted dredging area (T= x m)

Operating area notation	Assessment	A_0	A_1	e_1	A_2	e_2	L_c	h_{lu} **(1)**
unrestricted dredging area (T= x m)	Strength	0,9	1,30	1,80	0,90	1,80	552	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5

Note 1: (T= x m) indicates the maximum allowable draught x, in m, corresponding to the values of T_{Di} defined in [3.1.1]

Note 2: The operations area notation **unrestricted dredging area (T= x m)** is equivalent to the navigation notation **unrestricted navigation** when applying requirements of Part B.

(1) Reference height for loading/unloading fatigue assessment, in m, to be considered for the calculation of f_{plu} according to Pt B, Ch 5, Sec 3

Table 2 : Wave parameter H_{Di} coefficients for ships not assigned the additional service feature EOC

Ship length	Operating area notation	Assessment	A_0	A_1	e_1	A_2	e_2	L_c	h_{lu} **(1)**
≤ 110 m	**dredging ≤ 8 miles from shore or Hs ≤ 1,5 m (T= x m)**	Strength	0,21	1,64	2,26	0,17	1,50	141	–
		Fatigue	0,09	1,96	2,13	0,38	1,14	143	2,5
	dredging ≤ 15 miles from shore or Hs ≤ 2,5 m (T= x m)	Strength	0,47	1,55	2,13	0,29	1,69	244	–
		Fatigue	0,15	1,71	1,98	0,47	1,38	219	5,5
> 110 m and ≤ 150 m	**dredging ≤ 8 miles from shore or Hs ≤ 2,0 m (T= x m)**	Strength	0,25	1,63	2,25	0,18	1,55	155	–
		Fatigue	0,10	1,90	2,10	0,38	1,20	158	3,0
	dredging ≤ 15 miles from shore or Hs ≤ 3,0 m (T= x m)	Strength	0,51	1,54	2,10	0,32	1,70	263	–
		Fatigue	0,15	1,70	1,97	0,49	1,40	226	6,0
> 150 m	**dredging ≤ 8 miles from shore or Hs ≤ 2,0 m (T= x m)**	Strength	0,25	1,63	2,25	0,18	1,55	155	–
		Fatigue	0,10	1,90	2,10	0,38	1,20	158	3,0
	dredging ≤ 15 miles from shore or Hs ≤ 3,5 m (T= x m)	Strength	0,55	1,52	2,07	0,35	1,72	282	–
		Fatigue	0,16	1,69	1,96	0,49	1,41	230	6,5

Note 1: H_s : Maximum significant wave height, in m, associated to the operating area notation.

Note 2: (T= x m) indicates the maximum allowable draught x, in m, corresponding to the values of T_{Di} defined in [3.1.1]

(1) Reference height for loading/unloading fatigue assessment, in m, to be considered for the calculation of f_{plu} according to Pt B, Ch 5, Sec 3

Table 3 : Wave parameter H_{Di} coefficients for ships assigned the additional service feature EOC

Operating area notation	Assessment	A_0	A_1	e_1	A_2	e_2	L_c	h_{lu} **(1)**
dredging ≤ 8 miles from shore or Hs ≤ 1,0 m (T= x m)	Strength	0,07	1,66	2,29	0,16	1,29	107	–
	Fatigue	0,03	2,19	2,18	0,37	0,97	106	1,0
dredging ≤ 8 miles from shore or Hs ≤ 1,5 m (T= x m)	Strength	0,11	1,65	2,28	0,16	1,37	116	–
	Fatigue	0,05	2,11	2,17	0,37	1,03	116	1,5
dredging ≤ 8 miles from shore or Hs ≤ 2,0 m (T= x m)	Strength	0,16	1,65	2,28	0,17	1,44	127	–
	Fatigue	0,07	2,04	2,15	0,37	1,08	129	2,0
dredging ≤ 8 miles from shore or Hs ≤ 2,5 m (T= x m)	Strength	0,21	1,64	2,26	0,17	1,50	141	–
	Fatigue	0,09	1,96	2,13	0,38	1,14	143	2,5
dredging ≤ 8 miles from shore or Hs ≤ 3,0 m (T= x m)	Strength	0,25	1,63	2,25	0,18	1,55	155	–
	Fatigue	0,1	1,90	2,10	0,38	1,20	158	3,0
dredging ≤ 8 miles from shore or Hs ≤ 3,5 m (T= x m)	Strength	0,30	1,61	2,23	0,20	1,59	172	–
	Fatigue	0,12	1,84	2,07	0,40	1,25	173	3,5
dredging ≤ 15 miles from shore or Hs ≤ 2,5 m (T= x m)	Strength	0,35	1,60	2,21	0,21	1,62	189	–
	Fatigue	0,13	1,80	2,05	0,41	1,29	187	4,0

Note 1: H_s : Maximum significant wave height, in m, associated to the operating area notation.

Note 2: (T= x m) indicates the maximum allowable draught x, in m, corresponding to the values of T_{Di} defined in [3.1.1]

(1) Reference height for loading/unloading fatigue assessment, in m, to be considered for the calculation of f_{plu} according to Pt B, Ch 5, Sec 3.

Operating area notation	Assessment	A_0	A_1	e_1	A_2	e_2	L_c	h_{lu} **(1)**
dredging ≤ 15 miles from shore or Hs ≤ 3,0 m (T= x m)	Strength	0,39	1,59	2,19	0,24	1,64	207	–
	Fatigue	0,13	1,76	2,02	0,44	1,33	200	4,5
dredging ≤ 15 miles from shore or Hs ≤ 3,5 m (T= x m)	Strength	0,43	1,57	2,16	0,26	1,67	225	–
	Fatigue	0,14	1,73	2,00	0,46	1,36	210	5,0
dredging ≤ 15 miles from shore or Hs ≤ 4,0 m (T= x m)	Strength	0,47	1,55	2,13	0,29	1,69	244	–
	Fatigue	0,15	1,71	1,98	0,47	1,38	219	5,5
dredging ≤ 15 miles from shore or Hs ≤ 4,5 m (T= x m)	Strength	0,51	1,54	2,10	0,32	1,70	263	–
	Fatigue	0,15	1,70	1,97	0,49	1,40	226	6,0
dredging ≤ 15 miles from shore or Hs ≤ 5,0 m (T= x m)	Strength	0,55	1,52	2,07	0,35	1,72	282	–
	Fatigue	0,16	1,69	1,96	0,49	1,41	231	6,5

Note 1: H_s : Maximum significant wave height, in m, associated to the operating area notation.

Note 2: (T= x m) indicates the maximum allowable draught x, in m, corresponding to the values of T_{Di} defined in [3.1.1]

(1) Reference height for loading/unloading fatigue assessment, in m, to be considered for the calculation of f_{plu} according to Pt B, Ch 5, Sec 3.

3.2 Loading conditions

3.2.1 In addition to the requirements in Pt B, Ch 5, Sec 4, as applicable, still water hull girder loads are to be calculated for the following loading conditions:

- homogeneous loading at maximum dredging draught if higher than the maximum service draught
- partial loading conditions
- any specified non-homogeneous loading condition, in particular where dredgers are fitted with several hopper spaces
- hopper well(s) filled with water up to the load line
- hopper well(s) filled with spoil at a draught corresponding to the international freeboard
- ballast navigation conditions, with empty hopper well(s), if applicable.

Calculation of the still water bending moment and shear force for any loading case corresponding to a special use of the ship may be required by the Society on a case-by-case basis. In particular, in the case of stationary dredgers, the still water bending moment distribution, where the suction pipe is horizontal, is to be submitted to the Society for approval.

3.3 Hull girder loads for dredgers, hopper dredgers and hopper units of more than 65 m in length

3.3.1 Application

The provisions in [3.3.2] to [3.3.5] apply to ships with one of the service notations **dredger**, **hopper dredger** or **hopper unit** of more than 65 m in length.

3.3.2 Vertical still water bending moments

In addition to the vertical still water bending moments $M_{sw\text{-}max}$ and $M_{sw\text{-}min}$ in navigation situation (see [3.1.1]) defined in Pt B, Ch 5, Sec 4, [2.2], the vertical still water bending moments in any of the dredging situations (see [3.1.1]) are also to be considered. The same value, provided by the designer for each dredging situation is to be given to both $M_{sw\text{-}max,Di}$ and $M_{sw\text{-}min,Di}$, associated respectively to hogging and sagging conditions.

If the design vertical still water bending moments in dredging situations are not defined at a preliminary design stage, at any hull transverse section, $M_{sw\text{-}max,Di}$ and $M_{sw\text{-}min,Di}$ in kN.m may be taken as:

$$M_{sw-max,Di} = f_{sw}\left(190 \cdot \frac{1+n}{2} \cdot C \cdot L^2 \cdot B(C_B + 0,7) \cdot 10^{-3} - M_{wv-h-mid,Di}\right)$$

$$M_{sw-min,Di} = -f_{sw}\left(190 \cdot \frac{1+n}{2} \cdot C \cdot L^2 \cdot B(C_B + 0,7) \cdot 10^{-3} + M_{wv-s-mid,Di}\right)$$

where:

f_{sw} : Distribution factor along the ship length to be taken:
- equal to 1 from 0,35L to 0,65L and to 0 at the ship's ends for hopper dredgers with single hopper well. Intermediate values are to be obtained by linear interpolation
- as defined in Pt B, Ch 5, Sec 4, [2.2.3] for other cases

$M_{wv\text{-}h\text{-}mid,Di}$: Vertical wave bending moment for strength assessment in the dredging situation i (see [3.1.1]), in hogging conditions, defined in [3.3.3] where $F_M = 1$

$M_{wv\text{-}s\text{-}mid,Di}$: Vertical wave bending moment for strength assessment in the dredging situation i (see [3.1.1]), in sagging conditions, defined in [3.3.3] where $F_M = 1$

3.3.3 Vertical wave bending moments

In addition to the vertical wave bending moments $M_{wv\text{-}h}$ and $M_{wv\text{-}s}$ in navigation situation (see [3.1.1]) defined in Pt B, Ch 5, Sec 4, [3.1], the vertical wave bending moments in any of the dredging situations (see [3.1.1]) at any hull transverse section, $M_{wv\text{-}h,Di}$ and $M_{wv\text{-}s,Di}$ are to be obtained using definitions in Pt B, Ch 5, Sec 4, [3.1], replacing n by n_{Di} or H by H_{Di}.

3.3.4 Horizontal wave bending moments

In addition to the horizontal wave bending moment M_{wh}, in navigation situation (see [3.1.1]) defined in Pt B, Ch 5, Sec 4, [3.3], the horizontal wave bending moments in any of the dredging situations (see [3.1.1]), $M_{wh,Di}$ at any hull transverse section is to be obtained using definition in Pt B, Ch 5, Sec 4, [3.3], replacing H by H_{Di}.

3.3.5 Vertical wave shear forces

In addition to the vertical wave shear forces $Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$ in navigation situation (see [3.1.1]) defined in Pt B, Ch 5, Sec 4, [3.2], the vertical wave shear forces in any of the dredging situations (see [3.1.1]) at any hull transverse section $Q_{wv\text{-}pos,Di}$ and $Q_{wv\text{-}neg,Di}$ are to be obtained using definitions in Pt B, Ch 5, Sec 4, [3.2.1], replacing n by n_{Di}.

3.4 Hull girder loads for split hopper dredgers and split hopper units of more than 65 m in length

3.4.1 Application

The provisions in [3.4.2] to [3.4.8] apply to ships with one of the service notations **split hopper dredger** or **split hopper unit** of more than 65 m in length.

3.4.2 General

Horizontal bending moments are to be calculated assuming that the hopper well is simply supported at each end.

The clearance between the two half-hulls is to be large enough not to be suppressed when the hopper well is full up.

Details of the calculation of the necessary clearances are to be submitted to the Society for review.

However, the horizontal bending moments are generally to be calculated assuming that both ends of the hopper well are partly clamped, on condition that at deck and bottom level chocks are provided forward and aft of the well so that:

- the clearance between the two half-hulls is nil
- the chocks are long enough to withstand the end moments due to the horizontal forces developed along the hopper well.

3.4.3 Vertical still water bending moments

The vertical still water bending moments to be applied on one half-hull in navigation and dredging situations are to be taken equal respectively to half the vertical still water bending moments defined in [3.3.2].

3.4.4 Vertical wave bending moments

The vertical wave bending moments to be applied on one half-hull in navigation and dredging situations are to be taken equal respectively to half the vertical wave bending moments defined in [3.3.3]

3.4.5 Horizontal still water bending moments

The horizontal still water bending moments to be applied on one half-hull in navigation and dredging situations are to be obtained, in kN.m, from the formulae given in Tab 4, assuming that the hopper well is simply supported at each end.

If the hopper well may not be considered as simply supported at each end, the horizontal still water bending moments to be applied on one half-hull in navigation and dredging situations are to be determined on a case by case basis.

Table 4 : Split hopper dredgers and split hopper units - Horizontal still water bending moment on half-hulls

	$M_{sh\text{-}hh}$, in kN.m	
Hopper well mid-section **(1)**	for portside half-hull: $\left(\frac{1}{8}+\frac{c_1}{2\ell_p}\right)p\ell_p^2$	for starboard half-hull: $-\left(\frac{1}{8}+\frac{c_1}{2\ell_p}\right)p\ell_p^2$
Hopper well ends **(1)**	0	

(1) Between hopper well mid-section and ends, the value of the horizontal still water bending moment is to be obtained by linear interpolation.

Note 1:

p : Load per metre, in kN/m, applied along the hopper well, defined in Tab 5 depending on the loading condition

c_1 : Distance, in m, from deck hinges to ends of hopper well (see Fig 6).

Figure 6 : Definitions of dimensions in hopper well area

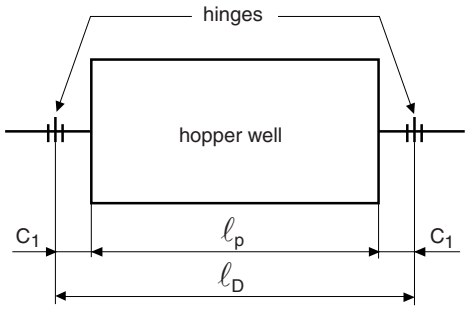
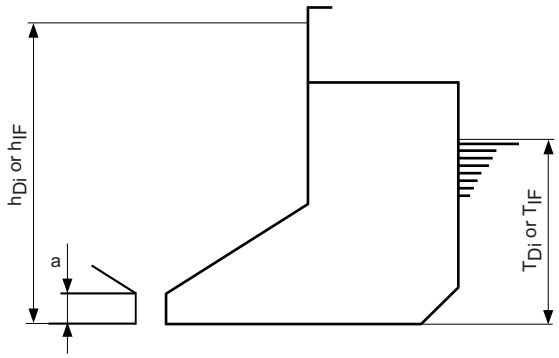


Table 5 : Load per metre applied along the hopper well

Loading condition	p, in kN/m
Navigation situation	0
Dredging with spoil loading corresponding to the international freeboard	$\frac{\delta_i(h_{IF}-a)^2-1,025(T_{IF}-a)^2}{2}g$
Dredging condition with well filled with water up to the waterline	0
Dredging condition with well filled with water up to the lowest weir level	$\frac{,025[(h_{OL}-a)^2-(T_{OL}-a)^2]}{2}\xi$
Other dredging situations	$\frac{\delta_i(h_{Di}-a)^2-1,025(T_{Di}-a)^2}{2}g$
Note 1: See Fig 7 for the definitions of distances for calculation of the loads applied along the hopper well	

Figure 7 : Definitions of distances for calculation of the load applied along the hopper well



3.4.6 Horizontal wave bending moments

The horizontal wave bending moments to be applied on one half-hull in navigation and dredging situations are to be obtained, in kN.m, from the formulae given in Tab 6, assuming that the hopper well is simply supported at each end.

If the hopper well may not be considered as simply supported at each end, the horizontal still water bending moments to be applied on one half-hull in navigation and dredging situations are to be determined on a case by case basis.

Table 6 : Split hopper dredgers and split hopper units - Horizontal wave bending moment on half-hulls

	$M_{wh\text{-}hh}$, in kN.m	
	Navigation situation	Dredging situations
Hopper well mid-section **(1)**	$\left[T_{IF}+0,079Cn\left(2\frac{\ell_D}{L}-1\right)(C_{B-LC}+0,7)\right]\frac{M_{wv}}{B}$	$\left[T_{Di}+0,079Cn_{Di}\left(2\frac{\ell_D}{L}-1\right)(C_{B-LC}+0,7)\right]\frac{M_{wv}}{B}$
Hopper well ends **(1)**	0	
(1) Between hopper well mid-section and ends, the value of the horizontal wave bending moment is to be obtained by linear interpolation.		
Note 1: M_{wv}: Vertical wave bending moment, in kN.m, in navigation or dredging situations, as applicable, in hogging or sagging conditions, as defined in [3.3.3].		

3.4.7 Combined still water and wave vertical bending moment

In the midship area, the total vertical bending moment M_V to be applied on half-hull is to be obtained, in kN.m, from Tab 7.

At hopper well ends, the total bending moment M_V is to be determined in accordance with Tab 7 considering:

- for the still water vertical bending moment: the greater of the values at the fore and aft hopper well ends
- for the vertical wave bending moment: the longitudinal distribution defined in Pt B, Ch 5, Sec 4, Fig 2.

Table 7 : Vertical bending moment applied on half-hull

Condition	Vertical bending moment M_V, in kN.m	
	Navigation situation	Dredging situation i
Hogging	$\frac{M_{sw-max} + M_{wv-h}}{2}$	$\frac{M_{sw-max,Di} + M_{wv-h,Di}}{2}$
Sagging	$\frac{M_{sw-min} + M_{wv-s}}{2}$	$\frac{M_{sw-min,Di} + M_{wv-s,Di}}{2}$

Note 1:

M_{sw-max}, M_{sw-min} : Maximum and minimum still water vertical bending moment in navigation situation as defined in Pt B, Ch 5, Sec 4, [2.2]

M_{wv-h}, M_{wv-s} : Wave vertical bending moment in navigation situation in hogging and sagging condition, respectively, defined in Pt B, Ch 5, Sec 4, [3.1]

$M_{sw-max, Di}$, $M_{sw-min, Di}$: Maximum and minimum still water vertical bending moment in the dredging situation i, as defined in [3.3.2]

$M_{wv-h, Di}$, $M_{wv-s, Di}$: Wave vertical bending moment in the dredging situation i, in hogging and sagging condition, respectively, defined in [3.3.3].

3.4.8 Combined still water and wave horizontal bending moment

The total horizontal bending moment M_H applied on half-hull at hopper well mid-section and at hopper well ends, in navigation and dredging situations, is to be obtained, in kN.m, from the following formula:

$M_H = M_{sh-hh} + M_{wh-hh}$

where:

M_{sh-hh} : Horizontal still water bending moment, defined in [3.4.5] at hopper well mid-section and at hopper well ends, in navigation and dredging situations

M_{wh-hh} : Horizontal wave bending moment, defined in [3.4.6] at hopper well mid-section and at hopper well ends, in navigation and dredging situations.

3.4.9 Combined still water and wave vertical shear forces

The combined still water and wave vertical shear forces may be taken as equally distributed between both half hulls.

3.5 Internal pressures in hopper well

3.5.1 Pressures for the strength and fatigue assessments in navigation and dredging situations

The internal pressure P_{in} due to the mixture of sea water and spoil acting on any load point of the hopper boundary, in kN/m^2, is to be taken as:

$P_{in} = P_S + P_W$

where:

P_S : Static pressure due to water and spoil in hopper, as defined in [3.5.2]

P_W : Dynamic pressure due to water and spoil in hopper, as defined in [3.5.3]

3.5.2 Still water pressure in hopper well

The still water pressure P_S in the hopper well, in kN/m^2, is to be taken as follows:

$P_S = g\ \delta_1\ K_D\ d$

without being taken less than:

- 12 kN/m^2 for prescriptive strength assessment
- 0 kN/m^2 for direct strength analysis and fatigue assessment

where:

δ_1 : Density, taken equal to:
  - for the navigation situation (see [3.1.1]: δ
  - for each of dredging situation i (see [3.1.1]: δ_i

K_D : Coeficient taken equal to:

- for the navigation situation:
  $K_D = 1,0$
- for each of dredging situation i:
  $K_D = \cos^2\alpha + \phi\sin^2\alpha$
  where:
  ϕ : friction coefficient, taken equal to:
  - for $\delta_i < 1,4$:
    $\phi = 1,0$
  - for $\delta_i \geq 1,4$:
    $\phi = 1,4/\delta_i$

α : Angle between the considered panel and horizontal plane

3.5.3 Inertial pressure in hopper well

The dynamic pressure P_{Wi} in the hopper well, in kN/m^2, is to be taken as follows:

- for the navigation situation:
  $P_W = \delta\,[a_x\,(x_0 - x) + a_y\,(y_0 - y) + a_z\,(z_0 - z)]$
- for each of the dredging situations i:

$$P_{Wi} = \delta_i\left(\frac{a_x(x_G - x) + a_y(y_G - y)}{4} + a_z d K_D\right)$$

without being taken less than:

- 12 kN/m^2 for prescriptive strength assessment
- 0 kN/m^2 for direct strength analysis and fatigue assessment

where:

x_0 : X coordinate, in m, of the reference point.

y_0 : Y coordinate, in m, of the reference point.

z_0 : Z coordinate, in m, of the reference point.

The reference point is to be taken as the point with the highest value of V_j, calculated for all the points that define the free spoil surface at the filling level of the considered navigation or dredging situation, as follows:

$V_j = a_x\,(x_j - x_G) + a_y\,(y_j - y_G) + (a_z + g)\,(z_j - z_G)$

where:

x_j : X coordinate, in m, of the point j on the free spoil surface at the filling level of the considered navigation or dredging situation;

y_j : Y coordinate, in m, of the point j on the free spoil surface at the filling level of the considered navigation or dredging situation;

z_j : Z coordinate, in m, of the point j on the free spoil surface at the filling level of the considered navigation or dredging situation.

x_G, y_G, z_G: X, Y and Z coordinates, in m, of the volumetric centre of gravity of spoil with respect to the reference coordinate system defined in Pt B, Ch 1, Sec 3, [2.6.1], to be taken as follows:

- x_G, y_G: Volumetric centre of gravity of the hopper well
- z_G: vertical position at mid height of the spoil, measured at the centerline.

K_D : Coefficient as defined in [3.5.2]

4 Hull girder strength of dredgers, hopper dredgers and hopper units

4.1 General

4.1.1 The hull girder strength of:

- ships of more than 90 m and assigned with the service notation **dredger**, and
- ships of more than 65 m and assigned with the service notation **hopper dredger** or **hopper unit**,

is to be checked for navigation situation and each of the dredging situations (see [3.1.1]) according to the criteria of Part B, Chapter 6, considering the still water and wave loads defined in [3.3].

4.1.2 For dredgers made of bolted structure, the Society may require the hull girder strength criteria to be applied to each individual element, considering the loads calculated according to [3.1.2].

4.2 Midship section modulus

4.2.1 In the determination of the midship section modulus according to Pt B, Ch 6, Sec 1, [1.4], account is to be taken of both 85% and 100% effectiveness of the sectional area of the cellular keel.

However the 85% and 100% effectiveness of the sectional area of the cellular keel may be replaced by the actual effectiveness of the cellular keel determined by a three dimensional finite element analysis.

4.2.2 Where cut-outs in the side shell are needed to fit the suction pipe guides, a section modulus calculation not taking account of the side shell plating may be required by the Society on a case-by-case basis, if the structural continuity is not correctly achieved.

5 Hull girder strength of split hopper dredgers and split hopper units

5.1 General

5.1.1 The yielding check of ships with one of the service notations **split hopper dredger** or **split hopper unit** and of more than 65 m in length is to be carried out for navigation situation and each of the dredging situations (see [3.1.1]) according to [5.2] to [5.4] considering:

- each half-hull as being subjected to independent bending
- the deck hinges and the hydraulic jacks acting as supports at the ends of the hopper well.

Both the vertical bending moment and horizontal bending moment acting within the well area are to be taken into account.

5.1.2 The hull section modulus, considered with the two half-hulls connected, is to be checked for navigation situation and each of the dredging situations (see [3.1.1]) according to the criteria of Pt B, Ch 6, Sec 1, [3], considering the still water and wave bending moments defined in [3.4]

See also [4.2] for the determination of the midship section modulus.

5.2 Definitions

5.2.1 Co-ordinate system

The hull girder strength is defined with reference to the following co-ordinate system, as shown in Fig 8:

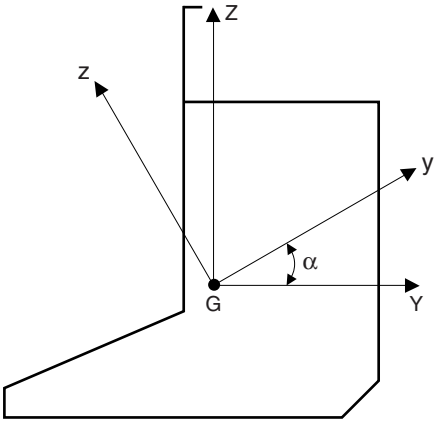
G : Centre of gravity of the half-hull transverse section

GY : Transverse axis, parallel to Y defined in Pt B, Ch 1, Sec 3, [2.6] and crossing through G

GZ : Vertical axis, parallel to Z defined in Pt B, Ch 1, Sec 3, [2.6] and crossing through G

Gy, Gz : Main axes of the half-hull transverse section, defined in [5.2.2].

Figure 8 : Half-hull co-ordinate system



5.2.2 Main axes

The main axes Gy and Gz are obtained from the axes GY and GZ by a rotation around the centre of gravity G of an angle α obtained from the following formula:

$$\alpha = \frac{1}{2}\operatorname{atan}\left(\frac{2I_{YZ}}{I_Z - I_Y}\right)$$

where:

I_Y : Net moment of inertia, in m^4, of the transverse section around the axis GY

I_Z : Net moment of inertia, in m^4, of the transverse section around the axis GZ

I_{YZ} : Net inertia product, in m^4, of the transverse section, in the reference (G, GY, GZ).

5.2.3 Bending moments

The bending moments M_y and M_z in relation to the main axes Gy and Gz, respectively, are to be obtained, in kN.m, from the following formulae:

$M_y = M_V \cos \alpha + M_H \sin \alpha$

$M_z = - M_V \sin \alpha + M_H \cos \alpha$

where:

M_V : Vertical bending moment defined in [3.4.7], in kN.m, to be considered in hogging and sagging conditions, for the navigation and dredging situations

M_H : Horizontal bending moment defined in [3.4.8], in kN.m, to be considered for the navigation and dredging situations

α : Angle defined in [5.2.2].

As the main inertia axes of each half-hull are oblique, the bending of each half-hull is a deviated bending.

5.3 Hull girder stress

5.3.1 At any point of the transverse section of each half-hull, the hull girder normal stresses are to be obtained, in N/mm^2, from the following formula:

$$\sigma_L = \left(z \frac{M_y}{I_{yM}} - y \frac{M_z}{I_{zM}} \right) 10^{-3}$$

where:

M_y, M_z : Bending moments, in kN.m, in hogging and sagging conditions, for the navigation and dredging situations (see [3.1.1]), defined in [5.2.3]

I_{yM}, I_{zM} : Net moments of inertia, in m^4, of the transverse section around its main axes

y, z : y and z coordinates, in m, of the calculation point with respect to the main axes Gy and Gz.

5.3.2 In the case of partly clamped ends of the hopper well (see [3.4.2]), the hull girder normal stresses are to be calculated in the hopper well mid-section and at hopper well ends.

In this case, the stresses are also to be calculated in the midship area assuming the ends supported as regards the horizontal moment. This calculation relates to the beginning of the hopper well drainage by opening of the two half-hulls.

5.3.3 In the case of supports at hopper well ends, the calculation of the hull girder normal stress is to be carried out in the hopper well mid-section.

5.3.4 For each section of calculation, the most unfavourable combination of moments is to be considered.

5.4 Checking criteria

5.4.1 It is to be checked that the normal stresses calculated according to [5.3.1] are in compliance with the requirements in Pt B, Ch 6, Sec 1, [3.5.2].

6 Hull scantlings

6.1 General

6.1.1 Hull scantlings are to be checked according to the applicable requirements of Part B, Chapter 7 for the additional design load sets defined in Tab 8.

Note 1: the design load sets SEA-Di are to be considered in addition to the design load set SEA-1 when applying the criteria for rounded bilge plating in Pt B, Ch 7, Sec 4, [6.2.1] item b).

For ships with one of the service notations **split hopper dredger** or **split hopper unit**, and of more than 65 m in length, the hull girder normal stresses to be used in the application of requirements of Part B, Chapter 7 are defined in [6.2].

Table 8 : Additional design load sets for dredgers

Item	Design load set	Load component	Draught	Acceptance criteria	Design load scenario / Loading condition
Outer shell and exposed deck	SEA-Di	P_{ex} , P_d	T_{Di}	AC-2	Sea-going / Dredging situation i
Hopper wells of dredgers	HW-N	$P_{in} - P_{ex}$ **(1)**	T_{IF}	AC-2	Seagoing / Navigation situation
	HW-Di	$P_{in} - P_{ex}$ **(1)**	T_{Di}	AC-2	Seagoing / Dredging situation i
Exposed deck, internal decks or platforms	DL-Di **(2)**	P_{dk} , F_U	T_{Di}	AC-2	Sea-going / Dredging situation i

(1) P_{ex} is to be considered for external shell only.

(2) Distributed or concentrated loads only. Need not be combined with simultaneously occurring green sea pressure.

6.2 Hull girder normal stress for split hopper dredgers and split hopper units of more than 65 m in length

6.2.1 The hull girder normal stress σ_L to be considered for the strength and buckling check of plating, stiffeners and primary supporting members according to Part B, Chapter 7 and Part B, Chapter 9 is to be obtained as calculated in [5.3].

6.3 Minimum net thicknesses of plating

6.3.1 The net thickness of plating is to be not less than the greater of the following values:

- 5 mm
- thickness, in mm, obtained from Tab 9.

Table 9 : Ships for dredging activities - Minimum net thicknesses of plating

Plating	Minimum net thickness, in mm
Hopper well • transverse and longitudinal bulkheads • cellular keel plating	$2,7 + 0,034\ L\ k^{1/2} + 0,0045\ b$
Splash coaming	6

6.3.2 Where no protection is fitted on the deck areas where heavy items of dredging equipment may be stored for maintenance, the net thickness of the deck plating is to be not less than the value obtained, in mm, from the following formula:

$t = 5,1 + 0,040\ L\ k^{1/2} + 0,0045\ b$

6.4 Transverse vertically corrugated bulkheads

6.4.1 Transverse vertically corrugated bulkheads forming the boundary of hopper wells are to comply with the requirements in Pt B, Ch 7, Sec 6, [4.6] considering an internal spoil pressure P as calculated in [3.5] for the design load sets HW-N and HW-Di.

6.5 Well bulkhead and cellular keel platings

6.5.1 The net thickness of the longitudinal bulkhead above the deck or within 0,1D below the deck is to be not less than the net thickness of the strength deck abreast of the hatchways.

6.5.2 The net thickness of the transverse and longitudinal bulkhead of a dredge pipe well is to be determined as for the side shell net thickness.

6.6 Transversely framed bottoms

6.6.1 Floors

The scantlings of floors located inside large compartments, such as pump rooms, are to be obtained from a direct calculation, according to Pt B, Ch 7, Sec 6 as applicable, and taking into account the following assumptions:

- floors are simply supported at ends
- local discontinuities in strength, due to the presence of wells, are to be considered.

7 Fatigue

7.1 General

7.1.1 Application

Loading and unloading fatigue assessment is to be performed according to the requirements of Pt B, Ch 10, Sec 1, [1.3] to all ships having a length equal to or greater than 150m or assigned with the additional service feature **EOC**, considering the requirements in [7.1.2] to [7.1.4].

7.1.2 Loading conditions

Loading conditions representative of the intended operation:

- navigation,
- ballast,
- dredging situation (see [3.1.1]) ,

and the fraction of time spent in each condition are to be considered for fatigue analysis.

Tanks filling levels associated to each loading condition are to be specified.

7.1.3 Still water loads for the fatigue assessment

The still water bending moment, M_{sw}, to be used for the fatigue assessment is to be taken:

- for the navigation and ballast conditions, as defined in Pt B, Ch 5, Sec 4, [2.1.3]
- for the dredging situations M_{sw} is to be taken equal to 1,00 $M_{sw\text{-}min,Di}$.

7.1.4 List of special structural details

The following details are to be assessed in addition to those listed in Pt B, Ch 13, Sec 5:

- end connections of deck and bottom longitudinal stiffeners to stiffeners of transverse bulkheads or web frames
- corners of bottom door openings
- crane rail details (e.g. expansion joints)
- splash coaming details (e.g. expansion joints)
- connections of the cellular keel to the transverse boxes and the hopper end bulkheads
- connections of transverse boxes to the side structure
- structural details in way of dredging equipment integration (e.g. gantries and winches deck foundations, cutter ladder integration,…)
- other details may be considered as special structural details whenever deemed necessary by the Society.

8 Hopper dredgers and hopper units: checking of hopper well structure

8.1 General

8.1.1 The requirements of Article [8] apply to ships with one of the service notations **hopper dredger** or **hopper unit**.

8.1.2 At the ends of the hopper spaces, the transverse bulkheads are to extend over the full breadth of the ship. Where this is not the case, web rings with special scantlings are to be provided.

8.2 Floors, webs, trunks, strongbeams and girders

8.2.1 Stresses in transverse primary members (such as floors, webs, trunks, strongbeams and girders) are to be obtained by a 2D or 3D beam model or FEM with the following assumptions:

- design loads as specified by the Designer
- load cases according to Pt B, Ch 5, Sec 2.

8.2.2 Stresses obtained according to [8.2.1] need to be combined with hull girder longitudinal stresses obtained according to Pt B, Ch 6, Sec 1, [2].

8.2.3 It is to be checked that stresses obtained according to [8.2.1] and [8.2.2] are not greater than the allowable stresses defined in Pt B, Ch 7, Sec 6, [5.1.4].

8.2.4 Alternatively, the transverse strength of the hopper well structure can be calculated considering the guidance provided in Ch 13, App 1.

9 Split hopper dredgers and split hopper units: superstructure hinges

9.1 General

9.1.1 For ships with one of the service notations **split hopper dredger** or **split hopper unit**, a check of the superstructure hinges according to [9.5] is to be carried out considering the forces defined in [9.4].

9.2 Arrangements

9.2.1 Chocks able to withstand the longitudinal forces induced by the superstructures are generally to be fitted on the deck located below the superstructures.

9.2.2 When the chocks are fitted on one side only, attention is to be paid to the longitudinal take over of forces by the hinges located on the side opposite to the chocks.

9.2.3 Chocks are to be able to work when the half-hulls swing apart to discharge the spoil.

9.2.4 Special attention is to be paid to the reinforcement below the deck in way of the hinges and chocks, as well as to the fixing of the hinge to the strength members of the superstructures.

The scantlings of these members are to be calculated considering the forces given in [9.4.3] applied at the level of the hinge pin.

9.2.5 Generally, no cut-out is to be fitted immediately near to hinges or chocks.

9.3 Materials used for the hinges

9.3.1 Grades of hull steel plates

In normal service conditions, the hull steel plates are to be of the grade defined in Tab 10.

Moreover, in low temperature service conditions, the choice of the steel grade is to be made with the Society on a case-by-case basis, according to the actual service conditions and to the design detail of the welded assembly.

Table 10 : Material grade requirements for superstructure hinges

Gross thickness, in mm	Normal strength steel	Higher strength steel
$t \leq 20$	A	AH
$20 < t \leq 25$	D	DH
$25 < t \leq 30$	E	DH
$t > 30$	E	EH

9.3.2 Grades of steel castings and steel forgings

The steel grade of the steel castings and steel forgings is to be defined according to the service temperature of the part and to the weld location on the part.

9.3.3 Grades of steel for hinge pins

The hinge pins are generally to be made of forged steel.

In addition to the rule checks defined in NR216 Materials and Welding, Chapter 5, a series of impact tests is to be carried out on three Charpy V test pieces and the minimum mean value of impact energy KVL is to be equal to or greater than 27 J at 0°C.

9.3.4 Inspections and tests of weld connections

For welds concerning the main members of the hinges, non-destructive examinations are to be carried out along the full length of the joint:

- for butt welds: 100% radiographic and ultrasonic examination
- for fillet welds with deep penetration: 100% ultrasonic examination and 100% magnetic particle inspection or penetrant fluid test
- for fillet welds with small penetration: 100% magnetic particle inspection or penetrant fluid tests.

9.4 Forces

9.4.1 The forces defined in [9.4.2] to [9.4.4] may be replaced by results from model tests or by representative calculations.

In such case, the method used and the assumed conditions for model tests or calculation are to be submitted to the Society for information.

9.4.2 The forces F_x, F_y and F_z , in kN, applied on superstructures in respectively x, y and z direction, are to be obtained as follows:

- for split hopper dredger/unit with a lenght $L < 65$ m:

  $F_x = 0$

  $F_y = F_T$

  $F_z = F_Z + F_V$

  with F_T, F_Z and F_V to be calculated from the formulae in NR600, Ch 6, Sec 1, [13.4.4], item c), with M, in t, to be taken as the mass of the superstructures.
- for split hopper dredger/unit with a lenght $L \geq 65$ m:

  F_x, F_y and F_z to be calculated from the applicable formulae of $F_{u\text{-}d}$, as defined in Pt B, Ch 5, Sec 6, [6.2.1] and Pt B, Ch 5, Sec 6, Tab 11 with m_u, in t, to be taken as the mass of the superstructures.

9.4.3 In the case of superstructures connected to the ship by means of two simple hinges and two hinges with connecting tie-rods (as shown in Fig 9 and Fig 10), the forces are to be obtained, in kN, from the following formulae:

- force in line with a tie-rod:

$$F = \frac{1}{\cos\beta}\left(\frac{1}{2} + \frac{\varepsilon_L}{d_L}\right)\left[\left(\frac{1}{2} - \frac{\varepsilon_T}{d_T}\right)F_Z + \frac{d_V}{d_T}F_Y\right]$$

- vertical force in a simple hinge:

$$F = \left(\frac{1}{2} + \frac{\varepsilon_L}{d_L}\right)\left[\left(\frac{1}{2} + \frac{\varepsilon_T}{d_T}\right)F_Z + \frac{d_V}{d_T}F_Y\right]$$

- transverse force in a hinge:

$$F = \left(\frac{1}{2} + \frac{\varepsilon_L}{d_L}\right)\left[\left(\frac{1}{2} - \frac{\varepsilon_T}{d_T}\right)F_Z \tan\beta + \left(1 - \frac{d_V}{d_T}\tan\beta\right)F_Y\right]$$

- longitudinal force for each chock:

$$F = \frac{F_X}{n_B}$$

where:

β : Angle of tie-rods with respect to the vertical line, in degrees

d_T : Transverse distance between a simple hinge and a tie-rod hinge, in m

d_V : Vertical distance from the centre of gravity of the superstructures to the horizontal plane passing through the hinge centreline, in m

d_L : Longitudinal distance between the fore and aft hinges, in m

ε_T : Transverse eccentricity of the centre of gravity of the superstructures (taken as positive if the centre of gravity is on the side of the simple hinges, and as negative otherwise), in m

ε_L : Longitudinal eccentricity of the centre of gravity of the superstructures (positive), in m

n_B : Number of longitudinal chocks.

Where a longitudinal chock is provided on one side only, the hinges are to be able to withstand the longitudinal force F_X.

The distribution of forces in the case of other arrangements is to be examined by the Society on a case-by-case basis.

Figure 9 : Connection between superstructure and ship - Transverse direction

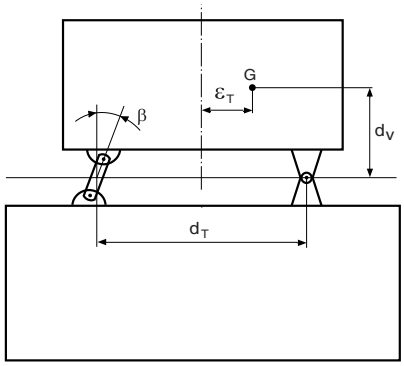
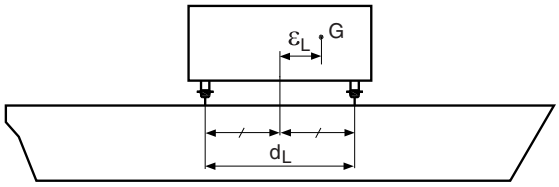


Figure 10 : Connection between superstructure and ship - Longitudinal direction



9.4.4 The force F to be considered for the check of the hinge scantlings is to be taken equal to:

- for a simple hinge:
  the resultant of the horizontal and vertical forces
- for a hinge with tie-rod:
  the force in the tie-rod centreline.

Moreover, the horizontal force in the hinges due to withstanding of the longitudinal force F_X in the case of a horizontal chock on one side only is to be considered alone.

9.5 Scantlings of the hinges

9.5.1 The hinges consist generally of two side straps and a centre eye connected by a pin, as shown in Fig 11.

The two main types of hinges are generally the following (see Tab 11):

- type I: welded assembly made of plates
- type II: welded assembly made of plates and of cast steel or forged steel parts.

The check of scantlings in [9.5.2] applies to the case of direct bearing of the pin on the side straps and the centre eye (see Fig 12) and to the case of load transfer by bearings (see Fig 13). In the second case, the designer is to demonstrate that the bearings can withstand the calculated forces.

Hinges whose manufacture is different from these two cases are to be examined by the Society on a case-by-case basis.

9.5.2 For the pins, centre eye and side straps of the hinges, the applied forces are to comply with the formulae given in Tab 12.

Figure 11 : Superstructure hinge arrangement

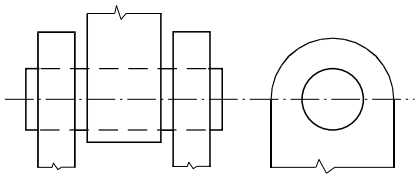


Table 11 : Type of hinges

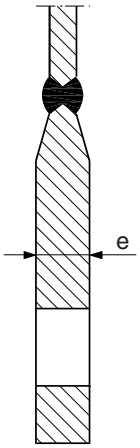
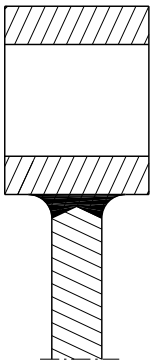
Type I superstructure hinges	Type II superstructure hinges
	

Figure 12 : Superstructure hinges: case of direct bearing

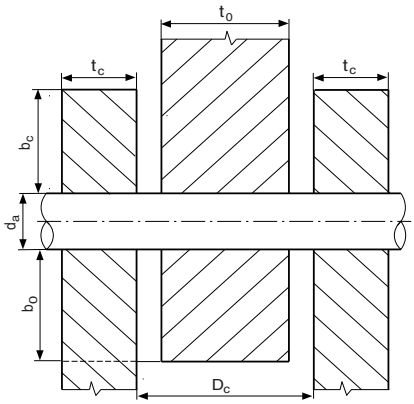


Figure 13 : Superstructure hinges: case of load transfer by bearings

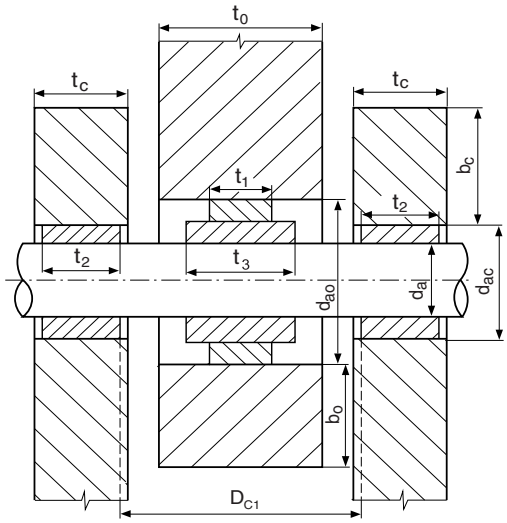


Table 12 : Scantling check of superstructures hinges

Case	Elements to be checked			
	Pins		Centre eye	Side straps
Direct bearing	$F < \frac{d_a^2 R_m}{5,76} 10^{-3}$ $F < \frac{2}{3} d_a t_0 R_{eH} 10^{-3}$	• if $t_0 < d_a$: $F < \frac{d_a^3}{2D_C - t_0} \frac{R_m}{5} 10^{-3}$ • if $t_0 \geq d_a$: $F < \frac{d_a^3}{2D_C - 2t_0 + d_a} \frac{R_m}{5} 10^{-3}$	$F < \frac{b_0 t_0 R_{eH}}{2,27} 10^{-3}$ $F < d_a t_0 R_{rad} 10^{-3}$	$F < \frac{b_C t_C R_{eH}}{1,14} 10^{-3}$ $F < 2 d_a t_C R_{rad} 10^{-3}$
Load transfer by bearings	$F < \frac{d_a^2 R_m}{5,76} 10^{-3}$ $F < \frac{2}{3} d_a t_3 R_{eH} 10^{-3}$	• if $t_3 < d_a$: $F < \frac{d_a^3}{2D_{C1} - t_3} \frac{R_m}{5} 10^{-3}$ • if $t_3 \geq d_a$: $F < \frac{d_a^3}{2D_{C1} - 2t_3 + d_a} \frac{R_m}{5} 10^{-3}$	$F < \frac{b_0 t_0 R_{eH}}{2,27} 10^{-3}$ $F < \frac{2}{3} d_{a0} t_1 R_{eH} 10^{-3}$	$F < \frac{b_C t_C R_{eH}}{1,14} 10^{-3}$ $F < \frac{4}{3} d_{aC} t_2 R_{eH} 10^{-3}$
Note 1: R_{rad} : Admissible radial pressure on the bearing, to be taken equal to 100 N/mm^2.				

10 Split hopper dredgers and split hopper units: decks hinges, hydraulic jack connections and chocks

10.1 General

10.1.1 For ships with one of the service notations **split hopper dredger** or **split hopper unit**, the scantlings of the deck hinges and the hydraulic jack attachments connecting the two half-hulls are to be determined according to [10.5] or by direct calculation.

The loads to be considered are the result of the most unfavourable combination of simultaneous static and dynamic forces (see [10.3] and [10.4]), calculated for the loading conditions in [3.2.1].

10.1.2 The locking devices of the two half-hulls, if any, are to be examined by the Society on a case-by-case basis.

10.2 Arrangements

10.2.1 Transverse chocks to be used upon closing the two half-hulls are to be provided in the bottom area, preferably in way of the hydraulic cylinders. These chocks may consist of heavy plates inserted in the bottom plating. They are to be arranged to come into contact before the end of the stroke of the jack, upon closing.

Moreover, if the calculation of the longitudinal strength is carried out assuming the hopper well ends are partly fixed, transverse chocks are to be provided at deck level.

10.2.2 Longitudinal chocks are to be provided at bottom and deck level, to prevent relative displacement of the two half-hulls.

Deck longitudinal chocks must also act in the open position.

For units of a capacity less than 700 m^3, longitudinal deck chocks need not be provided; in such case, one of the two deck hinges is to be designed to fulfil the function of a chock. The other hinge is then to have sufficient clearance.

10.3 Static forces

10.3.1 The method of calculation in [10.3.2] to [10.3.9] enables the determination of the static forces in the hydraulic jack, in the chocks and in the deck hinges only if the following conditions are met:

- the total number of hydraulic jacks connecting the two half-hulls is even
- there are no superposed jacks in the same section
- there is a deck hinge at each end of the hopper well.

Any other arrangement is to be examined by the Society on a case-by-case basis.

10.3.2 In the case of maximum loading corresponding to the dredging freeboard, the forces exerted on a half-hull to be considered to calculate the static forces in the hinges, transverse bottom chocks and jacks are shown in Fig 14 as well as their lever arm in relation to the deck hinge pins.

10.3.3 The horizontal static forces to be considered are the following:

- horizontal hydrostatic buoyancy F_h on the full length of the well, in kN. This force takes into account the hydrostatic buoyancy due to the water located between the two half-hulls below the sealing joint situated at the lower part of the hopper well, taken equal to:

  $F_h = 5{,}026\ (T_D - a)^2\ \ell_p$

- horizontal pressure of the spoil F_d, in kN, taken equal to:

  $F_d = 4{,}904\ \delta\ (h_{Di} - a)^2\ \ell_p$

- force F_{CY} in each jack, in kN, equal to the greater of F_{MC} and F_p
- force F_{CH} in each hinge, in kN, taken equal to:

$$F_{CH} = 0{,}5\left[F_h - F_d + n_1\left(1 - \frac{a_3}{a_4}\right)F_{CY} + \frac{M}{a_4}\right]$$

- force F_B in each bottom transverse chock, in kN, taken equal to:

$$F_B = \frac{n_1 a_3 F_{CY} - M}{n_2 a_4}$$

where:

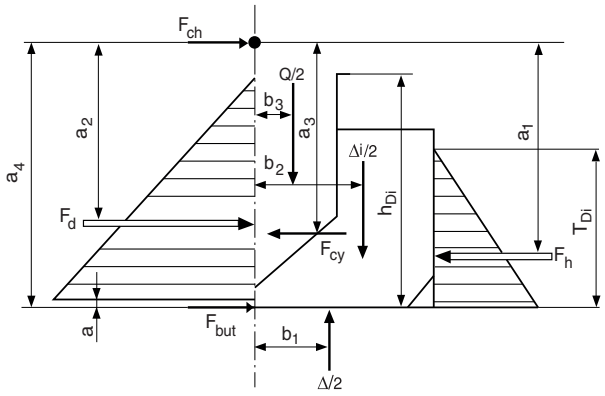
F_{MC} : Minimum force required to keep the dredger closed in the loading case considered, obtained from the following formula:

$F_{MC} = M / n_1\ a_3$

For a tendency to close, F_{MC} is negative and is not to be taken into account to determine F_{CY}

F_p : Force in the jack corresponding to a pressure on the rod side equal to the maximum pressure P_p of the pumps and of their pressure limiting device

Figure 14 : Forces exerted on a half-hull



M : Moment with respect to the hinge chocks, positive for a tendency to open, negative in the opposite case, taken equal to:

$$M = -F_h a_1 + F_d a_2 + \frac{1}{2}(\Delta b_1 - \Delta_1 \ell b_2 - Q b_3)$$

n_1 : Number of jacks

n_2 : Number of bottom transverse chocks

Δ, $\Delta_1\ell$, Q: Vertical forces, defined in [10.3.4]

a_1, a_2, a_3, a_4: Lever arms of horizontal forces, as shown in Fig 14

b_1, b_2, b_3: Lever arms of vertical forces, as shown in Fig 14.

10.3.4 The vertical static forces to be considered are the following:

- vertical hydrostatic buoyancy $\Delta/2$ on a half-hull, in kN
- weight $\Delta_1\ell$ / 2 of the half-hull without spoil, in kN
- weight Q / 2 of the half spoil loading, in kN

where:

Δ : Total displacement of the ship with spoil

$\Delta_1\ell$: Total displacement of the ship without spoil, including superstructures

Q : Total weight of the spoil in the well.

The following relation between vertical static forces is to be verified:

$\Delta = \Delta_1\ell + Q$

10.3.5 For every other loading case, the forces F_{CY}, F_{CH} and F_B are to be calculated according to [10.3.3], by replacing:

- a_1, a_2, b_1, b_2, b_3, Δ, $\Delta_1\ell$ and Q by the corresponding values for the loading case considered
- T_{Di}, δ_i and h_{Di} by values of external draught, density of water or spoils in the well and level inside the well for the loading case considered, i.e.:
  - in dredging condition, at the international freeboard: T_{IF}, δ and h_{IF}
  - in dredging condition, with the well filled up to the waterline: T_{WL}, 1,025 and h_{WL} taken equal to T_{WL}
  - in dredging condition, with well filled with water to the lowest weir level: T_{OL}, 1,025 and h_{OL}.

10.3.6 If, in the maximum loading condition corresponding to the dredging freeboard or the international freeboard, densities of spoil higher than δ may be considered with reduced heights (for constant mass of spoils), calculation of F_{CY}, F_{CH} and F_B is also to be carried according to [10.3.3], using the parameters corresponding to the maximum densities of spoil likely to be considered with draughts T_{Di} and T_{IF}.

10.3.7 The maximum static force F_S, actually developed by the jack, is the greatest of the values obtained for F_{CY} for the various loading cases and calculated according to [10.3.3], [10.3.5] and [10.3.6].

10.3.8 Where the hopper well ends are partly fixed, the end moments result in additional forces in the deck hinges, jacks, deck and bottom chocks, forward and aft of the well.

The distribution of these forces is to be determined by a direct calculation to be submitted to the Society for information.

10.3.9 The Designer is to give the value of the horizontal lever arm b_2 and the hull weight for the various loading cases as stated in [10.3.3]. In each case, the value to be taken into account is the most unfavourable one according to the distribution of the compartments, considering the tendency to open or to close.

However, the attention of the Owner and of the Designer is drawn to the fact that side tank ballasting can noticeably reduce the static forces necessary in the jacks to act against opening of the two half-hulls in the above operating conditions.

10.4 Dynamic forces

10.4.1 The Designer is to give the dynamic forces applied on the deck hinges and on the hydraulic jack attachments by means of a calculation to be submitted to the Society for information.

10.4.2 The dynamic forces are generally to be calculated by means of a long-term statistical analysis, under the conditions defined in Tab 13.

Table 13 : Probability for the determination of dynamic forces

Condition	Probability
Dredging and navigation with spoil, with sea state limited to $H_S = 3$ m **(1)**	10^{-5} for jacks and hinges
Navigation without spoil, without limitation on sea state **(2)**	10^{-7} for jacks 10^{-5} for hinges
(1) H_S : Significant wave height, in m. **(2)** In sailing condition without spoil, a different probability level may be adopted for the calculation of dynamic forces on the cylinders, subject to the Society's agreement, when a device intended to restore the pressure to the cylinders after opening of the safety valves is fitted (see also [11.3.1]). **Note 1:** The different calculation conditions are to be justified by the Designer.	

10.4.3 For each rule loading case, the results of the calculation are to give:

- the dynamic force F_{DCY} in each jack, in kN
- the horizontal dynamic force F_{DHC} in each hinge, in kN
- the vertical dynamic force F_{DVC} in each hinge, in kN.

10.4.4 If loading cases other than those defined in [3] are considered, calculations for such additional cases are to be defined in agreement with the Society on a case-by-case basis.

10.4.5 In the case of dredgers with a capacity of less than 700 m^3, the dynamic forces in the jacks and hinges may be taken into account without long-term statistical calculations. The calculations for jacks and hinges are to be justified to the Society.

10.4.6 For ships with one of the navigation notations **coastal area** or **sheltered area**, the dynamic forces in the cylinders and the hinges may be reduced by 10% in the case of navigation without spoil.

10.5 Scantlings

10.5.1 The maximum total force in the jack is to be taken equal to the greatest value, from all the loading cases foreseen, obtained, in kN, from the following formula:

$F_m = F_{CY} + F_{DCY}$

The jack is to be capable of developing a force at least equal to F_m, at the setting pressure of the safety valve of the jack considered as isolated.

10.5.2 The scantlings of the jack lugs are to comply with [9.5] considering the force F_m as determined in [10.5.1]. Cases where the force developed by the jack, at the setting pressure of the safety valve of the jack considered as isolated, is noticeably higher than F_m are to be examined by the Society on a case-by-case basis.

10.5.3 The scantlings of the deck hinges are to comply with [9.5], considering the resultant of the total horizontal force and the total vertical force, obtained, in kN, from the following formula:

$$F_{Res} = \sqrt{(F_{CH} + F_{DCH})^2 + F_{DVC}^2}$$

10.5.4 The scantling load of the transverse bottom chocks is to be defined in agreement with the Society.

10.5.5 The scantlings of the longitudinal bottom chocks provided for in [10.3.2] are to be determined considering for each chock the force obtained, in kN, from the following formula:

$$F = 0,15\frac{\Delta_m}{n_3}$$

where:

Δ_m : Maximum displacement of the ship, in kN, with the well loaded with spoil

n_3 : Total number of chocks (at deck and bottom).

The scantlings of the longitudinal deck chocks mentioned in [10.3.2] are to be determined considering for each chock the force obtained, in kN, from the following formula:

$$F = 0,15\frac{\Delta_n}{n_4}$$

where:

Δ_n : Displacement of the ship with the well filled with water up to the waterline

n_4 : Number of longitudinal deck chocks.

The permissible shear stress for bottom and deck chocks is to be obtained, in N/mm^2, from the following formula:

$$\tau = 0,9\frac{R_{eH}}{\sqrt{3}}$$

For the calculation of the shear stress in the deck chocks, a reduced sectional area corresponding to the efficient sectional area of the chocks when the well is open is to be considered.

10.5.6 The lugs of the jacks and the deck hinges may be calculated using a finite element model.

In such case, the finite element model and the applied loadings are to be preliminarily agreed upon by the Society.

The permissible stress is to be defined in agreement with the Society, depending on the finite element model and on the characteristics of the materials.

11 Split hopper dredgers and split hopper units: hydraulic jacks and associated piping systems

11.1 General

11.1.1 For ships with one of the service notations **split hopper dredger** or **split hopper unit**, the check of hydraulic jacks and associated piping systems intended for closing the two half-hulls of the ship is to be carried out according to [11.1] to [11.6].

11.1.2 Hydraulic jack design and construction are to be in accordance with the applicable requirements of Pt C, Ch 1, Sec 14, [2], while associated piping systems are generally to fulfil the relevant requirements of Pt C, Ch 1, Sec 10.

Materials used are to be in accordance with the applicable requirements of NR216 Materials and Welding.

11.2 Definitions

11.2.1 For the checking of hydraulic jacks and associated piping systems, the following definitions are to be considered:

P_m : Pressure on the rod side of the jack resulting from the extreme foreseen ambient conditions corresponding to the maximum force F_m, defined in [10.5.1]

P_C : Maximum pressure on the bottom side of the cylinder equal to the setting value of the safety valves protecting the bottom side of the cylinder

P_P : Maximum pressure which can be delivered through the pumps and their associated pressure limiting devices

P_S : Pressure on the rod side of the jack corresponding to the greatest of forces F_S, defined in [10.3.7], and F_P, defined in [10.3.3].

11.3 Arrangements

11.3.1 When large ships are concerned, the following arrangements are generally to be provided:

- for each hydraulic jack, a measuring system of the pressure in the cylinder is to be supplied
- this system, in addition to the indication of the pressure at the bridge and at the dredging room, is to comprise a visual and audible alarm at the same locations, to be activated when a certain limit is exceeded
- the measuring system, the alarm activating limit as well as the instructions to be followed after the alarm occurs are to be submitted to the Society for approval.

11.3.2 Special attention is to be paid to protection against corrosion.

11.4 Scantling of jacks

11.4.1 For the pressure parts of hydraulic jacks made of steel, the permissible stress related to the loading conditions resulting in pressure P_P or P_S (whichever is the greater) acting on the cylinder rod side without pressure on the other side is to be taken as the smaller of R_{eH} / 1,8 and R_m / 2,7.

The allowable stress applicable to the cylindrical envelope, for the loading conditions resulting in pressure P_m , may be taken as the smaller of R_{eH} / 1,5 and R_m / 2,25.

11.4.2 The scantlings of the jack end cover on the rod side are to be determined using P_m as design pressure.

The scantlings of the jack end cover on the bottom side as well as the mechanical connections (for example the bolts between the cover and the cylinder or between the piston and the rod) are to be based on F_m.

The calculations justifying the proposed scantlings and, as the case may be, the pre-stresses are to be submitted to the Society for information.

11.4.3 The scantlings of the rod are to be based on F_m and on the smaller value of R_{eH} / 2 and R_m / 2,4, for the mean permissible stress in traction. A calculation proving the adequate buckling strength of the rod is to be submitted to the Society for information.

11.4.4 The scantlings of the lugs and the pins at each end of the hydraulic cylinder are to be based on F_m.

11.5 Inspection and testing

11.5.1 In addition to inspections required in [11.1.2], where applicable, welded joints connecting parts subject to the load F_m are to fulfil the requirements for class I pressure vessels or equivalent.

11.5.2 Completed cylinders and attached piping up to and including the first isolating valve are to undergo, at works, a pressure test at the greater of the values 1,4 P_S and 1,2 P_m applied on the rod side and a pressure test at 1,4 P_C on the bottom side for the fully extended position.

11.5.3 The completed hydraulic circuit is to be subjected, on board, to pressure tests at 1,4 times the relevant maximum service pressure for normal conditions or static loads, for the part of the circuit considered.

11.6 Relief valve setting

11.6.1 At least one relief valve of appropriate capacity is to protect each part of the circuit which may be subject to overpressure due to external loads or due to pump action; in general, relief valves on the rod side of each cylinder or group of cylinders are to be set at P_m, while P_C applies to the bottom side for relief valve setting purposes.

Parts of the circuit possibly subject to overpressure from pumps only are to be protected by relief valves set at pressure P_P.

12 Rudders

12.1 General

12.1.1 The rudder stock diameter obtained from Pt B, Ch 12, Sec 1, [4] is to be increased by 5%.

12.2 Additional requirements for split hopper dredgers and split hopper units

12.2.1 Each half-hull of ships with one of the service notations **split hopper unit** or **split hopper dredger** is to be fitted with a rudder complying with the requirements of Pt B, Ch 12, Sec 1.

12.2.2 An automatic system for synchronising the movement of both rudders is to be fitted.

13 Equipment

13.1 General

13.1.1 The requirements of this Article apply to ships having normal ship shape of the underwater part of the hull.

For ships having unusual ship shape of the underwater part of the hull, the equipment is to be considered by the Society on a case-by-case basis.

13.1.2 The equipment is to be determined according to Pt B, Ch 12, Sec 4, [1], taking into account [13.1.3]. When calculating EN, bucket ladders and gantries may be excluded.

13.1.3 The equipment determined according to [13.1.2]] is independent from anchors, chain cables and ropes which may be needed for dredging operations.

13.1.4 For non-propelled vessels the requirements of Ch 14, Sec 2, [6] apply.

13.2 Additional requirements for split hopper dredgers and split hopper units

13.2.1 Arrangements of ships with one of the service notations **split hopper dredger** or **split hopper unit** are to be in accordance with [13.2.2] to [13.2.6].

13.2.2 For the calculation of equipment number, the displacement is to consider:

- draugth in navigation condition
- cylinder housings
- free space between the two half hulls.

13.2.3 One chain locker and one complete mooring chain cable are generally to be provided for each half-hull.

13.2.4 If the mass of the anchor permits, only one windlass needs to be provided on either of the half-hulls. In this case, in addition to the requirements in Pt B, Ch 12, Sec 4, [2], a chain stopper is to be fitted on the half-hull which is not equipped with a windlass.

13.2.5 Fairleads or rollers are to be located in suitable places between the windlass and the hawse pipe so that the dropping and the housing of the anchor are satisfactorily ensured.

13.2.6 Arrangements are to be made to avoid jamming of the cable during the opening and closing operations of the two half-hulls.

Section 3 Machinery and Dredging Systems

1 General

1.1 Application

1.1.1 This Section provides requirements for ships having the service notation **dredger**, **hopper dredger**, **hopper unit**, **split hopper unit** and **split hopper dredger**. These requirements are only applicable at the request of an Owner.

1.1.2 This Section does not cover the other aspects of the system and equipment design, in particular in respect of their performance.

1.1.3 The requirements for bottom doors and valves fitted on ships having the notation **hopper dredger**, **hopper unit**, **split hopper unit** and **split hopper dredger** are given in Ch 13, Sec 2.

2 Dredging system

2.1 Attachment of dredging equipment to the hull

2.1.1 The scantlings of the structure for attachment of the equipment intended for dredging operations (e.g. connection of the suction pipe to the hull, foundation of the suction pipe davits) are to be based on the service load of such equipment, as specified by the Designer.

In determining the above service load, the Designer is to take account of additional loads imposed by ship movements (in particular pitch and heave) in the most unfavourable sea and weather conditions expected during service.

3 Steering gear of split hopper dredgers and split hopper units

3.1 General

3.1.1 The rudder fitted to each half-hull of ships having the service notations **split hopper dredger** or **split hopper unit** (see Ch 13, Sec 2, [12.2.1]) is to be served by its own steering gear.

3.2 Design of the steering gear

3.2.1 The steering gear referred to in [3.1.1] is to consist of a control system and a power actuating system capable to operate the relevant rudder as required in Pt C, Ch 1, Sec 14, [2.2.1] or Ch 15, Sec 4, [24.3.1], as appropriate.

3.2.2 An auxiliary steering gear or a duplicated power actuating system need not be fitted.

3.3 Synchronisation

3.3.1 An automatic system for synchronising the movement of both rudders is to be fitted. It is to comply with the provisions of Pt C, Ch 1, Sec 14, [3.2.2].

4 Testing of dredging equipment

4.1 On board testing

4.1.1 Ship trials

a) Upon completion of construction, in addition to the conventional sea trials required in Pt C, Ch 1, Sec 18, specific tests may be required at the Society's discretion in relation to the particular service for which the ship is intended or the specific characteristics of machinery and equipment fitted on board.

b) In particular, as regards propulsion and steering systems, tests may be required to check the manoeuvring capability and the speed of the ship whilst operating.

4.1.2 Equipment trials

As far as the dredging system is concerned, tests are to be carried out to verify the proper operation of all relevant equipment in different sea and weather conditions, according to a specification submitted by the interested party.

Appendix 1 Guidance on Calculation of Transverse Strength Hopper Well Structure

1 Hopper dredgers and hopper units: checking of hopper well structure

1.1 General

1.1.1 The requirements in Articles [1] to [5] apply to ships with one of the service notations **hopper dredger** or **hopper unit**.

2 Floors

2.1 General

2.1.1 The scantlings of floors of ships with open wells fitted with bottom doors are to be obtained from a direct calculation, according to Pt B, Ch 7, Sec 6 or NR600, Ch 4, Sec 5, [1.2] as applicable, taking into account the following assumptions:

- the span is equal to half the sum of the upper face plate length and the distance between lower ends of the hopper well sloped bulkheads
- the floors have fixed ends
- the floors are subject to the uniform and concentrated loads detailed in [2.3]
- the central box (cellular keel) is supported by the floors

  However, where this box has sufficient dimensions and scantlings to support a part of the loads, this may be taken into account if a relevant calculation of grid type is submitted to the Society for information.
- in addition to the loads laid down in [2.3], the floor may support differential loads, for example when all the valves are not simultaneously opened, or compression loads when the well is empty
- the web cut-out section is deducted for the calculations of shear stresses and normal stresses (tension or compression)
- for the calculation of normal stresses and bending stresses, the face plate cross-section is taken into account only if these face plates are correctly offset on the adjacent structure

2.2 Different types of bottom and valves used

2.2.1 The different types of bottom doors and valves generally used, as well as the relevant symbols, are defined in Tab 1.

2.3 Load borne by floors

2.3.1 The loads borne by floors are a combination, according to the type of bottom doors, of the elementary loads [a], [b], [c], [d], [e] and [f], obtained, in kN, from the following formulae:

[a] : Uniform load of spoils, to be taken equal to:

$$Q_1 = g\,\delta\,(D + h_D)\,S_a\,\ell$$

[b] : External hydrostatic pressure, to be taken equal to:

$$Q_2 = g\,(T_D - 0{,}5\,h_0)\,S_a\,\ell$$

In the course of calculations, P_r is the reduced pressure, evenly distributed, to be taken equal to:

$$P_r = \delta\,(D + h_D) - (T_D - 0{,}5\,h_0)$$

The resultant load is to be taken equal to:

$$Q = Q_1 - Q_2 = g\,P_r\,S_a\,\ell$$

[c] : Load acting directly on a valve (to be deducted), to be taken equal to:

$$q = g\,P_r\,A_{bd}$$

This load is assumed to be evenly distributed along the length c_1. It is to be cut off from the load Q.

In the case of type 5 bottom doors (see Tab 1), q = 0

[d] : Reactions R_2 of the bottom doors on the floor (to be added), the absolute values and abscissae of which are indicated in Tab 2

Reactions R_1 on the rods of the hydraulic jacks of bottom doors type 1, type 2 and type 3 (see Tab 1) are given in Tab 2 for further calculations but they are not borne by the floors

[e] : Axial force due to the lack of spoils in the volume occupied by the cellular keel (to be deducted), to be taken equal to:

$$F_1 = g\,\delta\,S_a\,A$$

[f] : Axial force due to a possible transmission of the resultant reaction R_1 to the cellular keel, through a strong beam, an axial pillar or inclined pillars, to be taken equal to:

- with one axial pillar:

$$F_2 = 4\frac{vR_1}{\ell_0}$$

- with two inclined pillars:

$F_2 = 2\ R_1$

For determination of the scantlings of strong beams, girders and pillars, R_1 is to be replaced by F_M, in kN, when calculating F_2, if F_M is higher than R_1, F_M being the maximum force induced by the bottom door hydraulic jack.

where:

h_D : Distance, in m, from the highest weir level, corresponding to the draught T_D, to the deck-line (h_D is to be counted negatively where the level is located below the deck-line at side)

S_a : Transverse primary supporting ring spacing, in m

ℓ : Stiffener span, in m

In the case of floors, the span is equal to half the sum of the length of the upper flange plate and the distance between the lower ends of the sloping sides of the hopper space.

h_0 : Ship relative motion, in m, taken equal to h_W as defined in Pt B, Ch 5, Sec 5 or to h_1, as defined in NR600, Ch 3, Sec 3, as applicable

A_{bd} : Whole sectional area, in m^2, of the bottom door whatever its type may be

A : Area, in m^2, enclosed by the contour of the cellular keel

v : Distance, in m, from the hydraulic jack centreline to the end of the strong beam span

ℓ_0 : Span, in m, of the strong beam bearing the reactions of the hydraulic jacks

2.4 Shear force diagrams

2.4.1 The shear force diagrams corresponding to each elementary load defined in [2.3] are given in Tab 3.

The total shear force, at abscissa X, equal to the algebraical sum of the elementary shear forces corresponding to each type of bottom doors, is indicated in Tab 4.

Table 1 : Types of bottom doors and valves

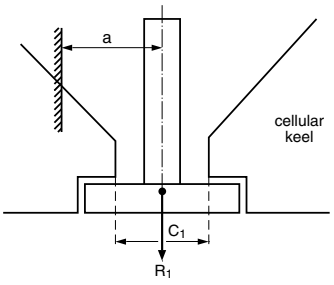
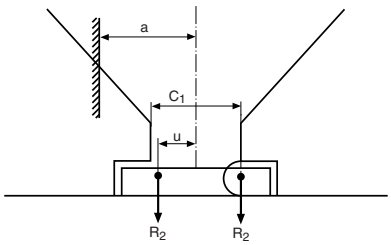
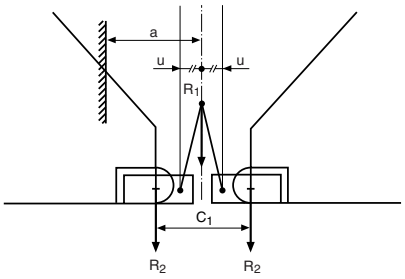
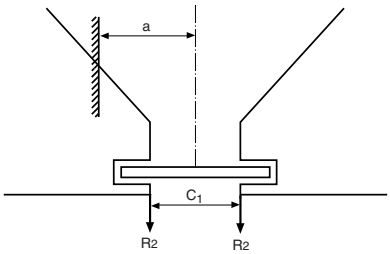
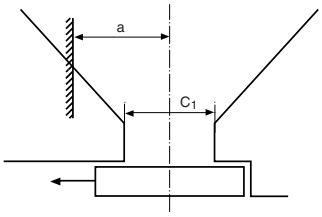
Type 1 Bottom valve, centrally operated by a vertical shaft 	**Type 2** Single bottom door, with hinges at one side (either cellular keel side or lower wing tank side) and operated by a vertical shaft at the other side 	**Type 3** Double bottom doors, with hinges at both sides and operated by one central vertical shaft connected to the doors by means of two rods 
Type 4 Longitudinal sliding bottom doors 	**Type 5** Transverse sliding bottom doors, guides being supported by floors 	

Table 2 : Reactions R_1 and R_2 for elementary load [d]

Bottom door type (see Tab 1)	Reactions R_2			Reactions R_1
	No.	Value, in kN	Abscissae	Value, in kN
Type 1		0		$g\ A_{bd}\ P_r$
Type 2	1	$gA_{bd}P_r\left(\frac{2u}{c_1+2u}\right)$	$(a + 0,5\ c_1)$ or $(a - 0,5\ c_1)$	$gA_{bd}P_r\left(\frac{c_1}{c_1+2u}\right)$
Type 3	2	$0,25gA_{bd}P_r\left(\frac{c_1-4u}{c_1-2u}\right)$	$(a + 0,5\ c_1)$ and $(a - 0,5\ c_1)$	$0,5gA_{bd}P_r\left(\frac{c_1}{c_1-2u}\right)$
Type 4	2	$0,5\ g\ A_{bd}\ P_r$	$(a + 0,5\ c_1)$ and $(a - 0,5\ c_1)$	0
Type 5		0		0

Note 1:

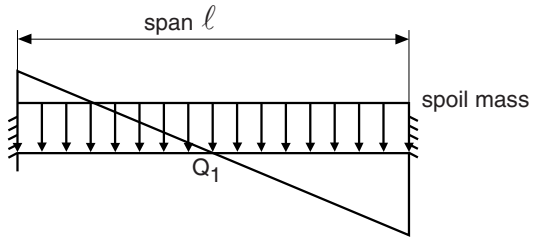
a : Distance, in m, from either end of the floor span to the centreline of the bottom door closest to that end

c_1 : Width of a bottom door, in m

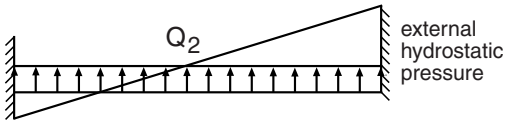
u : Distance, in m, from the fixing point of the hydraulic jack rod (or of the two rod hydraulic jack) to the centreline of the bottom door.

Table 3 : Shear force diagram

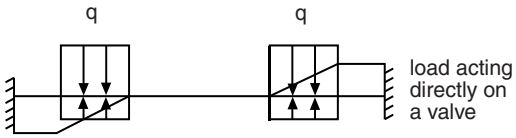
Elementary load [a] - Load Q_1



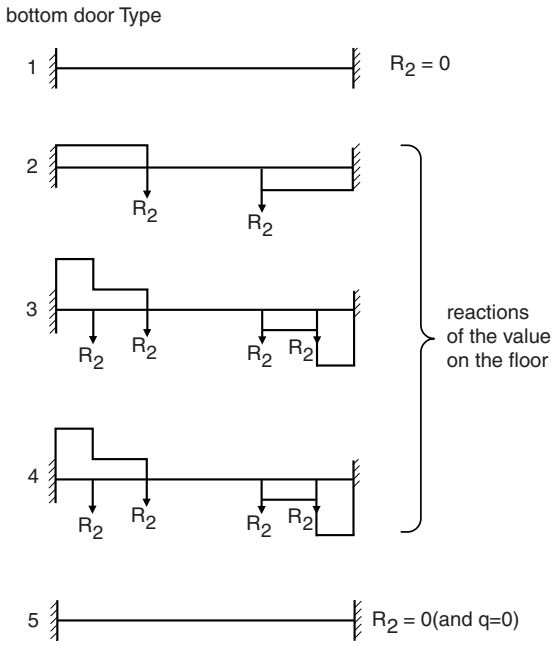
Elementary load [b] - Load Q_2



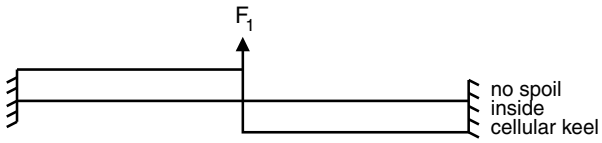
Elementary load [c] - Load q



Elementary load [d] - Reactions R_2



Elementary load [e] - Force F_1



Elementary load [f] - Force F_2

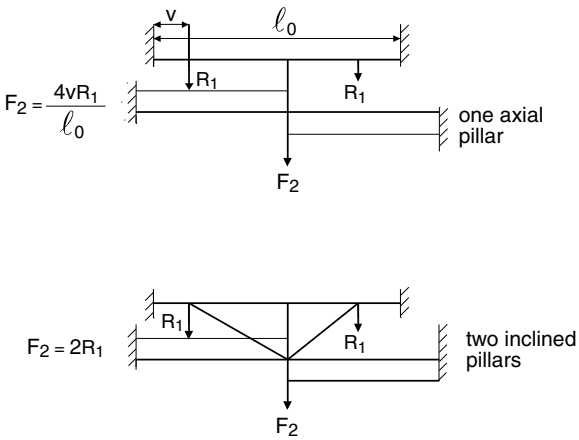


Table 4 : Shear force values

Bottom door type (see Tab 1)	Total shear force T(x) at abscissa X, in kN
Type 1	T_0
Type 2	$T_0 + R_2$
Type 3	$T_0 + 2\ R_2$
Type 4	$T_0 + 2\ R_2$
Type 5	$T_0 + q - 0,5\ F_2$

Note 1:

X : Distance, in m, from the cross-section under consideration to the end of the floor span

T_0 : Total shear force, in kN, at the left end of the span, to be taken equal to:

$$T_0 = \frac{1}{2}(Q_1 - Q_2 - 2q - F_1 + F_2)$$

2.5 Bending moments for each elementary load

2.5.1 The bending moments for each elementary load defined in [2.3] are given in Tab 5, at span ends and at mid-span.

2.6 Resultant bending moment

2.6.1 The resultant bending moment is the sum of the elementary moments for each type of valve.

The total moment value at abscissa X is determined by deducting algebraically from the total moment value at the span ends the value of the area bounded by the total shear force curve.

2.7 Normal load

2.7.1 The normal load is to be obtained, in kN, from the following formula:

$F_N = F_{N1} - F_{N2}$

where:

$$F_{N1} = \frac{3,3\,S_a\,\delta}{2D - h_V}(D + h_D)^2(2D - h_D)$$

$$F_{N2} = \frac{3,3\,S_a}{2D - h_V}(T_D - 0,5h_0)^2(3D - T_D + 0,5h_0)$$

h_V : Mean floor depth, in m.

Table 5 : Values of bending moments

Elementary load / Bottom valve type		Bending moment, in kN.m, at span ends	Bending moment, in kN.m, at mid-span
[a]		$-\frac{Q_1\ell}{12}$	$\frac{Q_1\ell}{24}$
[b]		$\frac{Q_2\ell}{12}$	$-\frac{Q_2\ell}{24}$
[c]		$\frac{qa(\ell - a)}{\ell}$	$-\frac{qa^2}{\ell}$
[d]	Type 1 or Type 5	0	0
	Type 2	$-R_2\frac{(2a + c_1)(2\ell - 2a - c_1)}{4\ell}$ **(1)**	$R_2\frac{(2a + c_1)^2}{4\ell}$
	Type 3 or Type 4	$-R_2\left[\frac{4a(\ell - a) - c_1^2}{2\ell}\right]$	$R_2\left[\frac{4a^2 + c_1^2}{2\ell}\right]$
[e]		$\frac{F_1\ell}{8}$	$-\frac{F_1\ell}{8}$
[f]		$-\frac{F_2\ell}{8}$	$\frac{F_2\ell}{8}$

(1) Formula valid for a hinge on cellular keel. In the case of a hinge on lateral wing tank, replace $(2\ a + c_1)$ with $(2\ a - c_1)$

2.8 Differential opening valves

2.8.1 In the case of a differential opening of the valves, the stresses induced by the bending moments and the shear forces are determined as follows:

- the upper flange is assumed to be simply supported at ends; its span ℓ_S is measured between the longitudinal bulkhead and the cellular keel
- the lower flange is assumed to have fixed ends and its span is taken equal to c_1
- the transverse section moduli of the flanges are determined with respect to a vertical axis located in the plane of the floor web
- for the upper flange, the transverse bending moment at mid-span is obtained, in kN.m, from the following formula:

$$M_S = 0{,}05\delta h_V^2[3\ell_S^2 - (\ell_S - c_1)^2]$$

- for the upper flange, the maximum shear force at ends of span ℓ_S is obtained, in kN.m, from the following formula:

$$T_S = 0{,}3\delta h_V^2(\ell_S + c_1)$$

- for the lower flange, the maximum bending moment and shear force at span ends are obtained, in kN.m, from the following formulae:

$$M_i = 1{,}33\left(\frac{c_1}{\ell_S}\right)^2 M_S$$

$$T_i = 2\left(\frac{c_1}{\ell_S}\right) T_S$$

2.9 Buckling of upper flange

2.9.1 When the ship is to navigate with empty hopper space(s), the buckling of the upper flange is to be checked, using the formulae given in [3] for strong beams and assuming that:

$$F_R = \frac{-3{,}3S_a}{2D - h_V}(T_2 + 0{,}5h_0)^2(3D - T_2 - 0{,}5h_0)\frac{A_S}{A_V}$$

where:

T_2 : Maximum draught for navigation with empty hopper space(s), in m

A_S : Sectional area, in cm², of the upper flange

A_V : Sectional area, in cm², of the floor, cut-outs in web deducted

3 Strong beams at deck level

3.1 Forces acting on strong beams

3.1.1 Where strong beams are fitted at deck level, the forces acting on them are to be obtained, in kN, from the following formulae:

- tension force due to the spoil pressure onto the longitudinal bulkheads of the well:

$$F_T = \frac{1{,}6\delta s(D + h_D)^2}{2D - h_V}[2(D + h_D) - 3h_V]$$

- compression force due to the external hydrostatic pressure:

$$F_{C1} = \frac{1{,}6s(T_D - 0{,}5h_0)^2}{2D - h_V}(2T_D - h_0 - 3h_V)$$

- compression force due to moment at floor ends:

$$F_{C2} = \frac{2M(0)}{2D - h_V}$$

- compression force due to floor reaction at span ends:

$$F_{C3} = \frac{d_1 + 2b_1}{2D - h_V}T(0)$$

where:

s : Spacing of strong beams, in m

d_1 : Distance, in m, from the side plating to the longitudinal bulkhead of the hopper well

b_1 : Distance, in m, between the fixed end of the floor and the hopper well longitudinal bulkhead or its extension

M(0), T(0): Total bending moment and shear force at fixed ends, determined, respectively, according to [2.5] and [2.4], for X = 0.

For strong beams with a large web depth, the upper flange of which is located at deck level, the term D may be replaced by (D – 0,5 h_{WS}), where h_{WS} is the web depth, in m, of strong beams.

The resultant of the forces is to be obtained, in kN, from the following formula:

$F_R = F_T - F_{C1} - F_{C2} - F_{C3}$

F_R is a tension load when positive, a compression load when negative.

3.2 Sectional area of strong beams

3.2.1 The sectional area of strong beams, after deduction of possible cut-outs, is to be obtained, in cm², from Tab 6.

Table 6 : Sectional area of strong beams

Condition		Sectional area A_T, in cm²
$F_R \geq 0$		$0,08\ F_R$
$F_R < 0$	when $\ell_F / r \leq 1,15$	$\left[0,085 + 0,064\left(\frac{\ell_F}{r}\right)^2\right] F_R$
	when $\ell_F / r > 1,15$	$0,1\left(\frac{\ell_F}{r}\right)^2 F_R$

Note 1:

ℓ_F : Buckling length, in m, of the strong beam considered as fixed at ends, to be taken equal to $0,5\ell_0$

r : Minimum gyration radius, in cm, to be taken equal to:

$$r = \sqrt{\frac{I}{A_T}}$$

I : Moment of inertia, in cm⁴, equal to the minimum of I_{XX} and I_{YY}

I_{XX} : Moment of inertia, in cm⁴, with respect to the axis perpendicular to the plane of the web

I_{YY} : Moment of inertia, in cm⁴, with respect to the axis parallel to the plane of the web.

4 Brackets for trunks

4.1 General

4.1.1 Brackets for trunks are to be provided in way of the strengthened transverse rings. They are to be securely fixed at their lower ends.

4.1.2 In order to check the stresses according to [4.1.3], the value of the bending moment at the lower end, in kN.m, and the value of the corresponding shear stress, in kN, may be obtained, respectively, from the following formulae:

$M_P = 1,64\ \delta\ s\ h_T^3$

$T_P = 4,9\ \delta\ s\ h_T^2$

where:

h_T : Height, in m, of the trunk above the deck-line.

4.1.3 It is to be checked that the normal stress, in N/mm², and the shear stress are, respectively, in compliance with the following formulae:

$\sigma \leq 0,65\ R_Y$

$\tau \leq 0,45\ R_Y$

5 Girders supporting the hydraulic cylinder in the hopper spaces (bottom door types 1, 2 and 3)

5.1

5.1.1 In order to check the stresses according to [5.1.2], the local bending stress due to the cylinder reaction and the corresponding shear stress, in N/mm², may be obtained, respectively, from the following formulae:

$$\sigma_{LX} = \frac{125 F \ell}{w}$$

$$\tau_{XY} = \frac{5F}{A_a}$$

where:

F : Maximum value, in kN, of R_1 and F_M defined in [2.3]

w : Girder web modulus, in cm^3

A_a : Girder web sectional area, in cm^2, possible cut-outs deducted.

5.1.2 It is to be checked that the normal stress, in N/mm^2, and the shear stress are, respectively, in compliance with the following formulae:

$\sigma \leq 0,65\ R_Y$

$\tau \leq 0,45\ R_Y$

Part D
Service Notations

CHAPTER 14
NON-PROPELLED UNITS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery Systems

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of one of the following notations applicable to no propulsion units, as defined in Pt A, Ch 1, Sec 2, [4.14]:

- service notations:
  - **barge**
  - **pontoon**
  - **pontoon-crane**
- additional service feature:
  - **no propulsion**

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.3 For ships dealt with in this Chapter and intended to carry only one type of cargo, the Society reserves the right to establish requirements and/or conditions additional to those contained in these Rules.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B	• NR566
	L < 65 or 90 m **(1)**	• NR600	• NR566
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 14, Sec 2	• Part B • Ch 14, Sec 2
	L < 65 or 90 m **(1)**	• NR600	• NR600
Stability		• Part B • Ch 14, Sec 2	• NR566 • Ch 14, Sec 2
Machinery and cargo systems		• Part C • Ch 14, Sec 3	• NR566 • Ch 14, Sec 3
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Hull and Stability

1 General

1.1 Application

1.1.1 General

Unless otherwise specified, the requirements of this Section apply to ships with one of the service notations **barge**, **pontoon** and **pontoon - crane**.

Specific requirements which apply only to ships with the service notation **barge** or ships with the service notation **pontoon** or **pontoon- crane** are indicated.

Barges with the additional service feature **tug combined** are also to comply with the applicable additional requirements in Pt E, Ch 1, Sec 4

1.1.2 Main characteristics of non-propelled units

The requirements of this Section are based on the following assumptions, relevant to the main characteristics of non-propelled units:

- the structural configuration and proportions of non-propelled units are similar to those of propelled ships
- the cargo is homogeneously distributed.

The scantlings of non-propelled units with unusual shapes and proportions or carrying cargoes which are not homogeneously distributed, such as containers or heavy loads concentrated in limited areas, are to be considered by the Society on a case-by-case basis, taking into account the results of direct calculations, to be carried out according to Pt B, Ch 8, Sec 1.

1.2 Additional class notations for lifting appliances of ships with service notation pontoon - crane

1.2.1 For ships with service notation **pontoon - crane**, one of the following additional class notations, defined in Pt A, Ch 1, Sec 2, [6.12], is generally to be granted:

- **ALP** or **(ALP)** for lifting appliances intended to be used in harbours or similary sheltered areas
- **ALM** or **(ALM)** for lifting appliances intended to be used in offshore conditions.

Note 1: when the lifting appliance is provided to be used essentially in harbour conditions or similarly sheltered areas and exceptionally in offshore conditions, the additional class notation **ALP** or **(ALP)** is generally assigned. For the exceptional using in offshore conditions, the lifting capacity is reduced to a value in accordance with the considered sea conditions.

2 Stability

2.1 Intact stability for ships with service notation pontoon or pontoon - crane

2.1.1 Application

The requirements of this item apply to seagoing ships with one of the service notations **pontoon** and **pontoon - crane** with the following characteristics:

- *unmanned*
- *having a block coefficient not less than 0,9*
- *having a breadth/depth ratio greater than 3,0*
- *having no hatchways in the deck except small manholes closed with gasketed covers.*

2.1.2 Trim and stability booklet

In addition to the information to be included in the trim and stability booklet specified in Pt B, Ch 3, App 2, [1.1], simplified stability guidance, such as a loading diagram, is to be submitted to the Society for approval, so that pontoons *may be loaded in compliance with the stability criteria.*

2.1.3 Stability calculations

Stability calculations may be carried out according to the following criteria:

- *no account is to be taken of the buoyancy of deck cargo (except buoyancy credit for adequately secured timber)*
- *consideration is to be given to such factors as water absorption (e.g. timber), trapped water in cargo (e.g. pipes) and ice accretion*

- *in carrying out wind heel calculations:*
  - *the wind pressure is to be constant and for general operations considered to act on a solid mass extending over the length of the cargo deck and to an assumed height above the deck*
  - *the centre of gravity of the cargo is to be assumed at a point mid-height of the cargo*
  - *the wind lever arm is to be taken from the centre of the deck cargo to a point at one half the draught*
- *calculations are to be carried out covering the full range of operating draughts*
- *the downflooding angle is to be taken as the angle at which an opening through which progressive flooding may take place is immersed. This would not be an opening closed by a watertight manhole cover or a vent fitted with an automatic closure.*

2.1.4 Intact stability criteria

The following intact stability criteria are to be complied with, for the loading conditions specified in Pt B, Ch 3, App 2, [1.2.1] and Pt B, Ch 3, App 2, [1.2.2]:

- *the area under the righting lever curve up to the angle of maximum righting lever is to be not less than 0,08 m·rad*
- *the static angle of heel due to a uniformly distributed wind load of 0,54 kPa (wind speed 30 m/s) may not exceed a heeling angle corresponding to half the freeboard for the relevant loading condition, where the lever of wind heeling moment is measured from the centroid of the windage area to half the draught*
- *the minimum range of stability is to be:*
  - *20°* *for L < 100 m*
  - *20° – 0,1° (L – 100)* *for 100 ≤ L ≤ 150 m*
  - *15°* *for L > 150 m.*

2.2 Additional intact stability criteria for ships with service notation pontoon - crane

2.2.1 Ships assigned with the service notation **pontoon-crane** are to comply with the stability criteria during lifting operations specified in Pt E, Ch 8, Sec 3, in addition to those in [2.1].

3 Structure design principles

3.1 Hull structure

3.1.1 Framing of ships with one of the service notations pontoon and pontoon - crane

In general, ships with one of the service notations **pontoon** and **pontoon - crane** are to be longitudinally framed.

3.1.2 Supports for docked non-propelled units

Adequate supports are to be fitted on the longitudinal centreline in order to carry loads acting on the structure when the non-propelled units are in dry dock.

3.1.3 Truss arrangement supporting deck loads

Where truss arrangements are used as supports of the deck loads, including top and bottom girders in association with pillars and diagonal bracing, the diagonal members are generally to have angles of inclination with the horizontal of about 45° and cross-sectional area of about 50% that of the adjacent pillars.

Where pillar arrangements are used without diagonal bracing, the scantlings of primary members can generally not be determined by means of isolated beam structural models.

3.2 Lifting appliances

3.2.1 Crane or derrick position during navigation

For ships with the service notation **pontoon - crane**, it is to be possible to lower the crane boom or the derrick structure and to secure them to the pontoon during the voyage.

4 Hull girder strength

4.1 Yielding check

4.1.1 Non-propelled units lifted by crane

For non-propelled units intended to be lifted on board ship by crane, the hull girder strength is to be checked, in the condition of fully-loaded barge lifted by crane, through criteria to be agreed with the Society on a case-by-case basis.

In general, the equivalent Von Mises stress σ_{eq} in the hull girder when lifted by crane are to comply with the criteria defined in Pt B, Ch 6, Sec 1, [3.5] for harbour/sheltered operations.

4.1.2 Ships with service notation pontoon carrying special cargoes

For ships with the service notation **pontoon** intended for the carriage of special cargoes, such as parts of offshore units, the hull girder strength is to be checked through criteria to be agreed with the Society on a case-by-case basis.

Moreover, where these ships are fitted with arrangements for launching the above special cargoes, additional calculations are to be carried out in order to evaluate the stresses during the various stages of launching. The Society may accept stresses higher than those in [4.1.1], to be considered on a case-by-case basis, taking into account favourable sea and weather conditions during launching.

4.1.3 Ships with service notation pontoon - crane

For ships with the service notation **pontoon - crane** having length greater than 65 m, the hull girder strength is to be checked when the lifting appliance is operated, in accordance with the requirements of Pt E, Ch 8, Sec 4.

5 Hull scantlings

5.1 General

5.1.1 Net thickness of strength deck plating

Within the cargo area, the thickness of strength deck plating is to be increased by 1,5 mm with respect to that calculated according to Pt B, Ch 7, Sec 4.

5.2 Hull scantlings of non-propelled units with the service notation pontoon fitted with arrangements and systems for launching operations

5.2.1 Additional information

In addition to the documentation specified in Pt B, Ch 1, Sec 4, the following information is to be submitted to the Society:

- maximum draught of the ship during the different stages of the launching operations
- operating loads and their distribution
- launching cradle location.

5.2.2 Scantlings draught

T_{SC} is to be taken not less than the maximum draught resulting from the different stages of launching.

5.2.3 Deck scantlings

The scantlings of decks are to be in accordance with Part B, Chapter 7, considering the maximum loads acting on the launching cradle.

The thickness of deck plating in way of launch ground ways is to be suitably increased if the cradle may be placed in different positions.

The scantlings of decks in way of pivoting and end areas of the cradle are to be obtained through direct calculations, to be carried out according to the criteria in Pt B, Ch 8, Sec 1.

5.2.4 Launching cradles

The launching cradles are to be adequately connected to deck structures and arranged, as far as possible, in way of longitudinal bulkheads or at least of girders.

5.3 Hull scantlings of non-propelled units with service notation pontoon - crane

5.3.1 Loads transmitted by the lifting appliances

The forces and moments transmitted by the lifting appliances to the ship's structures, during both lifting service and navigation, are to be submitted to the Society in the initial stage of the design.

5.3.2 Ship's structures

The ship's structures, subjected to the forces transmitted by the lifting appliances, are to be reinforced to the Society's satisfaction.

5.3.3 Lifting appliances

The check of the behaviour of the lifting appliances at sea is outside the scope of the classification and is under the responsibility of the Designer. However, where the requirements in [3.2.1] may not be complied with (i.e. sailing with boom or derrick up) or where, exceptionally, trips with suspended load are envisaged, the Designer is to submit the check of the lifting appliances during navigation to the Society for information.

6 Hull outfitting

6.1 Equipment

6.1.1 Manned non-propelled units

The equipment of anchors, chain cables and ropes to be fitted on board manned non-propelled units is to comply with Pt B, Ch 12, Sec 4.

Chain cables for anchors may be replaced by steel ropes having the same breaking load. The ropes are to be connected to the anchors by approximately 10 m of chain cable complying with Pt B, Ch 12, Sec 4.

Non-propelled units continuously assisted by a tug may have only one anchor complying with Pt B, Ch 12, Sec 4 and a chain rope having length neither less than 75% of the length obtained according to Pt B, Ch 12, Sec 4 nor less than 220 m.

6.1.2 Unmanned non-propelled units

For unmanned non-propelled units, the equipment is not required for classification purposes. The scantlings of anchors, chain cables and ropes to be fitted on board are the responsibility of the Designer.

6.1.3 Towing arrangements

Non-propelled units are to be fitted with suitable arrangements for towing, with scantlings under the responsibility of the Designer.

The Society may, at the specific request of the interested parties, check the above arrangements and the associated hull strengthening; to this end, the maximum pull for which the arrangements are to be checked is to be specified on the plans.

Section 3 Machinery and Systems

1 General

1.1 Application

1.1.1 This Section provides requirements for bilge systems of non propelled units.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document **(1)**	Status of the review
1	Diagram of the bilge system	A
2	Diagram of the central priming system intended for the bilge pumps, where provided	A
3	Capacity, prime mover and location of the bilge pumps	A
(1) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.		

2 Bilge system

2.1 Bilge system in ships having no source of electrical power

2.1.1 General

Where there is no source of electrical power on board, hand pumps are to be provided, in sufficient number and so positioned as to permit an adequate drainage of all the compartments of the ship.

2.1.2 Arrangement of the bilge system

The bilge system is to comply with one of the following arrangements:

a) At least one pump is to be provided for each compartment

b) At least two pumps connected to a bilge main are to be provided. The main is to have branch pipes allowing the draining of each compartment through at least one suction.

2.1.3 Hand pumps

a) Hand pumps are to be capable of being operated from positions above the load waterline and are to be readily accessible at any time.

b) Hand pumps are to have a maximum suction height not exceeding 7,30 m.

2.1.4 Size of bilge pipes

a) The internal diameter, in mm, of suction pipes is not to be less than the diameter given by the following formula:

$$d_1 = \frac{T}{100} + 50$$

where:

T : Underdeck tonnage, in t.

b) When the ship is subdivided into small watertight compartments, the diameter of these suctions need not exceed 50 mm.

2.2 Bilge system in ships having a source of electrical power

2.2.1 General

On board ships having no propelling machinery but having a source of electrical power, mechanical pumps are to be provided for draining the various compartments of the ship.

2.2.2 Arrangement of the bilge system

The bilge system is to comply with the provisions of Pt C, Ch 1, Sec 10, [6.3] to Pt C, Ch 1, Sec 10, [6.6] applicable to the spaces concerned, except that direct suctions need not be provided.

2.2.3 Bilge pumps

The number and capacity of the bilge pumps are to comply with the relevant requirements of Pt C, Ch 1, Sec 10, [6.7].

2.2.4 Size of bilge pipes

The size of bilge pipes is to comply with the relevant requirements of Pt C, Ch 1, Sec 10, [6.8].

CHAPTER 15
FISHING VESSELS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 4 Machinery

Section 5 Electrical Installations

Section 6 Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **Fishing vessel**, as defined in Pt A, Ch 1, Sec 2, [4.8].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Reference
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B • Ch 15, Sec 2
	L < 65 or 90 m **(1)**	• NR600
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 15, Sec 3
	L < 65 or 90 m **(1)**	• NR600
Stability		• Part B • Ch 15, Sec 3
Machinery and cargo system		• Part C • Ch 15, Sec 4
Electrical installations		• Part C • Ch 15, Sec 5
Automation		• Part C
Fire protection, detection and extinction		• Part C • Ch 15, Sec 6 **(2)**

(1) Refer to the scope of application of NR600.

(2) Articles Ch 15, Sec 6, [5], Ch 15, Sec 6, [6], Ch 15, Sec 6, [7], Ch 15, Sec 6, [8], Ch 15, Sec 6, [9] and Ch 15, Sec 6, [10] apply only to ships assigned with the additional service feature **F**.

Note 1:

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Ship Arrangement

1 General

1.1 Definitions

1.1.1 Working deck

The working deck is generally the lowest complete exposed deck above the deepest operating waterline from which fishing is undertaken.

The Society may accept a lower complete deck as a working deck provided that such a deck is situated above the deepest operating waterline.

2 General arrangement design

2.1 Subdivision arrangement

2.1.1 Disposition of collision bulkhead

The collision bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than 5% and no more than 8% of the length L_{LL} of the ship.

Where any part of the ship below the waterline extends forward perpendicular, e.g a bulbous bow, the above distance, in m, are to be measured from a point either:

- at mid-length of such extension, or
- at a distance 1,5% of the length L_{LL} of the ship forward of the forward perpendicular, where this distance is lesser.

2.1.2 Height of transverse watertight bulkheads

Transverse watertight bulkheads are to be watertight up to the working deck.

Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the next deck above the working deck. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in [2.1.1] and the part of the deck which forms the step is made effectively watertight.

2.1.3 Openings in collision bulkhead

Openings in the collision bulkhead below the working deck are not allowed.

Where penetration of the collision bulkhead is necessary for piping, arrangements are to be fitted to maintain the watertight integrity and strength, with suitable valves operable from above the freeboard deck, whose valve chest is to be secured at the bulkhead inside the fore peak.

Where the collision bulkhead extends above the working deck, openings above the working deck are allowed provided that they are supplied with weathertight means of closure.

2.1.4 Openings in watertight bulkheads

The number of openings in watertight bulkheads is to be kept to a minimum compatible with the design and proper working of the ship.

Where penetration of watertight bulkheads and internal decks is necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be fitted to maintain the watertight integrity and strength.

Section 3 Hull and Stability

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the following documents and information are to be submitted:

- minimum design temperature of refrigerated spaces,
- structural reinforcements in way of load carrying structures, such as masts, gantries, trawl gallows and winches, including the maximum brake load of the winches.

2 Stability

2.1 Intact stability

2.1.1 Application

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.14], with the assumptions in [2.1.2], is to be in compliance with the requirements in [2.1.3].

2.1.2 Assumptions for calculating loading conditions

The assumptions for calculating the loading conditions in Pt B, Ch 3, App 2, [1.2.14] are as follows:

- *allowance is to be made for the weight of the wet fishing nets and tackle, etc., on deck*
- *in all cases the cargo is to be assumed to be homogeneous unless this is inconsistent with practice*
- *deck cargo is to be included if such a practice is anticipated*
- *water ballast is normally to be included only if carried in tanks which are specially provided for this purpose.*

2.1.3 Intact stability criteria

- *the general intact stability criteria in Pt B, Ch 3, Sec 2, [2] are to be applied to fishing vessels equal to or greater than 24 m in length, except for the requirements below.*
- *the initial metacentric height GM_0 is to be not less than 0,35 m for single deck vessels.*
- *the metacentric height GM_0 may be reduced to the satisfaction of the Society but in no case is GM_0 to be less than 0,15 m for vessels with complete superstructure or vessels equal to or greater than 70 m in length.*

Where arrangements other than bilge keels are provided to limit the angle of roll, the above stability criteria are to be maintained in all operating conditions.

2.1.4 Severe wind and rolling criterion (weather criterion)

The requirements in Pt B, Ch 3, Sec 2, [3] are to be complied with by:

- *fishing vessels equal to or greater than 45 m in length*
- *fishing vessels in the length range between 24 m and 45 m, with the values of wind pressure defined in Tab 1, depending on the vertical distance h, in m, measured from the centre of the projected vertical area of the ship above the waterline to the waterline.*

2.1.5 Icing

For vessels operating in areas where ice accretion is expected, the requirements in Pt B, Ch 3, Sec 2, [6] are to be complied with.

Table 1 : Values of wind pressure

Vertical distance h, in m	Wind pressure, in kN/m^2
1	0,316
2	0,386
3	0,429
4	0,460
5	0,485
6 and over	0,504

3 Design loads

3.1 Fish holds

3.1.1 The internal liquid pressures in fish holds are to be determined according to Pt B, Ch 5, Sec 6, [1] with ρ_C as defined by the Designer. As a guidance, ρ_C may be taken as follows:

- 0,7 for holds intended to carry dry fish or fish stored in ice,
- 1,025 for holds intended to carry live fish or frozen fish into sea water,
- 1,2 for holds intended to freeze or store fish into brine.

Note 1: If applicable, a design vapour pressure P_{pv} is to be considered for live fish stored in sea water to take into account the injection of oxygen.

Note 2: In case of salt stored onboard for brine production, weight of salt and associated distribution along the ship are to be provided.

3.2 Working deck

3.2.1 The static pressure $P_{dl\text{-}s}$ to be considered on working decks is to be taken as defined by the Designer, without being less than 8,5 kN/m².

4 Hull scantlings

4.1 Fish holds

4.1.1 Fish holds scantlings are to be checked according to the applicable requirements of Part B, Chapter 7 for the design load sets LC-1, LC-3 and LC-4 as defined in Pt B, Ch 7, Sec 2, [2].

4.1.2 Wells in fish hold

The thickness of fish holds wells plating, not protected by insulation, is to be increased by 1 mm with respect to that calculated according to Pt B, Ch 7, Sec 4. This thickness increase is to be combined with the one defined in [4.2.1] if applicable.

4.2 Bottom, side and decks plating

4.2.1 The thickness of bottom, side and exposed decks other than superstructures plating is to be increased by 0,5 mm with respect to that calculated according to Pt B, Ch 7, Sec 4. This thickness increase is to be combined with the one defined in [4.1.2] if applicable.

4.3 Aft ramp

4.3.1 Plating of the aft ramp and of the lower part of the aft ramp side

The plating thickness of the aft ramp and of the lower part of the aft ramp sides is to be increased by 1,5 mm with respect to that calculated according to Pt B, Ch 11, Sec 3, [2.2] for side plating with the same plate panel dimensions.

The net plating thickness of the aft ramp and of the lower part of the aft ramp side is to be not less than 10,5 mm.

Note 1: The lower part of the aft ramp sides is that which can be in contact with the fish nets and ropes.

4.3.2 Plating of the upper part of the aft ramp sides

The plating thickness of the upper part of the aft ramp sides is to be not less than the value calculated according to Pt B, Ch 11, Sec 3, [2.2] for side plating with the same plate panel dimensions.

5 Arrangement for hull and superstructure openings

5.1 General

5.1.1 Door sills

The height of the sill of the doors is to be not less than:

- 600 mm above the working deck
- 300 mm above the deck of the lowest tier of superstructures.

For doors protected from the direct impact of waves, except for those giving direct access to machinery spaces, the height of the sill may be taken not less than:

- 380 mm above the working deck
- 150 mm above the deck of the lowest tier of superstructures

6 Lifting appliances and fishing devices

6.1 General

6.1.1 The limits of application to lifting appliances are defined in Pt B, Ch 1, Sec 1, [1.2].

6.1.2 The requirements in [6] apply to the reinforcements under decks supporting fishing devices, and to the strength check of fishing devices and masts if welded to the deck.

6.2 Design loads

6.2.1 The design loads and load angles to be considered for the strength check of masts, fishing devices and reinforcements under decks are to be submitted by the Designer based on the following assumptions:

- the weights of booms and net hauling fittings
- the cargo loads, to be taken equal to the maximum traction loads of the different lifting appliances, considering the rolling-up diameters defined in [6.2.2].

6.2.2 The rolling-up diameters to be taken for the maximum traction loads of the lifting appliances are:

- for the fishing winches: the mid rolling-up diameter
- for the net winches: the maximum rolling-up diameter
- for the winding-tackles: the minimum rolling-up diameter.

6.3 Strength check

6.3.1 Calculation of stresses in the structural elements

The stresses in the structural elements of masts, fishing devices and reinforcements under decks are to be obtained by means of direct calculations, using the design loads specified in [6.2].

6.3.2 Yielding check

The Von Mises equivalent stresses in the structural elements of masts, fishing devices and reinforcements under decks are to comply with the following formula:

- for beam grillage analysis:
  $\sigma_{eq} \leq 0,5\ R_{eH}$
- for standard mesh FE analysis (s x s):
  $\sigma_{eq} \leq 0,6\ R_y$
- for fine mesh FE analysis (50 x 50 mm):
  - for elements not adjacent to welding:
    $\sigma_{eq} \leq R_y$
  - for elements adjacent to welding:
    $\sigma_{eq} \leq 0,9\ R_y$

where:

σ_{eq} : Von Mises equivalent stress, in N/mm^2, to be obtained as a result of direct calculations

6.3.3 Buckling check

The buckling strength of the structural elements of masts and fishing devices is to be checked in compliance with Part B, Chapter 9.

7 Hull outfitting

7.1 Rudder stock scantlings

7.1.1 The rudder stock diameter is to be increased by 5% with respect to that obtained from the formula in Pt B, Ch 12, Sec 1, [4].

7.2 Equipment

7.2.1 General

Anchors referred to in this section are bower anchors.

Fishing vessels are to be provided with equipment in anchors, chain cables and ropes to be obtained from Tab 2, based on their Equipment Number EN, to be calculated according to Pt B, Ch 12, Sec 4, [1].

The equipment in anchors, chain cables and ropes of fishing vessels with the navigation notation **coastal area** may be obtained from Tab 2 based on the Equipment Number EN corresponding to the row above that relevant to the Equipment Number calculated for the ship considered.

In general, stockless anchors are to be adopted.

For ships with EN greater than 720, the determination of the equipment is to be considered by the Society on a case-by-case basis.

The mooring lines are given as a guidance, but are not required as a condition of classification.

7.2.2 Anchors

The required mass for each anchor is to be obtained from Tab 2.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 2.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 2 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

Table 2 : Equipment

Equipment number EN A< EN ≤ B		Stockless bower anchors		Stud link chain cables for bower anchors			Mooring lines **(1)**		
					Diameter, in mm				
A	B	N	Mass per anchor, in kg	Total length, in m	mild steel	high strength steel	N	Length of each line, in m	Ship design minimum breaking load, in kN
10	15	2	30	110	11	11	–	–	–
15	20	2	40	110	11	11	–	–	–
20	25	2	50	165	11	11	–	–	–
25	30	2	60	165	11	11	–	–	–
30	40	2	80	165	11	11	2	50	29
40	50	2	100	192,5	11	11	2	60	29
50	60	2	120	192,5	12,5	11	2	60	29
60	70	2	140	192,5	12,5	11	2	80	29
70	80	2	160	220	14	12,5	2	100	34
80	90	2	180	220	14	12,5	2	100	37
90	100	2	210	220	16	14	2	110	37
100	110	2	240	220	16	14	2	110	39
110	120	2	270	247,5	17,5	16	2	110	39
120	130	2	300	247,5	17,5	16	2	110	44
130	140	2	340	275	19	17,5	2	120	44
140	150	2	390	275	19	17,5	2	120	49
150	175	2	480	275	22	19	2	120	54
175	205	2	570	302,5	24	20,5	2	120	59
205	240	2	660	302,5	26	22	2	120	64
240	280	2	780	330	28	24	3	120	71
280	320	2	900	357,5	30	26	3	140	78
320	360	2	1020	357,5	32	28	3	140	86
360	400	2	1140	385	34	30	3	140	93
400	450	2	1290	385	36	32	3	140	101
450	500	2	1440	412,5	38	34	3	140	108
500	550	2	1590	412,5	40	34	4	160	113
550	600	2	1740	440	42	36	4	160	118
600	660	2	1920	440	44	38	4	160	123
660	720	2	2100	440	46	40	4	160	127
(1) The mooring lines are given as a guidance, but are not required as a condition of classification.									

7.2.3 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in NR 216 Materials, Ch 4, Sec 1, [2].

The diameter of stud link chain cables is to be not less than the value in Tab 2.

7.2.4 Chain cable arrangement

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cables, as required in Tab 2, is to be divided into approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are to be considered by the Society on a case-by-case basis.

When chain cables are replaced by trawl warps, the anchor is to be positioned on the forecastle deck so that it may be readily cast after it has been shackled to the trawl warp. Chocks or rollers are to be fitted at suitable locations, along the path of the trawl warps, between the winch and the mooring chocks.

8 Protection of hull metallic structures

8.1 Protection of cargo sides by battens

8.1.1 In cargo spaces, where thermal insulation is fitted, battens formed by spaced planks are generally to be fitted longitudinally.

8.2 Deck composition

8.2.1 The deck composition is to be of such a material as to prevent corrosion as far as possible and is to be effectively secured to the steel structures underneath by means of suitable connections.

Section 4 Machinery

1 General

1.1 Application

1.1.1 Machinery systems fitted on board ships having the notation **fishing vessel** are to comply with the relevant sections of Part C, Chapter 1, with the exception of tests and the following systems:

- bilge system
- scuppers and sanitary discharges
- air pipes and sounding devices
- ventilation
- oil fuel systems
- cooling systems
- lubricating oil systems
- compressed air systems
- hydraulic systems
- exhaust gas system
- refrigerating installations
- propelling and auxiliary machinery
- steering gear,

for which substitutive requirements are provided in this Section.

1.1.2 This Section does not cover the design and performances of the fishing equipment. However, the piping systems and pressure vessels serving the fishing equipment are required to comply with the relevant Sections of Part C.

1.2 Documents to be submitted

1.2.1 In addition to the documents listed in Tab 1 and Tab 2, the diagram of the piping systems (hydraulic system, etc.) serving the fishing equipment is to be submitted for approval.

Table 1 : Documents to be submitted

No.	Document **(1)**
1	Drawing showing the arrangement of the sea chests and ship side valves
2	Diagram of the bilge and ballast systems (in and outside machinery spaces)
3	Specification of the central priming system intended for bilge pumps, when provided
4	Diagram of the scuppers and sanitary discharge systems
5	Diagram of the air, sounding and overflow systems
6	Diagram of cooling systems (sea and fresh waters)
7	Diagram of fuel oil system
8	Drawings of the fuel oil tanks not forming part of the ship's structure
9	Diagram of the lubricating oil system
10	Diagram of the thermal oil system
11	Diagram of the hydraulic systems intended for essential services or located in machinery spaces
12	Diagram of the compressed air system
13	Diagram of the hydraulic and pneumatic remote control systems
14	Diagram of the exhaust gas system
15	Diagram of drip trays and gutterway draining system
16	Arrangement of the ventilation system

(1) To be submitted for approval.
Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

Table 2 : Information to be submitted

No.	I/A (1)	Document
1	I	Nature, service temperature and pressure of the fluids
2	A	Material, external diameter and wall thickness of the pipes
3	A	Type of the connections between pipe lengths, including details of the weldings, where provided
4	A	Material, type and size of the accessories
5	A	For plastic pipes: • the chemical composition • the physical and mechanical characteristics in function of temperature • the characteristics of inflammability and fire resistance • the resistance to the products intended to be conveyed
(1) A = to be submitted for approval ; I = to be submitted for information		

1.3 Tests - Trials in ships L ≥ 24 m

1.3.1 See Part C, Chapter 1.

1.4 Tests - Trials in ships L < 24 m

1.4.1 General

The building and fitting of fluid systems, pumps, pipes and their accessories, as well as other installations referred to in this Chapter are to be attended by a Society's Surveyor, at the Builder's request.

Pneumatic tests are to be avoided whenever possible. When such testing is essential in lieu of hydraulic pressure test, procedure for testing is to be submitted to the Society for acceptance prior to testing.

1.4.2 Testing on board

After assembly onboard, all fittings and accessories being fitted, a hydraulic pressure test is to be carried out for compressed air and oil fuel pipes.

As a rule, the test pressure is not to be less than 1,5 times the service pressure.

1.4.3 Hydraulic tests of oil fuel bunkers, tanks and accessories

The oil fuel bunkers and tanks not forming part of the ship's structure are to be submitted to a hydraulic test under a pressure corresponding to the maximum liquid level in these spaces or in the air or overflow pipes, subject to a minimum of 2,40 m above the top. This minimum height is to be 3,60 m for tanks intended to contain oil fuel having a flash point below 60°C.

Non metallic or metallic flexible pipes and expansion joints are to be tested in accordance with the requirements stated in [1.10.4] item e) and [1.11.7] item a), as appropriate.

1.5 General requirements applicable to all piping systems in ships L ≥ 24 m

1.5.1 See relevant requirements of Pt C, Ch 1, Sec 10, [1] and Pt C, Ch 1, Sec 10, [5].

1.6 General requirements applicable to all piping systems in ships L < 24 m

1.6.1 Materials

The manufacturer's test certificate for materials for valves and fittings can be accepted in lieu of the Society's materials certificate where the maximum conditions are not beyond those shown in Tab 3.

Table 3 : Maximum conditions for acceptance of manufacturer's test certificate

Material	Maximum conditions
Spheroidal or nodular cast iron	DN < 50 and PxDN < 2500
Carbon and low alloy steel	–10°C < t < 300°C and DN < 50, or –10°C < t < 300°C and PxDN < 2500
Cupreous alloy (1)	t < 200°C and DN < 50, or t < 200°C and PxDN < 1500
(1) See Pt C, Ch 1, Sec 10, [2.1]. **Note 1:** DN = nominal diameter, P = working pressure, t = working temperature.	

1.6.2 Fixing and arrangement of the pipes

a) Except where otherwise permitted, piping and pumping systems covered by this Chapter are to be permanently fixed onboard ship.

b) Unless otherwise specified, the fluid lines referred to in this Chapter are to consist of pipes connected to the ship's structure by means of collars or similar devices.

c) As far as possible, pipes are not to pass near switchboards or other electrical apparatuses. If this requirement is impossible to satisfy, gutterways or masks are to be provided wherever deemed necessary to prevent projections of liquid on live parts.

d) These provisions also apply to the exhaust pipes of internal combustion engines.

1.6.3 Protection of pipes

Pipes are to be efficiently protected against corrosion particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment.

1.6.4 Accessories

Locks, valves and other accessories are generally to be so placed that they are easily visible and accessible for manoeuvring, control and maintenance.

1.7 Sea inlets and overboard discharges in ships L ≥ 24 m

1.7.1 See Pt C, Ch 1, Sec 10, [2.8].

1.8 Sea inlets and ship side valves in ships L < 24 m

1.8.1 Valves

All sea inlet and outlet pipes are to be provided with valves fixed:

- directly on the plating, or
- on steel chests built on the plating, or
- on strong distance pieces as short as possible which may be welded to the plating.

1.8.2 Strainers

Sea inlets are to be fitted with strainers. The flow section through each strainer is not to be less than twice the total section of the suction pipes connected to the said inlet.

1.8.3 Materials

The valves on sea inlets and overboard discharges are to be of steel or appropriate non-brittle material.

Similar provisions apply to distance pieces connecting the valves to the shell plating.

1.8.4 Protection against corrosion

Efficient arrangements such as the fitting of zinc anodes are to be made in order to protect the steel parts of sea inlets and discharges against corrosion.

1.9 Non-metallic rigid pipes in ships L ≥ 24m

1.9.1 See Pt C, Ch 1, App 3.

1.10 Non-metallic rigid pipes in ships L < 24m

1.10.1 General

a) The Society may permit the use of rigid pipes made of plastics in lieu of metallic pipes in the conditions specified in [1.10.2], [1.10.3] and [1.10.4].

b) These requirements apply to thermoplastic materials but, where appropriate, may also be applied to pipes manufactured in fibre reinforced thermosetting resins.

c) For every application, characteristics of the proposed plastics are to be given to the Society, namely:

- the chemical composition
- the physical and mechanical characteristics in function of the temperature
- the fire properties
- eventually, the resistance to the various products likely to come into contact with those plastics.

1.10.2 Use of plastic pipes

a) Pipes made of plastics are permitted, as a general rule, for:

- scupper and sanitary discharge pipes
- ballast pipes except for the parts passing through engine rooms, dangerous spaces and oil fuel bunkers or located between pumps and their suctions and discharges
- individual bilge pipes for small compartments such as chain lockers.

b) For other pipes such as air and sounding pipes of compartments not intended to contain oil fuel, the Society may accept the use of plastics subject to an examination of the relevant drawings.

c) Pipes made of plastics may be used for fluid systems not covered by the classification provided the requirements given in [1.10.3] are complied with.

d) Pipes made of plastics are not to be used where they are subject to temperatures above 60°C or below 0°C.

The use at a higher temperature for particular applications is subject to special examination.

e) Any proposed service for plastic pipes not mentioned above is to be submitted to the Society for special consideration.

1.10.3 Intactness of watertight subdivision and fire divisions

a) As a rule, pipes made of plastics cannot pass through watertight bulkheads.

b) If, however, such a passage cannot be avoided, arrangements are to be made in order to ensure the integrity of the subdivision in case of pipe breakage. Such arrangements are to be submitted to the Society.

c) The use of pipes made of plastics is generally to be avoided wherever the destruction of these pipes in case of fire would compromise the intactness of subdivision or the safety of the ship.

d) Where pipes made of plastics are to pass through fire divisions, the arrangements taken to ensure the fire integrity of these divisions are to be submitted to the Society.

1.10.4 Design and construction

a) Pipes and fittings are to be of a robust construction and are to comply with the requirements of such national standards as may be consistent with their intended use.

Particulars of scantlings and joints are to be submitted for examination.

b) All pipes are to be adequately but freely supported. Suitable provision for expansion and contraction is to be made in each range of pipes to allow for important clearance between pipes made of plastics and steel structures, in consideration of the difference between their individual coefficients of thermal expansion.

c) All fittings and branches are to be suitable for the intended service and are to have joints of cemented, flanged or other approved types.

d) The bursting pressure of pipes, fittings and joints made of plastics, at their service temperature, is not to be less than 4 times their maximum service pressure, with a minimum of 5 bar.

e) After completion, pipes and fittings are to be subjected to a hydraulic pressure test, to be applied during at least 5 minutes under a pressure not less than 1,5 times the service pressure.

1.11 Flexible hoses and expansion joints

1.11.1 General

a) The Society may permit the use of flexible hoses and expansion joints, both in metallic and non-metallic materials, provided they are approved for the intended service.

b) Flexible hoses and expansion joints are to be of a type approved by the Society, designed in accordance with [1.11.3] and tested in accordance with [1.11.6].

c) Flexible hoses and expansion joints are to be installed in accordance with the requirements stated in [1.11.5].

d) Flexible hoses and expansion joints intended for piping systems with a design temperature below the ambient temperature will be given special consideration by the Society.

1.11.2 Documentation

The information, drawings and documentation listed in [1.2.1], Tab 1 and Tab 2 are to be submitted to the Society for each type of flexible hose or expansion joint intended to be used.

1.11.3 Design of flexible hoses and expansion joints

a) Flexible pipes and expansion joints are to be made of materials resistant to the marine environment and to the fluid they are to convey. Metallic materials are to comply with Pt C, Ch 1, Sec 10, [2.1.2].

b) Flexible pipes and expansion joints are to be designed so as to withstand:
   - external contact with hydrocarbons
   - internal pressure
   - vibrations
   - pressure impulses.

c) Flexible pipes intended to convey fuel oil or lubricating oil and end attachments are to be of fire-resisting materials of adequate strength and are to be constructed to the satisfaction of the Society.

d) Where a protective lining is provided for this purpose, it is to be impervious to hydrocarbons and to hydrocarbon vapours.

e) Flexible pipes intended to convey:
   - gaseous fluid at a pressure higher than 1 MPa
   - fuel oil or lubricating oil,

   are to be fitted with a metallic braid.

f) As a general rule, flexible hoses are to be fitted with crimped connections or equivalent. For water pipes subject to a pressure not exceeding 0,5 MPa, as well as for scavenge air and supercharge air lines of internal combustion engines, clips made of galvanised steel or corrosion-resistant material with thickness not less than 0,4 mm may be used.

g) Flexible pipes and expansion joints are to be so designed that their bursting pressure at the service temperature is not less than 4 times their maximum service pressure, with a minimum of 2 MPa. Exemptions from this requirement may be granted for expansion joints of large diameter used on sea water lines.

h) The junctions of flexible hoses and expansion joints to their couplings are to withstand a pressure at least equal to the bursting pressure defined in item f).

1.11.4 Conditions of use of flexible hoses and expansion joints

a) The use of flexible hoses and expansion joints is to be limited as far as practicable.

b) The position of flexible hoses and expansion joints is to be clearly shown on the piping drawings submitted to the Society.

c) The use of non-metallic expansion joints on pipes connected to sea inlets and overboard discharges is to be given special consideration by the Society. As a rule, the fitting of such joints between the ship side and the valves mentioned in Pt C, Ch 1, Sec 10, [2.8.3] or [1.8.1], as applicable, is not permitted. Furthermore, unless the above-mentioned valves are fitted with remote controls operable from places located above the freeboard deck, efficient means are to be provided, wherever necessary, to limit the flooding of the ship in the event of rupture of the expansion joints.

d) Expansion joints may be fitted in sea water lines, provided they are arranged with guards which effectively enclose, but do not interfere with, the action of the expansion joints and reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements.

e) Use of expansion joints in water lines for other services, including ballast lines in machinery spaces, in duct keels and inside double bottom water ballast tanks, and bilge lines inside double bottom tanks and deep tanks, is to be given special consideration by the Society.

1.11.5 Arrangement of flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be so arranged as to be accessible at all times.

b) Flexible hoses and expansion joints are to be as short as possible.

c) The radius of curvature of flexible hoses is not to be less than the minimum recommended by the manufacturer.

d) The adjoining pipes are to be suitably aligned, supported, guided and anchored.

e) Isolating valves are to be provided permitting the isolation of flexible hoses intended to convey flammable oil or compressed air.

f) Expansion joints are to be protected against over extension or over compression.

g) Where they are likely to suffer external damage, flexible hoses and expansion joints of the bellows type are to be provided with adequate protection.

1.11.6 Type tests of flexible hoses and expansion joints

a) Type approval tests are to be carried out on a flexible hose or an expansion joint of each type and each size, in accordance with Tab 4.

b) The flexible pipes or expansion joints subjected to the tests are to be fitted with their connections.

c) The fire-resistance test is to be carried out in the conditions hereafter; other test methods may be applied after special examination.

   The flexible pipe is to be subjected to fire for 30 minutes at a temperature of 800°C, while water at the maximum service pressure is circulated inside the pipe; the temperature of the water at the outlets is not to be less than 80°C. No leak is to be recorded during and after the test.

d) Flexible pipes or expansion joints granted with a type approval certificate issued by the Society for the intended conditions of use are exempted from type-tests.

1.11.7 Hydraulic tests

a) Each flexible pipe or expansion joint, together with its connections, is to undergo a hydraulic test under a pressure at least equal to twice the maximum service pressure, subject to a minimum of 10 bar.

b) During the test, the pipe or expansion joint is to be repeatedly deformed from its geometrical axis.

1.11.8 Marking

Each flexible pipe or expansion joint is to be stencilled or otherwise marked with its specified maximum service pressure and, when used in other than ambient temperature, its maximum or minimum service temperature or both.

Table 4 : Type tests to be performed for flexible hoses and expansion joints

Type test	Required
Bursting	Yes
Fire-resistance	Yes **(1)**
Vibration	Yes **(2)**
Pressure impulse	Yes
Flexibility	Yes **(3)**
Cyclic expansion	Yes **(4)**
Resistance	Yes **(5)**

(1) Only for flexible hoses and expansion joints used in flammable oil and sea water systems.
(2) Only for flexible hoses and expansion joints fitted to engines, pumps, compressors or other sources of high vibrations.
(3) Only for flexible hoses conveying low temperature fluids.
(4) Only for piping systems subjected to expansion cycles.
(5) Internal to the conveyed fluid and external to UV.

1.11.9 Periodical replacement - Spare parts

a) Flexible pipes or expansion joints are to be periodically replaced according to the periodicity depending on their types.

b) A spare is recommended for each type of flexible pipe or expansion joint the failure of which could impair the operation of main engines, that of auxiliary engines for essential services or the safety of the ship.

1.12 Metallic flexible pipes and joints

1.12.1 Metallic flexible pipes and joints are to comply with the requirements stated in [1.11], as far as applicable.

Fire-resistance tests need not be carried out.

2 Bilge system in ships L ≥ 24 m

2.1 General

2.1.1 Application

The following provisions supersede those given in Pt C, Ch 1, Sec 10, [6].

2.1.2 Principle

a) Fishing vessels are to be provided with an efficient bilge pumping system capable of pumping from and draining, under all practical conditions, any watertight compartment other than spaces exclusively intended for the carriage of fresh water, water ballast or fuel oil, for which other efficient means of pumping are to be provided.

b) In fishing vessels where fishing handling or processing may cause quantities of water to accumulate in enclosed spaces, adequate drainage is to be provided.

c) The bilge pumping system is to consist of pumps connected to a bilge main line so arranged as to allow the draining of all spaces mentioned in item a).

d) Bilge pumping arrangement may be dispensed with in particular compartments where no equipment nor openings are likely to leak.

e) Where expressly permitted, some small compartments may be drained by means of hand pumps.

f) Bilge and ballast systems are to be so designed as to prevent the possibility of water passing from the sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another. Provisions are to be made to prevent any space having bilge and ballast connections being inadvertently flooded from the sea when containing cargo, or being discharged through the bilge system when containing water ballast.

g) Where there are common valves between bilge and fire fighting lines, they are to have a locked device on his handwheels in order to avoid the discharge of bilge water into the fighting circuit.

2.2 Design of the bilge system

2.2.1 General

a) All suction pipes up to the connection with the bilge pumps are to be independent from any other piping system of the ship.

b) Non-return valves are to be fitted on:
- direct and emergency suctions in machinery spaces
- the pipe connections to bilge distribution boxes
- the suctions of pumps having also connections from the sea or from compartments normally intended to contain liquid
- the direct suctions connected to independent bilge pumps, where required.

c) All compartments are to be provided with at least one suction on each side. However, in the case of short and narrow compartments, a single suction ensuring an efficient draining may be accepted.

2.2.2 Draining of machinery spaces

a) Machinery spaces of ships with double bottom, or where the rise of floor is less than 5°, are to be provided on each side with one bilge suction connected to the bilge main.

b) Machinery spaces of ships without double bottom, or where the rise of floor exceeds 5°, may be provided with only one bilge suction located in the centreline and connected to the bilge main.

c) In addition to the bilge suctions required in items a) and b), machinery spaces are to be provided with a direct suction, which is to be led direct to an independent power bilge pump and so arranged that it can be used independently of the bilge main.

2.2.3 Emergency bilge suction

a) The emergency bilge suction is to be led directly from the drainage level of the machinery space to the greater capacity sea water pump. Its capacity is to be at least equal to the required capacity of each bilge pump as determined in [2.3.4].

b) The emergency bilge suction is to be located at the lowest possible level in the machinery spaces.

c) The diameter of emergency bilge suction pipes is to be at least the diameter of the suction connected to of the sea water pump in normal operation.

d) The high of the hand-wheels of the non-return valves controlling emergency bilge suctions are to rise at least 450 mm above the manoeuvring floor.

e) If the requirement mentioned in d) can not be verified, the height of the hand-wheels of the non-return valves is to be the minimum height to permit the easy operation of the valve.

2.2.4 Draining of holds

a) Holds of ships with double bottom, or where the rise of floor is less than 5°, are to be provided on each side with one bilge suction connected to the bilge main.

b) Holds of ships without double bottom, or where the rise of floor exceeds 5°, may be provided with only one bilge suction located in the centreline and connected to the bilge main.

c) Holds greater than 30 m in length, bilge suctions are to be provided in the fore and aft ends and connected to the bilge main.

2.2.5 Draining of refrigerated spaces

Refrigerated spaces are to be provided with drainage arrangement allowing the continuous drainage of condensates.

2.2.6 Draining of fore and aft peaks

a) Fore and aft peaks, where not used as tanks, are to be fitted with a bilge suction connected to the bilge main. Passage through the collision bulkhead is to comply with [2.5.2].

b) Peaks of small dimensions may be drained by means of a hand pump provided that the suction lift is well within the capacity of the pump and in no case exceeds 7,30 m.

2.2.7 Draining of double bottom compartments

Double bottom compartments, where not used as tanks, are to be provided with bilge suctions. Their number and location are to comply with the provisions of [2.2.4]. However, if deemed acceptable by the Society, the cofferdams fitted between two different compartments of the double bottom may be provided with one bilge suction only.

2.2.8 Draining of other compartments

a) Provision is to be made for the drainage of chain lockers and other fore spaces by means of hand or power pump suctions or hydraulic ejectors.

b) Provision is to be made for the drainage of the steering gear compartment and other spaces located above the aft peak by means of suctions connected to the bilge main or by means of hand pumps or hydraulic ejectors.

c) These spaces may, however, be drained by means of scuppers discharging to the shaft tunnel, provided that the discharge pipes are fitted with self-closing valves situated in easily visible and accessible positions.

d) Fish processing spaces are to be fitted with drainage means, the capacity of which is four times the normal feedwater flow in the space.

2.3 Bilge pumps

2.3.1 Number and arrangement of pumps

a) Fishing vessels are to be provided with at least two power bilge pumps of the self-priming type connected to the bilge main and having the capacity required in [2.3.4]. One of these pumps may be driven by the propulsion machinery.

b) Each bilge pump may be replaced by two or more pumps, provided that they are connected to the bilge main and that their total capacity is not less than that required in [2.3.4].

c) One of the bilge pumps required in item a) may be replaced by a hydraulic ejector having the capacity required in [2.3.4] and connected to a high pressure water pump.

d) Where permitted, hand pumps are to be operable from an easily accessible position above the load waterline.

2.3.2 Location of bilge pumps

Bilge pumps are to be located on the aft side of the collision bulkhead. This may not apply to those pumps only used for the draining of the spaces located on the fore side of the collision bulkhead.

2.3.3 Use of pumps intended for other duties

a) Pumps used for sanitary service, general service or ballast may be considered as independent bilge pumps provided that:

- they have the capacity required in [2.3.4]
- they are of the self-priming type
- they are connected to the bilge system.

b) Non-return valves are to be provided in accordance with [2.2.1], item b).

2.3.4 Bilge pump capacity

a) The water speed V in the bilge main and the capacity Q of each bilge pump are to be not less than the values given in Tab 5.

b) If the capacity of one of the pumps is less than the rule capacity, the deficiency may be compensated by an excess capacity of the other pumps. Such deficiency is, however, not to exceed 30% of the rule capacity.

Table 5 : Water speed and pump capacity

Ship's length	L < 35	L ≥ 35
Water speed	V = 1,22	V = 2,00
Pump capacity	$Q = 0{,}00345\ d^2$	$Q = 0{,}00565\ d^2$
L : Length of the ship, in m V : Minimum water speed in the bilge main, in m/s Q : Minimum capacity of each pump, in m^3/h d : Internal diameter of the bilge main, in mm, as defined in [2.4.1].		

2.4 Size of bilge pipes

2.4.1 Bilge main line

a) The diameter of the bilge main is to be calculated according to the following formula:

$$d = 25 + 1{,}68\sqrt{L(B + D)}$$

without being less than 50 mm,

where:

d : Internal diameter of the bilge main, in mm

L : Length of the ship between perpendiculars, in m

B : Breadth of the ship, in m

D : Depth of the ship, measured up to the bulkhead deck, in m.

b) The actual internal diameter may be rounded off. The nearest standard size is in no case to be more than 5 mm smaller than that obtained from the formula given in item a).

2.4.2 Branch bilge suction pipes

a) The diameter of the pipes situated between the distribution boxes and the suctions in the various spaces (holds, machinery space, etc) is to be calculated according to the following formulae:

$$d_1 = 25 + 2{,}16\sqrt{L_1(B + D)}$$

without being less than 50 mm,

where:

d_1 : Internal diameter of the suction pipe, in mm

L_1 : Length of the space considered, in m

L, B, D : Length, breadth and depth of the ship as defined in [2.4.1].

b) The actual internal diameter may be rounded off. The nearest standard size is in no case to be more than 5 mm smaller than that obtained from the formula given in item a).

2.5 Bilge piping arrangement

2.5.1 Passage through double bottom compartments and tanks

Bilge pipes are not to pass through double bottom compartments or tanks unless they are enclosed in appropriate pipe tunnels. Where this is not practicable, pipes are to be of reinforced thickness as per Pt C, Ch 1, Sec 10, Tab 6 and made of either one piece or several pieces assembled by welding or by reinforced flanges.

2.5.2 Passage through the collision bulkhead

a) A maximum of two pipes may pass through the collision bulkhead below the freeboard deck, unless otherwise justified. Such pipes are to be fitted with suitable valves operable from above the freeboard deck and the valve chest is to be secured at the bulkhead inside the fore peak. Such valves may be fitted on the after side of the collision bulkhead provided that they are readily accessible under all service conditions and the space in which they are located is not a cargo space. All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

b) The remote operation device of the valve referred to in a) is to include an indicator to show whether the valve is open or shut.

2.5.3 Bilge suctions in machinery spaces and shaft tunnels

In machinery spaces and shaft tunnels, the termination pipes of the bilge suctions are to be straight and vertical and are to be led to mud boxes so arranged as to be easily inspected and cleaned. The lower end of the termination pipe is not to be fitted with a strum box.

2.5.4 Bilge suctions in other compartments

In compartments other than machinery spaces and shaft tunnels, the open ends of bilge suction pipes are to be fitted with strum boxes or strainers having holes not more than 10 mm in diameter. The total area of such holes is not to be less than twice the required cross-section of the suction pipe.

2.5.5 Bilge alarms

Propulsion machinery spaces are to be fitted with a bilge level sensor capable of indicating water ingress in those spaces at the bridge by means of a visual and audible alarm.

2.6 Materials

2.6.1 All bilge pipes used in fuel storage tanks or in boiler or machinery spaces, including spaces in which oil-setting tanks or fuel oil pumping units are situated, are to be of steel or other suitable material non-sensitive to heat.

3 Bilge system in ships L < 24 m

3.1 General

3.1.1 Principle

All ships are to be provided with efficient means for pumping and draining any watertight space with at least one suction pipe when the ship is on an even keel and either is upright or has a list of up to 5°.

3.1.2 Independence of the lines

As a general rule, bilge lines are to be distinct from the other lines of the ship.

However, this requirement need not be applied to pipes located between collecting boxes and pump suctions or between pumps and overboard discharges.

3.1.3 Intactness of watertight subdivision

The lines and accessories are to be so arranged as to prevent intercommunication of compartments which are to remain segregated from each other or the accidental connection of these compartments directly to the sea.

3.1.4 Bilge main

A bilge main is to be provided for draining the different compartments for ships the length of which is greater than, or equal to, 12 m.

3.1.5 Number and distribution of suctions

At least two bilge suctions are to be provided for draining the propulsion engine room. At least one of these suctions is to be connected directly to a bilge pump.

The suctions are to be located at the lowest points of the compartment.

Additional suctions may be required if the flow of water towards the suctions is disturbed by irregularities of the bottom.

At least one bilge suction is to be provided in each compartment located between two watertight bulkheads.

3.2 Pumps and ejectors

3.2.1 Pumps

a) At least two power bilge pumps are to be provided; one of these pumps may be driven by a main propulsive engine.

b) The Society may permit, after special consideration, that one of the pumps be replaced by an ejector.

c) For ships the length of which is greater than, or equal to, 12 m, the bilge pumps are to be connected to the bilge main mentioned in [3.1.4].

d) For ships having the navigation notation **coastal area**, the Society may permit, after special consideration, that one of bilge pumps be a fixed hand pump.

e) Small compartments may be drained by means of portable or fixed hand pumps.

3.2.2 Ejectors

Where an ejector is used in lieu of a driven pump, its suction capacity is not to be less than the required capacity of the pump it replaces.

3.2.3 Capacity of the pumps

The capacity of the bilge pumps is to be such that a speed of water not less than 1,22 m/s may be obtained in the bilge main, the diameter of which is given in [3.3.1]. The capacity of each pump is therefore not to be less than:

$$Q = 0{,}00345\ d_1^2$$

where:

Q : Minimum capacity of each pump, in m^3/h

d_1 : Internal diameter, in mm, of the bilge main as defined in [3.3.1].

3.3 Size of bilge pipes

3.3.1 Bilge main

The internal diameter, in mm, of the bilge main, is to be of the commercial size nearest to the diameter given in the following formula:

$$d_1 = 25 + 1{,}68\sqrt{L(B + C)}$$

without being less than 35 mm,

where:

L, B : Rule length and breadth, respectively, of the ship, in m, defined in Pt B, Ch 1, Sec 3

C : Moulded depth of the ship, in m, at the freeboard deck.

3.3.2 Suctions in holds and machinery spaces

The internal diameter, in mm, of bilge pipes situated between collecting boxes and suctions in holds and machinery spaces, is to be of the commercial size nearest to the diameter given by the following formula:

$$d_2 = 25 + 2{,}16\sqrt{L_1(B + C)}$$

without being less than 35 mm,

where:

B, C : Dimensions having the same meaning as in [3.3.1]

L_1 : Length of the compartment, in m.

3.4 Arrangement of bilge lines and their accessories

3.4.1 Passage of pipes through certain compartments

If not contained in pipe tunnels, the part of bilge pipes passing through compartments intended to contain oil fuel are to have reinforced thickness and are to consist of a single piece. These pipes are to be provided with non-return valves at their ends in the holds.

3.4.2 Passage through watertight bulkheads

No bilge cock or similar device is to be fitted on the collision bulkhead.

The fitting of bilge cocks or similar devices on other watertight bulkheads is to be avoided as far as possible. However, where such accessories are provided, they are to be accessible at any time and capable of being closed from positions above the deck. An indication is to be provided to show whether these valves are open or close.

3.4.3 Non-return valves

Accessories are to be provided to prevent intercommunication of compartments or lines which are to remain segregated from each other. For this purpose, non-return valves or similar devices are to be fitted, namely on the pipe connections to bilge distribution boxes or to the alternative cocks, if any.

3.4.4 Strainers and mud boxes

Strainers and mud boxes are to be fitted on bilge lines wherever they are necessary.

4 Scuppers and sanitary discharges

4.1 Principle

4.1.1 Scuppers, sufficient in number and suitable in size, are to be provided to permit the drainage of water likely to accumulate in the spaces which are not located in the ship's bottom.

4.1.2 The number of scuppers and sanitary discharge openings in the shell plating is to be reduced to a minimum, either by making each discharge serve as many as possible of the sanitary and other pipes, or in any other satisfactory manner.

4.2 General

4.2.1 Discharges led through the shell either from spaces below the working deck or from within enclosed superstructures or deckhouses on the working deck fitted with weathertight doors are to be fitted with accessible means for preventing water from passing inboard.

4.2.2 Each separate discharge is to have an automatic non-return valve with a positive means of closing it from an accessible position, except when:

- satisfactory analysis is submitted to the Society, demonstrating that the entry of water into the vessel through the opening is not likely to lead to dangerous flooding, and
- the piping is of reinforced thickness as per Pt C, Ch 1, Sec 10, Tab 6.

4.2.3 The means for operating the positive action valve is to be provided with an indicator showing whether the valve is open or closed.

4.3 Discharges through manned machinery spaces

4.3.1 In manned machinery spaces, main and auxiliary discharges essential for the operation of machinery may be controlled locally. The controls are to be accessible and are to be provided with indicators showing whether the valves are open or closed.

4.4 Materials

4.4.1 Fittings attached to the shell and the valves required in [4.2.2] are to be of steel, bronze or other ductile material.

4.4.2 All pipes between the shell and the valves are to be of steel. However, in spaces other than machinery spaces of vessels constructed of material other than steel, the use of other materials may be permitted, subject to special consideration by the Society.

5 Air pipes and sounding devices in ships L ≥ 24 m

5.1 Air pipes

5.1.1 General

Air pipes are to be fitted to all spaces which are not fitted with alternative ventilation arrangements.

Air pipes are to be so arranged and the upper part of compartments so designed that air or gas likely to accumulate in the said compartments can freely evacuate.

When only one air pipe is provided, it is not to be used as filling pipe.

5.1.2 Exposed parts of air pipes

Where air pipes to tanks and void spaces below deck extend above the working or the superstructure decks, the exposed parts of the pipes are to be of strength equivalent to the adjacent structures and fitted with the appropriate protection.

5.1.3 Means of closing

Openings of air pipes are to be provided with means of closing, permanently attached to the pipe or adjacent structure.

5.1.4 Height of air pipes

The height of air pipes above deck to the point where water may have access below is to be at least:

- 760 mm on the working deck, and
- 450 mm on the superstructure deck.

The Society may accept reduction of the height of an air pipe to avoid interference with the fishing operations.

5.1.5 Special arrangements for air pipes of flammable oil tanks

a) Air pipes from fuel oil and thermal oil tanks are to discharge to a safe position on the open deck where no danger will be incurred from issuing oil or gases.

Where fitted, wire gauze diaphragms are to be of corrosion resistant material and readily removable for cleaning and replacement. The clear area of such diaphragms is not to be less than the cross-sectional area of the pipe.

b) Air pipes of lubricating or hydraulic oil storage tanks not subject to flooding in the event of hull damage may be led to machinery spaces, provided that in the case of overflowing the oil cannot come into contact with electrical equipment, hot surfaces or other sources of ignition.

c) The location and arrangement of vent pipes for fuel oil service, settling and lubrication oil tanks are to be such that, in the event of a broken vent pipe, there is no risk of ingress of seawater or rainwater.

d) Where seawater or rainwater may enter fuel oil service, settling and lubrication oil tanks through broken air pipes, arrangements such as water traps with:

- automatic draining, or
- alarm for water accumulation,

are to be provided.

5.1.6 Construction of air pipes

a) Where air pipes to ballast and other tanks extend above the freeboard deck or superstructure deck, the exposed parts of the pipes are to be of substantial construction, with a minimum wall thickness of at least:

- 6,0 mm for pipes of 80 mm or smaller external diameter,
- 8,5 mm for pipes of 165 mm or greater external diameter.

Intermediate minimum thicknesses may be determined by linear interpolation.

b) Air pipes with height exceeding 900 mm are to be additionally supported.

c) In each compartment likely to be pumped up, and where no overflow pipe is provided, the total cross-sectional area of air pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

d) The internal diameter of air pipes is not to be less than 50 mm, except for tanks of less than 2 m^3.

5.2 Sounding and level gauging devices

5.2.1 General

Sounding devices are to be fitted:

- to the bilges of those compartments which are not readily accessible at all times during voyages, and
- to all tanks and cofferdams.

5.2.2 Termination of sounding pipes

Where sounding pipes are fitted, their upper ends are to extend to a readily accessible position and, where practicable, above the working deck.

5.2.3 Means of closing

The openings of the sounding pipes are to be provided with permanently attached means of closing. Sounding pipes which are not extended above the working deck are to be fitted with automatic self-closing devices.

5.2.4 Special arrangements for sounding pipes of flammable oil tanks

Where tanks containing fuel oil or hydraulic oil are fitted with sounding pipes, their upper ends are to terminate in safe positions and are to be fitted with suitable means of closure.

Gauges made of heat-resistant glass of substantial thickness and protected with a metal case may be used, provided that automatic closing valves are fitted. The level gauge is to be of an approved type. Other means of ascertaining the amount of oil contained in the tank may be permitted provided their failure or overfilling will not permit release of fuel.

5.2.5 Construction of sounding pipes

a) Sounding pipes are normally to be straight. If it is necessary to provide bends in such pipes, the curvature is to be as small as possible to permit the ready passage of the sounding apparatus.

b) Bent portions of sounding pipes are to have reinforced thickness and be suitably supported.

c) The internal diameter of sounding pipes is not to be less than 32 mm. Where sounding pipes pass through refrigerated spaces, or through the insulation of refrigerated spaces in which the temperature may be below 0°C, their internal diameter is to be at least 60 mm.

d) Doubling plates are to be placed under the lower ends of sounding pipes in order to prevent damage to the hull. When sounding pipes with closed lower ends are used, the closing plate is to have reinforced scantlings.

6 Air pipes and sounding devices in ships L < 24 m

6.1 Air pipes

6.1.1 General

Air pipes are to be fitted to all compartments intended to contain liquid or which are not fitted with alternative ventilation arrangements.

These air pipes are to be so arranged as to be self-draining when the ship is on an even keel.

6.1.2 Number and position of air pipes

Air pipes are to be so arranged and the upper part of compartments so designed that air or gas likely to accumulate in the said compartments can freely evacuate.

When only one air pipe is provided, it is not to be used as filling pipe.

6.1.3 Tank air pipes

Air pipes of compartments likely to contain liquid hydrocarbons, cofferdams or any capacity likely to be pumped up are to be led out, at a sufficient height above the deck.

Air pipes of all compartments which can be run up from the sea are to be led to above the deck.

Moreover, air pipes of compartments containing liquid hydrocarbons are not to be led to a place where danger could be the consequence of the evacuation of hydrocarbons or hydrocarbon vapours through these openings.

Air pipes of lubricating oil tanks and bunkers may be led to the machinery spaces, provided that in case of overflow the oil cannot come into contact with electrical apparatus or with surfaces likely to be at a high temperature.

6.1.4 Open ends of air pipes

Efficient, permanently attached devices are to be provided permitting, should the necessity arise, to close the upper openings of air pipes in order to prevent any accidental entry of water into the spaces concerned.

Where the tank venting system is not of an automatic type approved by the Society, provision is to be made for relieving vacuum when the tanks are being pumped out, and for this purpose a hole of about 10 mm in diameter in the bend of the air pipe, or at a suitable position in the closing device, is acceptable.

6.1.5 Construction

In each compartment likely to be pumped up, and where no overflow pipe is provided, the total cross-sectional area of air pipes is not to be less than the cross-sectional area of the corresponding filling pipes.

6.2 Sounding and level gauging devices

6.2.1 General

Arrangements are to be made for sounding the tanks intended to contain liquid as well as all the compartments which are not readily accessible at all times.

6.2.2 Upper ends of sounding pipes

As a general rule, the sounding pipes are to end above the deck in easily accessible places and are to be fitted with efficient closing appliances.

However, in machinery spaces, when this requirement cannot be met, short sounding pipes may be used which are to lead to readily accessible positions above the floor and fitted with efficient closing appliances. When such sounding pipes are used for oil fuel or lubricating oil tanks, they are not to end close to electric motors or switchboards and are to be fitted with automatic closing devices.

6.2.3 Construction

a) Internal diameter of sounding pipes is not to be less than 30 mm.

b) Doubling plates are to be placed under the lower ends of sounding pipes in order to prevent damage to the hull.

6.2.4 Level-indicator systems

a) Level-indicator systems are to be of robust construction and suitably protected.

b) When used on fuel tanks or bunkers, level-indicator systems are to meet the requirements stated in [12.1.4].

7 Ventilation in ships ≥ 24 m

7.1

7.1.1 See Pt C, Ch 1, Sec 1, [3.1.1] and Pt C, Ch 1, Sec 1, [3.6.1].

See also Pt C, Ch 4, Sec 2, [2.1] and Pt C, Ch 4, Sec 6, [4].

8 Ventilation in ships < 24 m

8.1

8.1.1 Adequate ventilation is to be provided for spaces containing engines, boilers or other heat generating apparatuses, as well as for spaces where flammable vapours are likely to accumulate.

8.1.2 Ventilators serving the machinery spaces are to be capable of being closed in case of fire, from outside the said spaces. Skylights and other openings serving these spaces are to meet the following requirements:

- the skylights containing wire-reinforced glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached
- insulating materials in accommodation spaces, service spaces, control stations and machinery spaces except in refrigerated compartments are to be non-combustible. The surface of insulation fitted on the internal boundaries of machinery spaces is to be impervious to oil or oil vapours.

8.1.3 Ventilation of spaces containing propulsive plant and its auxiliaries is to be mechanical.

8.1.4 Mechanical ventilating fans are to be capable of being stopped from outside the space supplied by these ventilating fans.

9 Engine cooling systems in ships L ≥ 24 m

9.1

9.1.1 See Pt C, Ch 1, Sec 10, [10].

10 Engine cooling systems in ships L < 24 m

10.1 Principle

10.1.1

a) Provision is to be made so that the cooling of main engines and of lubricating oil or fresh water coolers for these engines can be suitably ensured in all normal operating conditions.

b) Generally, cooling water to propulsion engines and to lubricating oil or fresh water coolers is to be capable of being supplied by two separate means.

c) Engine cooling systems in ships having several propulsion engines are to be given special consideration by the Society.

10.2 Motorships

10.2.1

a) The second means stated in [10.1.1] item b) for engine cooling may consist of a satisfactory connection to a general service pump of sufficient capacity.

b) Where the power per engine does not exceed 370 kW or when the ratio of the power per engine expressed in kW to the rotating speed in revolutions per minute does not exceed 0,75, the Society may permit that the second means be a spare pump ready to be connected to the cooling system. Provision is to be made for the corresponding disassembling and reassembling operations to be carried out on board in a time as short as possible.

10.3 Fresh water cooling system

10.3.1 Where the engines are cooled by fresh water, the second means stated in [10.1.1] item b) may be omitted if a connection is fitted from the fresh water system to a suitable salt water system.

10.4 Cooling pumps

10.4.1 The pumps which may be connected to cooling systems may be either independent or driven by the machine they serve.

Relief valves are to be fitted on the discharge of cooling pumps driven by main engines, except for centrifugal type pumps.

10.5 Sea inlets

10.5.1

a) Not less than two sea inlets are to be provided for the engine cooling system. These sea inlets are to be distinct for the two means of cooling given in [10.1.1] item b), but they may be cross connected by a cross pipe.

b) These sea inlets are to be low inlets and one of them may be that of the ballast pump or of the general service pump. A sea-inlet is considered as low provided it remains submerged under all normal navigating conditions.

10.6 Filters

10.6.1 Where propulsive engines are directly cooled by sea water, either in normal service or in emergency, filters are to be fitted on the suction of cooling pumps.

10.7 Operating control

10.7.1 Means are to be provided for controlling the temperature and the water circulation of each engine.

10.8 Materials

10.8.1 The materials used for cooling systems are to be such as to limit the effects of galvanic corrosion and erosion, considering the circulation speeds adopted.

11 Oil fuel systems in ships L ≥ 24m

11.1

11.1.1 See Pt C, Ch 1, Sec 10, [11].

12 Oil fuel systems in ships L < 24m

12.1 General

12.1.1 Scope

The requirements stated in [12.1] and [12.2] are applicable to oil fuel systems for the service of propulsion engines and auxiliary machines. The flash point of the oil fuel used, determined by means of closed cup test, is not to be lower than 60°C.

The use for propulsion engines and auxiliary machine of oil fuel having a flash point lower than 60°C is subject to a special examination by the Society.

12.1.2 Pump controls

The power supply to oil fuel transfer pumps and to other pumps of the oil fuel system as well as to oil fuel separators is to be capable of being stopped from an always accessible place in the event of fire within the compartment where this equipment is located.

12.1.3 Drip-trays and gutterways

Drip-trays or gutterways with appropriate discharge devices are to be fitted:

- under pumps, valves and filters
- under oil fuel tanks and bunkers which are not part of the ship's structure, as well as
- under all the accessories subject to oil fuel leakage.

12.1.4 Level indicators

a) Gauge cocks for checking the level in the tanks are not to be used.

The glasses of any level indicator fitted on such tanks are to be made of heat-resistant material and are to be efficiently protected against shock. Such level indicators are to be fitted with self-closing cocks at their lower end as well as at their upper end if the latter is below the maximum liquid level.

b) Where the fuel transfer system does not include power pumps but only hand pumps, the valves to be provided at the lower end of level-indicators for fuel tanks, with the exception of daily service tanks, need not to be of the self-closing type. These valves are however to be readily accessible and instruction plates are to be fitted near these valves specifying that they are to be maintained closed except during transfer operations.

12.2 Oil fuel tanks and bunkers

12.2.1 Location of oil fuel tanks and bunkers

a) Location of oil fuel tanks and bunkers is to be chosen in a way to avoid any abnormal rise in temperature in these capacities.

b) The use of free standing oil fuel tanks is not permitted in high fire risk areas.

12.2.2 Suctions and discharges to oil fuel tanks and bunkers

a) All suction pipes to oil fuel tanks and bunkers, including those in double bottom, are to be provided with valves.

In the case of bunkers and oil fuel storage, settling or daily service tanks other than those in the double bottom, the valves are to be fitted directly on the plating of these bunkers and tanks and are to be so arranged that they can always be remotely closed in the event of fire taking place in the compartment where they are located.

b) Where the oil fuel transfer installation does not include power pumps but only hand pumps, the suction valves to oil fuel tanks and bunkers, with the exception of daily service tanks, need not to be provided with remote controls. These valves are however to be readily accessible and instruction plates are to be fitted in their vicinity specifying that they are to be maintained closed except during transfer operations.

c) Where the discharge pipes to oil fuel bunkers and tanks are not led to the upper part of the said bunkers and tanks, they are to be provided with non-return valves at their ends.

12.2.3 Drains

Daily service tanks are to be provided with drains permitting the evacuation of water and impurities likely to accumulate in the lower part of these tanks. These drains are to be fitted with self-closing valves or cocks.

12.2.4 Materials - Tests

a) The use of materials other than steel for fuel bunkers and tanks which are not part of the ship's structure is specially examined.

b) Oil fuel tanks and bunkers are to be tested under the conditions specified in [1.4.3].

12.3 Transfer pipes

12.3.1 Arrangement of the transfer system

The transfer system together with its accessories are to be so arranged that oil fuel cannot enter compartments the structure of which does not allow them to be filled with oil fuel or compartments intended to contain drinking water.

12.3.2 Transfer pumps

Where oil fuel is transferred by means of a power pump, arrangements are to be made so that oil fuel may be pumped, in the event of damage to this pump, by means of a stand-by pump, which can be a hand pump.

12.3.3 Passage through particular compartments

No fuel pipes are to pass through fresh water tanks and no fresh water pipes are to pass through fuel oil tanks.

12.4 Oil fuel supply to engines

12.4.1 The suctions of engine fuel pumps are to be so arranged as to prevent the suction of gathered water and sludge likely to accumulate after decanting at the lower part of service tanks.

12.4.2 Two filters, or similar devices, are to be provided and so arranged that one of the filters can be overhauled while the other is in use.

12.5 Materials - Construction

12.5.1 Low-pressure oil fuel pipes are generally to be made of steel. Where the internal diameter of these pipes does not exceed 25 mm, they may be of seamless copper or copper-alloy unless they pass through oil fuel tanks.

12.5.2 Transfer oil fuel pipes may be of non metallic hoses in the conditions stated in [1.10].

12.5.3 The pipes are to be connected by means of close-fitting flanges or other devices deemed equivalent for the application considered. The materials of the joints are to be impervious to liquid hydrocarbons.

13 Lubricating oil systems in ships L ≥ 24 m

13.1

13.1.1 See Pt C, Ch 1, Sec 10, [12].

14 Lubricating oil systems in ships L < 24 m

14.1 General

14.1.1 The lubricating oil systems are to be so arranged as to operate satisfactorily when the ship is inclined from the normal position to angles of up to 15° transversely or 5° longitudinally, or when rolling to angles of up to 22°30' or pitching up to 7°30'.

Lubricating oil pipes are to be independent of any other fluid system.

14.2 Lubricating pumps

14.2.1

a) Main engines are normally to be provided with at least two power lubricating pumps. Where the installation includes at least two propulsive units, the Society may permit that only one pump be provided for each propulsive unit.

b) Where the power per engine does not exceed 370 kW or when the ratio of the power per engine expressed in kW to the rotating speed in revolutions per minute does not exceed 0,75, the Society may permit that one of the pumps mentioned in item a) be a spare pump ready to be connected to the lubricating oil system. Provision is to be made for the corresponding disassembling and reassembling operations to be carried out on board in a time as short as possible.

14.3 Filters

14.3.1 In forced lubrication systems, a device is to be fitted which efficiently filters the lubricating oil in the circuit. The filters provided for this purpose are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

14.4 Safety devices

14.4.1 Lubricating oil systems for propulsive engines are to be provided with an alarm device giving audible warning in the event of an appreciable reduction of the oil pressure.

15 Hydraulic systems in ships L ≥ 24 m

15.1

15.1.1 See Pt C, Ch 1, Sec 10, [14].

16 Hydraulic systems in ships L < 24 m

16.1 General

16.1.1 Installations using flammable oils are to be given special consideration by the Society.

16.2 Safety and monitoring devices

16.2.1 Whenever practicable, the hydraulic power units are to be located outside the main engine or boiler rooms. Shields or similar devices are to be provided around the hydraulic power units in order to avoid accidental oil spray or oil mist on heated surfaces which may ignite oil.

17 Compressed air systems in ships L ≥ 24 m

17.1

17.1.1 See Pt C, Ch 1, Sec 10, [17].

18 Compressed air systems in ships L < 24 m

18.1

18.1.1 Starting compressed air systems

a) The compressed air system for starting main engines is to be so arranged that it is possible to ensure the initial charge of the air receiver(s). A hand compressor may be used for this purpose. Alternatively a compressor with a hand started prime mover may be used.

b) The prescription a) can be considered as fulfilled when the starting of the main engines is conducted, normally or under emergency, by starting devices such as fuses, inertia starters or other means deemed equivalent.

c) When only one air compressor is used for filling the air receivers, there are to be at least two air receivers.

d) The main engine air receivers are to have a total capacity sufficient to provide, without replenishment:

- 12 consecutive starts of the reversible type engines
- 6 consecutive starts of the non-reversible type engines.

18.2 Accessories for compressed air systems

18.2.1 The receivers, compressors, pipes and other accessories of the compressed air systems are to be fitted with adequate devices to avoid any appreciable overpressure in any point of the system.

18.3 Arrangement of compressed air systems

18.3.1

a) Efficient oil and water separators are to be provided on the discharge of compressors.

b) Non-return valves or other safety devices are to be provided on the starting air mains of each engine.

18.4 Construction - Material

18.4.1

a) The construction and scantlings of compressed air pipes and of their accessories are to comply with the requirements of Pt C, Ch 1, Sec 10.

b) Air receivers are to be constructed in accordance with the relevant requirements of Pt C, Ch 1, Sec 3.

19 Exhaust gas systems in ships L ≥ 24 m

19.1

19.1.1 See Pt C, Ch 1, Sec 10, [17].

20 Exhaust gas systems in ships L < 24 m

20.1 Hull outlet

20.1.1 Where exhaust gas pipes are led overboard close to the load waterline, arrangements are to be made to prevent any entry of water in the ship or in the engines while in normal operation.

20.2 Cooling and lagging

20.2.1 The exhaust gas pipes and silencers which pass through spaces of the ship where a temperature rise might be dangerous are to be efficiently cooled or lagged.

20.3 Water-cooled exhaust gas pipes

20.3.1 When water-cooled exhaust gas pipes are used, a high temperature alarm must be fitted after the water injection device. Alternatively, a low sea water flow rate may be fitted.

21 Refrigeration systems for the preservation of the catch

21.1 General

21.1.1 Refrigeration systems are to be so designed, constructed, tested and installed as to take account of the safety of the system and also the emission of chlorofluorocarbons (CFCs) or any other ozone-depleting substances from the refrigerant held in quantities or concentrations which are hazardous to human health or to the environment.

21.1.2 Methylchloride or CFCs whose ozone-depleting potential is higher than 5% of CFC-11 are not to be used as refrigerants.

21.1.3 Adequate guidance for the safe operation of the refrigeration system and emergency procedures are to be provided by means of suitable notices displayed on board the vessel.

21.2 Design of refrigeration systems

21.2.1 Refrigeration systems are to be adequately protected against vibration, shock, expansion, shrinkage, etc. and are to be provided with an automatic safety control device to prevent a dangerous rise in temperature and pressure.

21.2.2 Refrigeration systems in which toxic or flammable refrigerants are used are to be provided with drainage devices leading to a place where the refrigerant presents no danger to the vessel or to persons on board.

21.3 Arrangement of the refrigerating machinery spaces and refrigerating rooms

21.3.1 Any space containing refrigerating machinery, including condensers and gas tanks utilising toxic refrigerants, is to comply with the requirements of Pt C, Ch 1, Sec 16, [2.3.1] except that item b), Pt C, Ch 1, Sec 16, [2.3.1] is to be replaced by:

"At least one exit from each refrigerating machinery spaces and refrigerating rooms is to be capable of being opened from the inside. Where practicable, exits from spaces containing refrigerating machinery using toxic or flammable gas are not to lead directly into accommodation spaces."

21.3.2 For fishing vessels under 55 m in length, ammonia plants are allowed to be located in the machinery space provided that they comply with the provisions of Pt C, Ch 1, Sec 16, [2.3.2].

21.3.3 In refrigerating machinery spaces and refrigerating rooms, alarms are to be connected to the wheelhouse or control stations or escape exits to prevent persons from being trapped.

21.4 Breathing apparatus

21.4.1 Where any refrigerant harmful to persons is used in a refrigeration system, at least two sets of breathing apparatus are to be provided, one of which is to be placed in a position not likely to become inaccessible in the event of leakage of refrigerant. Breathing apparatus provided as part of the vessel's fire-fighting equipment may be considered as meeting all or part of this provision provided its location meets both purposes. Where self-contained breathing apparatus is used, spare cylinders are to be provided. Alternative arrangement authorized by the administration concerned may be accepted.

22 Propelling and auxiliary machinery in ships L ≥ 24 m

22.1

22.1.1 See Pt C, Ch 1, Sec 7.

23 Propelling and auxiliary machinery in ships L < 24 m

23.1 Shafting

23.1.1 Propeller shaft diameter

The diameter of the shaft going through the stern tube is not to be less than the diameter d, in mm, given by the following formula:

$$d = 126 \cdot \left(\frac{P}{N} \cdot \frac{560}{R_m + 160} \right)^{1/3}$$

where:

P : Maximum continuous power of the propulsion machinery, in kW

N : Shaft revolutions per minute

R_m : Minimum tensile strength of the shaft material, in N/mm^2. In the above formula, R_m is not to be taken greater than:

- 600 N/mm^2 for intermediate shaft in carbon and carbon manganese steels
- 800 N/mm^2 for intermediate shaft in alloy steels
- 600 N/mm^2 for propeller shaft in carbon, carbon manganese and alloy steels.

In case of stainless steels and in other particular cases, at the discretion of the Society, the value of R_m to be introduced in the above formula is to be specially considered.

Furthermore, the shaft diameter is not to be less than 25 mm for carbon steel or carbon manganese steel, and 20 mm for the other materials.

23.1.2 Intermediate shaft diameter

The diameter, in mm, of the intermediate shafts is not to be less than:

$d' = 0,87\ d$

23.2 Shaft accessories

23.2.1 Coupling bolts

The diameter of coupling bolts at the joining faces of the couplings is to be not less than the diameter D_b given, in mm, by the following formula, for intermediate, propeller and thrust shafts:

$$D_b = 0,65 \cdot \left(\frac{d'^3 \cdot (R_m + 160)}{n \cdot D_C \cdot R_b} \right)^{1/2}$$

where:

d' : Intermediate shaft diameter defined in [23.1.2]

n : Number of bolts in the coupling

D_C : Pitch circle diameter of the coupling bolts, in mm

R_b : Ultimate tensile strength of the bolt metal, in N/mm^2.

23.2.2 Shaft liners

The thickness of bronze shaft liners in way of the bushes and stern gland is to be not less than the thickness e, in mm, given by the following formula:

$$e = \frac{d + 230}{32}$$

where:

d : Actual diameter of the propeller shaft, in mm.

23.2.3 Stern bearing

a) Water lubrication

The length of the after bearing of the propeller shaft is not to be less than 4 times the rule diameter of the propeller shaft; furthermore the bearing is to be made of a type approved synthetic material.

For a bearing design substantiated by experimental data to the satisfaction of the Society, consideration may be given to a bearing length less than 4 times, but in no case less than 2 times, the rule diameter of the shaft in way of the bearing.

b) Oil lubrication

The length of the after bearing of the propeller shaft is not to be less than 2 times the rule diameter of the propeller shaft; furthermore:

- the bearing material is to be of the antifrictional type
- the oil gland is to be type approved.

c) Other arrangements

The other arrangements beside those defined in items a) and b) are to be given special consideration. The length of the after bearing of the propeller shaft is not to be less than 3,5 times the rule diameter of the propeller shaft.

23.2.4 Sealing gland

a) The sealing glands must be readily accessible, for inspection or replacement

b) The sealing glands are to be periodically inspected.

The temporary actions to be taken in case of accidental failure of a main component, as well as the inspection periodicity and the replacement schedule of parts subject to wear or deterioration, are to be specified.

The wear strength of non-metallic parts is to be established, either by satisfactory operations, or by relevant tests.

An easy to fit emergency device may be accepted.

24 Steering gear

24.1 Application

24.1.1 The provisions of this Article apply in addition to those of Pt C, Ch 1, Sec 14. with the exception of Sub-Articles Pt C, Ch 1, Sec 14, [2.1] to Pt C, Ch 1, Sec 14, [2.4].

24.2 General

24.2.1 Unless expressly provided otherwise, every ship is to be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.

24.3 Strength, performance and power operation of the steering gear

24.3.1 Main steering gear

The main steering gear and rudder stock are to be:

a) Of adequate strength and capable of steering the ship at maximum ahead service speed, which is to be demonstrated

b) Capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s

c) Operated by power where necessary to fulfil the requirements of b), and

d) So designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

24.3.2 Auxiliary steering gear

The auxiliary steering gear is to be:

a) Of adequate strength and sufficient to steer the ship at navigable speed and capable of being brought speedily into action in an emergency,

b) Capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater, and

c) Operated by power where necessary to meet the requirements of b).

24.3.3 Hand operation

Hand operation of steering gear is permitted when it requires an effort less than 160 N.

24.4 Control of the steering gear

24.4.1 Control of the main steering gear

a) Control of the main steering gear is to be provided on the navigation bridge.

b) Where the main steering gear is arranged in accordance with [24.5.2], two independent control systems are to be provided, both operable from the navigation bridge. This does not require duplication of the steering wheel or steering lever.

24.4.2 Control of the auxiliary steering gear

a) Control of the auxiliary steering gear is to be provided on the navigation bridge, in the steering gear compartment or in another suitable position.

b) If the auxiliary steering gear is power operated, its control system is also to be independent of that of the main steering gear.

24.5 Availability

24.5.1 Arrangement of main and auxiliary means for actuating the rudder

The main steering gear and the auxiliary means for actuating the rudder are to be arranged so that a single failure in one will not render the other inoperative.

24.5.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that the main steering gear is capable of operating the rudder:

a) As required in [24.3.1], item b), while operating with all power units

b) As required in [24.3.2], item b), while any one of the power units is out of operation.

24.5.3 Hydraulic power supply

Hydraulic power installations supplying steering gear may also supply other equipment at the same time provided that the operation of the steering gear is not affected:

a) By the operation of this equipment, or

b) By any failure of this equipment or of its hydraulic supply piping.

Section 5 Electrical Installations

1 General

1.1 Application

1.1.1 The requirements contained in Part C, Chapter 2 apply to fishing vessels, except for those contained in:

- Pt C, Ch 2, Sec 1, [2]; Pt C, Ch 2, Sec 1, [4];
- Pt C, Ch 2, Sec 3, [2]; Pt C, Ch 2, Sec 3, [3];
- Pt C, Ch 2, Sec 11, [1]; Pt C, Ch 2, Sec 11, [2]; Pt C, Ch 2, Sec 11, [3]; Pt C, Ch 2, Sec 11, [4], and Pt C, Ch 2, Sec 11, [5],

which are replaced by all those contained in this Section.

2 Documentation to be submitted

2.1

2.1.1 The documents listed in Tab 1 are to be submitted.

Where the length is less than 24 m, the Society may give exemptions to the documents to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents to be submitted
1	A	Single line diagram of main and emergency power and lighting systems
2	I	Electrical power balance (main and emergency supply)
3	A	Calculation of short-circuit currents for each installation in which the sum of rated power of the energy sources which may be connected contemporaneously to the network is greater than 500 kW
4	A	List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, the nominal and setting values of the protective and control devices
5	A	Single line diagram and detailed diagram of the main switchboard
6	A	Single line diagram and detailed diagram of the emergency switchboard
7	A	Diagram of the most important section boards and motor control centres (above 100 kW)
8	A	Detailed diagram of the navigation-light switchboard
(1) A: to be submitted for approval; I: to be submitted for information.		

3 Type approved components

3.1

3.1.1 The following components are to be type approved case-by-case based on submission of adequate documentation and execution of tests:

- Electrical cables
- Switching devices (circuit-breakers, contactors, disconnectors, etc.) and overcurrent protective devices
- Electronic components used for tasks essential to safety.

4 General requirements for system design, location and installation

4.1 Design and construction

4.1.1 The design and construction of electrical installations are to be such as to provide:

a) The services necessary to maintain the vessel in normal operational and habitable conditions without having recourse to an emergency source of power,

b) The services listed in [4.4.2] when failure of the main source of electrical power occurs, and

c) Protection of the crew and vessel from electrical hazards.

4.2 Distribution

4.2.1 Supply systems

Distribution systems given in Pt C, Ch 2, Sec 3, [1] may be used on board of fishing vessels. Where length is less than 24 m, on d.c. installations, two-wire systems with one pole earthed may be used.

4.2.2 General requirements given in Pt C, Ch 2, Sec 3, [1.1.3] and Pt C, Ch 2, Sec 3, [1.1.4] are applicable to fishing vessels. In addition, where length is less than 24 m, every conductor carrying the current from a circuit to the hull is to have the same cross section as the corresponding insulated conductor. In d.c. installations, one pole of generator and of supplied appliances is to be earthed in readily accessible places.

4.2.3 The hull return system of distribution is not to be used for power, heating or lighting in vessels of 75 m of length and over.

4.2.4 The requirement in [4.2.3] does not preclude, under conditions approved by the Society, the use of:

a) Impressed current cathodic protective systems

b) Limited and locally earthed systems, or

c) Insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable conditions.

4.2.5 Where the hull return system is used, all final subcircuits (all circuits fitted after the last protective device) are to be two-wire and special precautions are to be taken to the satisfaction of the Society.

4.3 Main source of electrical power

4.3.1 Where the electrical power constitutes the only means of maintaining auxiliary services essential for the propulsion and safety of the vessel, a main source of electrical power is to be provided which is to include at least two generating sets, one of which may be driven by the main engine. The Society may accept other arrangements having equivalent electrical capability.

4.3.2 The power of these sets is to be such as to ensure the functioning of the services referred to in [4.1.1] a), excluding the power required in fishing activities, processing and preservation of the catch, in the event of any one of the generating sets being stopped. However, in vessels of less than 45 m, in the event of any one of the generating sets being stopped, it is only necessary to ensure the functioning of the services essential for the propulsion and safety of the vessel.

4.3.3 The arrangement of the vessel's main source of electrical power is to be such that the services referred to in [4.1.1] a) can be maintained regardless of the number of revolutions and direction of the main propelling engines or shafting.

4.3.4 Where transformers constitute an essential part of the supply system required by this item, the system is to be so arranged as to ensure continuity of the supply.

4.3.5 The arrangement of the main electric lighting system is to be such that a fire or other casualty in spaces containing the main source of electrical power, including transformers, if any, will not render the emergency lighting system inoperative.

4.3.6 The arrangement of the emergency electric lighting system is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, including transformers, if any, will not render the main lighting system inoperative.

4.3.7 Navigation lights, if solely electrical, are to be supplied through their own separate switchboard and adequate means for the monitoring of such lights are to be provided.

4.3.8 For fishing vessels propelled by electrical power and having two or more constant voltage propulsion generating sets which constitute the source of electrical energy for the ship's auxiliary services, see Pt C, Ch 2, Sec 14.

4.3.9 Load shedding or other equivalent arrangements should be provided to protect the generators required in the present Article against sustained overload.

The load shedding should be automatic.

The non-essential services, services for habitability and, if necessary, the secondary essential services may be shed in order to make sure that the connected generator set(s) is/are not overloaded.

4.3.10 Where paralleling operation of the generators is needed, necessary instruments for this operation are to be provided.

4.3.11 Where the length is greater than 24 m, the measurement devices are to be in accordance with the general requirements given in Pt C, Ch 2, Sec 8, [1.7.1] to Pt C, Ch 2, Sec 8, [1.7.8].

Where the length is less than 24 m.

a) The following instruments are to be normally provided:
   - for each generator:
     - one ammeter with mark indicating the normal full load value (for installations where the rated voltage is below 24 V and fitted with a load limit, only a charge control lamp can be provided)
     - one voltmeter
     - one lamp indicator to indicate the generator voltage
     - one battery charging control lamp
   - for each battery:
     - one ammeter with two-sided deviation
   - for busbars:
     - one voltmeter
   - for three-phase system, it is to be provided, in addition:
     - one ammeter per phase or one ammeter with commutator permitting to measure the current in each phase
     - one frequency meter
     - one synchronising device if alternators are arranged to run in parallel
     - one wattmeter for alternators over 50 kVA.

b) Protection:

   Measuring instruments connected to the network and indicator lamps are to be protected by a fuse. Where a measuring instrument and an indicator lamp correspond to the same indication, each one is to be provided with a fuse.

Requirements given in Pt C, Ch 2, Sec 8, [1.7.13], Pt C, Ch 2, Sec 8, [1.7.14] and Pt C, Ch 2, Sec 8, [1.7.15], are applicable to all fishing vessels.

4.3.12 The main switchboards are to be placed far away from flammable gas, vapour accumulation, acid gas or other liquid. Their location is to be such that there is no pipe carrying liquids above, beside or near them. When this cannot be avoided, pipes are to be built joint less or provided with protections.

4.4 Emergency source of electrical power

4.4.1 A self-contained emergency source of electrical power located, to the satisfaction of the Society, outside machinery spaces is to be provided and so arranged as to ensure its functioning in the event of fire or other causes of failure of the main electrical installations.

4.4.2 The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of serving simultaneously for a period of at least three hours:

a) The VHF radio installation and, if applicable:
   1) the MF radio installation
   2) the ship earth station and
   3) the MF/HF radio installation

b) Internal communication equipment, fire detection systems and signals which may be required in an emergency

c) The navigation lights if solely electrical and the emergency lights:
   1) of launching stations and overside of the vessel
   2) in all alleyways, stairways and exits
   3) in spaces containing machinery or the emergency source of power
   4) in control stations, and
   5) in fishing handling and fish processing spaces, and

d) The operation of the emergency fire pump, if any.

4.4.3 The emergency source of electrical power may be either a generator or an accumulator battery.

4.4.4 Where the emergency source of electrical power is a generator, it is to be provided both with an independent fuel supply and with efficient starting arrangements to the satisfaction of the Society. Unless a second independent means of starting the emergency generator is provided, the single source of stored energy is to be protected to preclude its complete depletion by the automatic starting system.

4.4.5 Where the emergency source of electrical power is an accumulator battery, it is to be capable of carrying the emergency load without recharging whilst maintaining the voltage of the battery throughout the discharge period within plus or minus 12% of its nominal voltage. In the event of failure of the main power supply, this accumulator battery is to be automatically connected

to the emergency switchboard and is to immediately supply at least those services specified in [4.4.2], items b) and c). The emergency switchboard is to be provided with an auxiliary switch allowing the battery to be connected manually, in case of failure of the automatic connection system.

4.4.6 When the length is less than 24 m, the start of the main engine of the ship is carried out by electrical starter and where the emergency source of power is a storage battery, the emergency source of power can be considered as the second required starting power source for the main engine. Then:

- the starting system cables are to be designed to permit the necessary commutation with a change over switch and fixed connections.
- the available power of the emergency battery is to be adequate to supply the emergency services during the time specified in above paragraphs, and, in principle, have the capacity of six consecutive starts of the main engine.

4.4.7 The emergency switchboard is to be installed as near as is practicable to the emergency source of power and is to be located in accordance with [4.4.1]. Where the emergency source of power is a generator, the emergency switchboard is to be located in the same place unless the operation of the emergency switchboard would thereby be impaired.

4.4.8 An accumulator battery, other than batteries fitted for the radio transmitter and receiver in vessels of less than 45 m in length, is to be installed in a well ventilated space which is not to be the space containing the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the battery constituting the emergency source of power is being discharged.

4.4.9 The emergency switchboard is to be supplied in normal operation from the main switchboard by an interconnector feeder which is to be protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

For ships whose length is equal to or greater than 45 m, the arrangement at the emergency switchboard is to be such that in the event of failure of the main power supply an automatic connection of the emergency supply will be provided.

4.4.10 The emergency generator and its prime mover and any emergency accumulator battery are to be so arranged as to ensure that they will function at full rated power when the vessel is upright and when rolling up to an angle of 22,5° either way and simultaneously pitching 10° by bow or stern, or in any combination of angles within those limits.

4.4.11 The emergency source of electrical power and automation starting equipment is to be so constructed and arranged as to enable adequate testing to be carried out by the crew while the vessel is in operating condition.

4.4.12 When the length is less than 24 m, the Society may exempt Owners from the installation of the emergency source of electrical power.

4.4.13 Where emergency generator is used in port, the requirements stated in Pt C, Ch 2, Sec 3, [2.4] are applicable.

4.5 Precaution against shock, fire and other hazards of electrical origin

4.5.1 Exposed permanently fixed metal parts of electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live are to be earthed (grounded) unless:

a) They are supplied at a voltage not exceeding 50 V direct current or 50 V, root mean square between conductors; auto-transformers are not to be used for the purpose of achieving this alternative current voltage, or

b) They are supplied at a voltage not exceeding 250 V by safety isolating transformers supplying one consuming device only, or

c) They are constructed in accordance with the principle of double insulation.

4.5.2 Electrical apparatus is to be so constructed and installed that it will not cause injury when handled or touched in the normal manner.

4.5.3 Main and emergency switchboards are to be so arranged as to afford easy access as may be needed to apparatus and equipment, without danger to attendants. The sides, backs and, where necessary, the fronts of switchboards are to be suitably guarded. Exposed live parts having voltages to earth exceeding a voltage to be specified by the Society are not to be installed on the front of the switchboards. There are to be non-conducting mats or gratings at the front and rear, where necessary.

4.5.4 When a distribution system, whether primary or secondary, for power, heating or lighting, with no connection to earth is used, a device capable of monitoring the insulation level to earth is to be provided.

4.5.5 When a distribution system is in accordance with [4.5.4] and a voltage exceeding 50 V direct current or 50 V, root mean square, between conductors, is used, a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication of abnormally low insulation values is to be provided.

4.5.6 Distribution systems which are supplied at a voltage not exceeding 250 V direct current or 250 V, root mean square, between conductors, and which are limited in extent, may comply with [4.5.4], subject to the satisfaction of the Society.

4.5.7 Except as permitted by the Society in exceptional circumstances, all metal sheaths and armour of cables are to be electrically continuous and to be earthed.

4.5.8 All electrical cables are to be at least of a flame-retardant type and are to be so installed as not to impair their original flame-retarding properties. The Society may permit the use of special types of cables where necessary for specific applications, such as radio frequency cables, which do not comply with the foregoing.

4.5.9 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are as far as practicable to be routed clear of galleys, machinery spaces of category A and other high fire risk areas and laundries, fish handling and fish processing spaces and other spaces where there is a high moisture content. Cables connecting fire pumps to the emergency switchboard are to be of a fire-resistant type where they pass through high fire risk areas. Where practicable, all such cables are to be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads which may be caused by a fire in an adjacent space.

4.5.10 Where cables which are installed in spaces where the risk of fire or explosion exists in the event of an electrical fault, special precautions against such risk are to be taken to the satisfaction of the Society. When fitted in places where flammable gases or vapours may accumulate, or in rooms intended to mainly contain accumulators, paint or similar material, the equipment is to be of a safety type approved by the Society.

4.5.11 Wiring is to be supported in such a manner as to avoid chafing or other damage.

4.5.12 Terminations and joints in all conductors are to be made such that they retain the original electrical, mechanical, flame-retarding and, where necessary, fire-resisting properties of the cable.

4.5.13 Cables installed in refrigerated compartments are to be suitable for low temperatures and high humidity.

4.5.14 Circuits are to be protected against short-circuit. Circuits are also to be protected against overload, unless otherwise specified in these Rules or where the Society may exceptionally otherwise permit.

4.5.15 The rating or appropriate setting of the overload protective device for each circuit is to be permanently indicated at the location of the protective device.

4.5.16 Lighting fittings are to be so arranged as to prevent temperature rises which could damage the wiring and to prevent surrounding material from becoming excessively hot.

4.5.17 Lighting or power circuits terminating in a space where the risk of fire or explosion exists are to be provided with isolating switches outside the space.

4.5.18 The housing of accumulator batteries is to be constructed and ventilated to the satisfaction of the Society.

4.5.19 Electrical or other equipment which may constitute a source of ignition of flammable vapours is not permitted in these compartments except as provided for in [4.5.21].

4.5.20 An accumulator battery is not to be located in accommodation spaces unless installed in a hermetically sealed container.

4.5.21 In spaces where flammable mixtures are liable to collect and in any rooms assigned principally to the containment of an accumulator battery, no electrical equipment is to be installed unless the Society is satisfied that it is:

a) Essential for operational purposes

b) Of a type which will not ignite the mixture concerned

c) Appropriate for the space concerned, and

d) Appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.

4.5.22 Where shore supply is provided, requirements stated in Pt C, Ch 2, Sec 3, [3.7] are applicable. The socket-outlets used for the supply of the ship from the shore network and when the voltage exceeds 50 V, are to be provided with a built-in earth connection provided to be connected to the earth.

4.5.23 On board of ship with non-metallic hull, bonding is to be provided between the frame of generators, the bed plate of the pumps, the bed plate of the motors and the earth plate, if fitted. All the elements of the fuel installation are to be electrically bonded and connected to the above bonding.

4.5.24 If the protection of cables against overload current is made by fuses, their rating is to be selected according to the maximum permissible current in the cable.

4.5.25 Particular attention is to be paid to the fixing of equipment made of cast brass or other copper alloys on aluminium decks or bulkheads.

4.5.26 Heaters

Electric heaters are to be permanently installed.

They are to be constructed and installed in such a way that clothing or other combustible objects cannot be left there or be hung above these heaters.

4.6 Engineers' alarm

4.6.1 In vessels of 75 m in length and over, an engineers' alarm is to be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and is to be clearly audible in the engineers' accommodation.

4.7 Steering gear

4.7.1 For the steering gear, general requirements included in Ch 15, Sec 4, [24] are applicable. Where length of the fishing vessel is less than 24 m, the Society may give exemptions to these requirements.

4.8 Fire detection and fire alarm

4.8.1 The fire detection and fire alarm system are to be supplied from the main source and an emergency source.

4.9 Alarm - Communication

4.9.1 For the crew muster, an alarm system operated from the bridge is to be provided. This system may be part of the general alarm system.

4.9.2 Ships of 12 m or more in length are to be equipped with a system enabling the general broadcast of alarm and messages in case of damage or ship escape.

4.9.3 The bridge operating compartment is to be fitted with the internal communication and control means as quoted hereunder:

- An engine room telegraph with repeater, or equivalent system, is to be provided and duplicated by another independent system, enabling the communication with the engine control position. If the size and arrangement of the ship make useless the equipment mentioned above, only a dual calling system such as telephone, megaphone or bell may be fitted.
- If the propelling machinery is remote-controlled from the bridge-operating compartment, at least one order telegraph, reversible or with repeater, is to be fitted at the local direct engine control position.
- Furthermore, unless the size and arrangement of the ship make useless this equipment, the bridge operating compartment is to be connected by means of a reversible voice communication system to the local control of steering gear, propelling machinery and the service accommodation.

4.10 Final sub-circuits

4.10.1 Every final sub-circuit connected to a distribution panel is to be protected, unless otherwise specified, by a fuse or a maximum current circuit breaker on each insulated pole. These circuits can be controlled by single pole switches in dry spaces of the accommodation.

A separate final sub-circuit is to be provided for every apparatus assuming an essential service and for each motor rated 1 kW or more.

4.11 Electric cables

4.11.1 General requirements given in Pt C, Ch 2, Sec 3, [9] are applicable for all fishing vessels.

4.11.2 Choice of runs

a) Cable runs are to be as straight and accessible as possible.

b) Cable runs are to be fitted away from source of water. Cables exposed to the risk of mechanical damage, if not armoured or enclosed in steel conduits, are to be protected by a casing.

c) The cable runs are to be so designed that the internal radius of bend does not exceed at any point the permissible value for the cable concerned. In the absence of values specified by the manufacturer, the following values are to be adopted as minima for the internal radius of bend:

- 4 d for rubber-like insulated cables without metallic covering (6 d if d > 25 mm)
- 6 d for rubber-like insulated cables with metallic covering or for silicone asbestos cables.

4.11.3 Cable fixing

a) Cables are to be bunched as regularly as possible.

b) Cables are to be so arranged as to avoid any friction; if needed, fastening parts are to be used. The distance between fastening parts is to be defined according to the cable nature and the special installation provisions. The distance between two fastening parts is generally not to exceed 0,50 m.

4.12 Switchboard

4.12.1 Installation

When the voltage exceeds 50 volts, AC or DC, an insulated mat, grating or impregnated wood surface is to be provided in front of switchboards and also at the rear if access to the rear is provided. The insulated mat, grating or surface is to be oil-resistant and non-slippery.

4.12.2 Design - Construction

Generally, switchboards or enclosures containing switchboards are to be constructed of durable, flame retardant and non-hygroscopic materials. In addition, mechanical features of the materials are to be suitable for the service conditions.

Live parts normally submitted to a voltage exceeding 50 volts are not to be installed without protection on the front of switchboards.

The switchboard frame or enclosures containing switchboards are to be earthed.

Air clearances between live parts are to be suitable for the rated voltage or protected by means of insulating and fireproof shields.

Every switchboard part, including the connections, is to be easily accessible.

4.13 Rotating electrical machines

4.13.1 Location - Installation

Machines and their gears are to be located in spaces suitably ventilated where flammable dusts, vapours or gases cannot accumulate. Where this condition, in the case of motors, cannot be fulfilled, the Society is to be advised accordingly and a special consideration will be given, after examination, of the proposed arrangements.

4.13.2 Earthing

Bed plates and framework of machines or generating sets are to be efficiently earthed; no insulating material is to be placed between the prime movers and the alternators and generally between the prime movers and the driven machines, unless there is one efficient earthing of each part.

4.13.3 Generators speed control

Prime movers for driving generators are to be fitted with a speed regulator in such a way that at all loads between no load and rated power the permanent speed variations cannot exceed 5% of the rated speed. For Diesel generating sets, when the rated power is suddenly thrown off, the transient speed variations are not to exceed 10%.

The generators driven by the propulsion engine, by a geared shaft or by an auxiliary set intended for another purpose, are to be designed with consideration that the variation of speed may occur in service.

4.13.4 Particular provisions for the motor control device - Starters

a) DC and AC motors of more than 0,5 kW are to be fitted with a under-voltage protection and a protection against overload. Under-voltage protection may not be provided for steering gear motor or any other motor the continuous running of, which is essential.

b) When the starter, the selector switch or all other equipment used to cut off completely the supply of the motor is at a distance from it, it is recommended that one of the following measures be applied:

- locking of the disconnecting switch of the circuit in open position, or removable fuses
- installation near to the motor of a second disconnecting switch.

4.14 Batteries

4.14.1 As general, Pt C, Ch 2, Sec 11, [6] is applicable.

4.14.2 Where the length is less than 24 m, the following is also applicable:

- Batteries which can be charged by a power exceeding 2 kW (calculated from the maximum charging current of the charging apparatus and from the nominal voltage of the battery) are to be installed in a ventilated suitable space or in a locker protected from dangerous gas accumulation.

4.14.3 For all fishing vessels:

a) All spaces especially reserved for batteries, including lockers or chests, boxes, shelves are to be protected against the deleterious effects of the electrolyte. The batteries are to be so manufactured and installed that no electrolyte discharge may occur under 22°5 inclination.

b) Deck boxes are to be provided with exhaust ducts on top and air inlets at lower part. The assembly is to be suitably weatherproof. For battery of low capacity, only openings on the top of the battery box are required.

5 Lightning protection

5.1 Application

5.1.1 A lightning protection system is to be fitted for:

a) Ships with wooden hull or of composite construction with wooden masts

b) Ships with wooden hull or of composite construction with steel masts

c) Ships with steel hull with wooden masts.

5.1.2 Lightning conductors are to be fitted to all wooden masts or topmasts. In vessels constructed of non-conductive materials, the lightning conductors are to be connected to a copper plate fixed to the vessel's hull well below the waterline.

5.1.3 Lightning fittings exposed to risks of mechanical damage are to be suitably protected or strongly built.

Section 6 Fire Protection

1 General

1.1 Application

1.1.1 This Section provides requirements for the fire safety of ships having the service notation **fishing vessel** and a length of 65 m or less.

Type approval of materials and products listed in a) to h) of [1.3.1] and Articles [5], [6], [7], [8], [9] and [10] of this Section apply only to ships assigned with the additional service feature **F**.

The fire safety of fishing vessels having a length of more than 65 m is to comply with the provisions of Part C, Chapter 4.

1.2 National regulations

1.2.1 When the Administration of the State whose flag the ship is entitled to fly has issued specific regulations covering fire protection, the Society may accept such regulations for Classification purpose in lieu of those given in this Chapter.

In such cases, a memorandum indicating those specific regulations applied is issued.

1.3 Type approved products

1.3.1 The following materials, equipment, systems or products in general used for fire protection are be type approved by the Society, except for special cases for which the acceptance may be given for individual ships on the basis of suitable documentation and/or tests:

a) Fire-resisting and fire-retarding divisions (bulkheads or decks) and associated doors

b) Automatic closing devices of fire doors

c) Materials for pipes penetrating A or B class divisions (where they are not of steel or other equivalent material)

d) Materials for oil or fuel oil pipes (where they are not of steel or copper and its alloys)

e) Bulkhead or deck penetrations for electrical cables passing through A or B class divisions

f) Materials with low flame spread characteristics including paints, varnishes and similar, when they are required to have such characteristics

g) Non-combustible materials

h) Non-readily igniting materials for primary deck coverings

i) Fixed foam fire-extinguishing systems and portable foam fire-extinguishing units

j) Sensing heads for automatic fire alarm and fire detection systems

k) Portable fire extinguishers

l) Extinguishing media substitute for the foam in fire extinguishers

m) Fire hoses

n) Fire hydrants and nozzles, including dual-purpose nozzles, for fire hoses.

As regards the type approval, the requirements of Part A apply.

1.4 Definitions

1.4.1 Foreword

For the purpose of this Section, unless otherwise stated, the definitions given in [1.4.2] to [1.4.13] below apply.

1.4.2 Non-combustible material

Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C. Such property is to be demonstrated by means of a test performed in accordance with a procedure accepted by the Society.

Any other material is to be considered as a combustible material.

1.4.3 Standard fire test - A class divisions - B class divisions

Refer to the definitions given in Pt C, Ch 4, Sec 1, [2.1.1] and Pt C, Ch 4, Sec 1, [2.4.1].

The Society may require a test of a prototype bulkhead of A or B class to ensure that it meets the requirements for integrity or temperature rise.

1.4.4 Steel or other equivalent material

Where the words "steel or other equivalent material" occur, "equivalent material" means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy with appropriate insulation).

1.4.5 Low flame spread

"Low flame spread" means that the surface thus described offers an adequate resistance to the spread of flame. Such a property is to be demonstrated by a test procedure deemed acceptable by the Society.

1.4.6 Accommodation spaces

"Accommodation spaces" are those spaces normally used by the crew such as corridors, lavatories, cabins, offices, lounges, dining rooms and other similar spaces.

1.4.7 Service spaces

"Service spaces" are those spaces used for galleys, pantries containing cooking appliances, lockers, storerooms, workshops other than those forming part of machinery spaces, and similar spaces and trunks to such spaces. They also include the spaces used for the storage of the fishing nets.

1.4.8 Cargo spaces

"Cargo spaces" are all spaces used for the storage of the fish and the trunks to such spaces.

1.4.9 Machinery spaces of category A

"Machinery spaces of category A" are those spaces which contain internal combustion type machinery, used for:

- either main propulsion, or
- other purposes where such machinery has in the aggregate a total power output of not less than 750 kW,

or which contain any oil-fired boiler or fuel unit.

1.4.10 Machinery spaces

"Machinery spaces" are those machinery spaces of category A and all other spaces containing the propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electric motors, steering gear, oil filling stations, ventilation and air conditioning machinery, refrigerating machinery, stabilisers and similar spaces or trunks to such spaces.

1.4.11 Control stations

"Control stations" are those spaces containing the main navigating equipment, the ship's radio, the emergency source of power, or where the fire recording and fire control equipment is centralised.

1.4.12 Continuous B-class ceilings or linings

"Continuous B-class ceilings or linings" are those B-class ceilings or linings which terminate only at a "A" or "B" class division.

1.4.13 Materials which do not readily ignite

"Materials which do not readily ignite" are materials having approved characteristics of ignitability. These characteristics are to be obtained from a test procedure deemed acceptable by the Society.

2 Water fire-fighting system

2.1 General

2.1.1

a) Every ship is to be provided with a water fire-fighting system consisting of fire pumps, fire main, hydrants and hoses complying as applicable with the provisions of this Article, depending on the length of the ship.

b) The water fire-fighting system is to be independent of any other system of the ship. A connection with the washing system is permitted, however.

2.2 Number and type of fire pumps

2.2.1 Ships with L ≥ 45 m

All ships having a length of 45 m or more are to be provided with:

- at least two main fire pumps; one is to be independently driven and power operated and the other may be driven by the propulsion engine
- one emergency fire pump complying with [2.3.2], if a fire in any compartment could put all the fire pumps out of action.

Note 1: In the case of ships having a restricted navigation notation, the emergency fire pump may be omitted.

2.2.2 Ships with 24 m ≤ L < 45 m

Ships having a length of 24 m and above but less than 45 m are to be provided with:

- at least one main fire pump, independently driven and power-operated
- one emergency fire pump, except when the main fire pump, its source of power and its sea connection are located outside the spaces containing the propulsion machinery or oil fired boilers.

Note 1: In the case of ships having a restricted navigation notation, the emergency fire pump may be omitted.

2.2.3 Ships with 15 m ≤ L < 24 m

Ships having a length of 15 m and above but less than 24 m are to be provided with:

- at least one pump for the fire fighting service, power-operated
- one hand pump complying with [2.3.3], except when the power-operated pump is independently driven.

2.2.4 Ships with L < 15 m

Ships having a length less than 15 m are to be provided with at least one hand pump complying with [2.3.3].

2.3 Characteristics and arrangement of fire pumps

2.3.1 Main fire pumps

a) When delivering together for fire-fighting purposes at the pressure specified in [2.4.1], item b), the required fire pumps, other than hand pumps and the emergency fire pump, are to have a total capacity Q, in m^3/h, not less than that determined from the following formula:

$$Q = (0,15\sqrt{L(B+D)} + 2,25)^2$$

where:

L : Length of the ship between perpendiculars, in m

B : Breadth of the ship, in m

D : Depth of the ship, measured up to the bulkhead deck, in m.

However, the total capacity of the main fire pumps need not exceed 180 m^3/h.

b) When several power-operated fire pumps other than the fire emergency pump are required, each pump is to have a capacity not less than 80% of the total required capacity divided by the minimum number of required fire pumps. Each such pump is, in any event, to be capable of delivering at least the two jets of water required in [2.4.1], item b). These fire pumps are to be capable of supplying the fire main system under the required conditions. Where more than the minimum number of required pumps are installed, the capacity of such additional pumps may be less than that required above, provided it is deemed satisfactory by the Society.

c) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided they are not normally used for pumping oil and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable change-over arrangements are fitted.

2.3.2 Emergency fire pumps

The emergency fire pump and its location are to comply with the following requirements:

a) The capacity of the pump is not to be less than 40% of the total capacity of the main fire pumps and in any case not less than:
   - 25 m^3/h for ships having a length of 45 m or more
   - 15 m^3/h for ships having a length less than 45 m.

b) When the pump is delivering the quantity of water required by clause a) above, the pressure at any hydrant is not to be less than the minimum pressures required in [2.4.1], item b).

c) Any diesel driven power source for the emergency fire pump is to be capable of being readily started in all the temperature conditions likely to be encountered, taking into account the navigation assigned to the ship.

d) Any service fuel tank is to contain a sufficient quantity of fuel to enable the emergency fire pump to run on full load for at least 3 h and sufficient reserves of fuel are to be available outside machinery spaces to enable the pump to run on full load for an additional 15 h.

e) The emergency fire pump is to be of the self-priming type and capable of operating under all conditions of immersion, list, trim, roll and pitch likely to be encountered in service. The sea suction valve is to be capable of being operated from a position close to the pump.

f) The emergency fire pump and its source of power are to be installed in a safe and readily accessible position located in a separate compartment as far as possible from the compartment containing the main fire pumps and their source of power.

When this is not practicable, the emergency fire pump may be located in a compartment adjacent to the one containing the main fire pumps, provided that the bulkheads and decks forming the boundaries of both compartments are insulated to A-60 standard.

Note 1: For ships having a length less than 45 m and a restricted navigation notation, the emergency fire pump may also be portable and located in a space other than the one containing the main fire pump.

2.3.3 Hand pumps

Hand pumps are to have a capacity of at least two thirds of that required for the bilge pump and a total suction head to project a sufficient jet of water to the satisfaction of the Society.

2.4 Fire main, hydrants and hoses

2.4.1 Diameter of, and pressure in, the fire main

a) The diameter of the fire main and water service pipes is to be sufficient for the effective distribution of the maximum required discharge from all the main fire pumps operating simultaneously. However, this diameter need only be sufficient for the discharge of 140 m^3/h.

b) When main power fire pumps are delivering the quantity of water required in [2.3.1] item a) through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is not to be less than 0,25 N/mm^2.

2.4.2 Pipes and hydrants

a) Materials readily rendered ineffective by heat are not to be used for the fire main and hydrants unless adequately protected. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing.

b) A valve is to be fitted to serve each fire hose so that any hose may be removed while the fire pumps are at work.

c) Isolating valves to separate the section of the fire main within the machinery space containing the main fire pump or pumps from the rest of the fire main are to be fitted in easily accessible and safe positions outside the machinery space. The fire main is to be so arranged that, when the isolating valves are shut, all the hydrants of the ship except those in the machinery space referred to above may be supplied with water by a fire pump not located in this machinery space through pipes which do not enter this space. Exceptionally, the Society may permit short lengths of the emergency fire pump suction and discharge piping to penetrate the machinery space if it is impracticable to route it externally provided that the integrity of the fire main is maintained by the enclosure of the piping in a substantial steel casing.

2.4.3 Number and position of hydrants

a) Fire hydrants are to be positioned so as to allow easy and quick connection of fire hoses and so that at least one jet can be directed into any part of the ship which is normally accessible during navigation.

b) The jet required in item a) is to be from a single length of fire hose.

c) In addition to the requirements of item a), machinery spaces of category A are to be provided with at least one fire hydrant complete with fire hose and dual-purpose nozzle. This fire hydrant is to be located outside the space and near the entrance.

d) For every required fire hydrant there is to be one fire hose. At least one spare fire hose is to be provided in addition to this requirement.

e) Single lengths of fire hose are not to exceed 20 m.

f) Fire hoses are to be of an approved material. Each fire hose is to be provided with couplings and a dual-purpose nozzle.

g) Except where fire hoses are permanently attached to the fire main, the couplings of fire hoses and nozzles are to be completely interchangeable.

h) The nozzles as required by item f) are to be appropriate to the delivery capacity of the fire pumps fitted, but in any case are to have a diameter of not less than 12 mm.

3 Fire-extinguishing appliances in machinery spaces

3.1 Fixed fire-extinguishing systems

3.1.1 Spaces containing oil-fired boilers, fuel oil units or internal combustion machinery having a total power output of not less than 750 kW are to be provided with one of the following fixed fire-extinguishing systems, to the satisfaction of the Society:

- a pressure water-spraying installation
- a fire-smothering gas installation
- a fire-extinguishing installation using vapours from low toxicity vapourizing liquids, or
- a fire-extinguishing installation using high expansion foam.

3.1.2 Fire-extinguishing systems using halogenated hydrocarbon are prohibited.

3.1.3 Where the engine and boiler rooms are not entirely separated from each other or if fuel oil can drain from the boiler room into the engine room, the combined engine and boiler rooms are to be considered as one compartment.

3.1.4 Installations listed in [3.1.1] are to be controlled from readily accessible positions outside the protected spaces not likely to be cut off by a fire in the protected space. Arrangements are to be made to ensure the supply of power and water necessary for the operation of the system in the event of fire in the protected space.

3.2 Additional fire-extinguishing arrangements

3.2.1 In all machinery spaces of category A at least two portable extinguishers are to be provided, of a type suitable for extinguishing fires involving fuel oil. Where such spaces contain machinery, which has a total power output of not less than 250 kW, at least three such extinguishers are to be provided. One of the extinguishers is to be stowed near the entrance to the space.

3.2.2 Ships having machinery spaces not protected by a fixed fire-extinguishing system are to be provided with at least a 45 l foam extinguisher or its equivalent, suitable for fighting oil fires. Where the size of the machinery spaces makes this provision impracticable, the Society may accept an additional number of portable fire extinguishers.

4 Fire extinguishers

4.1 Design and installation of fire extinguishers

4.1.1 General

All fire extinguishers are to be of a type and characteristics approved by the Society.

4.1.2 Equivalences

a) The Society reserves the right to establish equivalences between the various types of extinguishers.

b) Foam extinguishers may be replaced by equivalent extinguishers deemed appropriate by the Society.

4.1.3 Capacity of portable fire extinguishers

The capacity of required portable fluid extinguishers is not to be more than 13,5 l and not less than 9 l. Other extinguishers are to be at least as portable as the 13,5 l fluid extinguishers and are to have a fire-extinguishing capability at least equivalent to a 9 l fluid extinguisher.

4.1.4 Extinguishing medium

Fire extinguishers containing an extinguishing medium which, in the opinion of the Society, either by itself or under expected conditions of use gives off toxic gases in such quantities as to endanger persons are not permitted.

4.1.5 Installation

One of the portable fire extinguishers intended for use in any space is to be stowed near the entrance to that space.

4.2 Arrangement of fire extinguishers in accommodation and service spaces

4.2.1 General

All ships are to be provided with a sufficient number of portable fire extinguishers such that, in any accommodation or service spaces, a fire extinguisher is readily available in case of need. The type of the extinguisher is to be suitable for the type of fire which is likely to break out in the space concerned.

4.2.2 Number and type of extinguishers in the various spaces

a) Accommodation spaces are to be provided with at least:
   - 5 water or foam extinguishers, with a minimum of one such extinguisher for each ‘tweendeck, for ships having a length of 45 m or more
   - 3 water or foam extinguishers, with a minimum of one such extinguisher for each ‘tweendeck, for ships having a length of 24 m or more but less than 45 m
   - 1 water or foam extinguisher for each ‘tweendeck, for ships having a length less than 24 m.

b) In the vicinity of switchboards or section boards having a power of 20 kW or more, at least one carbon dioxide or powder extinguisher is to be provided.

c) Spaces containing a galley are to be provided with at least one foam or powder extinguisher.

d) Stores containing paint or other easily flammable products used on board are to be provided with at least one foam or carbon dioxide or powder extinguisher.

e) The navigation bridge is to be provided with at least one foam or carbon dioxide extinguisher.

f) The spaces containing the ship's radio equipment are to be provided with at least two carbon dioxide extinguishers.

Note 1: In small ships where the sole electric switchboard and/or the sole radio station is/are located on the navigation bridge or in the same position as the wheelhouse, only two extinguishers need be provided, one of the water type, the other of the carbon dioxide type or equivalent.

5 Structural fire protection

5.1

5.1.1 Hull, superstructures, structural bulkheads, decks and deckhouses are to be of steel. However, in special cases, the Society may accept the use of other equivalent materials (such as aluminium alloys) when the fire risk has been taken into account and provided that such material is so insulated that, in the event of fire, the structure cannot collapse.

5.2 Ships of 45 m in length and over

5.2.1 The decks and bulkheads separating machinery spaces of category A from accommodation spaces, service spaces or control stations are to be constructed to "A-60" Class standard where the machinery space of category A is not provided with a fixed fire-extinguishing system and to "A-30" Class standard where such a system is fitted. Decks and bulkheads separating other machinery spaces from accommodation, service spaces and control stations are to be constructed to "A-0" Class standard. Decks and bulkheads separating control stations from accommodation and service spaces are to be constructed to "A" Class standard, insulated to the satisfaction of the Society, except that the Society may permit the fitting of "B-15" Class divisions for separating such spaces as skipper's cabin from the wheelhouse.

5.2.2

a) The bulkheads of corridors serving accommodation spaces, service spaces and control stations are to be of "B-15" Class divisions.

b) Any bulkhead required by item a) is to extend from deck to deck unless a continuous ceiling of the same Class as the bulkhead is fitted on both sides of the bulkhead, in which case the bulkhead can terminate at the continuous ceiling.

5.2.3 Interior stairways serving accommodation spaces, service spaces or control stations are to be of steel or other equivalent material. Such stairways are to be within enclosures constructed of "B-15" Class divisions, provided that where a stairway penetrates only one deck, it need be enclosed at one level only.

5.2.4 Doors and other closures of openings in bulkheads and decks referred to in [5.2.1] and [5.2.2], doors fitted to stairway enclosures referred to in [5.2.3] and doors fitted in engine and boiler casings, are to be as far as practicable equivalent in resisting fire to the divisions in which they are fitted. Doors to machinery spaces of category A are to be self-closing.

5.2.5 Lift trunks, which pass through the accommodation and service spaces, are to be constructed of steel or equivalent material and are to be provided with means of closing which will permit control of draught and smoke.

5.2.6

a) The boundary bulkheads and decks of spaces containing any emergency source of power and bulkheads and decks between galleys, paint rooms, lamp rooms or any store-rooms which contain appreciable quantities of highly flammable materials, and accommodation spaces, service spaces or control stations are to be of "A" Class divisions insulated to the satisfaction of the Society, having in mind the risk of fire, except that the Society may accept "B-15" Class divisions between galley and accommodation spaces, service spaces and control stations when the galley contains electrically heated furnaces, electrically heated hot water appliances or other electrically heated appliances only.

b) Highly flammable products are to be carried in suitably sealed containers.

5.2.7 Where bulkheads or decks, required by [5.2.1], [5.2.2], [5.2.4] or [5.2.6] to be of "A" Class or "B" Class divisions, are penetrated for the passage of electrical cables, pipes, trunks, ducts, etc., arrangements are to be made to ensure that the fire integrity of the division is not impaired.

5.2.8 Air spaces enclosed behind ceilings, panellings or linings in accommodation spaces, service spaces and control stations are to be divided by close-fitting draught stops spaced not more than 7 m apart.

5.2.9 Windows and skylights to machinery spaces are to be as follows:

a) Where skylights can be opened they are to be capable of being closed from outside the space. Skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached.

b) Glass or similar materials are not to be fitted in machinery space boundaries. This does not preclude the use of wire-reinforced glass for skylights and glass in control rooms within the machinery spaces; and

c) In skylights referred to in item a) wire-reinforced glass is to be used.

5.2.10 Insulating materials in accommodation spaces, service spaces except domestic refrigerating compartments, control stations and machinery space are to be non-combustible. The surface of insulation fitted on the internal boundaries of machinery spaces of category A is to be impervious to oil or oil vapours.

5.2.11 Within compartments used for stowage of fish, combustible insulation is to be protected by close-fitting cladding.

5.2.12 Notwithstanding the requirements of this sub-article, the Society may accept "A-0" class divisions in lieu of "B-15" class divisions, having regard to the amount of combustible materials used in adjacent spaces.

5.3 Ships of 24 m in length and over but less than 45 m

5.3.1 The decks and bulkheads separating machinery spaces of category A from accommodation spaces, service spaces or control stations are to be constructed to "A-60" Class standard where the machinery space of category A is not provided with a fixed fire-extinguishing system and to "A-0" Class standard where such a system is fitted. Decks and bulkheads separating other machinery spaces from accommodation, service spaces and control stations are to be constructed to "A-0" Class standard. Decks and bulkheads separating control stations from accommodation and service spaces are to be constructed to "B" Class standard, insulated to the satisfaction of the Society.

5.3.2

a) The bulkheads of corridors serving accommodation spaces, service spaces or control stations are to be of "B-0" Class divisions.

b) Any bulkhead of corridors serving accommodation spaces, services and central stations is to extend from deck to deck unless a continuous ceiling of the same Class as the bulkhead is fitted on both sides of the bulkhead, in which case the bulkhead can terminate at the continuous ceiling.

5.3.3 Interior stairways serving accommodation spaces, service spaces or control stations are to be of steel or other equivalent material. Such stairways connecting more than two decks are to be within enclosures constructed of "B-15" Class divisions.

5.3.4 Doors and other closures of openings in bulkheads and decks referred to in [5.3.1] and [5.3.2], doors fitted to stairway enclosures referred to in [5.3.3] and doors fitted in engine and boiler casings, are to be as far as practicable equivalent in resisting fire to the divisions in which they are fitted. Doors to machinery spaces of category A are to be self-closing.

5.3.5 Lift trunks, which pass through the accommodation and service spaces, are to be constructed of steel or equivalent material and are to be provided with means of closing which will permit control of draught and smoke.

5.3.6

a) The boundary bulkheads and decks of spaces containing any emergency source of power and bulkheads and decks between galleys, paint rooms, lamp rooms or any store-rooms which contain appreciable quantities of highly flammable materials, and accommodation spaces, service spaces or control stations are to be of "A" Class divisions insulated to the satisfaction of the Society, having in mind the risk of fire, except that the Society may accept "B-15" Class divisions between galley and accommodation spaces, service spaces and control stations when the galley contains electrically heated furnaces, electrically heated hot water appliances or other electrically heated appliances only.

b) Highly flammable products are to be carried in suitably sealed containers.

5.3.7 Where bulkheads or decks, required by [5.3.1], [5.3.2], [5.3.4] or [5.3.6] to be of "A" Class or "B" Class divisions, are penetrated for the passage of electrical cables, pipes, trunks, ducts, etc., arrangements are to be made to ensure that the fire integrity of the division is not impaired.

5.3.8 Air spaces enclosed behind ceilings, panellings or linings in accommodation spaces, service spaces and control stations are to be divided by close-fitting draught stops spaced not more than 7 m apart.

5.3.9 Windows and skylights to machinery spaces are to be as follows:

a) Where skylights can be opened they are to be capable of being closed from outside the space. Skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached.

b) Glass or similar materials are not to be fitted in machinery space boundaries. This does not preclude the use of wire-reinforced glass for skylights and glass in control rooms within the machinery spaces; and

c) In skylights referred to item a) wire-reinforced glass is to be used.

5.3.10 Insulating materials in accommodation spaces, service spaces except domestic refrigerating compartments, control stations and machinery space are to be non-combustible. The surface of insulation fitted on the internal boundaries of machinery spaces of category A is to be impervious to oil or oil vapours.

5.3.11 Within compartments used for stowage of fish, combustible insulation is to be protected by close-fitting cladding.

5.3.12 Notwithstanding the requirements of this sub-article, the Society may accept "A-0" class divisions in lieu of "B-15" class divisions, having regard to the amount of combustible materials used in adjacent spaces.

5.4 Ships of less than 24 m in length

5.4.1 If steel decks or steel bulkheads in accommodation form the top or side of a fuel oil tank, they are to be coated with a non-combustible material of thickness and density to the satisfaction of the Society. Manholes or other openings to fuel oil tanks are not to be positioned in the accommodation.

5.4.2 External bulkheads and ship's sides, which delimit the accommodation spaces, are to be insulated with an appropriate insulating material. Bulkheads between accommodation spaces and machinery spaces or cargo spaces are to be insulated with a non-combustible material of thickness and density to the satisfaction of the Society. The surface of insulation fitted on the internal boundaries of the machinery spaces of category A and in spaces into which oil products may penetrate is to be impervious to oil or oil vapours.

5.4.3 All insulation in accommodation spaces and the wheelhouse is to be made of non-combustible materials. Combustible insulation fitted in spaces used for the storage or processing of fish is to be protected by a tight non-combustible covering.

5.4.4 Where there is a door between the accommodation space and the machinery space, this door is to be a self-closing door of steel or equivalent. Doors between galley rooms and dining rooms might be permitted, provided they are made of fire-retardant material; the same applies to a serving hatch. Where only electric cooking appliances are used in the galley, the galley and the mess room could be seen as one common room, divided into two appropriate compartments.

6 Ventilation systems

6.1

6.1.1 Means are to be provided to stop fans and close main openings to ventilation systems from outside the spaces served.

6.1.2 Means are to be provided for closing, from a safe position, the annular spaces around funnels.

6.1.3 Ventilation openings may be permitted in and under the doors in corridor bulkheads except that such openings are not permitted in and under stairway enclosure doors. The openings are to be provided only in the lower half of a door. Where such opening is in or under a door, the total net area of any such opening or openings is not to exceed 0,05 m^2. When such opening is cut in a door, it is to be fitted with a grill made of non-combustible material.

6.1.4 Ventilation ducts for machinery spaces of category A or galleys are not in general to pass through accommodation spaces, service spaces or control stations. Where the Society permits this arrangement, the ducts are to be constructed of steel or equivalent material and arranged to preserve the integrity of the divisions.

6.1.5 Ventilation ducts of accommodation spaces, service spaces or control stations are not in general to pass through machinery spaces of category A or through galleys. Where the Society permits this arrangement, the ducts are to be constructed of steel or equivalent material and arranged to preserve the integrity of the divisions.

6.1.6 Storerooms containing appreciable quantities of highly flammable products are to be provided with ventilation arrangements, which are separate from other ventilation systems. Ventilation is to be arranged at high and low levels and the inlets and outlets of ventilators are to be positioned in safe areas. Suitable wire mesh guards to arrest sparks are to be fitted over inlet and outlet ventilation openings.

6.1.7 Ventilation systems serving machinery spaces are to be independent of systems serving other spaces.

6.1.8 Where ducts serve spaces on both sides of "A" Class bulkheads or decks, dampers are to be fitted so as to prevent the spread of smoke between compartments. Manual dampers are to be operable from both sides of the bulkhead or the deck. Where the ducts with a free cross-sectional area exceeding 0,02 m^2 pass through "A" Class bulkheads or decks, automatic self-closing dampers are to be fitted.

6.1.9 Where the ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 pass through "A" Class bulkheads or decks, the opening is to be lined with a steel sheet sleeve, unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead and comply, in that portion of the duct, with the following:

a) For ducts with a free cross-sectional area exceeding 0,02 m^2, the sleeves are to have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length is preferably to be divided evenly on each side of the bulkhead. Ducts with free cross-sectional area exceeding 0,02 m^2 are to be provided with fire insulation. The insulation is to have at least the same fire integrity as the bulkhead or deck through which the duct passes. Equivalent penetration protection is to be provided to the satisfaction of the Society; and

b) Ducts with a free cross-sectional area exceeding 0,075 m^2 are to be fitted with fire dampers in addition to the recommendations of item a). The fire damper is to operate automatically but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" Class divisions without serving those spaces, provided those ducts have the same fire integrity as the bulkheads which they penetrate.

6.1.10 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges are to be constructed of "A" Class divisions. Each exhaust duct is to be fitted with:

- a grease trap readily removable for cleaning
- a fire damper located at the lower end of the duct
- arrangements, operable from within the galley, for shutting off the exhaust fans
- fixed means for extinguishing a fire within the duct.

The outlet ducts are to be easily accessible for cleaning.

7 Prevention of fire

7.1

7.1.1 The insulation of accommodation spaces, service spaces, control stations and machinery spaces is to consist of non-combustible material.

The insulation of refrigerated spaces and fish holds may consist of self-extinguishing materials, at the satisfaction of the Society.

7.1.2 Impervious linings and adhesives used for the insulation of refrigeration plants, as well as for the insulation of the related piping, may be of combustible materials, but their quantity is to be as limited as possible and their exposed surfaces are to have a resistance to the flame spread deemed satisfactory by the Society.

7.1.3 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours.

7.1.4 All exposed surfaces in accommodation spaces, service spaces, control stations, corridors, stairways trunks and associated hidden and inaccessible spaces behind bulkheads, ceilings, panels and linings are to have low flame spread characteristics.

7.1.5 Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke or toxic gases or vapours. The Society is to be satisfied that they are not of a nature to offer undue fire hazard.

7.1.6 Primary deck coverings within accommodation and service spaces and control stations are to be of approved material which will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures.

7.1.7

a) In accommodation and service spaces and control stations, pipes penetrating "A" or "B" Class divisions are to be of approved materials having regard to the temperature that such divisions are required to withstand. Where the Society permits the conveying of oil and combustible liquids through accommodation and service spaces, the pipes conveying oil or combustible liquids are to be of an approved material having regard to the fire risk.

b) Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

7.1.8 All waste receptacles other than those used in fish processing are to be constructed of non-combustible materials with no openings in the sides and bottom.

7.1.9 Machinery driving fuel oil transfer pumps, oil fuel unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they can be stopped in the event of a fire arising in the space in which they are located.

7.1.10 Drip trays are to be fitted where necessary to prevent oil leaking into bilges.

7.1.11 Electric heating appliances are to be so designed and installed as to reduce fire risks to a minimum. The decks and bulkheads on which they are installed are to be adequately protected with non-combustible material.

Heating appliances having exposed electrical parts or naked flame and stoves burning solid fuels are not permitted.

8 Means of escape

8.1

8.1.1 Stairways and ladders leading to and from all accommodation spaces and in spaces, in which the crew is normally employed, other than machinery spaces, are to be so arranged as to provide ready means of escape to the open deck and thence to the survival craft. In particular in relation to these spaces:

a) At all levels of accommodation, at least two widely separated means of escape are to be provided which may include the normal means of access from each restricted space or group of spaces

b)
- below the weather deck, the means of escape is to be a stairway and the second escape may be a trunk or a stairway; and
- above the weather deck, the means of escape are to be stairways or doors to an open deck or a combination thereof. Where it is not practicable to fit stairways or doors, one of these means of escape may be by means of adequately sized portholes or hatches protected where necessary against ice accretion

c) Exceptionally the Society may permit only one means of escape, due regard being paid to the nature and location of spaces and to the number of persons who normally might be accommodated or employed there

d) A corridor or part of a corridor from which there is only one route of escape is preferably not to exceed 2,5 m in length and in no case to be greater than 5,0 m in length, and

e) The width and continuity of the means of escape are to be to the satisfaction of the Society.

8.1.2 Two means of escape are to be provided from every machinery space of category A, which are to be as widely separated as possible. Vertical escapes are to be by means of steel ladders. Where the size of the machinery spaces makes it impracticable, one of these means of escape may be omitted. In such cases special consideration is to be given to the remaining exit.

8.1.3 Lifts are not to be considered as forming one of the required means of escape.

9 Fire detection

9.1

9.1.1 Where appreciable amounts of combustible materials are used on the construction of accommodation spaces, service spaces and control stations, special consideration is to be given to the installation of an automatic fire alarm and fire detection system in those spaces, having due regard to the size of those spaces, their arrangement and location relative to control stations as well as, where applicable, the flame-spread characteristics of the installed furniture.

10 Storage of gas cylinders and dangerous materials

10.1

10.1.1 Cylinders for compressed, liquefied or dissolved gases are to be clearly marked by means of prescribed identifying colours, are to have a clearly legible identification of the name and chemical formula of their contents and are to be properly secured.

10.1.2 Cylinders containing flammable or other dangerous gases and expended cylinders are to be stored, properly secured, on open decks and all valves, pressure regulators and pipes leading from such cylinders are to be protected against damage. Cylinders are to be protected against excessive variations in temperature, direct rays of the sun, and accumulation of snow. However, the Society may permit such cylinders to be stored in compartments complying with the requirements of [10.1.3] to [10.1.5].

10.1.3 Spaces containing highly flammable liquids, such as volatile paints, paraffin, benzole, etc., and, where permitted, liquefied gas are to have direct access from open decks only. Pressure-adjusting devices and relief valves are to exhaust within the compartment. Where boundary bulkheads of such compartments adjoin other enclosed spaces, they are to be gastight.

10.1.4 Except as necessary for service within the space, electrical wiring and fittings are not permitted within compartments used for the storage of highly flammable liquids or liquefied gases. Where such electrical fittings are installed, they are to be to the satisfaction of the Society for use in a flammable atmosphere. Sources of heat are to be kept clear of such spaces and “No Smoking” and “No Naked Light” notices are to be displayed in a prominent position.

10.1.5 Separate storage is to be provided for each type of compressed gas. Compartments used for the storage of such gases are not to be used for storage of other combustible products nor for tools or objects not part of the gas distribution system. However, the Society may relax these requirements considering the characteristics, volume and intended use of such compressed gases.

CHAPTER 16
OFFSHORE PATROL VESSELS

Section 1 General

Section 2 Stability

Section 3 Machinery

Section 4 Electricity and Automation

Section 5 Fire safety

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **OPV**, as defined in Pt A, Ch 1, Sec 2, [4.7.1].

1.1.2 Requirements apply as a function of number of persons on board as defined in [1.2] and in any case the number of passengers as defined in [1.2.3] is limited to 12.

1.1.3 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.4 References given in Tab 1 are specified for the use of technical criteria and do not mean the full adoption of referenced documents.

1.1.5 Attention is to be drawn on the possible additional requirements of the flag administration, if any.

1.2 Number of persons on board

1.2.1 The number of persons on board, N, is defined as the sum of:

- number of members of the crew
- number of special personnel, as defined in [1.2.2]
- number of passengers, as defined in [1.2.3], limited to 12.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement and hull integrity	L ≥ 90 m	• Part B • Part C, Chapter 1 **(1)**	• NR566 **(2)**
	L < 90 m	• NR600 • Part C, Chapter 1 **(1)**	• NR566 **(2)**
Hull	L ≥ 90 m	• Part B • NR396 **(3)**	• Part B • NR396 **(3)**
	L < 90 m	• NR600 **(2)**	• NR600 **(2)**
Stability		• NR566 • Ch 16, Sec 2	• NR566 • Ch 16, Sec 2
Machinery		• Part C • Ch 16, Sec 3	• NR566 **(2)** • Ch 16, Sec 3
Electrical installations and automation	N ≤ 60 **(4)**	• Part C	• NR566 **(2)**
	N > 60 **(4)**	• Part C • Ch 16, Sec 4	• NR566 **(2)** • Ch 16, Sec 4
Fire protection, detection and extinction		• See Tab 2	• See Tab 2

(1) Applicable requirements with respect to discharges and scuppers. see Pt C, Ch 1, Sec 10, [8].

(2) Application of these requirements are to be applied except that specific rules for passenger ships are not to be taken into account.

(3) In addition, requirements of NR396, Chapter 3 apply if $V \geq 7{,}16\Delta^{1/6}$ where V is the ship speed, in knots, and Δ is the displacement of the ship, in tons.

(4) The number of persons N is defined in [1.2].

Note 1:

NR396: Rules for the Classification of High Speed Craft.

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

1.2.2 Special personnel means all persons who are not passengers or members of the crew or children of under one year of age and who are carried on board in connection with the special purpose of that ship because of special work being carried out aboard that ship.

1.2.3 Passengers means every persons other than:

- the captain and the members of the crew or other persons employed or engaged in any capacity on board a ship on business of that ship and
- a child under one year of age.

Table 2 : Applicable requirements for fire safety

		Greater than 1000 GT	Between 500 and 1000 GT	Less than 500 GT	
				Unrestricted navigation	Restricted navigation
Steel or aluminium material	N ≤ 60	• Part C, Chapter 4 • Ch 16, Sec 5	• NR566	• NR566	• NR566
	N >60 **(1)**	• Part C, Chapter 4 • Ch 16, Sec 5	• Part C, Chapter 4 • Ch 16, Sec 5	• Part C, Chapter 4 • Ch 16, Sec 5	• NR566 • Ch 16, Sec 5
Composite material	N ≤ 60	NA **(2)**	• NR566	• NR566	• NR566
	N >60 **(1)**	NA **(2)**	NA **(2)**	NA **(2)**	• NR566 • Ch 16, Sec 5

(1) Offshore patrol vessels with more than 200 persons will be subject to special consideration by the Society.
(2) The present Chapter does not include this case (NA = not applicable).

Section 2 Stability

1 General

1.1 Application

1.1.1 Offshore patrol vessels may be assigned the service notation **OPV** only after it has been demonstrated that their stability is adequate.

Adequate stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Section.

In any case, the level of stability is not to be less than that provided by the Rules.

1.1.2 Intact stability

Ships granted with service notation **OPV** are to comply with:

- the provision of NR566, Ch 1, Sec 3, [2] regarding intact stability
- additional requirements of this Section, as applicable.

1.1.3 Damage stability

Damage stability should comply with provisions of NR566, Ch 1, Sec 3, [3] and additional requirements of this Section, as applicable, when at least one of the following conditions is met:

- the additional class notation **SDS** is granted
- the offshore patrol vessel is carrying more than 60 persons on board.

When damage stability is required, the additional class notation **SDS** is to be granted to the offshore patrol vessel.

In case a double bottom is not in accordance with the applicable rules then it is to be demonstrated that the ship is capable of withstanding bottom damages as per [3.2].

2 Intact Stability

2.1 Maximum turning angle

2.1.1 The angle of heel on account of turning may not exceed 10° when calculated using the following formula:

$$M_R = 0{,}02\, V_0^2 \Delta \frac{(KG - T_1/2)}{L_{WL}}$$

where:

M_R : Heeling moment, in t.m

V_0 : Maximum service speed, in m/s

T_1 : Mean draught above the keel, in m

KG : Height of centre of gravity above keel, in m

L_{WL} : Length measured at waterline corresponding to mean draught T_1.

2.2 Crowding angle for offshore patrol vessels carrying more than 60 persons

2.2.1 The angle of heel on account of crowding of persons to one side as defined below may not exceed 10°:

- a minimum weight of 75 kg is to be assumed for each person except that this value may be increased subject to the approval of the Society
- the height of the centre of gravity for person is to be assumed equal to 1m above deck level for person standing upright
- persons are to be considered as distributed to produce the most unfavourable combination of person heeling moment and/or initial metacentric height, which may be obtained in practice. In this connection, a value higher than four persons per square meter is not necessary.

3 Damage stability

3.1 Offshore patrol vessels carrying more than 60 persons

3.1.1 Application of requirements in NR566, Ch1, Sec3, [3] where the ship is considered as a passenger ship. However the requirement regarding the margin line is not to be considered.

3.2 Bottom damages

3.2.1 Bottom damage stability should comply with provision of NR566, Ch 1, Sec 3, [3] assuming bottom damages at any position along the ship's bottom and with an extent specified in Tab 1.

4 Damage control documentation for ships greater than or equal to 500 GT

4.1

4.1.1 The damage control documentation is to be submitted.

Table 1 : Assumed extent of damage

	For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 $L^{2/3}$ or 14,5 m, whichever is less	1/3 $L^{2/3}$ or 14,5 m, whichever is less
Transverse extent	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	B/20 or 2 m, whichever is less	B/20 or 2 m, whichever is less

Section 3 Machinery

1 General

1.1 Application

1.1.1 This Section concerns specific requirements regarding:

- capacity of service tanks for offshore patrol vessels with GT ≥ 500
- bilge pumping arrangement and prevention for progressive flooding for ship where damage stability is required in accordance with Ch 16, Sec 2, [1.1.3].

1.2 Capacity of service tanks for offshore patrol vessels with GT ≥ 500

1.2.1 Notwithstanding Pt C, Ch 1, Sec 10, [11.9.2], items b), c) and d), the capacity of service tanks should comply with NR566, Ch 2, Sec 6, [4.2.2], Note 2 excluded.

1.3 Progressive flooding

1.3.1 Application

Requirements [1.3.2] and [1.3.3] apply for offshore vessels for which damage stability is required.

1.3.2 Offshore patrol vessels with GT ≥ 500

Pt C, Ch 1, Sec 10, [5.5] is to be replaced by NR566, Ch 2, Sec 4, [5.9].

1.3.3 Offshore patrol vessels with GT < 500

Requirements as stated in NR566, Ch 2, Sec 4, [5.9] should apply.

1.4 Bilge pumping after flooding

1.4.1 Application

Requirements [1.4.2] and [1.4.3] apply for offshore vessels carrying more than 60 persons, for which damage stability is required.

1.4.2 Offshore patrol vessels with GT ≥ 500

In addition to the requirements as stated in Pt C, Ch 1, Sec 10, [6], provision of NR566, Ch 2, Sec 5, [1.6] should apply.

1.4.3 Offshore patrol vessels with GT < 500

Requirements as stated in NR566, Ch 2, Sec 5, [1.6] should apply.

Section 4 Electricity and Automation

1 General

1.1 Application

1.1.1 The requirements in this Section apply to offshore patrol vessels carrying more than 60 persons.

1.2 General alarm for ships with GT < 500

1.2.1 In addition to the requirements required in NR566, Ch 3, Sec 2, [3.11.1], the following requirements in NR566, Ch 3, Sec 2, [3.11.2], item b), should apply.

1.3 Emergency source of electrical power for ships with GT ≥ 500

1.3.1 Notwithstanding Pt C, Ch 2, Sec 3, [2.3.13], items b) and c), where the emergency source of electrical power is a generator, it shall be started automatically upon failure of the electrical power supply to the emergency switchboard and shall be automatically connected to the services referred in Pt C, Ch 2, Sec 3, [3.6.7]. The automatic starting system and the characteristics of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s.

In addition, a transitional source of emergency electrical power as specified in Pt C, Ch 2, Sec 3, [2.3.16] is to be provided in all cases when the emergency source of power is a generator.

1.4 Public address system for ships with GT ≥ 500

1.4.1 Where the public address system is used to supplement the general emergency alarm system as per Pt C, Ch 2, Sec 3, [3.14.2], it is to be arranged to operate on the main source of electrical power, the emergency source of electrical power and the transitional source of electrical power as required in [1.3] and Pt C, Ch 2, Sec 3, [3.6].

Section 5 Fire safety

1 General

1.1 Application

1.1.1 The applicable requirements are defined in Ch 16, Sec 1, Tab 2.

Part C, Chapter 4 and Rule Note NR566 are to be applied except that specific rules for passenger ships are not to be taken into account.

1.1.2 Fire safety of offshore patrol vessels carrying more than 200 persons will be subject to special consideration by the Society.

2 Materials

2.1 Steel or equivalent

2.1.1 In case the application of Part C, Chapter 4 is required, all indications “steel” (without the extension “or equivalent”) in these rules, can be replaced by “steel or equivalent”.

2.1.2 In case the application of Part C, Chapter 4 is required, aluminium bulkheads are generally to be insulated on both sides. However, if one of the two spaces have little or no fire risk such as voids, sanitary spaces, carbon dioxide rooms and similar spaces, insulation need only to be applied on the side that is exposed to the greatest fire risk.

3 Specific requirements

3.1 Offshore patrol vessels carrying more than 60 persons

3.1.1 For offshore patrol vessels carrying more than 60 persons and when the application of NR566 is authorised, the following additional rules apply:

- exposed surfaces of bulkheads, walls, linings and ceilings in accommodation and service spaces and control stations are to be low flame spread
- remote starting of one fire pump is to be provided from wheel house.

3.2 Ammunition storage compartments

3.2.1 The protection of ammunition storage compartments will be subject to special consideration by the Society. Applicable rules will be based on a common agreement with the shipowner and the shipyard, including aspects of fire detection, structural fire integrity, ventilation, fire fighting and electrical equipment protection.

Part D
Service Notations

CHAPTER 17
CEMENT CARRIERS

Section 1 General

Section 2 Ship Arrangement

Section 3 Hull and Stability

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **cement carrier**

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• Part B • Ch 17, Sec 2	• NR566 • Ch 17, Sec 2
	L < 65 m	• NR600	• NR566 • Ch 17, Sec 2
Hull	L ≥ 65 m	• Part B • Ch 17, Sec 3	• Part B • Ch 17, Sec 3
	L < 65 m	• NR600	• NR600
Stability		• Part B • Ch 17, Sec 3	• NR566 • Ch 17, Sec 3
Machinery and cargo systems		• Part C	• NR566
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT. NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.			

Section 2 Ship Arrangement

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the following document is to be submitted.

Table 1 : Additional documents to be submitted

No	I/A **(1)**	Document
1	I	Documentation of the loading and unloading system
(1) A: to be submitted for approval ; I: to be submitted for information		

2 General arrangement design

2.1 General

2.1.1 Cargo region

Within the cargo region, the ship is to have a continuous single deck. Deck openings are to be limited to those required for access and for the integration of the loading and unloading system.

2.1.2 Loading and unloading

The cargo holds are to be arranged with a closed loading and unloading system.

As far as practicable, the cargo is to be pumped in and out of each hold through deck penetrations.

3 Access arrangement

3.1 Access arrangement to double bottom and pipe tunnel

3.1.1 Means of access

Adequate means of access to the double bottom and the pipe tunnel, if any, are to be provided.

3.1.2 Manholes in the inner bottom, floors and girders

Manholes cut in the inner bottom are to be located at a minimum distance of one floor spacing from the lower stool, or transverse bulkhead if no stool is fitted.

The location and size of manholes in floors and girders are to be determined to facilitate the access to double bottom structures and their ventilation. However, they are to be avoided in the areas where high shear stresses may occur.

3.2 Access arrangement to and within spaces in, and forward of, the cargo area

3.2.1 Means of access

Ships of less than 150 m in length and of 20,000 gross tonnage and over, are to comply with SOLAS, Ch II-1, Reg 3-6.

In addition to the requirements in [3.2.2] and [3.2.3], as far as practicable, permanent or movable means of access stored on board are to be provided to ensure proper survey and maintenance of cargo holds and, in particular, of the lower part of cargo hold side frames.

3.2.2 Access hatches to cargo holds

Each access hatch is to have a clear opening of at least 600 mm x 600 mm.

Accesses and ladders are to be so arranged that personnel equipped with self-contained breathing apparatus may readily enter and leave the cargo hold.

Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with cargo hold ladders.

3.2.3 Ladders within cargo holds

Each cargo hold is to be provided with at least two ladders as far apart as practicable longitudinally. If possible these ladders are to be arranged diagonally, e.g. one ladder near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side, from the ship's centerline.

Ladders are to be so designed and arranged that the risk of damage from the cargo handling gear is minimized.

Vertical ladders may be permitted provided they are arranged above each other in line with other ladders to which they form access and resting positions are provided at not more than 9 metres apart.

Tunnels passing through cargo holds are to be equipped with ladders or steps at each end of the hold so that personnel may get across such tunnels.

Where it may be necessary for work to be carried out within a cargo hold preparatory to loading, consideration is to be given to suitable arrangements for the safe handling of portable staging or movable platforms.

Section 3 Hull and Stability

1 Stability

1.1 Intact stability

1.1.1 The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.5] is to comply with the requirements of Pt B, Ch 3, Sec 2 and as applicable, with the requirements of [1.1.2].

1.1.2 Except for ships which, according to their approved loading manual, are required to remain alongside for 12 hours after loading for the cement to settle, the requirements applicable to grain loading as defined in Pt B, Ch 4, Sec 3, [1.1] and Pt B, Ch 4, Sec 3, [1.2] are to be complied with.

For this purpose:

- reference is made to the definitions in Pt B, Ch 4, Sec 3, [1.1], except for the term “grain” to be understood as “non-settled cement” whose behavior is similar to that of grain in its natural state.
- the term “grain loading manual” is to be replaced by “loading manual”.

The cement settlement operational procedure, if any, is to be included in the ship's safety management system.

2 Structure design principles

2.1 Double bottom structure

2.1.1 Longitudinally framed double bottom

In ships greater than 120 m in length, the sloped double bottom is to be longitudinally framed.

The girder spacing is to be not greater than 4 times the spacing of bottom or inner bottom ordinary stiffeners and the floor spacing is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

2.1.2 Transversely framed double bottom

The sloped double bottom may be transversely framed in ships equal to or less than 120 m in length, when this is deemed acceptable by the Society on a case-by-case basis. In this case, however, the floor spacing is to be not greater than 2 frame spaces.

2.1.3 Floors in way of transverse bulkheads

The thickness and material properties of the supporting floors and pipe tunnel beams are to be not less than those required for the bulkhead plating or, when a stool is fitted, of the stool side plating.

2.2 Double side structure

2.2.1 Side primary supporting members

The spacing of transverse side primary supporting members is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

In any case, transverse side primary supporting members are to be fitted in line with web frames in topside tanks if any.

2.3 Topside structure

2.3.1 Topside tank sloping plates

In case of structural arrangement with topside tanks, the spacing of web frames within these tanks is to be not greater than 6 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Pt B, Ch 7, Sec 6 for the primary supporting members in the cargo holds.

2.3.2 Topside tank structure

In case of structural arrangement with topside tanks, they are to extend as far as possible within the machinery spaces and are to be adequately tapered.

3 Design loads

3.1 Hull girder loads in flooded conditions

3.1.1 Application

These requirements apply to all ships of length greater than or equal to 150 m.

3.1.2 Flooding assumptions

Each cargo hold is to be considered individually flooded up to the equilibrium waterline. For ships equipped with unloading systems that do not maintain watertightness, the extent of flooding is to be defined according to the damage stability assumptions.

For cement, a minimum permeability of 0,3 with a corresponding bulk density of 1,3 t/m^3 is to be used. In this respect, "permeability" means the ratio of the floodable volume between the particles of the cargo, to the gross volume of the bulk cargo.

The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken equal to 0,95.

For settled cargo conditions, the actual density of the cargo is to be used with a permeability of zero.

3.1.3 Still water hull girder loads

The permissible still water loads $Ms_{w,f}$ and $Q_{sw,f}$ in flooded conditions are to be calculated for each of the cargo and ballast conditions considered in the intact longitudinal strength calculations, as specified in Pt B, Ch 5, Sec 8 exception made of harbour conditions, docking condition afloat, loading and unloading transitory conditions in port and loading conditions encountered during ballast water exchange.

3.1.4 Wave hull girder loads

The wave loads in flooded conditions are taken as follows:

$M_{wv,f}$: Vertical wave bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, to be taken equal to 0,8 M_{wv}

M_{wv} : Vertical wave bending moment in seagoing operation, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 4, [3.1.1]

$Q_{wv,f}$: Vertical wave shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be taken equal to 0,8 Q_{wv}

Q_{wv} : Vertical wave shear force in seagoing condition, in kN, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 4, [3.2.1].

3.2 Load combinations for direct strength analysis

3.2.1 Applicable general load combinations

The following loading conditions are to be considered for direct strength analysis:

- full load at scantling draught T_{SC}, the loaded holds being completely filled with cargo.
- alternate loading conditions, if allowed by the loading manual, and draught amidships corresponding to these conditions in the loading manual.

Unless otherwise specified, these loading conditions are to be associated with the all dynamic load cases.

In addition, harbour conditions covering the loading/unloading sequences and associated draughts amidships as defined in the loading manual are to be considered.

4 Hull girder strength

4.1 Hull girder yield strength in flooded conditions

4.1.1 Application

These requirements apply to all ships of length greater than or equal to 150 m.

The damaged structure is assumed to remain fully effective in resisting the applied loads.

4.1.2 Stresses

The normal stresses in flooded conditions $\sigma_{L,f}$ at any point are to be obtained, in N/mm^2, according to the requirements given in Pt B, Ch 6, Sec 1, [2.1.1], in which M_{sw} and M_{wv} are to be replaced respectively by $M_{sw,f}$ and $M_{wv,f}$ as defined in [3.2].

The shear stresses $\tau_{L,f}$ of the side shell and the inner hull (longitudinal bulkhead) if any, at any point, are to be obtained, in N/ mm^2, according to the requirements given in Pt B, Ch 6, Sec 1, [2.2.1], in which Q_{sw} and Q_{wv} are to be replaced respectively by $Q_{sw,f}$ and $Q_{wv,f}$ as defined in [3.1].

The equivalent Von Mises stresses $\sigma_{eq,f}$ are to be obtained, in N/mm^2, according to the requirements given in Pt B, Ch 6, Sec 1, [3.5.1], in which σ_L and τ_L are to be replaced respectively by $\sigma_{L,f}$ and $\tau_{L,f}$.

4.1.3 Checking criteria

It is to be checked that the equivalent Von Mises stresses $\sigma_{eq,f}$ calculated according to [4.1.2] is in compliance with the acceptance criteria Pt B, Ch 6, Sec 1, [3.5.1] for seagoing operations.

5 Hull scantlings

5.1 Buckling check in flooded conditions

5.1.1 Application

These requirements apply to ships of length greater than or equal to 150 m.

5.1.2 General

Plating and ordinary stiffeners contributing to the hull girder longitudinal strength are to be checked in the flooded conditions specified in [3.2] according to Pt B, Ch 9, Sec 1, considering the hull girder stresses defined in [4.1.2].

6 Protection of hull metallic structures

6.1 Protection of cargo holds

6.1.1 Coating

It is the responsibility of the shipbuilder and of the Owner to choose coatings suitable for cement and to see that they are applied in accordance with the Manufacturer's requirements.

6.1.2 Application

The double side and transverse bulkhead areas to be coated are specified in [6.1.3] to [6.1.4].

6.1.3 Double side areas to be coated

The areas to be coated are, as a minimum, the internal surfaces of:

- the inner side plating
- the internal surfaces of the topside tank sloping plates, if any, for a distance of 300 mm above their lower ends.
- the sloped double bottom of cargo holds, for a distance of 300 mm below its upper end.

These areas are shown in Fig 1.

6.1.4 Transverse bulkhead areas to be coated

The areas to be coated are, as a minimum, the upper parts down to 300 mm below the top of the lower stool. Where there is no lower stool, the area to be coated is the whole transverse bulkhead.

These areas are shown in Fig 2.

Figure 1 : Double side - Areas to be coated

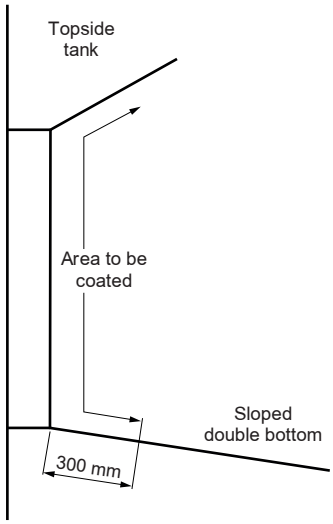
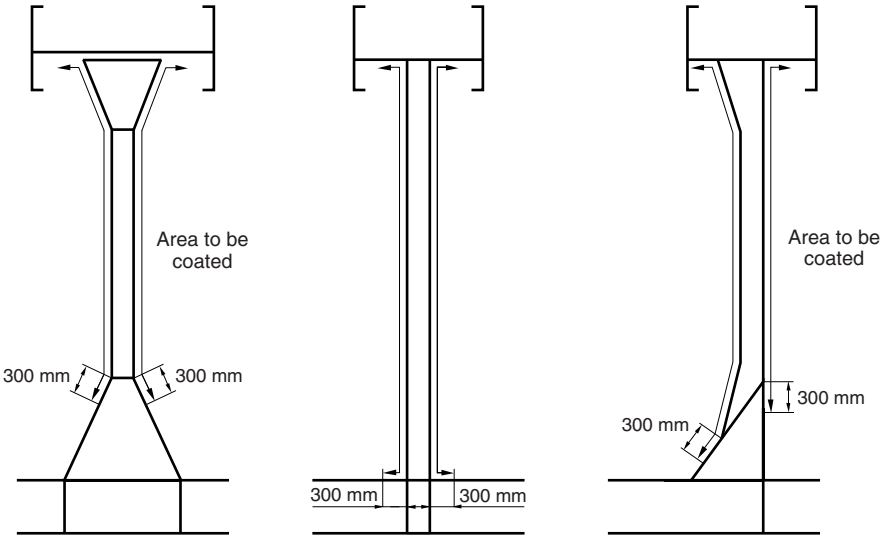


Figure 2 : Transverse bulkheads - Areas to be coated



7 Construction and testing

7.1 Welding and weld connections

7.1.1 The weld factors for some hull structural connections are specified in Tab 1. These weld factors are to be used, in lieu of the corresponding factors specified in Pt B, Ch 13, Sec 3, Tab 2, to calculate the leg length of fillet weld T connections according to Pt B, Ch 13, Sec 3, [3.2].

7.1.2 For the connections in Tab 1, continuous fillet welding is to be adopted.

Table 1 : Weld factor W_F

Hull area	Connection		Weld factor W_F
	of	to	
Double bottom in way of cargo holds	girders	bottom and inner bottom plating	0,48
		floors (interrupted girders)	
	floors	bottom and inner bottom plating	
		girders (interrupted floors)	

NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

Chapter 1	Tugs
Chapter 2	Anchor Handling Vessels
Chapter 3	Supply Vessels
Chapter 4	Fire Fighting Ships
Chapter 5	Oil Recovery Ships
Chapter 6	Cable-Laying Ships
Chapter 7	Diving Support Vessels
Chapter 8	Lifting Units
Chapter 9	Semi-Submersible Cargo Ships
Chapter 10	Standby Rescue Vessels
Chapter 11	Accommodation Units
Chapter 12	Pipe Laying Units

July 2025

Table of Content

Chapter 1 Tugs

Section 1 General

1 General 23

1.1 Application

2 Definitions 24

2.1 Design bollard pull
2.2 Reference towline force
2.3 Design load
2.4 Winch brake holding load
2.5 Towline breaking strength
2.6 Escort tugs indirect towing modes
2.7 Escort forces and speed
2.8 Towing winch emergency release systems

3 Fire safety 27

3.1 Suppression of fire

Section 2 Stability

1 Application 28

1.1

2 General requirements 28

2.1 Openings
2.2 Stability booklet
2.3 Intact stability

3 Additional requirements for escort tugs 30

3.1 Intact stability
3.2 Stability booklet
3.3 Inclinometer

Section 3 Hull Structure

1 General 33

1.1 Application
1.2 Documents to be submitted

2 General requirements 33

2.1 Typical design arrangements
2.2 Structure design principles
2.3 Hull scantlings
2.4 Other structures
2.5 Rudder and bulwarks
2.6 Anchoring and mooring equipment
2.7 Towing equipment

3 Additional requirements for escort tugs 39

3.1 Structural design principles
3.2 Equipment for escort operations

4 Additional requirements for salvage tugs 41

4.1 Equipment

Table of Content

Section 4 Integrated Tug / Barge Combination

1 General 42

1.1 Application
1.2 Permanent connections
1.3 Removable connections
1.4 Documents to be submitted

2 General arrangement design 43

2.1 Bulkhead arrangement

3 Integrated tug/barge combinations with permanent connection: stability, freeboard, design loads, hull scantlings and equipment 43

3.1 Stability calculations
3.2 Freeboard calculation
3.3 Still water hull girder loads
3.4 Wave hull girder loads
3.5 Still water local loads
3.6 Wave local loads
3.7 Hull girder strength
3.8 Scantlings of plating, ordinary stiffeners and primary supporting members
3.9 Equipment

4 Integrated tug/barge combination with removable connection: stability, freeboard, design loads, hull scantlings and equipment 44

4.1 Stability calculations
4.2 Freeboard calculation
4.3 Still water hull girder loads
4.4 Wave hull girder loads
4.5 Still water local loads
4.6 Dynamic local loads
4.7 Hull girder strength
4.8 Scantlings of plating, ordinary stiffeners and primary supporting members
4.9 Equipment

5 Connection 45

5.1 General
5.2 Scantlings

6 Other structures 46

6.1 Tug fore part
6.2 Tug aft part
6.3 Barge fore part
6.4 Barge aft part

7 Hull outfitting 47

7.1 Rudder and steering gear

8 Construction and testing 47

8.1 Test of the disconnection procedure of removable connection

Section 5 Testing

1 General 48

1.1 Application

2 General requirements 48

2.1 Bollard Pull test
2.2 Towing winches
2.3 Towing hooks
2.4 Emergency release system

Table of Content

3 Additional requirements for escort tugs 49

3.1 Escort performance simulations
3.2 Escort performance trials
3.3 Escort equipment testing

Appendix 1 Bollard Pull Trials

1 General 52

1.1 Purpose
1.2 Application

2 General requirements 52

2.1 Bollard pull trial
2.2 Bollard pull trial conditions
2.3 Engine rating
2.4 Steady state phase

3 Requirements for the trial site 53

3.1 Water depth and radius
3.2 Ship to shore distance
3.3 Current
3.4 Water density
3.5 Waves
3.6 Wind
3.7 Outside temperature
3.8 Towline
3.9 Vessel orientation relative to the quay

4 Instrumentation 55

4.1 Load cell
4.2 Engine speed measurement
4.3 Power measurement
4.4 Data logging

5 Trial preparation 59

5.1 Draught and trim
5.2 Propellers
5.3 Fuel

6 Trial execution 59

6.1 General
6.2 Steps to be performed

7 Data analysis 59

7.1 Validation of recorded data
7.2 Identification of steady state performance

8 Reporting 60

8.1 Trial report requirements

9 Part load bollard pull re-evaluation trials 60

9.1 Application
9.2 Trial overview
9.3 Prerequisites
9.4 Step 1: Evaluation of engine power
9.5 Step 2: Re-evaluation of propulsion efficiency
9.6 Step 3: Re-evaluation of bollard pull capability at available power
9.7 Presentation of results

Table of Content

Chapter 2 Anchor Handling Vessels

Section 1 General

1 General 65

1.1 Application
1.2 Definitions

Section 2 General Arrangement

1 General 67

1.1 Access to machinery space and spaces below the exposed cargo deck

Section 3 Stability

1 General 68

1.1 Assumptions
1.2 Definitions
1.3 Heeling moment
1.4 Permissible tension
1.5 Calculation of stability curves
1.6 Intact stability
1.7 Information to be displayed
1.8 Stability booklet
1.9 Stability instrument

Section 4 Hull Structure

1 Documentation 75

1.1 Documents to be submitted

2 General requirements 76

2.1 Deck equipment
2.2 Loading manual
2.3 Design loads
2.4 Deck structure
2.5 Anchor handling winch
2.6 Anchor handling deck equipment other than winches
2.7 Stern roller
2.8 Wire
2.9 Anchor handling arrangements

Section 5 Testing

1 General 79

1.1 Load test
1.2 Functional test
1.3 Operational tests

Chapter 3 Supply Vessels

Section 1 General

1 General 81

1.1 Application
1.2 IMO regulations
1.3 Classification notations
1.4 Applicable rules
1.5 Specific requirements
1.6 Definitions

2 Documents to be submitted 86

2.1 General

Section 2 General Arrangement

1 Compartment arrangement 88

1.1 General
1.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features
1.3 Compartment arrangement in way of oil product cargo tanks

2 Access arrangement and access to spaces 89

2.1 Access arrangement in way of cargo tanks for oil products
2.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

3 Arrangement for hull and forecastle openings 90

3.1 General

Section 3 Stability

1 General 91

1.1 Application
1.2 Relaxation
1.3 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

2 Intact stability 91

2.1 General
2.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

3 Damage stability 92

3.1 Damage stability when the additional class notation SDS is assigned

Section 4 Hull Structure

1 Structure design principles 95

1.1 General
1.2 Side structure exposed to bumping
1.3 Deck structure
1.4 Structure of cement tanks and mud compartments
1.5 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features
1.6 Additional requirements for ships granted with notation -acids

2 Design loads 96

2.1 Dry uniform cargoes

Table of Content

3 Hull scantlings 96

3.1 Plating
3.2 Stiffeners
3.3 Primary supporting members

4 Other structure 97

4.1 Aft part
4.2 Superstructures and deckhouses
4.3 Structure of cargo tanks

5 Hull outfitting 97

5.1 Rudders
5.2 Bulwarks
5.3 Equipment

Section 5 Machinery and Cargo Systems

1 Machinery systems 99

1.1 Cargo heating systems
1.2 Exhaust pipes
1.3 Inert gas system
1.4 Other machinery systems
1.5 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features
1.6 Additional requirements for ships granted with notations -FP≤60°C and/or -acids and/or -toxic
1.7 Additional requirements for ships granted with notation -FP≤60°C
1.8 Additional requirements for ships granted with notation -toxic
1.9 Additional requirements for ships granted with notation -acids

2 Cargo piping design 100

2.1 Cargo separation
2.2 Design and materials
2.3 Piping arrangement
2.4 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features
2.5 Additional requirements for ships granted with notations -FP≤60°C and/or -acids and/or -toxic

3 Cargo tanks 101

3.1 Cargo oil tanks
3.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

4 Cargo pumping system 101

4.1 General

5 Cargo tank fittings 101

5.1 Level gauging systems and overflow control
5.2 Cargo tank venting systems
5.3 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features
5.4 Additional requirements for ships granted with notation -toxic
5.5 Additional requirements for ships granted with notation -acids

6 Mechanical ventilation in the cargo area 102

6.1 Cargo pump-room ventilation
6.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

7 Discharging and loading of portable tanks on board 102

7.1 Ships granted with additional service features HNLS and/or WELLSTIM

8 Additional requirements for carriage of liquid carbon dioxide and liquid nitrogen 103
8.1 Ships granted with notation -LG

Section 6 Electrical Installations, Instrumentation and Automation
1 Hazardous location and types of equipment 104
1.1 General
2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features 104
2.1 General
2.2 Additional requirements for ships granted with notations -FP≤60°C and/or -toxic
2.3 Additional requirements for ships granted with notation -acid

Section 7 Fire Prevention, Protection and Extinction
1 General 105
1.1 Application
2 Fire prevention and protection 105
2.1 Ships granted with additional service features HNLS and/or WELLSTIM
3 Fire fighting 105
3.1 Ships carrying oil product
3.2 Ships granted with additional service features HNLS and/or WELLSTIM
4 Personnel protection 105
4.1 Ships carrying oil products
4.2 Ships granted with additional service features HNLS and/or WELLSTIM
4.3 Additional requirements for ships granted with notation -LG

Chapter 4 Fire Fighting Ships

Section 1 General
1 General 107
1.1 Application

Section 2 Hull and Stability
1 Stability 108
1.1 Intact stability
2 Structure design principles 109
2.1 Hull structure
2.2 Water and foam monitors
3 Other structures 109
3.1 Arrangement for hull and superstructure openings

Section 3 Machinery and Systems
1 General 110
1.1 Application
1.2 Documentation to be submitted
2 Design of machinery systems 110
2.1 Manoeuvrability
2.2 Fuel oil capacity
2.3 Scuppers

3 General requirements for fire-fighting systems 111
3.1 General
3.2 Independence of pumping and piping systems
3.3 Design and construction of piping systems
3.4 Monitors
3.5 Monitor control
4 Water fire-fighting system 112
4.1 Characteristics
4.2 Monitors
4.3 Piping
5 Fixed foam fire-extinguishing system 113
5.1 General
5.2 Characteristics
5.3 Arrangement
6 Portable fire-fighting equipment 114
6.1 Portable high expansion foam generator
6.2 Hydrants and fire hoses
7 Fire-fighter's outfits 114
7.1 Number and characteristics
7.2 Compressed air system for breathing apparatuses
8 Electrical installations 115
8.1 General
8.2 Searchlight
9 Testing 115
9.1 General
9.2 Type testing
9.3 Workshop tests
9.4 On board tests

Section 4 Fire Protection and Extinction
1 General 116
1.1 Application
1.2 Documents to be submitted
2 Fire protection of exposed surfaces 116
2.1 Structural fire protection
2.2 Deadlights and shutters
3 Self-protection water-spraying system 117
3.1 General
3.2 Capacity
3.3 Arrangement
3.4 Pumps
3.5 Piping system and spray nozzles

Chapter 5 Oil Recovery Ships

Section 1 General
1 General 119
1.1 Application
1.2 Definitions

Table of Content

Section 2 Hull and Stability

1 General 121

1.1 Documents to be submitted
1.2 General arrangement

2 Stability 122

2.1 Intact stability

3 Hull scantlings 122

3.1 Additional loads

4 Construction and testing 122

4.1

Section 3 Machinery and Systems

1 General 123

1.1 Documents to be submitted

2 Machinery installation and piping system other than oil recovery system 123

2.1 Sea water cooling system
2.2 Water fire-extinguishing system
2.3 Exhaust gas systems

3 Pumping system, piping system and pump-rooms intended for recovered oil 123

3.1 Design of pumping and piping systems
3.2 Arrangement of piping systems
3.3 Oil recovery pumps
3.4 Oil recovery pump-rooms

4 Oil recovery tank fittings 125

4.1 Vent pipes
4.2 Level gauging and overfilling control

5 Heating systems 125

5.1

6 Additional requirements 125

6.1 Ships assigned with the additional service feature OILTREAT

Section 4 Electrical Installations

1 General 126

1.1 Application
1.2 Documentation to be submitted

2 Design requirements 126

2.1 System of supply
2.2 Earth detection

3 Hazardous locations and types of equipment 127

3.1 Electrical equipment permitted in hazardous areas
3.2 Additional requirements for machinery installations in hazardous areas
3.3 Openings, access and ventilation conditions affecting the extent of hazardous areas

Section 5 Fire Protection, Detection and Extinction

1 General 129

1.1 Documents to be submitted

2 Mechanical ventilation in the oil recovery area 129

2.1 General
2.2 Ventilation of recovered oil pump rooms
2.3 Ventilation of enclosed spaces normally entered during oil recovery operation other than recovery oil pump rooms

3 Fire protection and fighting 130

3.1 Vapor detector
3.2 Structural fire protection
3.3 Fire-fighting

Chapter 6 Cable-Laying Ships

Section 1 General

1 General 132

1.1 Application

Section 2 Hull and Stability

1 General 133

1.1 Application
1.2 Documents to be submitted

2 Stability 133

2.1 Intact stability
2.2 Damage stability for ships where the notation SDS has been required

3 Hull scantlings 134

3.1 Cable tanks
3.2 Connection of the machinery and equipment with the hull structure

4 Other structures 134

4.1 Fore part

5 Hull outfitting 134

5.1 Equipment

Section 3 Machinery and Systems

1 General 135

1.1 Propulsion and manoeuvrability
1.2 Documents to be submitted

2 Arrangements for cable laying, hauling and repair 135

2.1 Typical machinery and equipment of cable laying ships
2.2 Design of cable handling machinery and equipment
2.3 Safety
2.4 Testing of cable handling machinery and equipment

3 On board trials 136

3.1 Ship trials
3.2 Equipment trials

Section 4 Fire Protection

1 Cable tanks 137

1.1 Means for fire fighting

Chapter 7 Diving Support Vessels

Section 1 General

1 General 139

1.1 Application
1.2 Scope

2 Diving system 140

2.1 Description
2.2 Classification of the diving system

3 References 141

3.1 Acronyms
3.2 Definitions
3.3 Reference rules and regulations

4 Documents to be submitted 142

4.1 General
4.2 Diving system documentation

Section 2 General Arrangement

1 General arrangement 145

1.1 Diving system arrangements
1.2 Machinery spaces
1.3 Hazardous areas
1.4 Breathing gas storage
1.5 Location of deck decompression chamber
1.6 Diving operations

2 Access arrangement 145

2.1 General
2.2 Means of evacuation

Section 3 Structural Assessment

1 Diving equipment foundations 146

1.1 General
1.2 Design loads
1.3 Allowable deflection

2 Launching system foundations 146

2.1 General

Section 4 Machinery and Systems

1 Sea inlets 147

1.1 General

2 Position keeping 147

2.1 General
2.2 Dynamic positioning

3 Electrical installations 147

3.1 General
3.2 Electrical power supply

4 Diving control station 148

4.1 General
4.2 Communication and relocation system

5 Diver heating system 148
5.1 Oil fired heaters

Section 5 Safety Features

1 Fire safety 149
1.1 Personnel protection
1.2 Structural fire protection
1.3 Detection and alarm
1.4 Fire-fighting equipment

2 Breathing gas system 150
2.1 Storage on board
2.2 Piping
2.3 Oxygen installation
2.4 Colour code
2.5 Signboards

3 Ventilation 151
3.1 General

4 Means of evacuation of the divers in saturation 151
4.1 Application
4.2 Hyperbaric evacuation system
4.3 Launching arrangement

Section 6 Specific Requirements for Ships Assigned with the Service Notation diving support-capable

1 General 152
1.1 Application
1.2 Documents to be submitted
1.3 Activation of service notation diving support-portable

2 General arrangement 153
2.1 General

3 Structural assessment 153
3.1 General

4 Machinery and systems 153
4.1 Position keeping
4.2 Sea inlets

5 Electrical installations and automations 153
5.1 Electrical power supply

6 Safety features 153
6.1 Fire safety
6.2 Breathing gas facilities
6.3 Ventilation

Section 7 Initial Inspection and Testing

1 General 155
1.1 Application
1.2 Non-permanent diving system

2 On-board testing 155
2.1 Diving installations

Chapter 8 Lifting Units

Section 1 General

1 General 158

1.1 Application
1.2 Scope

2 Lifting equipment 158

2.1 Certification of the lifting equipment

3 References 159

3.1 Acronyms
3.2 Definitions

4 Documents to be submitted 159

4.1 General
4.2 Lifting equipment documentation

Section 2 General Arrangement

1 General 161

1.1 Location of lifting appliances
1.2 Position of the crane during navigation

Section 3 Stability and Subdivision

1 General 162

1.1 Application
1.2 Definitions
1.3 Loading conditions
1.4 Trim and stability booklet
1.5 Model tests or direct calculations
1.6 Operational procedures against capsizing
1.7 Guidance on wind force

2 Intact stability 165

2.1 General stability criteria
2.2 Lifting operations conducted under environmental and operational limitations
2.3 Intact stability criteria in the event of sudden loss of the lifted load

3 Intact stability - alternative method 167

3.1 General
3.2 Alternative stability criteria

4 Additional intact stability criteria for crane overload test 168

4.1 General

5 Alternative damage stability for lifting operations for ships where additional class notation SDS is assigned 168

5.1 Application
5.2 Data to be submitted
5.3 Extent of damage
5.4 Alternative damage stability criteria

Section 4 Structural Assessment

1 General 170

1.1 Application

Table of Content

2 Structural design principles 170

2.1 General
2.2 Materials
2.3 Crane pedestal
2.4 Mobile lifting equipment
2.5 Devices for equipment stowage

3 Design loads 171

3.1 General
3.2 Hull girder loads
3.3 Loading conditions
3.4 Load cases
3.5 Lifting loads
3.6 Environmental loads

4 Hull girder strength 172

4.1 Principles
4.2 Hull girder stress

5 Allowable stress 173

5.1 General
5.2 Criteria
5.3 Basic allowable stress factor
5.4 Material strength
5.5 Equivalent stress

6 Buckling 174

6.1 General
6.2 Buckling strength criteria

7 Fatigue 175

7.1 General

8 Welding 175

8.1 Welding

Section 5 Machinery and Systems

1 General 176

1.1 Essential service
1.2 Hazardous areas

2 Position keeping 176

2.1 General
2.2 Dynamic positioning

3 Power supply 176

3.1 General

4 Lifting equipment controls 176

4.1 General
4.2 Overload prevention
4.3 Emergency system
4.4 Communication means

Section 6 Initial Inspection and Testing

1 General 178

1.1 Application

2 Onboard testing 178

2.1 Lifting installations

Table of Content

Section 7 Self-Elevating Ships

1 General 179

1.1 Application
1.2 Applicable rules and regulations

2 Classification principles 179

2.1 Classification limits
2.2 Design criteria statement

3 Definitions 180

3.1 Self-elevating ship
3.2 Modes of operation
3.3 Water levels, crest elevation and water depth
3.4 Configuration of a self-elevating unit in elevated position

4 Documents to be submitted 181

4.1 General
4.2 Operating manual

5 Structure design principles 182

5.1 General

6 Design conditions 182

6.1 General
6.2 Design conditions in elevated configuration
6.3 Transit conditions
6.4 Installation conditions

7 Structural analysis 183

7.1 Structural analysis in elevated position
7.2 Structural analysis in transit conditions and installations conditions

8 Jacking system 183

8.1 General
8.2 Electricity and automation

9 Fire and safety 184

9.1 Firefighting water supply

10 Construction survey 184

10.1 Self-elevating system

Chapter 9 Semi-Submersible Cargo Ships

Section 1 General

1 General 186

1.1 Application
1.2 Scope
1.3 Definitions

2 Documents to be submitted 187

2.1 General
2.2 Submersion operating manual

Section 2 General Arrangement

1 General 189

1.1 Draft marks

2 Ballast system arrangement 189
2.1 General
2.2 Central ballast control station

Section 3 Stability, Subdivision and Load Line

1 General 190
1.1 Loading instrument
1.2 Stability verification in temporary submerged conditions
1.3 Submersion procedure

2 Loading conditions 190
2.1 Transit conditions
2.2 Temporary submerged conditions

3 Intact stability in transit conditions 191
3.1 General
3.2 Buoyancy of the cargo

4 Damage stability in transit conditions 191
4.1 General
4.2 Buoyancy of the cargo
4.3 Type B freeboard
4.4 Type B-60 and B-100 freeboard

5 Intact stability in temporary submerged conditions 192
5.1 Criteria

6 Damage stability in temporary submerged conditions 193
6.1 General
6.2 Extent of damage
6.3 Compartment permeability
6.4 Damage criteria
6.5 Intermediate stage of flooding

7 Temporary submersion 193
7.1 International Load Line Certificate
7.2 Reserve buoyancy
7.3 Watertight openings
7.4 Openings

Section 4 Hull Structure

1 General 195
1.1 Application
1.2 Internal ballast pressure when using overflow tanks

2 Loading conditions 195
2.1 General

3 Design loads 195
3.1 Vertical wave bending moments
3.2 Horizontal wave bending moments
3.3 Vertical wave shear forces
3.4 Still water and dynamic pressures

4 Hull girder strength 196
4.1 General

5 Hull scantlings 196
5.1 General

6 Connection of the buoyancy casings 196
6.1 General
6.2 Design loads
6.3 Strength criteria
7 Fatigue strength assessment 197
7.1 General

Section 5 Machinery and Systems
1 General 198
1.1 Sea pressure
2 Ballast system 198
2.1 Failure modes and effects analysis
2.2 Failure modes
2.3 Definitions
2.4 Safety principles
2.5 Air pipes
2.6 Overflow tanks
2.7 Valves and actuators
2.8 Pressurized ballast tanks
2.9 Control and monitoring
3 Scuppers and sanitary discharges 200
3.1 Arrangement of scuppers and sanitary discharges

Section 6 Electrical Installations and Controls
1 Emergency source of power 201
1.1 Essential service
2 Controls 201
2.1 Draft mark automatic gauges
2.2 Ballast tanks gauging system
2.3 Ballast valves monitoring
2.4 Communication means

Section 7 Safety Features
1 Fire safety 202
1.1 General
1.2 Fire hydrants
2 Means of escape 202
2.1 Transit conditions
2.2 Temporary submerged conditions
3 Life-saving appliances 202
3.1 Temporary submerged conditions

Section 8 Initial Inspection and Testing
1 General 203
1.1 Application
2 Commissioning 203
2.1 At quay
2.2 Sea trials

Chapter 10 Standby Rescue Vessels

Section 1 General

1 General 205

1.1 Application
1.2 Documents to be submitted

Section 2 Rescue Arrangement, Accommodation and Equipment

1 General 207

1.1 Wheelhouse

2 Rescue equipment and facilities 207

2.1 Rescue zone
2.2 Scrambling net
2.3 Retrieval device
2.4 Rescue hooks
2.5 Fast Rescue Craft (FRC)
2.6 Safety equipment
2.7 Helicopter winching area

3 Survivors spaces 208

3.1 General
3.2 Decontamination area
3.3 Reception area
3.4 Treatment room
3.5 Accommodations
3.6 Non-survivors

4 Medical equipment and supplies 209

4.1 Water
4.2 Meals
4.3 Sundries
4.4 Medical equipment

Section 3 Hull and Stability

1 Stability 210

1.1 General
1.2 Additional requirements for towing operations
1.3 Additional requirements for water spraying

2 Hull 210

2.1 Vessels intended for towing operations
2.2 Lifeboat towing

Section 4 Machinery

1 General 211

1.1 Application
1.2 Ship propulsion and manoeuvrability
1.3 Exhaust pipes

Section 5 Electrical Installations

1 General 212

1.1 Electrical installations
1.2 Searchlight

Section 6 Fire Protection

1 General 213

1.1 Additional requirements for water spraying

Chapter 11 Accommodation Units

Section 1 General

1 General 215

1.1 Application
1.2 Applicable rules
1.3 Definitions

2 Documents to be submitted 216

2.1 General

Section 2 Electrical Installations and Automation

1 Interaction with operational ships or units 217

1.1 Application
1.2 Emergency Shutdown

Section 3 Fire Protection, Detection and Extinction

1 Interaction with operational ships or units 218

1.1 Application
1.2 Structural integrity
1.3 Installation layout

Section 4 Specific Requirements for Ships assigned the Additional Service Feature SPxxx-capable

1 General 219

1.1 Application
1.2 Documents to be submitted

2 Design review 219

2.1 Specific requirements
2.2 Stability assessment
2.3 Safe Return to Port

Section 5 Specific Requirements for Ships assigned the Additional Service Feature IPxxx-Capable

1 General 221

1.1 Application
1.2 Documents to be submitted

2 Design review 221

2.1 Specific requirements
2.2 Stability assessment
2.3 Safe Return to Port

Chapter 12 Pipe Laying Units

Section 1 General

1 General 225

1.1 Application
1.2 Scope

2 Pipe laying system 225

2.1 General
2.2 Certification of the pipe laying equipment

3 Documents to be submitted 226

3.1 General
3.2 Pipe laying equipment documentation

Section 2 Stability and Subdivision

1 General 227

1.1 Application
1.2 Loading conditions

Section 3 Structural assessment

1 General 228

1.1 Application

2 Hull girder strength 228

2.1 Principles

3 Materials and welding 228

3.1 Structural category and steel grades for the foundations of the pipe laying equipment

4 Pipe laying equipment foundations 228

4.1 General
4.2 Connecting bolts

Section 4 Initial Inspection and Testing

1 General 229

1.1 Application

2 Onboard testing 229

2.1 Pipe laying installations

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 1
TUGS

Section	1	General
Section	2	Stability
Section	3	Hull Structure
Section	4	Integrated Tug / Barge Combination
Section	5	Testing
Appendix	1	Bollard Pull Trials

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of one of the following service notations:

- **tug**
- **salvage tug**
- **escort tug**

as defined in Pt A, Ch 1, Sec 2, [4.10].

These service notations are always completed by the additional service feature **standardized design bollard pull = [T_{BP} /9,81] t**, where the design Bollard Pull T_{BP} is defined in [2.1].

The service notation **escort tug** is always completed by the following additional service features:

- **design maximum braking force = [$T_{X,MAX}$ /9,81] t**
- **design maximum escort speed = [V_{MAX}] kn**
- **design maximum steering force = [$T_{Y,MAX}$ /9,81] t**

where the design maximum values are defined in [2.7].

Ships which are likely to operate at sea within specific limits may, under certain conditions, be granted an operating area notation. For the definition of operating area notation, reference is made to Pt A, Ch 1, Sec 2, [5.3].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1 and specific requirements for testing as detailed in Ch 1, Sec 5
- Ch 1, Sec 4 for tugs assigned with the additional service feature **barge combined**.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 90 m	• Part B	• NR566
	L < 90 m	• NR600	• NR566
Hull	L ≥ 90 m	• Part B • Ch 1, Sec 3	• Part B • Ch 1, Sec 3
	L < 90 m	• NR600 • Ch 1, Sec 3	• NR600 • Ch 1, Sec 3
Stability		• Part B • Ch 1, Sec 2	• NR566 • Ch 1, Sec 2
Machinery and cargo systems		• Part C	• NR566
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566 • Article [3]
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.			

2 Definitions

2.1 Design bollard pull

2.1.1 The design bollard pull T_{BP}, in kN, is the maximum sustained towline force the tug is capable of generating at zero forward speed, to be initially specified by the Designer and to be verified by a full scale test, generally referred to as bollard pull test (see Ch 1, Sec 5, [2.1.1]).

2.1.2 Where the value of the design bollard pull is not provided, the following default values may be used for preliminary design review:

- $T_{BP} = 0{,}204\ N\ P_S$
  for conventional tugs with propellers fitted with nozzles, as described in Ch 1, Sec 3, [2.1.2]
- $T_{BP} = 0{,}176\ N\ P_S$
  for tractor tugs and ASD tugs with steerable propellers fitted with nozzles, as described in Ch 1, Sec 3, [2.1.3] and Ch 1, Sec 3, [2.1.4] respectively.

where:

N : Number of propellers

P_S : Maximum continuous power per propeller shaft, in kW.

2.2 Reference towline force

2.2.1 The reference (quasi-static) towline force T, in kN, is considered to represent:

- the design bollard pull T_{BP} for service notations **tug** and **salvage tug**, see [2.1]
- the design maximum steady towline force $T_{ESC,MAX}$ for service notation **escort tug**, see [2.7].

2.3 Design load

2.3.1 The design load DL, in kN, is the force taken into consideration for the strength assessment and testing of the towing equipment and the associated supporting structures, and is to be taken as not less than:

$DL = DAF\ T$

where:

T : Reference towline force, in kN, defined in [2.2.1]

DAF : Dynamic amplification factor taking into consideration dynamic effects.

Reference values for the DAF are given in:

- for service notations **tug** and **salvage tug**:
  Ch 1, Sec 3, [2.7.2]
- for service notation **escort tug**:
  Ch 1, Sec 3, [3.2.2].

2.4 Winch brake holding load

2.4.1 The winch brake holding load BHL, in kN, is the maximum towline force the towing winch can withstand without slipping of the (activated) brake, considering the towline at the first inner layer.

2.4.2 The BHL is a reference for the strength assessment and testing of towing winches and associated towing fittings (e.g. fairlead, staple, gob-eye) as well as their supporting structures.

2.5 Towline breaking strength

2.5.1 The towline breaking strength, in kN, is the tension required to cause failure of the towline (parting of the towline).

2.6 Escort tugs indirect towing modes

2.6.1 General

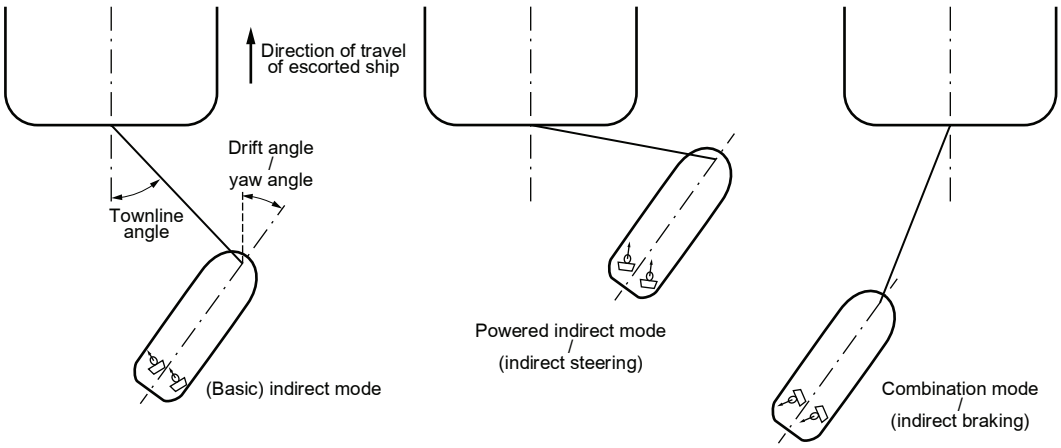
Escorting is considered to include active (emergency) steering, braking and otherwise controlling of the escorted ship by the tug operating in indirect towing mode, whereby the ahead speed of the escorted ship is within a typical speed range of 6 to 10 knots.

Escort tugs may work in different indirect towing modes, depending on the required action towards the escorted ship (e.g. steering, braking). The main indirect towing modes relevant for escort tugs are schematically shown in Fig 1.

Where reference is made to “indirect steering” the objective is to maximise the steering force in indirect towing mode.

Where reference is made to “indirect braking” the objective is to maximise the braking force in indirect towing mode.

Figure 1 : Schematic overview of indirect towing modes (escort tug)



2.6.2 Indirect towing principle

In indirect towing mode, the towline force is resulting from the (quasi-static) equilibrium condition reached between the forces and moments arising from the hydrodynamic lift and drag forces acting on the hull and appendices of the tug advancing through the water at a drift angle relative to the water flow, the thrust vector and the towline force.

Note 1: In direct towing mode the thrust is directly applied to generate the towline force, whereby hydrodynamic lift and drag forces play no significant role.

2.6.3 Various indirect towing modes

a) In (basic) indirect mode the towline force is generated primarily by the hydrodynamic forces acting on the hull and skeg, with the thrust used solely to maintain the desired drift angle (also referred to as yaw angle)

b) In powered indirect mode (indirect steering) the transverse component of thrust is used to maintain the desired drift angle, while a significant longitudinal component of thrust is applied in forward direction of the tug.

Compared to the (basic) indirect mode, the tug is operating more sideways of the escorted ship with a relatively large towline angle, generating a higher steering force

c) In combination mode (indirect braking) the same principle as for the indirect steering mode is applied, except that the longitudinal component of thrust is applied in aftward rather than forward direction.

Compared to the (basic) indirect mode, the tug is operating more behind the escorted ship with a relatively small towline angle, generating a higher braking force.

2.6.4 Specific considerations

a) For indirect towing modes it is recommended to design the tug to generate high (indirect) towline forces with minimal propulsion thrust, while respecting the limits imposed by stability and strength considerations (towing equipment, general hull structure).

b) The propulsion engines are to ensure sufficient thrust for manoeuvring the tug quickly for any drift angle (refer to angle β as defined in [2.7.2]).

c) In the case of loss of propulsion, the heeling moment due to the remaining forces is to lead to a safe equilibrium position of the tug with reduced heeling angle.

2.7 Escort forces and speed

2.7.1 The steady towline force during escorting, T_{ESC}, in kN, is the towline force associated with the considered (quasi-static) equilibrium in indirect towing mode, excluding short time-duration dynamic effects, for a given loading condition and escort speed V, see Fig 2. The steady towline force is applied by the tug on the stern of the escorted ship.

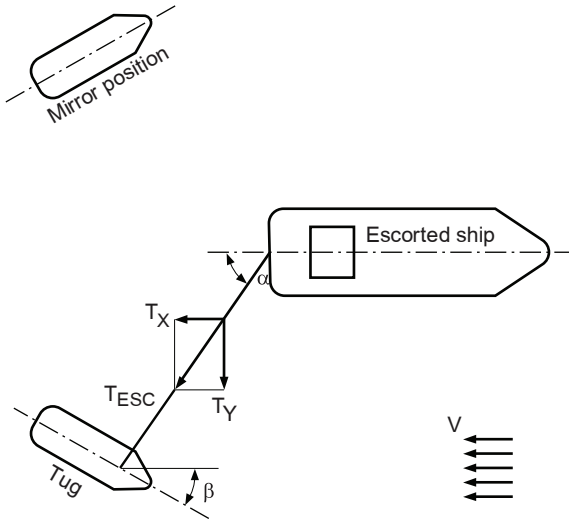
2.7.2 The following angles are defined in relation to escort operations (see Fig 2):

- The towline angle α, in deg, is the angle between the towline and the centreline of the escorted ship, and
- The drift angle β, in deg, is the angle between the centreline of the tug and the centreline of the escorted ship (also referred to as yaw angle).

2.7.3 The steady towline force T_{ESC} can be decomposed into a steering force T_Y and a braking force T_X (see Fig 2):

- The steering force T_Y, in kN, is the transverse component of the steady towline force T_{ESC} with respect to the escorted ship
- The braking force T_X, in kN, is the longitudinal component of the steady towline force T_{ESC} with respect to the escorted ship.

Figure 2 : Typical escort configuration



2.7.4 The design maximum escort speed V_{MAX}, in kn, is the highest escort speed V for which the escort tug is designed to perform escort operations, to be specified by the Designer and not to be taken higher than 10 knots.

Note 1: For high powered escort tugs with a free running speed of more than 15 knots the Society may, on a case-by-case basis, accept a design maximum escort speed of 12 knots.

2.7.5 The following rated values of the above defined escort forces are to be specified by the designer:

- The rated steady towline force $T_{ESC,R}$, in kN, is the highest anticipated steady towline force T_{ESC}, as obtained from the evaluation of the escort forces for a particular loading condition and escort speed, taking into account the applicable stability and strength criteria
- The rated steering force $T_{Y,R}$, in kN, is the highest anticipated steering force T_Y, as obtained from the evaluation of the escort forces for a particular loading condition and escort speed, taking into account the applicable stability and strength criteria
- The rated maximum braking force $T_{X,R}$, in kN, is the highest anticipated braking force T_X, as obtained from the evaluation of the escort forces for a particular loading condition and escort speed, taking into account the applicable stability and strength criteria.

2.7.6 The following maximum values of the above defined rated escort forces are to be specified by the designer:

- The design maximum steady towline force $T_{ESC,MAX}$, in kN, is the highest rated steady towline force $T_{ESC,R}$ over the applicable range of loading conditions and escort speeds
- The design maximum steering force $T_{Y,MAX}$, in kN, is the highest rated steering force $T_{Y,R}$ over the applicable range of loading conditions and escort speeds
- The design maximum braking force $T_{X,MAX}$, in kN, is the highest rated braking force $T_{X,R}$ over the applicable range of loading conditions and escort speeds.

2.7.7 The matrix of rated steady towline forces $T_{ESC,R}$, steering forces $T_{Y,R}$ and braking forces $T_{X,R}$ is to be initially specified by the Designer and to be verified by the Society on the basis of the results of:

- full scale trials, or
- model testing, or
- a computer simulation program accepted by the Society.

2.7.8 Full scale trials, where applicable, should be performed in accordance with a procedure agreed with the Society prior to commencement of the trials and comply with the requirements of Ch 1, Sec 5, [3.2].

2.7.9 Model testing, where applicable, should be performed in accordance with a procedure agreed with the Society prior to commencement of the tests and comply with the requirements of Ch 1, Sec 5, [3.2]. Special attention is to be paid to scale effects when processing the measurement result to create predictions at full scale.

2.7.10 Computer simulation programs for predicting escort performance are to comply with the requirements of Ch 1, Sec 5, [3.1].

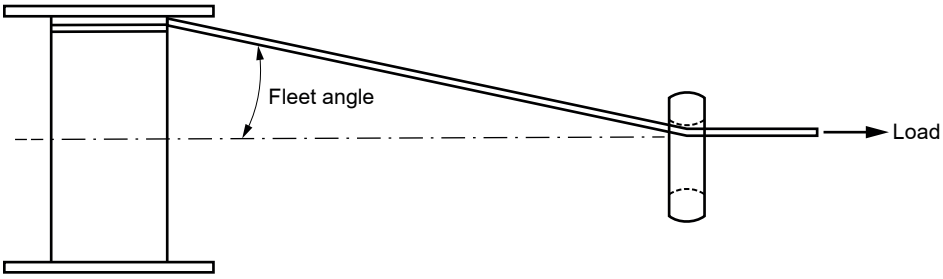
2.8 Towing winch emergency release systems

2.8.1 Emergency release system refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and blackout conditions.

2.8.2 Maximum design load is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer's rating).

2.8.3 Fleet angle is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum (see Fig 3).

Figure 3 : Towline fleet angle



3 Fire safety

3.1 Suppression of fire

3.1.1 Fire pumps

For tugs assigned with the operating area notation **operating within 5 miles from shore**, the portable fire pump required in NR566, Ch 4, Sec 5, [2.2.3] may be omitted.

3.1.2 Fixed fire-extinguishing system

Tugs assigned with the operating area notation **operating within 5 miles from shore** may considered as ships of less than 12 m operating in **coastal area** or **sheltered area** according to NR566, Ch 4, Sec 5, [4.2].

Section 2 Stability

1 Application

1.1

1.1.1 The requirements of this Section apply as follows depending on the ship service notation:

- **tug**, mainly intended for towing services, are to comply with the requirements in Article [2]
- **salvage tug**, having specific equipment for salvage services, are to comply with the requirements in Article [2]
- **escort tug**, mainly intended for escort services such as for steering, braking and otherwise controlling escorted ships, are to comply with the requirements in Articles [2] and [3].

In addition, ships with the additional service feature **barge combined** are to comply with the applicable requirements in Ch 1, Sec 4.

2 General requirements

2.1 Openings

2.1.1 Openings which cannot be closed weathertight

Openings in the hull, superstructures or deckhouses which cannot be closed weathertight are to be considered as unprotected openings and, consequently, as down-flooding points for the purpose of stability calculations (the lower edge of such openings is to be taken into account).

2.1.2 Ventilation openings of machinery space and emergency generator room

It is recognised that for tugs, due to their size and arrangement, compliance with the requirements of ICLL Reg. 17(3) for ventilators necessary to continuously supply the machinery space and the emergency generator room may not be practicable. Lesser heights of the coamings of these particular openings may be accepted if the openings:

- are positioned as close to the centreline and as high above the deck as practicable in order to maximise the down-flooding angle and to minimise exposure to green water
- are provided with weathertight closing appliances in combination with suitable arrangements, such as separators fitted with drains
- are equipped with efficient protective louvers and mist eliminators
- have a coaming height of not less than 900 mm above the deck
- are considered as unprotected openings and, consequently, as down-flooding points for the purpose of stability calculations.

2.2 Stability booklet

2.2.1 *The stability booklet for ships engaged in harbour, coastal or ocean going towing operations and/or escort operations is to contain additional information on:*

- *maximum bollard pull*
- *details on the towing arrangement, including location and type of the towing point(s) such as towing hook, staple, fairlead or any other point serving that purpose*
- *recommendations on the use of roll reduction systems*
- *If any wire, etc. is included as part of the lightship weight, clear guidance on the quantity and size is to be given*
- *maximum and minimum draught for towing and escort operations*
- *instructions on the use of the quick-release device*

2.3 Intact stability

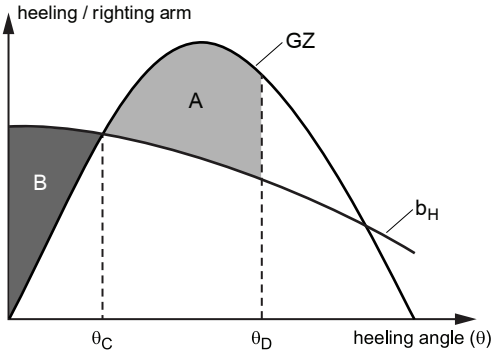
2.3.1 The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.11] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2.

2.3.2 Additional intact stability criteria

All the loading conditions reported in the trim and stability booklet which are intended for towing operations are also to be checked in order to investigate the ship's capability to withstand the effect of the transverse heeling moments induced by:

- the combined action of the towline force and the thrust vector (self-tripping, see [2.3.3]),
- the hydrodynamic resistance of the hull (tow-tripping, see [2.3.4]).

Figure 1 : Heeling and righting arms curves



2.3.3 Self-tripping

A tug may be considered as having sufficient stability to withstand the self-tripping heeling moment if the following condition is complied with (see Fig 1):

$A \geq B$

where:

A : Area, in m·rad, contained between the righting arm and the heeling arm curves, measured from the heeling angle θ_C to the heeling angle θ_D

B : Area, in m.rad, contained between the heeling arm and the righting arm curves, measured from zero heel ($\theta = 0$) to the heeling angle θ_C

θ_C : Heeling angle of equilibrium, corresponding to the first intersection between heeling and righting arms curves

θ_D : Heeling angle, to be taken as the lesser of:

- heeling angle corresponding to the second intersection between heeling and righting arm curves
- the angle of downflooding.

The self-tripping heeling arm curve is to be calculated as follows:

$b_H = \Sigma b_{Hi}$

where:

b_{Hi} : Heeling arm induced by one thruster or group of thrusters i, in m, calculated as follows:

$$b_{Hi} = \frac{T_{BPi} c_i (h_i \cos\theta - r \sin\theta)}{9{,}81\Delta}$$

T_{BPi} : Amount of thrust, in kN, generated by one thruster or group of thrusters i. The sum of all the individual thrusts is to be equal to the design Bollard Pull, as defined in Ch 1, Sec 1, [2.1].

h_i : Vertical distance, in m, between the towing point (fairlead, staple, towing hook or equivalent fitting) and the horizontal centreline of the propulsion unit or group of units i, as relevant for the considered towing situation

r : Transverse offset, in m, between the towing point and the ship's centerline.

The towing point is the location where the towline force is applied to the ship (fairlead, staple, towing hook or equivalent fitting).

When the towing point is not at the center line, the most unfavourable tow line position is to be considered.

c_i : Coefficient to be taken equal to:

- $c = 0{,}90 / (1 + d_i / L_{LL})$ for a group of 2 azimuthing thrusters, but is in no case to be taken less than:
  - 0,70 for ASD tugs towing over the stern and tractor tugs towing over the bow
  - 0,50 for ASD tugs towing over the bow and tractor tugs towing over the stern, respectively
- $c = 1 / (1 + d_i / L_{LL})$ for a single azimuthing thruster
- $c = 0{,}50$ for non-azimuth propulsion unit or group of units

Δ : Loading condition displacement, in tons

θ : Angle of heel, in degrees

d_i : Longitudinal distance, in m, between the towing point (fairlead, staple, towing hook or equivalent fitting) and the vertical centreline of the propulsion unit or group of units i, as relevant for the considered towing situation

L_{LL} : Load line length, in m, defined in Pt B, Ch 1, Sec 3, [2.1.2].

2.3.4 Tow-tripping

A tug may be considered as having sufficient stability to withstand the tow-tripping heeling moment if the first intersection between the righting arm curve and the tow-tripping heeling arm curve for tow-tripping occurs at an angle of heel less than the angle of downflooding.

The tow-tripping heeling arm curve is to be calculated as follows:

$$b_H = \frac{C_1 C_2 \gamma V^2 A_p (h\cos\theta - r\sin\theta + C_3 T)}{19,62\Delta}$$

where:

C_1 : Lateral traction coefficient, taken equal to:

$$C_1 = 2,8\left(\frac{L_s}{L_{LL}} - 0,1\right)$$

without being taken lower than 0,1 and greater than 1

L_s : Longitudinal distance, in m, from the aft end of L_{LL} to the towing point

C_2 : Angle of heel correction for C_1, taken equal to:

$$C_2 = \left(\frac{\theta}{3\theta_d} + 0,5\right)$$

without being taken lower than 1

θ_d : Angle to deck edge, in deg, taken equal to:

$$\theta_d = \text{atan}\left(\frac{2f}{B}\right)$$

f : Freeboard amidships, in m

γ : Specific water density, in t/m^3, to be taken equal to 1,025

V : Lateral velocity, in m/s, to be taken equal to 2,57 (5 knots)

A_p : Lateral projected area, in m^2, of the underwater hull

C_3 : Distance from the center of A_p to the waterline as a fraction of the draught related to the heeling angle, taken equal to:

$$C_3 = \left(\frac{\theta}{\theta_d}\right)0,26 + 0,3$$

without being taken lower than 0,5 and greater than 0,83

T : Loading condition draught, in m

h : Vertical distance, in m, from the waterline to the towing point.

3 Additional requirements for escort tugs

3.1 Intact stability

3.1.1 All the loading conditions reported in the trim and stability booklet which are intended for escorting operations are also to be checked in order to investigate the tug's capability to withstand the effect of the transverse heeling moment induced by the combined action of the following forces:

- hydrodynamic forces acting on the hull and appendices
- thrust forces
- steady towline force.

3.1.2 *Allowance is to be made for the anticipated type of wire or rope on storage reels and wire on the winches when calculating loading conditions.*

3.1.3 The stability calculations are to be performed on the basis of the highest anticipated heeling moment for the considered loading condition, which is to be obtained from the results of full scale tests, model tests, or, alternatively, the results of a computer simulation program accepted by the Society (refer to Ch 1, Sec 5, [3.1]).

3.1.4 For each relevant loading condition the evaluation of the highest anticipated heeling moment is to be performed for the applicable range of speeds and towline angles, as defined in the escort towing arrangement plan. As a minimum, the conditions corresponding to the design maximum steering force $T_{Y,MAX}$, and design maximum braking force $T_{X,MAX}$, as defined in Ch 1, Sec 1, [2.7], are to be included in the evaluation.

3.1.5 The highest anticipated heeling moment is to be assumed constant for the purpose of the stability calculations.

3.1.6 The value of the highest anticipated heeling moment is to be specified by the Designer in the stability calculations. In addition, an arrangement drawing with the location of the towing points and propulsion units is to be included in the stability booklet. In this drawing the longitudinal and vertical distance, in m, from the towing point to the relevant centrelines of the propulsion units and the baseline, respectively, are to be specified.

3.1.7 Preliminary stability calculations on the basis of estimated highest heeling moment and associated heeling arm values may be submitted for (preliminary) examination. If after verification of the heeling arm values on the basis of the results of escort performance trials, model tests or a computer simulation program accepted by the Society (refer to Ch 1, Sec 5, [3.1]) the final values exceed the estimated values, the stability calculations have to be updated for the final heeling moment and heeling arm values. It is recommended to include a reasonable margin in the estimated values (on the basis of design experience).

3.1.8 Criteria

An escort tug may be considered as having sufficient stability to withstand the heeling moment arising from the towline, if the three following conditions are complied with:

$A \geq 1{,}25\ B$

$C \geq 1{,}40\ D$

$\theta_C \leq 15°$

where:

A : Righting arm curve area, in m·rad, measured from the heeling angle θ_C to a heeling angle of 20° (see Fig 2)

B : Heeling arm curve area, in m·rad, measured from the heeling angle θ_C to a heeling angle of 20° (see Fig 2)

C : Righting arm curve area, in m·rad, measured from zero heel ($\theta = 0$) to the heeling angle θ_D (see Fig 3)

D : Heeling arm curve area, in m·rad, measured from zero heel ($\theta = 0$) to the heeling angle θ_D (see Fig 3)

Figure 2 : Definition of the areas A and B

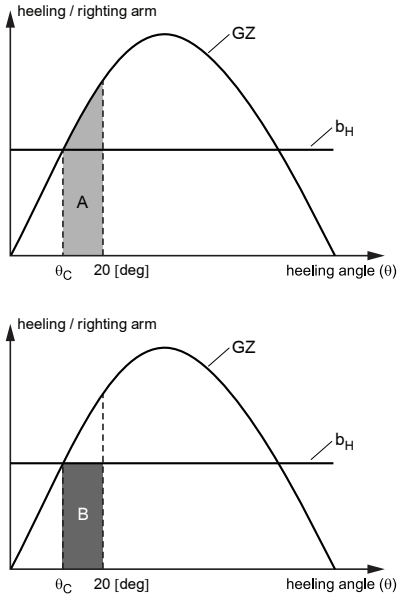
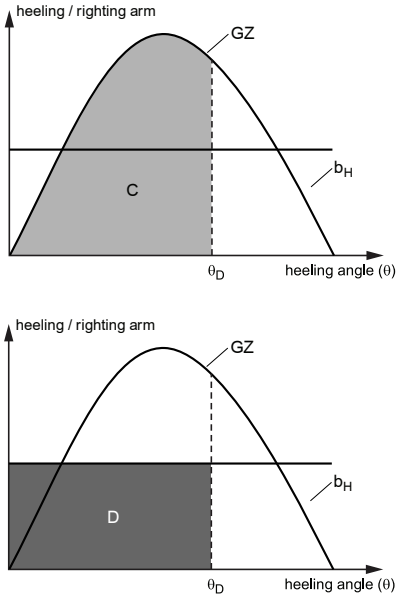


Figure 3 : Definition of the areas C and D



θ_C : Heeling angle of equilibrium, corresponding to the first intersection between heeling arm and righting arm curves, to be obtained when the highest anticipated heeling moment resulting from the steady towline force T_{ESC} as defined in Ch 1, Sec 1, Fig 2, is applied to the escort tug

θ_D : Heeling angle, to be taken as the lesser of:

- the angle of downflooding
- 40°
- the heeling angle corresponding to the second intersection between heeling and righting arms heeling and righting arm curves.

3.2 Stability booklet

3.2.1 Additional operating information is to be provided in the stability booklet in relation to the design limitations related to the assignment of the service notation **escort tug**.

As a minimum, the following information is to be included:

- Design operating area and environmental conditions for performing escort operations (refer to Pt A, Ch 1, Sec 2, [4.10])
- The maximum escort speed V_{MAX} (refer to Ch 1, Sec 1, [2.7])
- A table with permissible values of heeling angle and steady towline force as function of loading condition and escort speed (based on the rated steering and braking forces as obtained from Ch 1, Sec 5, [3.1] or Ch 1, Sec 5, [3.2], as applicable)
- Instructions to the master regarding the handling of the escort tug and the associated towing equipment, demonstrating the implementation of effective means to limit the steady towline force and heeling angle within the permissible limits and the use of the emergency release system.

Note 1: Adjustable audible or visible alarms, providing a warning to the master when the heeling angle and/or steady towline force exceeds the permissible value(s) applicable to the relevant loading condition and escort speed, in combination with appropriate handling instructions are as effective means.

The table with permissible values of heeling angle and steady towline force as function of loading condition and escort speed is to be displayed in the wheelhouse next to the control desk or another appropriate location.

3.3 Inclinometer

3.3.1 Escort tugs are to be equipped with a calibrated heeling angle measurement system (inclinometer).

The measured heeling angle is to be displayed in the wheelhouse next to the control desk or another appropriate location.

Section 3 Hull Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply as follows depending on the ship service notation:

- **tug**, mainly intended for towing services, are to comply with the requirements in Article [2]
- **salvage tug**, having specific equipment for salvage services, are to comply with the requirements in Articles [2] and [4]
- **escort tug**, mainly intended for escort services such as for steering, braking and otherwise controlling escorted ships, are to comply with the requirements in Articles [2] and [3].

In addition, ships with the additional service feature **barge combined** are to comply with the applicable requirements in Ch 1, Sec 4.

1.2 Documents to be submitted

1.2.1 In addition to the documentation requested in Part B, the following documents are to be submitted for approval:

- description of the connection between the towing system (winch and hook) and the hull structure with indication of the design loads.

2 General requirements

2.1 Typical design arrangements

2.1.1 General

In general, tugs are completely decked ships provided with an ample drift surface and, where intended for service outside sheltered areas, with a forecastle or half forecastle, or at least with a large sheer forward.

2.1.2 Conventional tugs

Conventional tugs have fixed single or multiple shaft arrangement. The propeller(s) can be of fixed pitch or controllable pitch type, normally fitted with Kort nozzle(s). Steering is done by means of rudder(s) or steerable nozzle(s). The towing point is normally located slightly aft of the centre of lateral resistance for towing over the stern with a towing hook and/or towing winch.

Conventional tugs may also be equipped to perform pushing operations.

2.1.3 Tractor tugs

Tractor tugs are fitted with omnidirectional thrusters (typically two steerable propellers or Voith-Schneider type cycloidal propulsion units), which are located forward of the towing point (usually not more than 30% of the length from the forward end). A skeg or vertical fin is fitted aft. Towing is performed over the stern with a towing winch and/or towing hook.

Tractor tugs may also be equipped to perform pushing operations.

2.1.4 Azimuth stern drive tugs (ASD tugs)

Azimuth stern drive (ASD) tugs are fitted with multiple steerable propellers located near the aft end. Typically, ASD tugs can perform towing operations over the bow with the forward towing winch (towing operation similar to a tractor tug) and over the stern with a towing hook and/or second towing winch (towing operation similar to a conventional tug). In both cases the towing point is located forward of the thrusters. ASD tugs may be fitted with a skeg, the size and location depending on the intended function.

ASD tugs may also be equipped to perform pushing operations.

2.1.5 Other design arrangements

Other tug design arrangements, having towing and propulsion configurations different from the design arrangements described in [2.1.1] to [2.1.4], have been developed and built, and are to be considered by the Society on a case-by-case basis.

For tugs with combined aft and fore thrusters, every thruster having the same longitudinal location is to be considered as belonging to the same group of thrusters.

2.2 Structure design principles

2.2.1 Bollards

For tugs equipped for side towing, the relevant bollards are to be effectively fixed on the deck in way of side transverses and deck beams or bulkheads.

2.2.2 Fenders

A strong fender for the protection of the tug's sides is to be fitted at deck level.

Alternatively, loose side fenders may be fitted, provided that they are supported by vertical ordinary stiffeners extending from the lightship waterline to the fenders themselves.

2.2.3 Floors

Floors are to be arranged with a welded face plate in the machinery space; elsewhere, floor flanging may be accepted as an alternative to the fitting of welded face plates.

2.2.4 Shaft tunnels

For tugs having small depth, the shaft tunnel may be omitted. In this case, access to the shaft line is to be given through the floor of the space above.

2.3 Hull scantlings

2.3.1 General

The net scantlings of plating, ordinary stiffeners and primary supporting members are to be in accordance with the applicable requirements defined in Ch 1, Sec 1, considering a scantling draught T not less than 0,85 D for the calculation of hull girder loads and local loads.

2.4 Other structures

2.4.1 Machinery casings

Exposed machinery casings are to be not less than 900 mm in height, measured from the upper surface of the deck, and provided with weathertight means of closure.

In general, the longitudinal sides of the machinery casings are to be extended downwards by a deck girder to which the deck beams are to be connected.

Side ordinary stiffeners are to be connected to the deck. Their spacing is to be not greater than 0,75 m.

2.4.2 Emergency exits from machinery space

Emergency exits from the machinery space to the upper deck are to be located as high as possible above the waterline and in way of the ship's centreline, so that they may be used even at extreme angles of heel.

Escape hatch coaming heights are to be not less than 600 mm above the upper surface of the deck.

Escape hatch covers are to have hinges fitted such that the predominant direction of green sea will cause the cover to close and are to be capable of being opened and closed weathertight from either side.

2.4.3 Height of hatchway coamings

The height of the hatchway coamings is to be not less than 300 mm. Hatch covers are to be fitted with efficient securing devices.

2.5 Rudder and bulwarks

2.5.1 Rudder

For tugs, the rudder stock diameter is to be increased by 5% with respect to that calculated according to the applicable requirement.

2.5.2 Bulwarks

The bulwarks are to be sloped inboard to avoid distortions likely to occur during contact. Their height may be reduced where required by operational necessities.

2.6 Anchoring and mooring equipment

2.6.1 In the formula in Pt B, Ch 12, Sec 4, [1.2.2] for the determination of the Equipement Number, the term "2,0 h B" may be replaced by the term:

$$2{,}0\left(aB + \sum h_n b_n\right)$$

to give:

$$EN = \Delta^{2/3} + 2\left[\left(aB + \sum h_n b_n\right) + S_{fun}\right] + 0{,}1\ A$$

where:

b_n : breadth, in m, of the widest superstructure or deckhouse of each tier having a breadth greater than B/4

Δ, a, B, h_n, S_{fun} and A as defined in Pt B, Ch 12, Sec 4, [1.2.2].

2.6.2 Number of anchors

The number of anchors depends on the service notation and optional operating area notation, the propulsion arrangement and the application of a fixed fire-fighting installation. In general, the recommended number of anchors and chain cables is shown in Tab 1.

A reduction of the number of anchors and chain cables may be accepted as depicted in Tab 1 if th following conditions, based on redundancy principles, are complied with:

- the tug is equipped with at least twin propulsion, of which each main engine can maintain sufficient propulsion power to safely return to berth. For this purpose, the main engines should be able to run self-supporting, i.e. independent of generator sets intended for auxiliary power, unless these are able to run parallel and, in case of black-out, have automatic starting and connecting to switchboard within 45 seconds
- a single failure, except fire, is not to cause total propulsion failure
- a fixed fire fighting installation is provided.

It may be considered by the tug builder and operator to apply a spare anchor as an alternative to a second bower anchor. In such case special provisions, such as a crane and suitable storage space for the spare anchor, are to be present on board and the weight and dimensions of the anchor are to be such that it can be handled swiftly. For tugs with the operating area notation **operating ≤ 4 h from a place of refuge**, effectively operating in a fixed and limited area, the spare anchor may be stored ashore.

Table 1 : Number of anchors and chain cables

Service notation	Operating area notation	Number of anchor and chain cables	
		General	Reduced based on redundancy principles **(1)**
tug	**operating within 5 miles from shore**	1	0
tug	**operating ≤ 4 h from a place of refuge**	2	1
tug	–	2	2
salvage tug	–	2	2
escort tug	**operating ≤ 4 h from a place of refuge**	2	1
escort tug	–	2	2
(1) As detailed in [2.6.2].			

2.7 Towing equipment

2.7.1 General

Towing winches, towing hooks and towline guiding fittings (fairleads, staples, gob-eyes, towing pins, etc.) are normally to be arranged in way of the tug's centerline, in such a position as to minimise heeling moment exerted by the towline force. Effective means are to be provided to lead and restrain the towline within the designed limits of its sweep.

Materials used in towing equipment are to comply with the applicable class requirements for materials. Class certificates are required for the materials used for winch drums, drum shafts, winch brake components, winch supporting frames, towing hooks and towline guiding fittings.

2.7.2 Design load

The design load DL to be considered for the strength assessment of the towing equipment and the associated supporting structures is given in Tab 2.

Table 2 : Design loads for equipments used for towing operations and supporting structures

Service notation	Operating area notation	T_{BP}, in kN	DL, in kN
tug	**operating within 5 miles from shore**	$T_{BP} \le 200$	$2\ T_{BP}$
		$200 < T_{BP} < 800$	$[(2600 - T_{BP}) / 1200]\ T_{BP}$
		$T_{BP} \ge 800$	$1,5\ T_{BP}$
tug **salvage tug** **escort tug**	–	$T_{BP} \le 400$	$2,5\ T_{BP}$
		$400 < T_{BP} < 1000$	$[(3400 - T_{BP}) / 1200]\ T_{BP}$
		$T_{BP} \ge 1000$	$2\ T_{BP}$
Note 1: The DL takes into consideration dynamic effects through the application of the dynamic amplification factor (DAF) (see also Ch 1, Sec 1, [2.3]).			

2.7.3 Towing winches

a) The winch brake shall normally act directly on the drum and shall be operable in case of failure of the primary power supply system (either manually or otherwise arranged).

b) The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

c) Towing winches are to be provided with an emergency release system as described in [2.7.4].

d) Means are to be provided to prevent the fleet angle as shown on Ch 1, Sec 1, Fig 3 from becoming great enough to inhibit operation of the emergency release system.

e) The dimensioning of the winch drum is to take into account the rope bending specifications provided by the towline manufacturer.

f) Due consideration is to be given to the proper spooling of the towline on the winch drum, as well as preventing the towline to slip over the flanges of the drum.

g) Towing winches (in particular the components which are exposed to the tension in the towline, such as the winch drums, drum shafts, brakes, support frame and connection to the hull structure) shall be able to:

- sustain the DL, as specified in [2.7.2] without permanent deformation, and
- sustain the BHL, as defined Ch 1, Sec 1, [2.4], without exceeding an equivalent stress level (based on Von Mises criterion) of 0,80 R_{eH}.
- sustain the loads for the rated pull condition, as foreseen by the Designer, without exceeding an equivalent stress level (based on Von Mises criterion) of 0,40 R_{eH}.

where:

R_{eH} : Minimum specified yield stress of material, in N/mm^2

rated pull: Winch maximum hauling in load at the first inner layer.

h) Where deemed necessary by the Society, buckling and/or fatigue analysis, performed in accordance with a standard or code of practice recognised by the Society, may be required to be submitted for information.

i) Towing winches may be equipped with an active pay- out and haul-in system for automatic adjustment of towline. In that case the relevant requirements of [3.2.3] and Ch 1, Sec 5, [3.3]are to be complied with.

j) It is recommended that the towing winch is fitted with equipment to continuously measure the tension in the towline.

In case a towline measurement system is installed on board, the measured data are to be displayed in the wheelhouse next to the control desk or another appropriate location.

2.7.4 Emergency release system

a) Performance:

1) The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

2) The emergency release system is to be capable of operating with towline loads up to at least 100 per cent of the maximum design load.

3) The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

4) The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

5) Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

- the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or
- 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

6) Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with item 7) below.

7) The sources of energy required by item 6) are to be sufficient to achieve the most onerous of the following conditions (as applicable):

- sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.
- Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power) sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in

the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in item 5) if this is less than five minutes.

b) Monitoring and control:

1) Emergency release operation is to be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location.

A position in close proximity to the winch is not regarded as “safe location”, unless it is documented that the position is at least protected against towline break or winch failure.

2) The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and both are to be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

3) The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

4) Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It is always to be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

5) Controls for emergency use are to be protected against accidental use.

6) Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

The following emergency release system alarms and indications are to be provided on the bridge:

- Low fluid pressure in the control system
- Low accumulator/ air pressure
- Low battery voltage (separate alarm and indication not required where electrical power is supplied from the tug's emergency batteries).

7) Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

8) Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems (see Pt C, Ch 3, Sec 3, [3]).

9) Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

c) General test requirements

1) For each emergency release system or type thereof, the performance requirements of paragraph a) are to be verified either at the manufacturer’s works or as part of the commissioning of the towing winch when it is installed on board. In any case, this test is to be witnessed by a Surveyor. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with the Society.

2) The performance capabilities, as well as instructions for operation, of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.

3) Instructions for surveys of the emergency release system are to be documented by the manufacturer, agreed by the Society and made available on board the ship on which the winch has been installed.

4) Where necessary for conducting the annual and special surveys of the winch, adequately sized strong points are to be provided on deck.

d) Installation trials

1) The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

2) Where the performance of the winch in accordance with paragraph a) has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

2.7.5 Towing hooks

a) Towing hooks and their load carrying attachments (connecting the towing hook to the hull structure) shall be able to sustain the DL, as specified in [2.7.2], without exceeding an equivalent stress level (based on Von Mises criterion) of 0,80 R_{eH}.

b) Towing hooks shall be provided with an emergency release system operable from a position on the bridge with full view and control of the towing operation, as well as at a location near the hook where the device can be safely operated. Identical means of control for the emergency release systems shall be provided at each control station and are to be protected against unintentional use.

The force necessary to open the hook under load is to be not greater than 150 N.

The applicable procedures for the emergency quick-release device shall be communicated to the crew and vital information shall be displayed next to the control desk or another appropriate location.

2.7.6 Towlines

a) The breaking strength of towlines is not to be less than the DL, as specified in [2.7.2].

In addition, the breaking strength of towlines used on a towing winch is not to be less than the BHL of the associated winch (see Ch 1, Sec 1, [2.4]).

b) The towline shall be protected from being damaged by chafing and abrasion. To this end cargo rails, bulwarks, and other elements supporting the towline should be sufficiently rounded with consideration to the bend radius limit of the towline in order to ensure that the towline breaking strength is maintained.

c) It is recommended that the total length of the towline applied on a towing winch is such that under normal operation, at least half a layer remains on the drum. In no case less than three turns shall remain on the drum in under normal operation.

2.7.7 Towline guiding fittings

a) Towline guiding fittings, such as fairleads, staples, gob-eyes, towing pins, stern rollers and equivalent components which guide the towline, shall be able to sustain the force exerted by the towline loaded under a tension equal to the DL, as specified in [2.7.2], in the most unfavourable anticipated position of the towline without exceeding the following stress level criteria:

- Normal stress:

  $\sigma \leq 0,75\ R_{ref}$

- Shear stress:

  $\tau \leq 0,47\ R_{ref}$

- Equivalent stress:

  $\sigma_{VM} \leq 0,85\ R_{ref}$

where:

R_{ref} : Reference stress of the material, in N/mm^2, normally to be taken as 235/k, but may be taken as R_{eH} for fittings not made of welded construction.

b) Towline guiding fittings used for guiding the towline when towing on a towing winch shall be able to sustain the force exerted by the towline loaded under a tension equal to the BHL of the associated winch, as specified in Ch 1, Sec 1, [2.4], in the most unfavourable anticipated position of the towline without exceeding the stress level criteria mentioned in a).

c) Where a towline guiding fitting (e.g. fairlead or guide pin) has been designed for a specific Safe Working Load SWL, defined as the maximum static working load, the fitting shall be able to sustain a force equal to 2 times the SWL without exceeding the stress level criteria mentioned in a).

d) In case the yielding check of the towline guiding fittings is carried out by means of a three dimensional finite element model, the permissible stress levels given above may be increased by 10 per cent (compared to a beam model).

2.7.8 Supporting structures

a) The supporting structures of towing equipment shall be able to sustain the load exerted on the supporting structure under the action of the towline loaded under a tension equal to the DL, as specified in [2.7.2], in the most unfavourable anticipated position of the towline, without exceeding the stress level criteria specified in [2.7.7].

b) Supporting structures of towing equipment engaged when towing on a towing winch shall be able to sustain the load exerted on the supporting structure under the action of the towline loaded under a tension equal to the BHL of the associated winch, as specified in Ch 1, Sec 1, [2.4], in the most unfavourable anticipated position of the towline without exceeding the stress level criteria specified in [2.7.7].

c) Where a towline guiding fitting has been designed for a specific Safe Working Load SWL, defined as the maximum static working load, the associated supporting structure shall be able to sustain a force equal to 2 times the SWL without exceeding the stress level criteria specified in [2.7.7].

d) In case the yielding check of the towing equipment supporting structures is carried out by means of a three dimensional finite element model, the permissible stress levels given above may be increased by 10 per cent (compared to a beam model).

2.7.9 Fendering

a) A robust and efficient fendering system is to be fitted in areas intended for pushing. The fendering system purpose is to distribute the pushing force and limit its dynamic component on the hull structure of both the tug and the assisted ship.

b) For the purpose of this requirement, it is considered that during pushing operations, the contact between the tug and the assisted ship is maintained and that no bouncing (e.g. under wave action) is taking place. Forces resulting from bouncing loads are not taken into consideration, as it is understood that pushing operations (in waves) are normally halted when bouncing starts taking place (due to operational difficulties to keep position within the pushing area of the assisted ship as well as to control the associated impact type loads).

c) The design load DL to be considered for the strength assessment of the fender supporting structure may be taken as follows:

$DL = 1,5\ T_{BP}$

where:

T_{BP} : Design bollard pull, as defined in Ch 1, Sec 1, [2.1].

The DL takes into consideration anticipated dynamic effects through the application of the dynamic amplification factor (see also Ch 1, Sec 1, [2.3]), but not bouncing effects (see above).

The fender supporting structure shall be able to sustain the DL, as specified above, without exceeding the stress level criteria specified in [2.7.7].

3 Additional requirements for escort tugs

3.1 Structural design principles

3.1.1 Hull shape

The hull shape is to be such as to provide adequate hydrodynamic lift and drag forces and to avoid excessive trim angles for large heeling angles.

3.1.2 Bulwark

A bulwark is to be fitted all around the weather deck.

3.2 Equipment for escort operations

3.2.1 General

Towing winches and towline guiding fittings (fairleads, staples, etc.) used for escort services are normally to be arranged in way of the tug's centreline, in such a position as to minimise heeling moment.

Materials used in towing equipment are to comply with the applicable class requirements for materials. Class certificates are required for the materials used for winch drums, drum shafts, winch brake components, winch supporting frames and towline guiding fittings.

3.2.2 Design load

The design load DL to be considered for the strength assessment of the towing equipment used for escort services and the associated supporting structures is given in Tab 3.

Table 3 : Design Loads for equipment used for escort operations and supporting structures

$T_{ESC,MAX}$, in kN	DL, in kN	
	General case	Escort tugs assigned with the operating area notation **escort service limited to non-exposed waters**
≤ 500	3 $T_{ESC,MAX}$	2,4 $T_{ESC,MAX}$
500 < $T_{ESC,MAX}$ ≤ 1000	[(2000 - $T_{ESC,MAX}$) / 500] $T_{ESC,MAX}$	[(2000 - $T_{ESC,MAX}$) / 625] $T_{ESC,MAX}$
> 1000	2 $T_{ESC,MAX}$	1,6 $T_{ESC,MAX}$
Note 1: The DL takes into consideration dynamic effects through the application of the Dynamic Amplification Factor (DAF) (see also Ch 1, Sec 1, [2.3]).		

3.2.3 Escort winches

a) The winch brake shall normally act directly on the drum and shall be operable in case of failure of the primary power supply system (either manually or otherwise arranged).

b) Escort winches intended to be used in conditions where dynamic oscillations of the towline are likely to occur, such as in open sea areas or other areas exposed to waves, are to be equipped with an active pay-out and haul-in system.

This system is to automatically and reliably pay-out the towline in a controlled manner when the towline force exceeds a pre-set (adjustable) level equal to 110 per cent of the rated towline force $T_{ESC,R}$ and, as the towline force is reduced, actively haul-in the towline to prevent slack-line events and maintain a pre-set or adjustable towline force consistent with the rated towline force.

Pay-out and haul-in speeds and pull capability shall be chosen taking into account the anticipated escort services and the dynamic characteristics of the escort tug.

c) Escort operations in conditions where dynamic oscillations of the towline are likely to occur may not be based on the use of the brakes of the winch drum.

d) Escort operations performed by escort tugs with the operating area notation **escort service limited to non-exposed waters** and any escort operation in calm water conditions, such as in ports and sheltered (confined) waters, may be based on the use of the brakes of the winch drum. As a minimum, the winch brake holding load BHL is to be equal to or greater than two times the maximum steady towline force $T_{ESC,MAX}$.

e) Escort winches are to be fitted with equipment to continuously measure the tension in the towline.

The measured data are to be displayed in the wheelhouse next to the control desk or another appropriate location.

f) The escort towing system is to be designed so as to enable the proper spooling of the towline on the winch drum when hauling in. Generally this can be achieved by a suitable design of the fairlead or staple guiding the towline between the escort winch and the assisted ship.

Where a spooling device is fitted, this device should be designed for the same Design Load and stress criteria as the towline guiding fittings, see [3.2.5].

g) Winches are to be provided with an emergency release system as defined in [2.7.4].

h) The dimensioning of the winch drum is to take into account the rope bending specifications provided by the towline manufacturer.

Due consideration is to be given to preventing the towline to slip over the flanges of the drum.

i) Escort winches (in particular the components which are exposed to the tension in the towline, such as the winch drums, drum shafts, brakes, support frame and connection to the hull structure) shall be able to:

- sustain the DL, as specified in [3.2.2] without permanent deformation, and
- sustain the BHL, as defined in Ch 1, Sec 1, [2.4], without exceeding an equivalent stress level (based on Von Mises criterion) of 0,80 R_{eH}
- sustain the loads for the rated pull condition, as foreseen by the Designer, without exceeding an equivalent stress level (based on Von Mises criterion) of 0,40 R_{eH}.

where:

R_{eH} : Minimum specified yield stress of material, in N/mm^2

rated pull: Winch maximum hauling in load at the first inner layer.

j) Where deemed necessary by the Society, buckling and/or fatigue analysis, performed in accordance with a standard or code of practice recognized by the Society, may be required to be submitted for information.

3.2.4 Towlines

a) The breaking strength of towlines used for escort services is not to be less than the DL, as specified in [3.2.2].

In addition, the breaking strength for towlines used for escort services on an escort winch is not to be less than the BHL of the associated escort winch (see Ch 1, Sec 1, [2.4]).

b) The towline shall be protected from being damaged by chafing and abrasion. To this end cargo rails, bulwarks, and other elements supporting the towline should be adequately rounded.

c) It is recommended that the total length of the towline applied on a towing winch is such that under normal operation, at least half a layer remains on the drum. In no case less than three turns shall remain on the drum in under normal operation.

3.2.5 Towline guiding fittings

a) Towline guiding fittings used for escort services, such as fairleads, staples and equivalent components which guide the towline, shall be able to sustain the force exerted by the towline loaded under a tension equal to the DL, as specified in [3.2.2], in the most unfavourable anticipated position of the towline without exceeding the stress level criteria specified in [2.7.7].

b) In addition, towline guiding fittings shall be able to sustain the force exerted by the towline loaded under a tension equal to the BHL of the associated winch, as specified in Ch 1, Sec 1, [2.4], in the most unfavourable anticipated position of the towline without exceeding the stress level criteria specified in [2.7.7].

c) Where a towline guiding fitting has been designed for a specific safe working load SWL, defined as the maximum static working load, the fitting shall be able to sustain a force equal to 2 times the SWL without exceeding the stress level criteria specified in [2.7.7].

d) In case the yielding check of the towline guiding fittings is carried out by means of a three dimensional finite element model, the permissible stress levels given above may be increased by 10 per cent (compared to a beam model).

3.2.6 Supporting structures

a) The supporting structures of towing equipment used for escort services shall be able to sustain the load exerted on the supporting structure under the action of the towline loaded under a tension equal to the DL, as specified in [3.2.2], in the most unfavourable anticipated position of the towline, without exceeding the stress level criteria specified in [2.7.7].

b) In addition, supporting structures of towing equipment used for escort services shall be able to sustain the load exerted on the supporting structure under the action of the towline loaded under a tension equal to the BHL of the associated winch, as specified in Ch 1, Sec 1, [2.4], in the most unfavourable anticipated position of the towline without exceeding the stress level criteria specified in [2.7.7].

c) Where a towline guiding fitting has been designed for a specific safe working load SWL, defined as the maximum static working load, the associated supporting structure shall be able to sustain a force equal to 2 times the SWL without exceeding the stress level criteria specified in [2.7.7].

d) In case the yielding check of the towing equipment supporting structures is carried out by means of a three dimensional finite element model, the permissible stress levels given above may be increased by 10 per cent (compared to a beam model).

4 Additional requirements for salvage tugs

4.1 Equipment

4.1.1 Ships with the navigation notation **salvage tug** are to be fitted with the additional equipment specified in Tab 4.

Table 4 : Additional equipment for salvage tugs

Arrangement or equipment	Number of items
Fixed or movable drainage pumps having approximately the same capacity **(1) (2) (3)**	2 or more pumps of total capacity ≥ 400 m^3/h
Fire pumps each capable of throwing two simultaneous jets of water having a horizontal reach not less than 30 m **(4)**	2 pumps, each having a capacity ≥ 60 m^3/h
Breathing apparatuses for divers	2
Gas masks with filter	2
Cargo boom	1, with service load ≥ 1 t
Power operated winch capable of producing an adequate pull	1
Water stops to stop leaks of approximately 1 x 2 m	4
Complete set of equipment for flame cutting with at least 25 metres of flexible piping	1
Drain hoses	at least 20 m per pump
Fire hoses	10
Connections for fire main	at least 3
Power operated diver's compressor, with associated equipment **(5)**	1
Additional towline equipment	1
Lamps for underwater operation	2
Floodlight of power ≥ 500 W	1
Working lamps	2
Winding drums with wire ropes	see **(6)**
Electrical cables, each not less than 100 metres long and capable of supplying at least 50 kW	3
Tackles with lifting capacity of 1 t	2
Tackles with lifting capacity of 3 t	2
Radar with a range not less than 24 nautical miles	1
Echo-sounding device with a range of 100 m	1
Hydraulic jackets with lifting capacity of 10 t	2
Hydraulic jackets with lifting capacity of 20 t	2
Portable electrical drill with a set of twist bits having diameters up to 20 mm	1

(1) For each pump fitted on board, a suction strainer and, in the case of non self-priming pumps, a foot valve, are also to be provided.

(2) Where portable pumps are used, they are to be capable of effectively operating even with transverse and longitudinal inclinations up to 20°.

(3) These pumps are additional to the drain pumps intended for the drainage service of the ship.

(4) These pumps may be the same required for drainage purposes provided they have an adequate head.

(5) As an alternative, a compressor for recharging the oxygen tanks of divers may be provided together with two complete sets of equipment for divers.

(6) Winding drums fitted on board are to be capable of housing wire ropes of suitable size and length not normally less than 350 m.

Section 4 Integrated Tug / Barge Combination

Symbols

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified.

1 General

1.1 Application

1.1.1 General

The requirements of this Section apply to the integrated tug/barge combinations constituted by:

- a tug, to which the additional service feature **barge combined** is assigned
- a barge, to which the additional service feature **tug combined** is assigned

and specify the criteria these combinations are to satisfy in addition to those in:

- Ch 1, Sec 3, [2] Ch 1, Sec 2, [2], and Ch 1, Sec 5, [2] for the tug
- Pt D, Ch 14, Sec 2 for the barge.

1.1.2 When a series of barges may be operated in combination with a specific tug, the identification numbers of such barges are to be indicated in the tug class certificate.

1.1.3 When a series of tugs may be operated in combination with a specific barge, the identification numbers of such tugs are to be indicated in the barge Certificate of Classification.

1.2 Permanent connections

1.2.1 An integrated tug/barge combination is connected with permanent connection if the tug and the barge cannot be disconnected in open sea. The connection is such that no relative motion between the tug and the barge is permitted.

1.3 Removable connections

1.3.1 General

An integrated tug/barge combination is connected with removable connection if the tug and the barge can be disconnected in open sea. The disconnecting procedure is to be performed safely by one man and is to take less than 5 min. After disconnection in open sea, the tug is to be arranged to tow the barge by hawser.

The procedure for disconnecting and reconnecting at sea the integrated tug/barge combination is to be made available for guidance to the Master.

1.3.2 Types of removable connections

The removable connection is classed in the two following types:

- rigid connection, if no relative motion between the tug and the barge is permitted
- flexible connection, if relative motion between the tug and the barge is permitted (e.g. the tug is free to pitch with respect to the barge).

1.3.3 Tug

The tug is to have the capability of separating from the barge and shifting to tow it by hawser.

1.4 Documents to be submitted

1.4.1 In addition to the documentation requested in Pt B, Ch 1, Sec 4, the following documents are to be submitted:

- Structural arrangement of the fore part of the tug, showing details of reinforcements in way of the connecting point,
- Structural arrangement of the aft part of the barge, showing details of reinforcements in way of the connecting point,
- Details of the connection system.

2 General arrangement design

2.1 Bulkhead arrangement

2.1.1 Number and disposition of barge transverse watertight bulkheads

In applying the criteria in Pt B, Ch 2, Sec 1, the barge is to be fitted at least with an aftermost transverse watertight bulkhead located forward of the connection area and extended from side to side.

The cargo spaces are to be separated from the other spaces not used for cargo by watertight bulkheads.

2.1.2 Barge collision bulkhead

The collision bulkhead of the barge is to be located at a distance, in m, from the fore end of L of not less than 0,05 L_{LLC} or 10 m, whichever is the lesser, and not more than 0,08 L_{LLB}, where:

L_{LLC} : Ship's length, in m, measured between the aft and fore ends of L of the integrated tug/barge combination, taken at the fore and aft ends of the load line length

L_{LLB} : Ship's length, in m, measured between the aft and fore ends of L of the barge considered as an individual ship, taken at the fore and aft ends of the load line length.

3 Integrated tug/barge combinations with permanent connection: stability, freeboard, design loads, hull scantlings and equipment

3.1 Stability calculations

3.1.1 The integrated tug/barge combination is to comply with the applicable intact and, where additional notation SDS is requested, damage stability requirements in Part B, Chapter 3 considering the integrated tug/barge combination as a ship of the size of the combination.

3.2 Freeboard calculation

3.2.1 The freeboard is to be taken as the greatest of:

- the freeboard of the tug, considered as an individual ship
- the freeboard of the barge, considered as an individual ship
- the freeboard of the integrated tug/barge combination, considered as a ship of the size of the combination. For the freeboard calculation the barge is to be considered as being manned.

3.3 Still water hull girder loads

3.3.1 The still water hull girder loads and the forces transmitted through the connection are to be calculated for each loading condition considering the integrated tug/barge combination as a ship of the size of the combination.

3.4 Wave hull girder loads

3.4.1 The wave hull girder loads and the forces transmitted through the connection are to be calculated according to Pt B, Ch 5, Sec 4 considering the integrated tug/barge combination as a ship of the size of the combination.

3.4.2 Direct calculation

When deemed necessary by the Society, the wave hull girder loads and the forces transmitted through the connection are to be obtained from a complete analysis of the integrated tug/barge combination motion and acceleration in irregular waves, unless such data are available from similar ships.

These loads are to be obtained as the most probable the integrated tug/barge combination, considered as a ship of the size of the combination, may experience during its operating life for a return period of 25 years. For this calculation, the wave statistics relevant to the area of navigation and/or worst weather condition expressed by the navigation notation assigned to the integrated tug/barge combination are to be taken into account. For unrestricted navigation, the wave statistics relevant to the North Atlantic are to be taken into account.

When the difference between the tug and the barge depths is not considered negligible by the Society, its effects are to be considered in evaluating the buoyancy force distributions and the corresponding hull girder loads on the tug structures immediately aft of the connection section, for the different wave encountering conditions.

3.5 Still water local loads

3.5.1 The still water local loads are to be calculated according to Pt B, Ch 5, Sec 5 and Pt B, Ch 5, Sec 6 for each loading condition and draught of the integrated tug/barge combination. The draught of the integrated tug/barge combination is to be taken not less than 0,85 D, where D is the greater of the tug and the barge depths and not greater than the draught of the barge.

3.6 Wave local loads

3.6.1 The wave local loads are to be calculated according to Pt B, Ch 5, Sec 5and Pt B, Ch 5, Sec 6 considering the integrated tug/barge combination as a ship of the size of the combination. The draught of the integrated tug/barge combination is to be taken not less than 0,85 D, where D is the greater of the tug and the barge depths and not greater than the draught of the barge.

3.7 Hull girder strength

3.7.1 Strength check

The longitudinal strength is to comply with Part B, Chapter 6, where the hull girder loads are those defined in [3.3] and [3.4].

3.7.2 Loading manual

The loading manual is to include the (cargo and ballast) loading conditions of the integrated tug/barge combination at sea and in port conditions on the basis of which the approval of its hull structural scantlings is based.

The manual is to indicate the still water bending moment and shear force along the length of the integrated tug/barge combination as well as the permissible values at each hull section.

Information on loading and unloading sequences is to be provided for guidance to the Master.

3.8 Scantlings of plating, ordinary stiffeners and primary supporting members

3.8.1 The scantlings of plating, ordinary stiffeners and primary supporting members are to be in accordance with Part B, Chapter 7 or NR600, as applicable, where the hull girder and local loads are those defined in [3.3] to [3.6].

In any case, the scantlings of plating, ordinary stiffeners and primary supporting members of the tug and the barge are to be not less than those obtained according to Ch 1, Sec 3 and Pt D, Ch 14, Sec 2 for the tug alone and the barge alone, respectively.

3.9 Equipment

3.9.1 The equipment is to be in accordance with the requirements in both

- Ch 1, Sec 3, [2.6] for the tug, and
- Pt D, Ch 14, Sec 2, for the barge, considering the barge as a ship of the size of the integrated tug/barge combination.

4 Integrated tug/barge combination with removable connection: stability, freeboard, design loads, hull scantlings and equipment

4.1 Stability calculations

4.1.1 The integrated tug/barge combination is to comply with the applicable intact stability requirement in Part B, Chapter 3, considering the integrated tug/barge combination as a ship of the size of the combination.

4.2 Freeboard calculation

4.2.1 The freeboard is to be calculated for the tug and the barge considered as individual ships.

4.3 Still water hull girder loads

4.3.1 General

The still water hull girder loads and the forces transmitted through the connection are to be calculated for each loading condition considering the integrated tug/barge combination as a ship of the size of the combination.

4.3.2 Integrated tug/barge combination with removable flexible connection

For integrated tug/barge combinations with removable flexible connection, the effect of the degrees of freedom of the connection on the still water hull girder loads in the combination may be taken into account (e.g. free pitch of the tug with respect to the barge implies vertical bending moment equal to zero in the connection).

4.4 Wave hull girder loads

4.4.1 The wave hull girder loads and the forces transmitted through the connection are to be calculated according to [3.4].

4.4.2 Integrated tug/barge combination with removable flexible connection

For integrated tug/barge combinations with removable flexible connection, the effect of the degrees of freedom of the connection on the wave hull girder loads in the combination may be taken into account (e.g. free pitch of the tug with respect to the barge implies vertical bending moment equal to zero in the connection).

4.5 Still water local loads

4.5.1 The still water local loads are to be calculated according to Pt B, Ch 5, Sec 5 and Pt B, Ch 5, Sec 6 or NR600, as applicable, for each loading condition and draught of the integrated tug/barge combination. The draught of the integrated tug/barge combination is to be taken not less than 0,85 D, where D is the greater of the tug and the barge depths and not greater than the draught of the barge.

4.6 Dynamic local loads

4.6.1 The dynamic local loads are to be calculated according to Pt B, Ch 5, Sec 5 and Pt B, Ch 5, Sec 6 considering the integrated tug/barge combination as a ship of the size of the combination. The draught of the integrated tug/barge combination is to be taken not less than 0,85 D, where D is the greater of the tug and the barge depths and not greater than the draught of the barge.

4.7 Hull girder strength

4.7.1 The longitudinal strength is to comply with Part B, Chapter 6, where the hull girder loads are those defined in [4.3] and [4.4].

4.7.2 Loading manual

The loading manual is to include the items specified in [3.7.2].

4.8 Scantlings of plating, ordinary stiffeners and primary supporting members

4.8.1 Integrated tug/barge combinations with removable rigid connection

For integrated tug/barge combinations with removable rigid connection, the scantlings of plating, ordinary stiffeners and primary supporting members are to be in accordance with Part B, Chapter 7 or NR600, as applicable, where the hull girder and local loads are those defined in [4.3] to [4.6].

In any case, the scantlings of plating, ordinary stiffeners and primary supporting members of the tug and the barge are to be not less than those obtained according to Ch 1, Sec 3, for the tug alone, and Pt D, Ch 14, Sec 2 for the barge alone.

4.8.2 Integrated tug/barge combinations with removable flexible connection

For integrated tug/barge combinations with removable flexible connection, the scantlings of plating, ordinary stiffeners and primary supporting members of the tug and the barge are to be not less than those obtained according to Ch 1, Sec 3 and Pt D, Ch 14, Sec 2 for the tug alone and the barge alone, respectively.

4.9 Equipment

4.9.1 The equipment is to be in accordance with [3.9.1].

5 Connection

5.1 General

5.1.1 The components of the connecting/disconnecting system are to be fitted on the tug.

Where the connecting system is located on a tug superstructure, this is to be checked according to Pt B, Ch 11, Sec 5 or NR600, as applicable. The efficiency of the structural connection between this superstructure and the underlying hull structures is to be ensured.

5.1.2 The connecting system is to comply with the following requirements:

- it is to be permanently locked in position, at sea, with remote indication and control on the bridge
- it is to remain locked in the event of damage to the control system. A local control is to be provided for enabling the disconnection from the coupler machinery room.

5.2 Scantlings

5.2.1 General

The bow of the tug and the stern of the barge are to be reinforced in order to withstand the connection forces.

The structure reinforcements are to be continued in aft and fore directions of the integrated tug/barge combination in order to transmit the connection forces to the hull structure of the tug and the barge.

5.2.2 Calculation of stresses in the connection

The stresses in the connection are to be obtained by means of direct calculations, where the connection forces are to be obtained according to [3.3] and [3.4] or [4.3] and [4.4], as applicable.

When calculating the stresses in the connection, pre-loading from locking devices, if any, is to be taken into account.

For notch type connections, the analysis of the barge wing walls is to take into account the effects of bending moment, shear force and torque.

5.2.3 Shear check of the structural elements of the connection

The shear stresses in the structural elements of the connection are to comply with the following formula:

$\tau \leq 0,5\ R_y$

where:

τ : Shear stress, in N/mm^2, to be obtained as a result of direct calculations.

5.2.4 Yielding check of the structural elements of the connection

The Von Mises equivalent stresses in the structural elements of the connection are to comply with the following formula:

$\sigma_E \leq 0,78\ R_y$

where:

σ_E : Von Mises equivalent stress, in N/mm^2, to be obtained as a result of direct calculations.

5.2.5 Deflections

Deflections of the structural elements in the connection are to be obtained from direct calculations, to be carried out in accordance with [5.2.2] and submitted to the Society for review.

Deflection and pre-loading of the connection, if any, are to be considered in order to avoid hammering in the connection area.

6 Other structures

6.1 Tug fore part

6.1.1 General

For integrated tug/barge combinations with permanent connection or removable rigid connection, the tug fore structure is to be aligned with the barge aft structure in way of the notch or the dock bottom.

6.1.2 Scantlings

The scantlings of the fore part of the tug are to be in accordance with Part B, Chapter 7 or NR600, as applicable, considering the hull girder loads, the local loads and the connection forces defined in [3.3] to [3.6] for integrated tug/barge combinations with permanent connection or [4.3] to [4.6] for integrated tug/barge combinations with removable connection.

6.2 Tug aft part

6.2.1 Scantlings for integrated tug/barge combinations with permanent or removable rigid connections

The scantlings of the aft part of the tug are to be in accordance with Pt B, Ch 11, Sec 3 or NR600, as applicable, considering this part as belonging to a ship of the size of the integrated tug/barge combination.

6.2.2 Scantlings for integrated tug/barge combinations with removable flexible connections

The scantlings of the aft part of the tug are to be in accordance with Pt B, Ch 11, Sec 3 or NR600, as applicable, considering the tug as an individual ship.

6.3 Barge fore part

6.3.1 Scantlings for integrated tug/barge combinations with permanent or removable rigid connections

The scantlings of the fore part of the barge are to be in accordance with Pt B, Ch 11, Sec 1 or NR600, as applicable, considering this part as belonging to a ship of the size of the integrated tug/barge combination.

6.3.2 Scantlings for integrated tug/barge combinations with removable flexible connections

The scantlings of the fore part of the barge are to be in accordance with Pt B, Ch 11, Sec 1 or NR600, as applicable, considering the barge as an individual ship.

6.4 Barge aft part

6.4.1 For integrated tug/barge combinations with permanent connection or removable rigid connection, the barge aft structure is to be aligned with the tug fore structure in way of the notch or the dock bottom.

6.4.2 Scantlings

The scantlings of the aft part of the barge are to be in accordance with Part B, Chapter 7 or NR600, as applicable, considering the hull girder loads, the local loads and the connection forces defined in [3.3] to [3.6] for integrated tug/barge combinations with permanent connection or [4.3] to [4.6] for integrated tug/barge combinations with removable connection.

7 Hull outfitting

7.1 Rudder and steering gear

7.1.1 The tug rudder and steering gear are to be in accordance with Pt B, Ch 12, Sec 1 and Pt C, Ch 1, Sec 14, respectively, considering the maximum service speed (in ahead and astern condition) of the tug as an individual ship and the maximum service speed (in ahead and astern condition) of the integrated tug/barge combination.

The characteristics and performance of the rudder and the steering gear are to ensure the manoeuvrability of the integrated tug/barge combination.

8 Construction and testing

8.1 Test of the disconnection procedure of removable connection

8.1.1 Tests are to be carried out in order to demonstrate the capability of the tug to be safely disconnected from the barge within 5 min by one man.

These tests may be performed in harbour. However, additional information is to be submitted to the Society in order to demonstrate the capability of the tug and the barge of being safely disconnected and reconnected at sea. The operating procedure, indicating the maximum or pre-fixed sea states, is to be made available for guidance to the Master, as indicated in [1.3.1].

Section 5 Testing

1 General

1.1 Application

1.1.1 The requirements of this Section apply as follows depending on the ship service notation:

- **tug**, mainly intended for towing services, are to comply with the requirements in Article [2]
- **salvage tug**, having specific equipment for salvage services, are to comply with the requirements in Article [2]
- **escort tug**, mainly intended for escort services such as for steering, braking and otherwise controlling escorted ships, are to comply with the requirements in Articles [2] and [3]

In addition, ships with the additional service feature **barge combined** are to comply with the applicable requirements in Ch 1, Sec 4.

2 General requirements

2.1 Bollard Pull test

2.1.1 The design bollard pull is to be verified by means of a bollard pull test performed in accordance with Ch 1, App 1.

2.1.2 For tugs capable of towing over the stern (ahead towing) as well as over the bow (astern towing), the bollard pull test is to be performed for both.

2.1.3 The measured Bollard Pull is to be not less than 3% lower and not more than 1% higher than the design bollard pull specified in Pt A, Ch 1, Sec 2, [4.10], otherwise the design bollard pull is to be amended accordingly.

In case the measured pollard pull is more than 1% higher than the design bollard pull, it is to be demonstrated by the Designer that the applicable hull structure and stability requirements of this Chapter are complied with.

2.1.4 The bollard pull test is to be carried out in the presence of a Surveyor of the Society. The test procedure location and conditions (see Ch 1, App 1, [3]) are to be agreed with the Society.

2.2 Towing winches

2.2.1 Towing winches, including the associated emergency release systems are to be load tested at the DL, as defined in Ch 1, Sec 3, [2.7.2], or at the BHL, as defined in Ch 1, Sec 1, [2.4], whichever is the greatest, unless a complete calculation verifying that all the load bearing parts of the winch comply with the requirements in Ch 1, Sec 3, [2.7.3] is submitted to the Society for information and is deemed acceptable.

Generally, load testing is to be conducted at a special facility equipped to generate the required line tension (e.g. maker's premises) and to be witnessed by the Society.

In case a towing winch is of conventional, proven design, for which load testing has been previously performed and deemed acceptable by the Society, it is sufficient to perform on board function testing in accordance with [2.2.2].

Note 1: The Society may request the winch manufacturer to supply records of the load tests performed.

2.2.2 Towing winches are to be function tested on board.

The correct functioning of the winch brake, the load carrying winch components and the associated supporting structure is to be demonstrated at a towline force equal to the design bollard pull, as defined in Ch 1, Sec 1, [2.1].

Winch operating modes to be function tested include hauling in and paying out of the towline, as well as braking.

Hydraulic and electrical systems shall be function tested on board in accordance with the Society's requirements for machinery and electrical systems.

2.3 Towing hooks

2.3.1 Towing hooks, including the associated emergency release systems, are normally to be load tested at the DL, as defined in Ch 1, Sec 3, [2.7.2], unless complete calculation verifying that the hook complies with the requirements in Ch 1, Sec 3, [2.7.5] is submitted to the Society for information and is deemed acceptable.

Generally, load testing is to be conducted at a special facility equipped to generate the required line tension (e.g. maker's premises) and to be witnessed by the Society.

In case a towing hook is of conventional, proven design, for which load testing has been previously performed and deemed acceptable by the Society, it is sufficient to perform on board function testing in accordance with [2.3.2].

Note 1: The Society may request the winch manufacturer to supply records of the load tests performed.

2.3.2 Towing hooks are to be function tested on board. The correct functioning of the hook and the associated supporting structure is to be demonstrated at a towline force equal to the design Bollard Pull, as defined Ch 1, Sec 1, [2.1].

2.4 Emergency release system

2.4.1 For each emergency release system or type thereof, the performance requirements of Ch 1, Sec 3, [2.7.4] are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration on a case-by-case basis.

2.4.2 The performance capabilities of the emergency release system are to be documented and made available on board the ship on which the winch has been installed.

2.4.3 The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a Bollard Pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

2.4.4 Where the performance of the winch in accordance with Ch 1, Sec 3, [2.7.4] has previously been verified, the load applied for the installation trials is not to be lower than 30% of the BHL of the associated winch, as specified in Ch 1, Sec 1, [2.4].

2.4.5 For novel or particular designs the emergency release systems are also to be load tested with the towline at an upward angle of 45 degrees with the horizontal plane at a towline force of not less than 50 per cent of the design bollard pull, as defined Ch 1, Sec 1, [2.1].

3 Additional requirements for escort tugs

3.1 Escort performance simulations

3.1.1 Where the highest anticipated heeling moment is obtained from the results of a computer simulation program, the basic assumptions and theoretical models underlying the software are to be presented in detail to the Society. Items to be addressed include:

- hydrodynamic lift and drag computation (hull and appendices)
- modelling of thrust forces
- interaction effects between hull, skeg and (steerable) propulsion units
- flow separation effects
- water pile-up effects
- effects of waves and/or swell
- dynamic effects before a steady state is reached (e.g. during initiation and turning manoeuvres) and scaling effects (if any).

3.1.2 A validation report, containing comparisons between simulation results and full scale and/or model test results, is to be presented to the Society.

3.1.3 A clear description of the input and output data is to be provided, along with explanations on how the output data are obtained/calculated by the software.

3.1.4 As a minimum, for each relevant loading condition (see Ch 1, Sec 2, [3.1.1]) the following set of results is to be provided in tabular form as function of the escort speed for the rated values of the steering force $T_{Y,R}$ and the braking force $T_{X,R}$:

- Rated steering force $T_{Y,R}$ or steering force T_Y corresponding to rated braking force $T_{X,R}$, as applicable
- Rated braking force $T_{X,R}$ or braking force T_X corresponding to rated steering force $T_{Y,R}$, as applicable
- Corresponding towline force T_{ESC}
- All corresponding forces acting in transverse direction (hydrodynamic, thrust and towline)
- Corresponding heeling angle
- Corresponding heeling moment
- Corresponding towline angle relative to the escorted ship (refer to α in Ch 1, Sec 1, [2.7.2])
- Corresponding drift angle of the escort tug (refer to β in Ch 1, Sec 1, [2.7.2]).

Note 1: The highest anticipated values of the steering force, braking force, towline force and heeling moment do not normally all occur in the same condition (defined by the position of escort tug relative to the escorted ship and the drift angle), although more than one parameter may have its highest value in a particular condition. Hence it is necessary to consider at least two conditions: one for the highest anticipated steering force and one for the highest anticipated braking force. In case the highest anticipated heeling moment and/or towline force do not occur in either one of these two conditions, the relevant conditions are to be added.

3.1.5 It is recommended that the results of the escort performance simulations are presented in the form of diagrams showing the envelope of the (steady state) combinations of steering and braking forces obtained from the simulations. Such diagrams should cover the applicable escort speed range, with a recommended step of 2 knots.

3.2 Escort performance trials

3.2.1 Escort performance trials at full scale or model scale may be carried out in order to obtain the characteristics of escort tugs defined in Ch 1, Sec 1, [2.7].

3.2.2 The trials are to cover the applicable range of loading conditions and escort speeds.

3.2.3 The following documents are to be submitted for information prior to testing:

- Relevant loading conditions, defined by draught (or displacement) and trim, for which the tug is designed to perform escort services
- Applicable range of test speeds of the escorted ship: the speed is defined as the relative speed with respect to the sea, taking into account current effects
- Main propulsion characteristics, in particular power and maximum orientation angle of the rudder(s) (propellers);
- Preliminary calculation of the rated steering force $T_{Y,R}$, rated braking force $T_{X,R}$ and rated steady towline force $T_{ESC,R}$ as defined in Ch 1, Sec 1, [2.7], as well as the corresponding heeling moments and heeling angles, for the range of test speeds
- Calculation of the route deviation of the escorted ship (for testing purposes the escorted ship is to be selected so that the route deviation induced by the tug is kept reasonably small
- Preliminary stability calculations for the above mentioned conditions
- Escort towing arrangement plan, including the load cell and specification of the components
- Documentation relevant to the Bollard Pull test, see [2.1.1].

3.2.4 Prior to commencing the escort performance trials the following data are to be recorded:

- Wind speed and direction
- Sea state, including significant wave height and peak period
- Current speed and direction
- Water depth
- Loading condition of the escort tug: draught (or displacement) and trim
- Loading condition of the escorted ship.

3.2.5 Testing is to be performed over the applicable range of towline angles as defined in the escort towing arrangement plan. The length of the towline and the angle of the towline with the horizontal plane are to represent a typical operating condition.

3.2.6 As a minimum, the following data is to be collected during testing for post-processing and analysis:

- Towline force (tension) T_{ESC}
- Towline angle α, as defined in Ch 1, Sec 1, [2.7.2]
- Drift angle β, as defined Ch 1, Sec 1, [2.7.2]
- Heeling angle of the escort tug
- Towline length and angle of towline with the horizontal plane.

3.2.7 It is also recommended to measure the following data:

- Power setting and orientation angle of rudder(s) (propellers) of the escort tug
- Time needed to make the tug swing from the equilibrium position to its mirror position (see Ch 1, Sec 1, Fig 2).

3.2.8 For each combination of loading condition and test speed:

- The rated steering force $T_{Y,R}$ and rated braking force $T_{X,R}$ are to be calculated on the basis of the corresponding measured steady towline force T_{ESC} and the associated measured towline angle, drift angle and the angle between the towline and the horizontal plane.
- The maximum heeling arm is to be calculated on the basis of the corresponding measured steady towline force T_{ESC}, as defined in Ch 1, Sec 1, [2.7], the associated measured heeling angle and the GZ curve applicable to the loading condition considered.

Note 1: The GZ curve is to be based on the escort tug in upright position before commencing the escort operation.

3.2.9 As a minimum, for each tested loading condition the following set of results is to be provided in tabular form as function of the escort speed for the rated values of the steering force $T_{Y,R}$ and the braking force $T_{X,R}$:

- Rated steering force $T_{Y,R}$ or steering force T_Y corresponding to rated braking force $T_{X,R}$, as applicable
- Rated braking force $T_{X,R}$ or braking force T_X corresponding to rated steering force $T_{Y,R}$, as applicable
- Corresponding towline force $T_{ESC,R}$

- Corresponding heeling angle
- Corresponding heeling moment
- Corresponding towline angle relative to the escorted ship (refer to α in Ch 1, Sec 1, [2.7.2])
- Corresponding drift angle of the escort tug (refer to β in Ch 1, Sec 1, [2.7.2]).

Note 1: The highest anticipated values of the steering force, braking force, towline force and heeling moment do not normally all occur in the same condition (defined by the position of escort tug relative to the escorted ship and the drift angle), although more than one parameter may have its highest value in a particular condition. Hence it is necessary to consider at least two conditions: one for the highest anticipated steering force and one for the highest anticipated braking force. In case the highest anticipated heeling moment and/or towline force do not occur in either one of these two conditions, the relevant conditions are to be added.

3.2.10 For model testing, due consideration is to be paid to scale effects for establishing the escort tug characteristics at full scale from the model test results.

3.3 Escort equipment testing

3.3.1 Load testing

Escort winches, including the associated emergency release system are normally to be load tested at the DL, as defined in Ch 1, Sec 3, [3.2.2], or the BHL, as defined in Ch 1, Sec 1, [2.4], whichever is the greatest, unless a complete calculation verifying that all the load bearing parts of the winch comply with the requirements in Ch 1, Sec 3, [3.2.3] is submitted to the Society for information and is deemed acceptable.

Generally, load testing is to be conducted at a special facility equipped to generate the required line tension (e.g. maker's premises) and to be witnessed by the Society.

In case an escort winch is of conventional, proven design, for which load testing has been previously performed and deemed acceptable by the Society, it is sufficient to perform on board function testing in accordance with [3.3.2].

Note 1: The Society may request the winch manufacturer to supply records of the load tests performed.

3.3.2 Function testing

In general, the proper functioning of the towing equipment used for escort services is to be verified by on board testing and to be witnessed by the Society. Function testing is to be performed both for normal operating conditions and in accordance with the escort towing arrangement plan as well as in emergency conditions (emergency release, failure of main power supply). The safe operation of the escort winch from all control stations is to be demonstrated.

Escort winches are to be function tested on board.

The correct functioning of the winch brake, the load carrying winch components and the associated supporting structure is to be demonstrated at a towline force equal to the design Bollard Pull, as defined in Ch 1, Sec 1, [2.1].

The emergency release systems are to be function tested according to [2.4].

Winch operating modes to be function tested include hauling in and paying out of the towline, braking and the active pay-out and haul-in system when fitted (see Ch 1, Sec 3, [3.2.3]).

Hydraulic and electrical systems shall be function tested onboard in accordance with the Society's requirements for machinery and electrical systems.

Appendix 1 Bollard Pull Trials

1 General

1.1 Purpose

1.1.1 The purpose of this Appendix is to:

- ensure that the reported bollard pull figure represents the realistic performance of the vessel that can be met in service conditions at an acceptable level of accuracy, irrespective of the specific conditions met during the execution of the bollard pull trial that are known to affect the vessel's performance
- facilitate a repeatable performance figure in accordance with clear definitions.

1.2 Application

1.2.1 This Appendix applies to ships with multiple propulsors, with or without nozzles.

1.2.2 This Appendix does not apply to the following ships:

- ships whereby propulsors are mounted under a large flat bottom (e.g. specialised ships with multiple thrusters for dynamic positioning operation)
- single propulsor towing vessels.

2 General requirements

2.1 Bollard pull trial

2.1.1 A bollard pull trial is a full scale test with a vessel to determine the horizontal towline force which the main propulsion systems can generate at a vessel speed equal to zero knots.

The bollard pull trial is to be executed in unrestricted and calm water, without external influences such as wind and current. One end of the towline is to be attached to a dedicated towing point on the vessel (e.g. towing winch or hook) and the other end is to be attached to an external strongpoint (fixed bollard ashore, seabed secured anchor or otherwise). The towline force is to be measured by a calibrated load cell which is normally fitted between the towline and the external strongpoint. The engine power at which the bollard pull trial is executed is to be measured and reported in conjunction with the steady state line pull.

2.2 Bollard pull trial conditions

2.2.1 The vessel's bollard pull is the towing force provided by the specified propulsors, recorded as being maintained in a steady state condition for a duration of not less than 5 minutes and performed at rated power as defined in [2.3.1] at a speed through water of zero knots.

2.2.2 The operating profile for the bollard pull trial condition is to represent normal service conditions, such that sufficient auxiliary power is available for normal and safe operation of the vessel.

2.2.3 Engine speed and brake power are to be measured simultaneously with towline force during the bollard pull trial and are to be reported on the test report (see [8]).

2.2.4 Bollard pull trials conducted in hybrid mode, whereby batteries or other supplementary power devices are used to provide additional power for a limited period of time, are to be separately listed as “Hybrid Bollard Pull (HBP)”, and have an associated time of validity for each operational mode of such HBP.

2.3 Engine rating

2.3.1 The bollard pull trial is to be performed up to the maximum power of the engines which is available in service. Maximum power means:

a) For marine diesel and/or gas engines: The maximum brake power that the engine can deliver in service, and that corresponds to the power recorded during 100% load testing at the Factory Acceptance Tests of the engine.

b) For electric propulsion machines: Design power for normal service conditions defined for the electric motor, specified on the motor name plate.

c) For Hybrid propulsion systems (diesel or gas mechanical propulsion with electrical power take-in):

The sum of the power defined in item a) and item b) above for all propulsion machines.

d) In case the design power of the propeller is less than the maximum power of the engine(s), the maximum power is to be taken as the design power of the propeller.

2.3.2 The engine speed is to be within the Original Equipment Manufacturer (OEM) specified speed range, which is to be consistent with the type approval of the engine and the certification of the propulsion train (e.g. Torsional Vibration Calculations).

2.3.3 The available output power has to match the conditions stated in [2.2.2].

2.3.4 The propulsion and engine configuration used during the bollard pull trial is to be stated on the certificate. This includes a specification of the power generation systems (output of engines / fuel cells / battery banks etc.), propulsion motors (mechanical, electrical, hybrid) and propulsion systems (number of propellers, use of (retractable) thrusters etc.) used during the bollard pull trial.

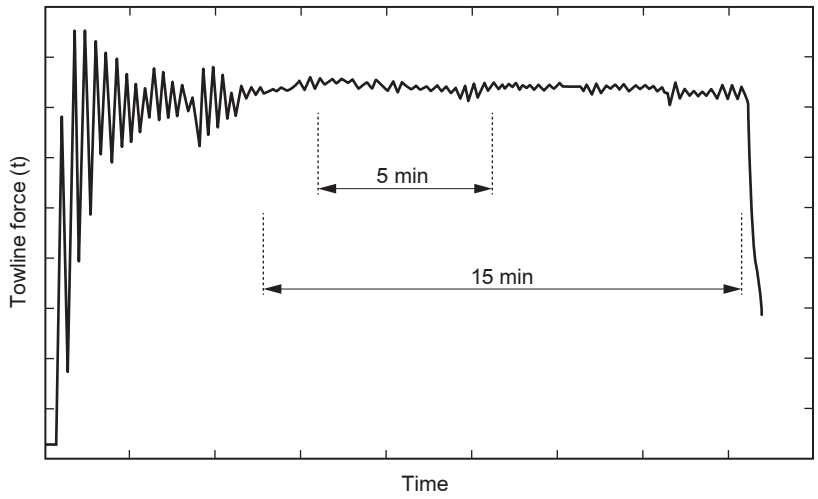
2.4 Steady state phase

2.4.1 The steady state phase of the bollard pull trial is the time interval during which a steady towline force is measured. The steady state phase represents the highest consecutive 5 minute period, logged as per [4.4] during a 15 minute trial under effectively constant trial conditions stated in this trial test procedure. The definition of the highest consecutive 5 minutes period is to be in accordance with [7.2].

2.4.2 The 15 minute trial window starts after the initial build up and subsidence in line tension of associated dynamic effects, as shown in Fig 1. During this period only small changes in steering angles associated with maintenance of vessel position are permitted. Strong sway motions are to be avoided.

2.4.3 In Hybrid mode (Diesel/Diesel-Electric power plus that available from the batteries) the available battery power for propulsion might decrease during the execution of the bollard pull trial. In this case the reported bollard pull is to be defined by calculating the mean power and towline force over a period of 5 minutes as minimum, and noted down as a separate entry in the bollard pull certificate as 'Hybrid Bollard Pull (HBP)' with an associated maximum time for which that HBP rating is valid in service. The designed power availability duration is to be provided by the designer of the propulsion system.

Figure 1 : Schematic representation of towline force as a function of time during bollard pull trial



3 Requirements for the trial site

3.1 Water depth and radius

3.1.1 The minimum total water depth, which is to be maintained at least in a radius of 2 times the ship's length around the towing vessel, is 4 times the propeller immersion depth (h_{imm}).

3.1.2 The propeller immersion depth is the distance between the water surface and the centre of the propulsion unit, as indicated in Fig 2. For propulsion systems with vertical axis, the centreline of the jet-stream is used, i.e. the middle of the blades as indicated in Fig 3.

3.1.3 The water depth during the trial is to be recorded on the bollard pull trial report.

3.2 Ship to shore distance

3.2.1 The minimum distance between quay and centre of the propeller closest to shore is 50 times the propeller diameter to avoid water circulation affecting the bollard pull.

Figure 2 : Definition of propeller immersion depth and ship to shore distance

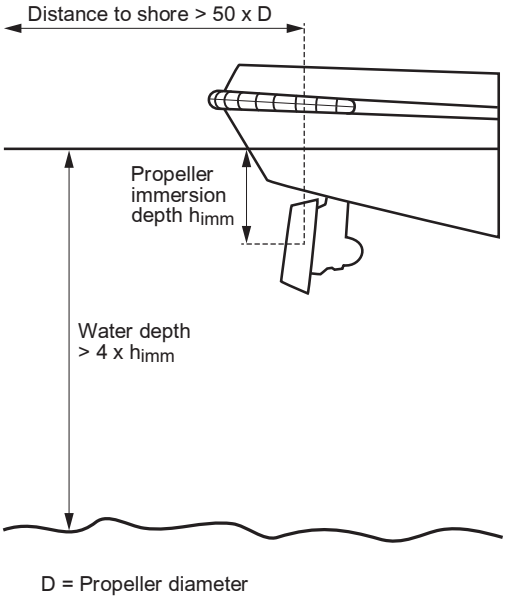
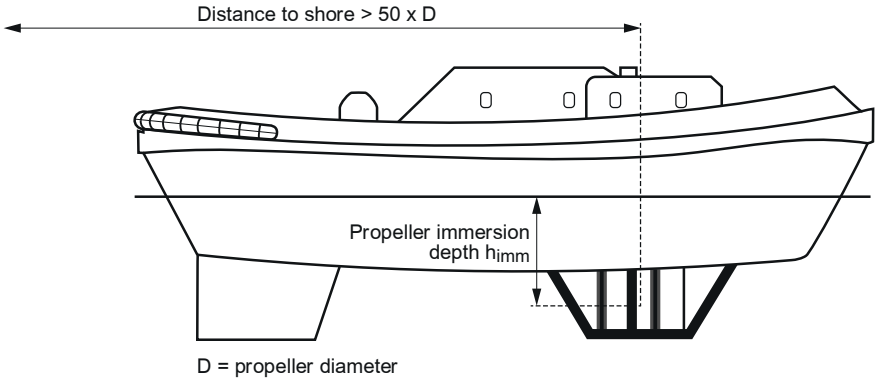


Figure 3 : Definition of immersion depth and ship to shore distance for a propulsion system with vertical axis



3.3 Current

3.3.1 The current speed is to be less than 0,5 knots from the bow or sides. If the current is approaching the vessel from the stern, the current is to be less than 0,3 knots. When the bollard pull trial is performed with side current, the towing vessel is to be allowed to shift position by letting it move with the current and not to steer against it, while maintaining heading relative to the towline. It is not allowed to fix the position of the towing vessel by cables, other vessels or other means. Bow thrusters may be used to hold position if this does not negatively affect the power available for main propulsion, see also [6.1.1].

3.4 Water density

3.4.1 Water density is to be recorded on the bollard pull trial report. No corrections for water density are to be applied.

3.5 Waves

3.5.1 The bollard pull trial is to be conducted in calm water conditions as far as possible. In any case, the maximum significant wave height encountered during the bollard pull trial is not to exceed 0,5 m. No corrections for waves are to be applied.

3.6 Wind

3.6.1 Transverse wind may cause sway movements that have to be compensated by applying rudder. This may degrade vessel bollard pull performance. Wind speed during the bollard pull trial is to be as low as possible but not more than 10m/s (5 Beaufort scale).

3.7 Outside temperature

3.7.1 It is recommended to perform trials in non-tropic conditions (air temperature < 45°C, water temperature < 32°C) to avoid engine performance degradation. No corrections for environmental conditions are to be applied.

Note 1: It is recommended to log relevant engine parameters during the trials.

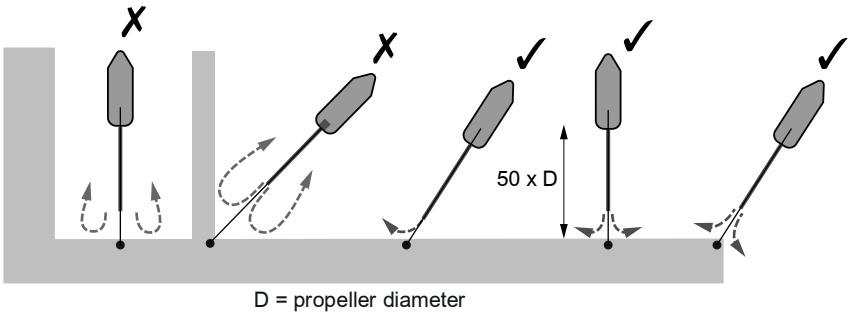
3.8 Towline

3.8.1 A torsion-free towline (e.g. synthetic) is recommended to ensure that the load cell measures, as intended, in direct tension.

3.9 Vessel orientation relative to the quay

3.9.1 The heading relative to the quay side (assuming solid quay sides) is to be chosen such that propeller wash can freely move without being re-directed in the direction of the vessel. Towing is not to be done in enclosed harbours, as recirculation is more likely to occur, resulting in unsteady performance. Minimum line length, water depth and associated radius are to be observed. Fig 4 presents examples of acceptable and unacceptable vessel orientations relative to the quay.

Figure 4 : Positioning of the vessel during bollard pull trials



4 Instrumentation

4.1 Load cell

4.1.1 The load cell is to be installed between the strongpoint and towline, either on board or on shore. The load cell is to have a digital output and be capable of sampling at a rate of 1 Hz or faster.

4.1.2 To maximise accuracy the following conditions are to be met:

a) The load cell calibration and certificate is not to be older than 12 months and is to be provided with the bollard pull certificate. The calibration procedure of the load cell is to be in accordance with the requirements stated in [4.1.3].

b) The load cell is to have an uncertainty in accordance with an ISO 7500-1:2018 Class 1 machine, which is to be stated on the load cell calibration certificate.

c) When a steel stranded wire is used during the bollard pull trial, the load cell is to be proven to be torsion insensitive in accordance to the requirements in [4.1.4].

d) Spacer rings are to be installed between load cell and shackle ears as indicated in Fig 5 to avoid misalignments during testing. Spacer rings are plastic rings specially made to fill the gaps between shackle ears and load cell, and thus centrally align the load cell.

e) Shackle pins are to be free from surface imperfections such as dents or bend.

f) The towline is to be connected first to a shackle, which is consecutively connected to a second shackle that holds the load cell (see Fig 5).

g) When a load pin shackle is used, a centralising bobbin as indicated in Fig 6 is to be used in order to ensure correct alignment, in addition to additional shackles. The towline is not to be connected directly to the load shackle.

h) The load cell / load shackle and connected shackles are not to touch the quayside edge or ground (see Fig 7) to avoid misalignment, bending and corresponding offsets in measurements. The shackles denoted by 'Additional Shackles' in Fig 5 are allowed to touch the ground if not possible otherwise.

i) The test is to be conducted at the same temperature as during the calibration of the load cell, within a tolerance of ±10°C. If this condition cannot be fulfilled, the load cell is to be certified to be suitable for the temperature during the trial.

j) The load cell is to be set to zero prior to the trial, when the towline is not yet connected and free from any load. After the trial, when the load cell is free from any load, the reading is to be checked again.

Figure 5 : Recommended load cell arrangement with spacer rings and additional shackles

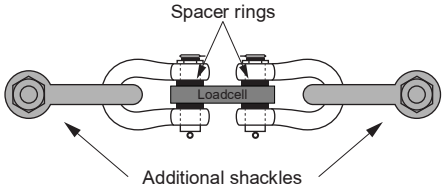


Figure 6 : Recommended load shackle arrangement with centralising bobbin and shackles

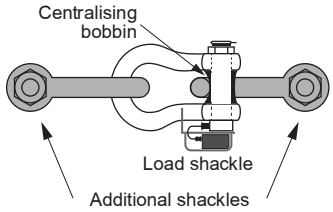


Figure 7 : Load cell touching ground, causing bending moments and misalignment of the load cell

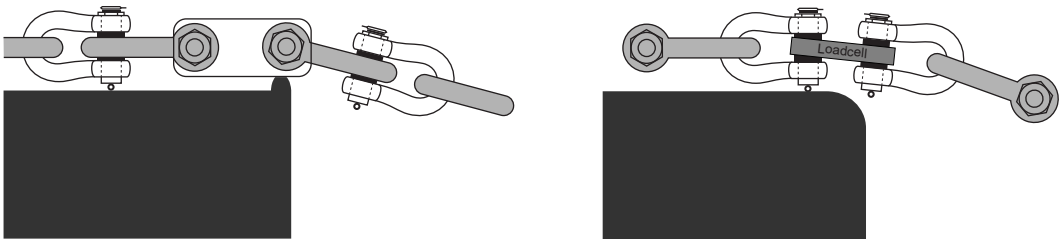
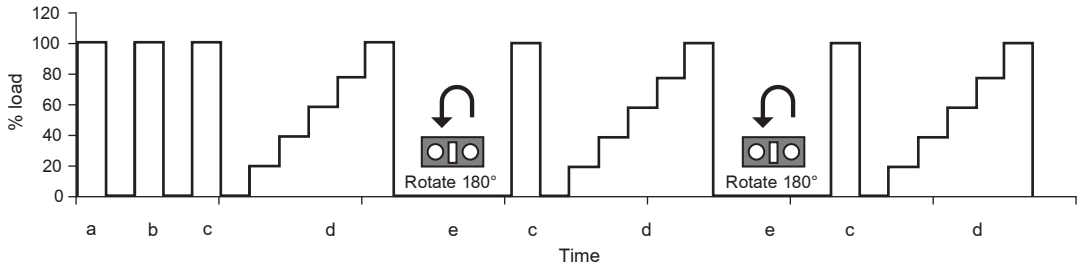


Figure 8 : Schematic of calibration procedure according to ISO 7500-1:2018



4.1.3 Load cell calibration requirements

Load cells are to be calibrated according to ISO 7500-1:2018 (“standard calibration”). The load cell is to be calibrated with the same shackle pin diameter as it is used during bollard pull testing. If calibration is done on a horizontal calibration machine, spacer rings are to be used to improve alignment.

Fig 8 presents a schematic of the calibration procedure, which consists of the following steps in chronological order:

a) pre-load to the maximum of the load cell's scale

b) pre-load to the maximum of the load cell's scale

c) pre-load to the maximum of the load cell's scale

d) stepwise load increase comprising at least five discrete force levels at equal intervals between 20% and 100% of the maximum range of the scale

e) rotation of the load cell by 180 degrees, around the X, Y or Z axis and a rotation of the shackle pins connected with the load cell by 30 degrees

f) repetition of steps c- e for two more times.

For each discrete force, the arithmetic mean of the values obtained for each series of measurements is to be calculated. From these mean values, the relative accuracy error and the relative repeatability error are to be calculated. The preload runs are to be omitted.

4.1.4 Torsional insensitivity

When a steel stranded wire is used during the bollard pull trial, the load cell is to be proven to be torsional insensitive to a torsion value T, in kN.m, of at least:

$$T = C_1 \cdot BP_{design} \cdot D_{line}$$

Where:

BP_{design} : Vessel's design bollard pull at 100% engine load, in kN

C_1 : Towline wire torsion factor (c_1 = 0,07 for 6/36 steel stranded wires, unless documented otherwise)

D_{Line} : Diameter of the towline, in m.

The insensitivity of the load cell is to be proven by the load cell manufacturer by means of systematic tests. When a rotation resistant rope is used (e.g. some synthetic ropes), this requirement is not applicable.

4.2 Engine speed measurement

4.2.1 The engine speed is to be continuously measured using a pickup sensor or via the engine control system of the engine's manufacturer and recorded digitally during the trial.

4.3 Power measurement

4.3.1 Engine brake power is to be measured using a dedicated shaft torque / engine speed measurement system for first and second ships of a series. Torque measurement systems based on strain gauges are most common, but other techniques, e.g. using optical deflection measurement, are also allowed. Engine speed can be measured using an optical or magnetic pickup sensor.

4.3.2 The power measurement is to represent engine brake power as tested during shop tests. For third and further of series the engine control system can be used provided its accuracy has been verified based on the first two vessels of a series. The dedicated shaft torsion/engine speed sensor reading is leading for the engine power.

4.3.3 The uncertainty of the engine power measurement should be according to ITTC standard 7.5-04-01-01.1 (total bias uncertainty +/-2%).

4.3.4 Shaft material properties, i.e. the G-Modulus, are to be fully described and documented by the Shipbuilder. If no certificate based on an actual shaft torsional test is available, a G-Modulus of 82400 N/mm^2 is to be used for regular shaft steel.

4.3.5 If power cannot be measured directly on the engine's output shaft, it may be calculated by measuring power on the propeller shaft and correcting for power losses between engine flywheel and measurement point. These losses are to be confirmed by their respective manufacturer and stated in the trial report. Suggested measurement locations for various propulsion configurations are included in Note 1.

Note 1: The objective of the power measurement is to measure engine brake power. For ships with a diesel direct propulsion layout (see Fig 9), the shaft power measurement system can be installed directly on the output shaft of the engine, as close to the engine as possible to avoid shaft losses.

For ships with multiple engines coupled to a gearbox (see Fig 10), where there is insufficient space between main engine and gearbox to install a shaft power meter shaft power is to be measured on the propeller shaft. If a PTO is installed, it is to be declutched or unloaded. Auxiliaries connected to the gearbox or PTO that are necessary for the normal operation of the engine such as cooling or oil circulation pumps are to remain operational during the test. The main engine brake power is to be calculated by calculating the gearbox losses and adding them to the measured shaft power.

For ships with a hybrid propulsion system (see Fig 11), where both an electric motor and combustion engine provide power to a single shaft, the combined power is to be measured. Both the combustion engine and PTI are not to run at a rating higher than 100% load.

For diesel electric ships (see Fig 12) the design power of the electric motor is the limiting factor for power output. The brake power of the electric motor is to be determined using a power measurement system on the output shaft. If this is not possible, the power to the electric motor is to be determined with a power spectrum analyser or other means.

4.3.6 In case carbon shafts are used and no steel section is available for the installation of a power measurement system, the engine rating during the bollard pull trial is to be determined on a case by case basis with the parties involved. Without a direct measurement of the shaft brake power, no power is to be reported on the trial certificate.

4.3.7 The power meter zero setting is to be done according to its maker's instructions prior to the trials.

Figure 9 : Power measurement on a diesel direct propulsion arrangement

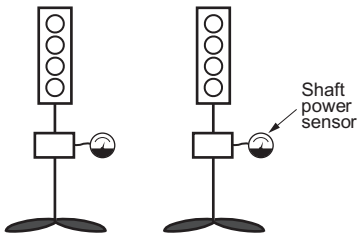


Figure 10 : Power measurement on a geared diesel direct propulsion arrangement with PTO (declutched)

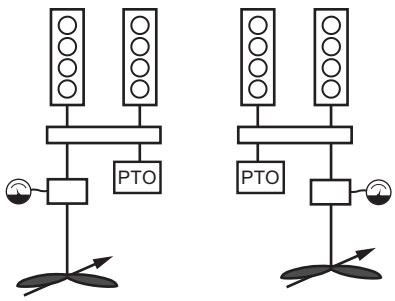


Figure 11 : Power measurement on a Hybrid propulsion arrangement

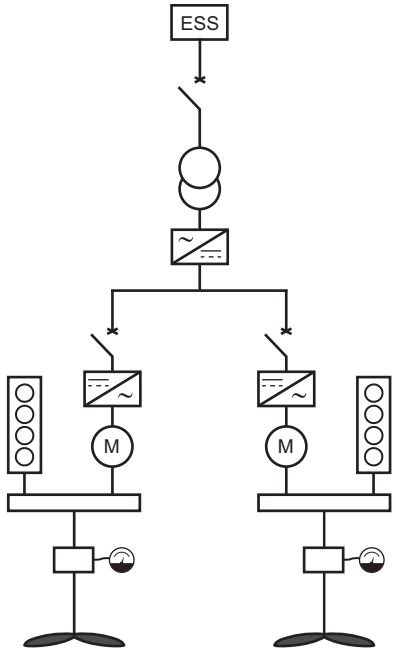
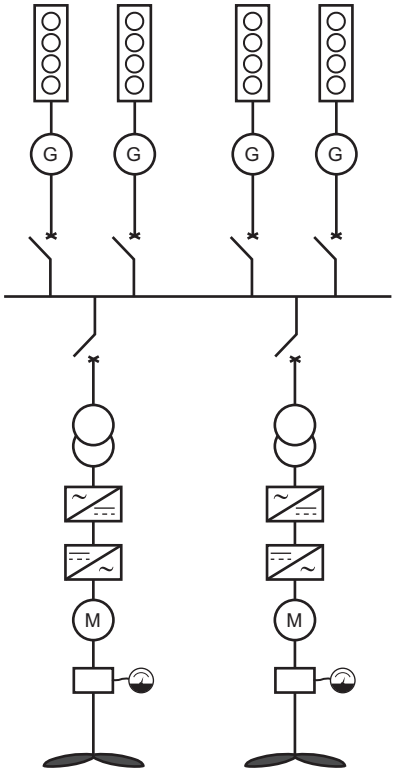


Figure 12 : Power measurement on a Diesel-Electric propulsion arrangement



4.4 Data logging

4.4.1 The readings of the towline force, engine speed and shaft torque are to be recorded continuously and automatically on a digital system with a sample frequency of at least 1 Hz in order to capture the natural fluctuations in the forces. A higher sampling rate is recommended to identify measurement errors and dynamic effects more clearly. Each load cell reading is to be tagged with a time stamp and synchronised with the power measurements on the vessel.

4.4.2 Measurement is to commence prior to the bollard pull trial, so that the steady state phase and no-load reading can be identified during post processing of the data.

4.4.3 The following data are to be recorded at the beginning of the trial: Draft and trim, wind, waves, current, water depth, water density, distance to quay, fuel quality, towline diameter, length, and material. If conditions vary during the test, the variances at completion of the trial are also to be recorded.

5 Trial preparation

5.1 Draught and trim

5.1.1 The draught and trim of the towing vessel are to be representative for typical service conditions and are to be stated on the certificate.

5.2 Propellers

5.2.1 The propellers used during the trial are to be the same as used for service conditions. It is strongly recommended to clean/ polish the propellers immediately before trials, as blade roughness and fouling negatively affects thrust and power efficiency.

5.3 Fuel

5.3.1 The fuel used during the trial is to be representative for the normal service operation of the vessel. The fuel type and calorific value are to be stated on the certificate.

6 Trial execution

6.1 General

6.1.1 During the trial a visual observation of the load cell reading on the bridge is recommended, so that the commencement of the steady state phase can be judged. Minimal sway motion is recommended to avoid performance drops. The use of a bow thruster is allowed to maintain position during the trial, when this does not affect the power available to the main propulsion system. Stern side thrusters are not to be used unless it is demonstrated that they do not affect the inflow velocity.

6.1.2 At least four power settings are to be tested between 25% and 100% load: maximum power in accordance with [2.3.1], 85%, 60% and 40% of the rated power are recommended.

6.2 Steps to be performed

6.2.1 The following steps are to be performed for the bollard pull trial:

a) Make sure the load cell, wireless indicator, test location and environmental conditions are according to the requirements stated in this Appendix.

b) Tare the load cell (set to zero) prior to the test when the load cell and shackles are not yet connected.

c) Connect load cell and towline. Slowly put tension on the towline. Ensure correct alignment of the load cell and shackles. Re-align when necessary.

d) Increase tension on the towline until the maximum power, as defined in [2.3.1] is reached. Check power rating using the engine shaft power meter.

e) When the vessel has a stable position and heading and line fluctuations are constant, start a 15 minute run recording the towline force, power and engine speed.

f) Reduce power to other engine ratings (85%, 60% and 40% recommended). When the vessel is stable and line fluctuations are constant, start measurement. The minimum measurement period is hereby 5 minutes. A longer period (15 min) is recommended to capture a more stable performance.

g) Repeat steps b) to f) for the other direction of towing (stern / bow) if applicable.

6.2.2 During the test a log sheet is to be filled in. Minimum reporting requirements are listed in Article [8].

7 Data analysis

7.1 Validation of recorded data

7.1.1 The logged towline force is to be plotted on a time scale and evaluated for measurement errors, outliers and to identify the steady state period. The towline force is to have a smooth, sinusoidal character as a function of the mass-spring system behaviour of the towline and vessel. If the data quality is poor, indicated by stepwise data, missing data and large non-periodic fluctuations, the bollard pull trial is to be repeated.

7.2 Identification of steady state performance

7.2.1 The determination of the highest consecutive 5 minute period of stationary performance is to be performed after the trial using the logged data. The calculation of the average bollard pull over the 5 minute period is performed using a normal arithmetic average over the selected period (using at least 300 consecutive data points). Clear outliers due to sensor errors are to be removed prior to calculation of the average. The average of the propulsion power and engine speed is to be determined over the same 5 minute data period.

8 Reporting

8.1 Trial report requirements

8.1.1 The bollard pull test certificate is to be accompanied with a trial report. The report is to contain at least the following information:

- characteristics of the vessel, propulsion system and main engines/propulsion motors, including Original Equipment manufacturer (OEM)-defined consecutive periods of available maximum power
- the propulsion and engine configuration used during the bollard pull trial. This includes a specification of the power generation systems (output of engines / fuel cells / battery banks etc.), propulsion motors (mechanical, electrical, hybrid) and propulsion systems (number of propellers, use of retractable thrusters etc.) used during the bollard pull trial
- used method of power measurement and used mechanical/electrical efficiency if applicable
- fuel characteristics
- location, water depth and line length during the trial
- environmental characteristics: ambient temperature, wave height, water density, wind and current speed and direction relative to the vessel
- towline and load cell-shackle arrangement
- calibration certificate of load cell
- log sheet with results of each 5 minute trial, including power, engine speed and line pull for all tested load cases
- name and contact information for persons performing and witnessing the trial on behalf of shipyard, owner and main component manufacturers
- for re-evaluation trials at part-load operation: the original bollard pull - shaft power curve including the measured points at part load, and the calculation method to derive to the resulting extrapolated bollard pull at maximum power.

9 Part load bollard pull re-evaluation trials

9.1 Application

9.1.1 A new bollard pull trial is required:

- for class renewal; or
- in case of overhaul or alteration of the engines and/or propulsion system.

In those cases where a suitable bollard is unavailable, e.g. because the available bollard has an insufficient safe working load, bollard pull trials may be performed at reduced load. These trials are no substitute for full bollard pull trials, but can be used to evaluate the validity of previous test results performed at 100% load. This Article lists the prerequisites for such trials, the test and analysis procedure.

9.2 Trial overview

9.2.1 A full-range bollard pull trial as described in Article [6] provides a bollard pull versus shaft power performance curve over the complete power range. This curve is to be evaluated in the performance re-evaluation trials at part load. The performance re-evaluation is to be done in three steps:

- Step 1: The capabilities of the engines after overhaul are evaluated, by testing each individual prime mover separately at the highest power the engine can deliver (in compliance with [2.3]). The engine power is hereby logged.
- Step 2: A bollard pull trial is performed at the maximum safe working load of the bollard with all prime movers in operation, but at part load.
- Step 3: The measured bollard pull is compared with the original performance curve of the vessel. If the measurement results are within ±3% the original curve, the original curve is still valid and can be intersected at the combined maximum power measured in step 1. If the deviations are larger the curve is to be shifted accordingly.

9.3 Prerequisites

9.3.1 Bollard Pull Performance Re-evaluation Trials are only valid when the following conditions are met:

a) Bollard pull trials have been performed in the past where a minimum of 4 power settings have been tested between 25% and 100% rated power according to this Appendix, whereby delivered power is measured using a dedicated power measurement system on the drive shafts.

b) The maximum rated power of each prime mover can be tested separately. For ships with combinator mode and father/son arrangement, a temporary change in engine speed-pitch may be necessary to avoid overloading the engine when testing one engine per shaft.

c) The same propeller and nozzles as during the initial full load bollard pull trial are in place.

d) The propellers are re-conditioned (polished) to the same condition as for the initial full load bollard pull trial according to the relevant ISO propeller class or similar.

e) The propeller nozzles have no surface damage and are in the same condition as for the initial full load bollard pull trial.

f) A bollard is available with a safe working load that exceeds the power rating of each individual prime mover, so that the maximum power of each prime mover can be safely tested. For example, for tugs with a father/son engine arrangement, with two engines providing 60% / 40% of the total available power, the bollard is to be strong enough to hold the bollard pull obtained at 60% of the total available power.

9.3.2 If the above conditions cannot be met, normal bollard pull trials according to Article [6] are to be performed.

9.4 Step 1: Evaluation of engine power

9.4.1 The engine capability of each prime mover is determined by loading the engine up to 100% load in a bollard pull setup (zero ship speed). The following procedure is to be followed:

a) Tare the shaft power measurement system according to manufacturer recommendations

b) Make sure the test location and environmental conditions are according to the requirements stated in this Appendix

c) Slowly put tension on the towline
- for vessels with multiple prime movers per propeller: engage one prime mover per shaft. Operate both shafts for symmetric operation (see Fig 13, left arrangement)
- for vessels with 2 propellers and two engines: disengage one propulsion unit so only one propeller is in operation. The other propeller may weather vane or stand still (see Fig 13, right arrangement)
- for vessels with multiple propellers: engage one prime mover

d) Increase power up to the power as stated in [2.3]

e) Stabilise vessel and start a 5 minute power measurement. Bollard pull is not measured. For ships with one propeller in operation strong rudder usage may be necessary to stabilize vessel

f) Repeat step c) and d) to test the other prime movers

g) Calculate the total power capacity, P_{Total}, of the main engines using:

$$P_{Total} = \frac{\sum_{i=1}^{n} P_{ME(i)}}{\eta_{gear}}$$

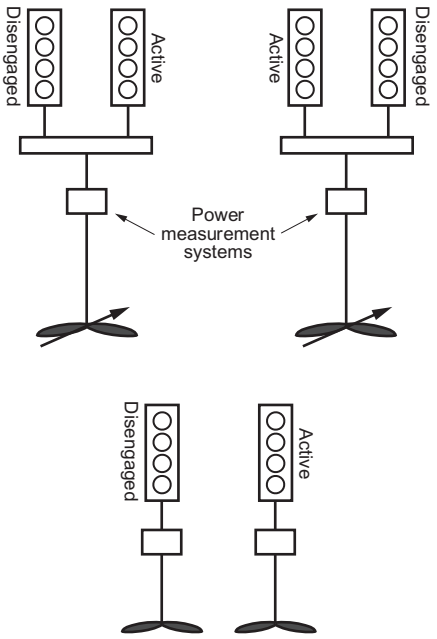
Where:

P_{Total} : Total available power for all prime movers combined

P_{ME} : Engine power for each 'i' prime mover as obtained in step (d) and (e)

η_{gear} : Gearbox efficiency ($\eta_{gear} = 1$ when there is no gearbox between measurement system and engine output shaft). The same gearbox efficiency as used during the new-build bollard pull trials is to be used.

Figure 13 : Propulsion configurations for individual engine performance testing



9.5 Step 2: Re-evaluation of propulsion efficiency

9.5.1 The propulsion efficiency curve (towline force versus shaft power) is to be evaluated at the maximum safe working load of the bollard. The following procedure is to be followed:

a) Make sure the load cell, wireless indicator, test location and environmental conditions are according to the requirements stated in this Appendix.

b) Tare the load cell prior to the test when the load cell and shackles are not yet connected.

c) Ensure correct alignment of the load cell and shackles. Re-align when necessary.

d) Engage all engines and propellers and increase power until towline tension has reached maximum safe working load of bollard.

e) When the vessel is stable and line fluctuations are constant, start a 15 minute run recording the bollard pull, power and engine speed in accordance with the procedure documented in [6].

f) Reduce power to 40% of the total available power. When the vessel is stable and line fluctuations are constant, start a new 15 minute run recording the bollard pull, power and engine speed.

g) Repeat above steps for astern operation if applicable.

h) Plot measurement results in the original propulsion efficiency curve.

Steps a) to f) are to be performed in accordance with the normal procedures and environmental restrictions as documented in this Appendix.

9.6 Step 3: Re-evaluation of bollard pull capability at available power

9.6.1 The offset between the measured data points and the original performance is to be assessed through the towline pull ratio, α_{BP}:

$$\alpha_{BP} = \frac{BP_{Evaluate}}{BP_{original}}$$

Where

$BP_{Evaluate}$: Bollard pull-power performance curve obtained during re-evaluation trials, (see [9.5])

$BP_{Original}$: Original Bollard pull-Power performance curve from full power trials.

To obtain the bollard pull at P_{Total} either the original performance curve is used, or the curve is first shifted:

a) if $0,97 < \alpha_{BP} < 1,03$

the original BP-Power curve is used to intersect the new bollard pull capability at P_{Total}, as shown in Fig 14

b) if $\alpha_{BP} > 1,03$

the curve is shifted vertically by multiplying the curve with α_{BP} to match the data points, as depicted in Fig 15. It is to be demonstrated that the applicable hull structure and stability requirements are complied with.

c) if $\alpha_{BP} < 0,97$

the curve is shifted vertically by multiplying the curve with α_{BP} to match the data points, as depicted in Fig 15.

If P_{Total} is more than the highest power rating from the original BP-trial, the bollard pull is determined from the highest rating from the original BP-trial. No extrapolation beyond the original curve is allowed.

For tests in ahead direction the curve for ahead trials is to be used; for astern trials the curve for astern direction.

9.7 Presentation of results

9.7.1 The original Shaft power - Bollard pull curve including its measurement points, and the method to derive to the resulting extrapolated bollard pull at rated power, is to be clearly documented.

Figure 14 : Procedure for estimating bollard pull at P_{Total} from part load trials

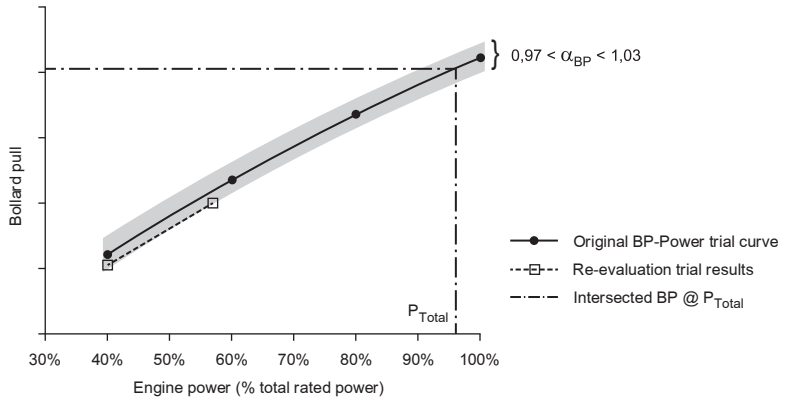
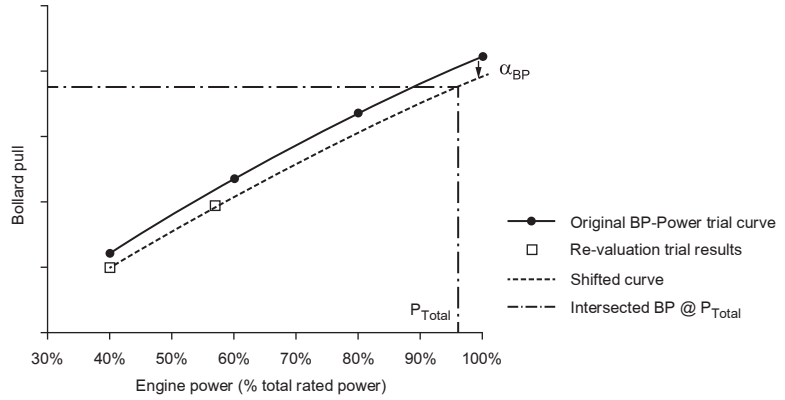


Figure 15 : Procedure for estimating bollard pull at P_{Total} when α_{BP} < 0,97 or α_{BP} > 1,03



CHAPTER 2
ANCHOR HANDLING VESSELS

Section 1 General
Section 2 General Arrangement
Section 3 Stability
Section 4 Hull Structure
Section 5 Testing

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **anchor handling** as defined in Pt A, Ch 1, Sec 2, [4.11.2].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1 and specific requirements for testing as defined in Ch 2, Sec 5.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 90 m	• Part B • Ch 2, Sec 2	• NR566 • Ch 2, Sec 2
	L < 90 m	• NR600 • Ch 2, Sec 2	• NR566 • Ch 2, Sec 2
Hull	L ≥ 90 m	• Part B • Ch 2, Sec 4	• Part B • Ch 2, Sec 4
	L < 90 m	• NR600	• NR600
Stability		• Part B • Ch 2, Sec 3	• NR566 • Ch 2, Sec 3
Machinery and cargo systems		• Part C	• NR566
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.			

1.2 Definitions

1.2.1 Anchor handling winch

Winch dedicated to anchor handling operations.

1.2.2 Wire

A dedicated line (wire rope, synthetic rope or chain cable) used for the handling of anchors by means of the anchor handling winch.

1.2.3 Stern roller

A roller or similar equipment arranged at the aft boundary of the ship to launch and recover the anchors.

The stern roller is designed to adequately support the working line during the launching/recovering of anchors.

1.2.4 Wire stopper (i.e. shark jaw, karm fork)

Deck equipment designed to temporary secure the inboard end of the working line.

1.2.5 Guide pin

Deck equipment guiding the working lines to the intended sectors

1.2.6 Design bollard pull (BP)

The design bollard pull T_{BP}, in kN, is the maximum sustained towline force the vessel is capable of generating at zero forward speed, as defined in Ch 1, Sec 1, [2.1.1].

1.2.7 Safe working load (SWL)

Load to be specified by the applicant of each shipboard fitting. Individual SWLs are to be marked on each concerned fitting.

1.2.8 Loads on anchor handling winch

- Rated line pull (RP): Maximum rope tension, in kN, that the winch can haul at the relevant layer, in normal service condition, when the drum rotates at its maximum service speed. The rated line pull is defined for a specific reeled layer which is to be specified by the party applying for classification. The reeled layer may be the first layer (in contact with the drum) or the outer layer.
- Brake holding load (BHL): Maximum rope tension, in kN, with holding brake activated
- Rendering load (RL): Maximum rope tension, in kN, at the drum exit when the drum just starts rotating in the opposite direction of the applied driving torque with a first layer of rope wound on the drum.

Section 2 General Arrangement

1 General

1.1 Access to machinery space and spaces below the exposed cargo deck

1.1.1 *Access to the machinery space excluding emergency access and removal hatches, should, if possible, be arranged within the forecastle. Any access to the machinery space from the exposed cargo deck should be provided with two weathertight closures.*

Access to spaces below the exposed cargo deck should be from a position within or above the superstructure deck.

Other arrangement may be considered by the Society on a case by case basis

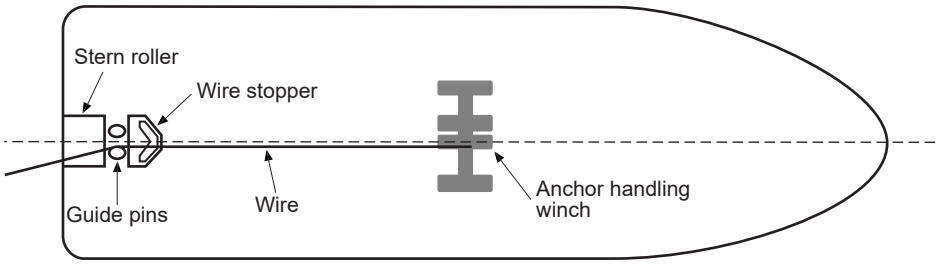
Section 3 Stability

1 General

1.1 Assumptions

1.1.1 During anchor handling, the wire comes from the anchor handling winch and is controlled by the guide pins and connected, over the stern roller, to the lifted item (see Fig 1).

Figure 1 : Schematic definition of equipment



1.1.2 For vessels used for anchor handling while their towing capacity and/or the traction power of their winches is/are already in action, calculations are to be made showing the maximum acceptable tension to which the vessel is able to be exposed.

1.1.3 The compliance with the relevant stability criteria are to be made for each set of towing pins and its associated permissible line tensions, including any physical element or arrangement that can restrict the line movement

Moreover, the loading conditions defined in Pt B, Ch 3, App 2, [1.2.12] are to be checked regarding the stability criteria defined in [1.6] when applying the design tension T_w, for the tow pin set nearest to centreline, as a minimum for the lowest α equal to 5 degrees.

Allowance is to be made for the anticipated weight of cargo on and below deck, chain in lockers, anticipated type of wire or rope on storage reels and wire on the winches when calculating loading conditions.

1.2 Definitions

1.2.1 The tension T_W in the wire, its vertical component T_{Wz} and its horizontal component T_{Wy}, as well as the angles α and β defining the wire position are shown in Fig 2, where:

T_W : Permissible tension in the wire, in t, which can be applied to the ship as loaded while working through a specified tow pin set, at each α, for which all stability criteria can be met. T_W should in no circumstance be taken as greater than T_D.

T_D : Design maximum wire tension, to be taken as the maximum winch wire pull or maximum static winch brake holding force, whichever is greater.

T_{Wz} : Vertical component of the wire tension causing the ship to trim: $T_{Wz} = T_W \sin\beta$

T_{Wy} : Horizontal component of the wire tension causing the ship to heel: $T_{Wy} = T_W \sin\alpha \cos\beta$

α : Horizontal angle between the centreline and the vector at which the wire tension is applied to the ship in the upright position, positive outboard.

β : Vertical angle between the waterplane and the vector at which the wire tension is applied to the ship, positive downwards. β is to be taken at the maximum heeling moment angle as $\tan^{-1}(y / (h \cdot \sin\alpha)$, but not less than $\cos^{-1}(1{,}5\ T_{Bp} / T_W \cdot \cos\alpha)$, using consistent units.

T_{BP} : Design bollard pull as defined in Ch 2, Sec 1, [1.2.6]

y : Torque arm, in m, of the vertical component T_{Wz} (see Fig 3 and Fig 4).

y is equal to the transverse distance from the vessel centreline to the outboard point at which the wire tension is applied to the ship and is obtained by the formula:

$y = y_0 + x \tan\alpha$

y is not to be taken greater than B/2 and may be limited to a physical restriction of the transverse wire movement. Cargo rails, cranes, A-frames may be considered as physical restrictions.

y_0 : Transverse distance, in m, between the vessel centreline and the inner part of the guide pin or any physical restriction of the transverse wire movement

x : Longitudinal distance, in m, between the stern and the guide pin or any physical restriction of the transverse wire movement

Figure 2 : Tension and position of wire

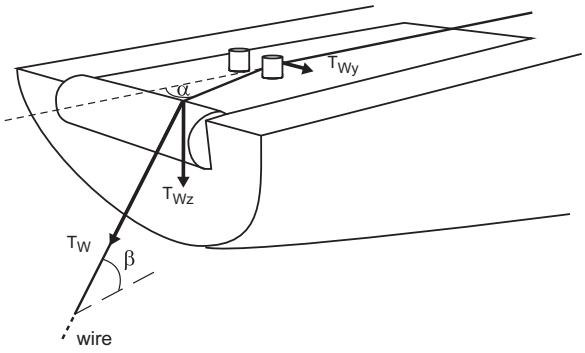


Figure 3 : Vessel with single pair of guide pins

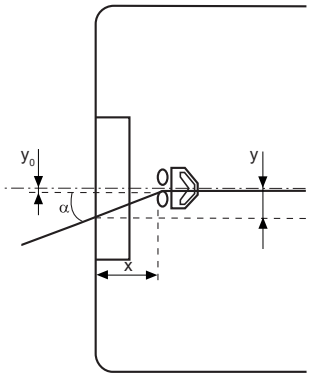
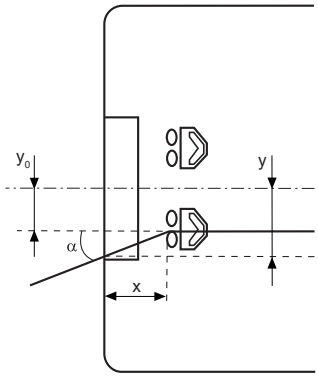


Figure 4 : Vessel with double pair of guide pins



1.3 Heeling moment

1.3.1 The most unfavourable conditions for transverse tension are to be considered for the calculations.

Calculations are to be made for the maximum acceptable wire tension T_W allowing the vessel to fulfil the requirements of [1.6] during anchor handling operations.

The heeling arm b_h is to be calculated, in m, as the total effect of the horizontal and vertical transverse components T_{Wy} and T_{Wz} of wire tension T_W, as follows:

$$b_h = T_W(h\sin\alpha\cos\beta + y\sin\beta)\frac{\cos\theta}{D} = (T_{Wy}\cdot h + T_{Wz}\cdot y)\frac{\cos\theta}{D}$$

where:

h : Torque arm, in m, of the horizontal component T_{Wy}

h is equal to the vertical distance from the centre of the main propulsion propeller or of the stern side propellers, whichever is deeper (see Fig 5), to either:

- the uppermost part of the guide pins
- a point on a line defined between the highest point of the winch pay-out and the top of the stern or any physical restriction of the transverse wire movement.

In case of azimuth thrusters, h is to be measured from the centre of the deepest drive (see Fig 6)

D : Displacement of the considered loading condition, in t, including the vertical component T_{Wz} of the towing force

θ : Angle of heel, in deg.

Figure 5 : Vessel with stern side propellers and a fixed propulsion propeller

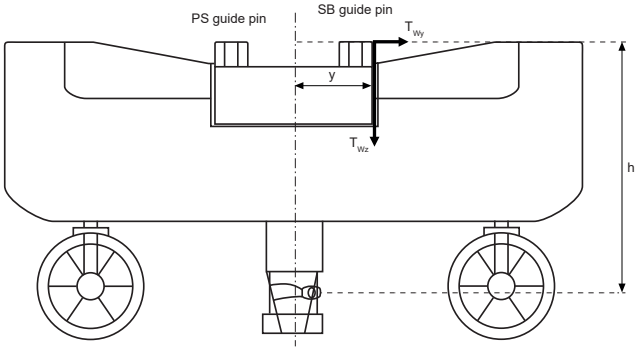
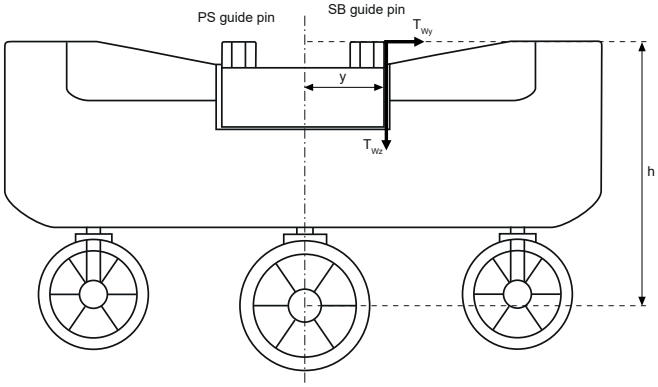


Figure 6 : Vessel with azimuth thrusters and a moveable propulsion propeller



1.4 Permissible tension

1.4.1 The permissible tension T_W as function of α can be calculated by direct stability calculations, provided that the following are met:

- the heeling lever is to be taken as defined in [1.3] for each α
- the stability criteria defined in [1.6] is to be met
- α is not to be taken less than 5 degrees, except as permitted by [1.4.2]
- Intervals of α are not to be more than 5 degrees, except that larger intervals may be accepted, provided that the permissible tension is limited to the higher α by forming working sectors.

1.4.2 For the case of a planned operation to retrieve a stuck anchor in which the ship is on station above the anchor and the ship has low or no speed, α may be taken as less than 5 degrees.

1.5 Calculation of stability curves

1.5.1 Curves (or tables) of the permissible tension as a function of permissible KG (or GM) are to be provided for the draught (or displacement) and trim values covering the intended anchor handling operations. The curves (or tables) are to be developed under the following assumptions:

- the maximum allowable KG from the approved stability booklet
- information of permissible tension curve or table for each set of towing pins, including any physical element or arrangement that can restrict the line movement as function of the stability limiting curve are to be included
- where desirable, a permissible tension curve or table is to be provided for any specific loading condition
- the draught (or displacement), trim and KG (or GM) to be taken into consideration are those before application of the tension
- where tables are provided that divide the operational, cautionary and stop work zones (see [1.7.2]), the limiting angles associated with physical features of the stern, including the roller, may be used to define the boundaries between the operational and cautionary zones.

1.6 Intact stability

1.6.1 The stability of the vessel, for the loading conditions included in Pt B, Ch 3, App 2, [1.2.11], is to be in compliance with the requirements of Pt B, Ch 3, Sec 2.

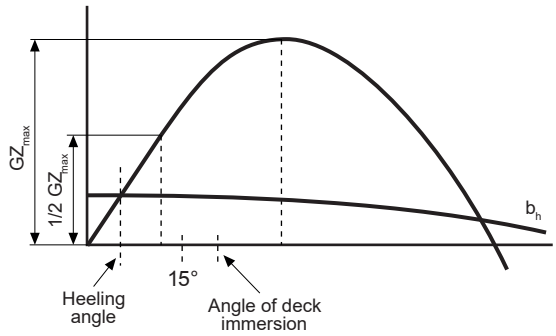
For all loading condition intended for anchor handling operations, the vessel is to comply with the following criteria, under the assumptions set out in [1.1]:

a) The residual area between the righting lever curve and the heeling arm curve calculated in accordance with [1.3.1] should not be less than 0,070 metre-radians. The area is determined from the first intersection of the two curves to the second intersection or the angle of down-flooding, θf, whichever is less.

b) The maximum residual righting lever GZ between the righting lever curve and the heeling arm curve calculated in accordance with [1.3.1] should be at least 0,2 m.

c) The maximum heeling angle is to be limited to one of the following angles, whichever occurs first (see Fig 7):
   - heeling angle equivalent to GZ value equal to 50% of GZ_{max}
   - angle of deck immersion
   - 15°.

Figure 7 : Heeling and righting arm curves



d) A minimum freeboard at stern, on centreline, of at least 0,005L should be maintained in all operating conditions, with a displacement D, as defined in [1.3.1]. In the case of anchor retrieval operation, a lower minimum freeboard may be accepted provided that due consideration has been given to this in the operation plan.

e) Loading conditions other than the most unfavourable ones and associated with anchor handling operations need to be calculated in the same way as described in item a), taking into account the prevailing practice with regards to loads on deck and winch reels.

Generally, when calculating the trim and the righting arm curve, the vertical component of the towing force is added as a weight in the loading condition located at the centreline and at the stern of the vessel (normally the stern roller).

1.7 Information to be displayed

1.7.1 Information stating the maximum allowed tension in the wire, as well as the corresponding angle α, in accordance with the calculations performed for each loading condition, are to be communicated to the vessel's crew and displayed next to the control desk or at any location where the navigator on duty can easily see the information from his command post.

The displayed information is to be under the form of diagrams, prepared so that the master can easily determine the maximum tension that can be applied to the vessel, as a function of the angle α, for a given value of trim and displacement (or draught), so as to satisfy the stability criteria (see Fig 9).

1.7.2 The results are to be given in tables (see Tab 2 completed by Fig 8) and diagrams (see Fig 9) showing the maximum tension (corresponding to the maximum acceptable heeling moment) as a function of angle α, provided for the draught (or displacement) and trim values covering the intended anchor handling operations (values before application of the tension), as well as the operational zones defined as follows:

- an “operational zone” in which normal operations up to the permissible tension are to occur
- a “cautionary zone” where operations may be reduced or halted to assess the ship’s options to return to the operational zone: the cautionary zone is to be not less than an angle of 10 degrees unless information in Tab 1 provides otherwise.
- a “stop work zone” in which the operation is to be stopped, for which, in normal operations, the “cautionary zone”/“stop work zone” boundary is not to exceed 45 degrees or the point at which the wise rises above the deck. Notwithstanding this, due consideration may be given to different operations from typical anchor handling operations where the planned operation ensures the safety of the ship

1.7.3 Definitions of permissible tensions and zones based on the availability of tension monitoring and onboard stability instrument are provided in Tab 1.

1.8 Stability booklet

1.8.1 The following information is to be included in the stability booklet in addition to the information required in Pt B, Ch 3, App 2:

- maximum bollard pull, winch pull capacity and brake holding force

- details on the anchor handling arrangement such as location of the fastening point of the wire, type and arrangement of towing pins, stern roller, all points or elements where the tension is applied to the ship
- identification of critical downflooding openings
- guidance on the permissible tensions for each mode of operation and for each set of towing pins, including any physical element or arrangement that can restrict the wire movement, as function of all relevant stability criteria
- recommendations on the use of roll reduction systems
- additional information defined in [1.7].

1.9 Stability instrument

1.9.1 A stability instrument may be used for determining the permissible tension and checking compliance with relevant stability criteria.

Two types of stability instrument may be used on board.

- either a software checking the intended or actual tension on the basis of the permissible tension curves, or
- a software performing direct stability calculations to check compliance with the relevant criteria, for a given loading condition (before application of the tension force), a given tension and a given wire position (defined by angles α and β)

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Pt B, Ch 1, Sec 5, [3].

Figure 8 : Example of the operational, cautionary and stop work zones illustration

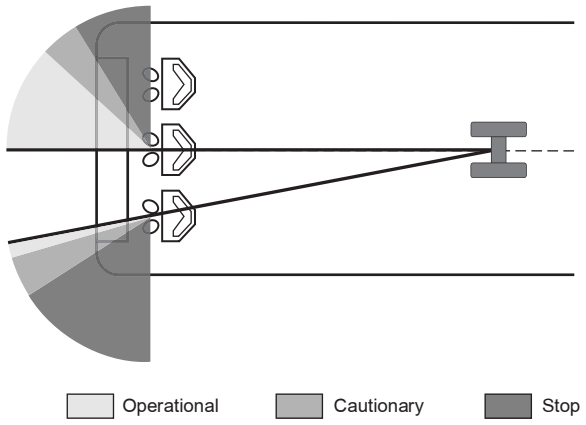


Figure 9 : Example of permissible tension sector diagram

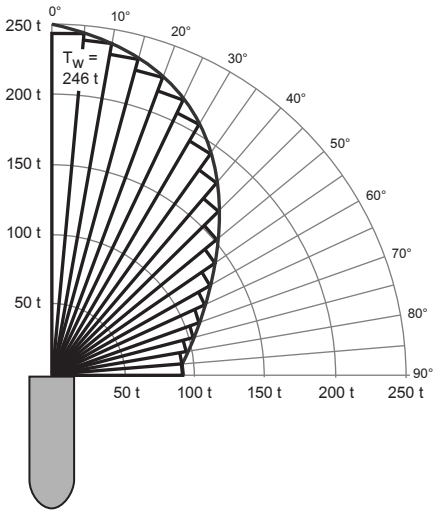


Table 1 : Definition of permissible tensions and zones

	Availability of tension monitoring and onboard stability instrument		
	Tension monitoring is not available	Tension monitoring is available but no stability instrument is available	Both tension monitoring and stability instrument are available
Permissible tension T_W	Design maximum line tension, T_W, in the operational zone	T_W as described in stability booklet, operational planning guidelines, or specific operational plan	T_W as calculated by the stability instrument for the actual loading condition
Permissible table	• First α is to be 5° • The only permissible tension is the design maximum wire tension, T_D • Figures in the table will be T_D for α which $T_W \geq T_D$ • The cautionary zone would include positions where $T_D > T_W \geq$ maximum winch wire pull • The stop work zone is every other position where $T_W <$ maximum winch wire pull. If criteria is not fulfilled at $\alpha = 5°$, anchor handling is not to be performed without winch information	• Tables may be prepared for different values of draft, trim, KG or GM, or specific predefined loading conditions • Values in the tables are to range from $\alpha = 0°$ to $\alpha = 90°$ • A table is to identify T_W at critical points and is to be provided for each set of towing pins	Tables or curves provided in the stability booklet may be used where T_W, throughout the non specific operational zone, exceeds the maximum anticipated wire tension; otherwise, tables or curves calculated for the actual loading condition must be developed
Zones	• The operational zone is to be defined as the sector between the two outboard α values for which $T_W \geq T_D$ • The cautionary zone is to be defined as the sector between the α at which $T_W = T_D$ and the α at which $T_W =$ maximum winch wire pull • The stop work zone is to cover every other positions. The definition of the sectors is to be documented in the stability booklet, the operational planning guidelines, or the specific operational plan • The sector diagram may be prepared for multiple loading conditions • If the limiting α is less than 5° anchor handling operations should not be performed without winch modifications	• The zones may be developed based on normal operational practices contained in the operational planning guidelines, e.g. the operational zone on the stern roller, cautionary zone for not more than 15° past the stern roller and the stop work zone otherwise or developed for a specific operation where the outboard α values at which $T_W =$ maximum anticipated wire tension minus 10° defines the operational zone, if α is greater than 20° • If this α is less than 20°, the operational zone is defined as the sector between half the outboard α values at which $T_W =$ maximum anticipated wire tension • In each case, the cautionary zone is defined between the limit of the operational zone and the α value at which $T_W =$ maximum anticipated wire tension • In each case, the operational zone must be identified for the anticipated wire tension	

Table 2 : Example of permissible wire tension table

Table of permissible wire tension Tw (in tonnes) (Rated line pull = 600 t; Brake holding load = 700 t)																					
	Wire horizontal angle α (deg)																				
	0			10			20			30			45			60			90		
Trim (m)	–0,5	0	0,5	–0,5	0	0,5	–0,5	0	0,5	–0,5	0	0,5	–0,5	0	0,5	–0,5	0	0,5	–0,5	0	0,5
Wire between the centerline guide pins																					
Draft = 4,8 m	700	700	700	700	700	690	625	580	540	460	460	435	290	290	290	190	190	190	165	165	165
	Operational zone			Operational zone			Operational zone			Operational zone			Cautionary zone			Stop zone			Stop zone		
Draft = 5,8 m	700	700	700	700	700	690	655	600	550	430	485	435	285	285	310	190	180	200	170	165	170
	Operational zone			Operational zone			Operational zone			Operational zone			Cautionary zone			Stop zone			Stop zone		
Draft = 6,8 m	700	635	520	700	635	520	645	575	510	550	485	415	355	355	305	230	240	220	200	205	200
	Operational zone			Operational zone			Operational zone			Operational zone			Cautionary zone			Stop zone			Stop zone		
Wire between the outer guide pins																					
Draft = 4,8 m	545	500	465	480	435	405	385	380	350	300	300	300	215	215	215	170	170	170	165	165	165
	NA			Operational zone			Cautionary zone			Stop zone			Stop zone			Stop zone			Stop zone		
Draft = 5,8 m	575	520	465	500	455	405	360	390	350	275	300	300	220	210	240	180	175	190	170	165	170
	NA			Operational zone			Cautionary zone			Stop zone			Stop zone			Stop zone			Stop zone		
Draft = 6,8 m	555	480	410	500	435	370	440	385	330	365	340	295	260	270	235	210	215	200	200	205	200
	NA			Operational zone			Cautionary zone			Stop zone			Stop zone			Stop zone			Stop zone		

Note 1:

- Trim is negative by the bow. Interpolate between drafts only. For intermediate trim values, use lower permissible tension.
- Table is for planning and monitoring anchor handling operation. Specific loading conditions may be required for each anchor move.
- Trim should be minimized or by bow for anchor moves where high wire tensions are expected.
- Wire horizontal angle is relative to vessel's centerline. For intermediate angle values, use the higher table value.

Note 2:

- NA indicates where the angle of tow wire is not geometrically possible (i.e. at centerline in the case of wire going through outer guide pins). Permissible tensions are provided for reference only.
- If wire angle falls into the "Cautionary zone" and the wire tension exceeds the permissible value, corrective actions are required.
- If wire angle falls into the "Stop zone" and the wire tension exceeds the permissible value, operations are to be stopped and tension in the line is to be reduced.
- If planned wire tension exceeds the permissible values of the "Operational zone", additional calculations are required. Operations should not be planned for high angles.

Note 3: Vessel loading must be in accordance with the approved stability booklet and include assumed margins.

Section 4 Hull Structure

1 Documentation

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the plans and documents listed in Tab 1 are to be submitted as applicable.

The listed plans are to be construction plans complete with all the dimensions and are to contain full indication on the type of materials employed.

Plans of equipment which are type-approved by the Society need not be submitted, provided the types and model numbers are made available.

Table 1 : Documents to be submitted

No.	A / I **(1)**	Document
1	I	General arrangement showing: - detail arrangement of anchor handling deck equipment (wire stopper, guide pins, etc.) - typical arrangement of cargo on deck (anchors, wires, chain cables, etc.) - chain lockers used for mooring deployment - anchor handling/towing winch - tugger winches - stern roller, including lateral limits on both ends - lifting appliances, if any - typical paths of lines between winches and stern roller, showing the limit line sectors
2	I	Design information of deck winches, including: - detailed drawing of winches - maximum rated line pull (RP), and the reeled layer for which the rated line pull is defined - brake holding load (BHL), and the reeled layer for which the rated line pull is defined - rendering load (RL) - specification of emergency quick release system including response time and intended remaining holding force after release - strength calculation of the drum with flanges, shafts with coupling, framework and brakes - minimum guaranteed breaking strength of the wire
3	I	Design information of wire stopper, including: - safe working load (SWL) - emergency release capabilities in normal and dead ship conditions
4	I	Design information of guide pins, including: - safe working load (SWL) - emergency release capabilities in normal and dead ship conditions
5	I	Safe working load (SWL) of stern roller
6	I	Design bollard pull (T_{BP})
7	I	Maximum weight of anchors on deck
8	I	Maximum weight of wire/chain cable stored on deck
9	I	Operational manual
10	A	Detailed drawing of wire stopper
11	A	Detailed drawing of guide pins
12	A	Detailed drawing of stern roller
13	A	Deck reinforcements in way of deck equipment, including foundations and supports
14	I / A	Loading manual, if relevant (see [2.2])
(1)	A = to be submitted for approval; I = to be submitted for information	

2 General requirements

2.1 Deck equipment

2.1.1 It is the Designer's responsibility to check the consistency of strength capacity of the deck equipment (stern roller, wire stopper, guide pins) in relation to the performance of the winch.

2.2 Loading manual

2.2.1 For ships greater than 90 m in length, the loading manual is to include a loading condition corresponding to the chain lockers being fully loaded and winches fully loaded with the heaviest anticipated line type.

2.3 Design loads

2.3.1 The design loads DL defined below are to be taken not less than the maximum value of the tension in the wire (or chain cable) during anchor handling resulting from the stability analysis.

Local strength of deck structure is to be based on the following design loads:

- in way of anchor handling winch:
  DL = max (1,5 T_{BP}; 1,5 RP; BHL)
- in way of guide pins:
  DL = max (2 SWL; 1,5 RP; BHL)
- in way of wire stopper:
  DL = max (2 SWL; 1,5 RP; BHL)
- in way of stern roller:
  DL = max (2 SWL;1,5 RP; BHL)

Strength of anchor handling winch is to be based on the two following design loads DL:

- case 1:
  DL = max (1,5 T_{BP}; 1,5 RP)
- case 2:
  DL = BHL as defined in Ch 2, Sec 1, [1.2].

Strength of deck equipment (guide pins, wire stopper, stern roller) is to be based on the same design loads as those considered for the deck foundations.

2.4 Deck structure

2.4.1 Local reinforcements are to be provided in way of deck areas subjected to concentrated loads.

The strength checking required in [2.5], [2.6] and [2.7] are to be based on the following criteria:

- Stress level in the deck structure is not to exceed the following permissible stresses:
  - normal stress:
    $\sigma \leq 0,75\ R_y$
  - shear stress:
    $\tau \leq 0,47\ R_y$
  - equivalent stress:
    $\sigma_{VM} \leq 0,85\ R_y$

  where:

  R_y : Minimum yield stress, in N/mm², of the material, to be taken equal to 235/k unless otherwise specified.
- In case the yielding check of the structure is carried out by means of a three-dimensional finite element model, these permissible stress levels may be increased by 10 per cent.
- Where necessary, buckling strength is to be checked.

Strength of the deck structure is to be checked considering:

- in way of anchor handling winch, including welds:
  design load DL as defined in [2.3], with the following assumptions:
  - wire considered at the most unfavourable layer of the drum, in general
  - direction of wire cable taken in the most unfavourable direction allowed by the anchor handling equipment.
- in way of anchor handling deck equipment other than winches (i.e. guide pins, wire stopper), including welds:
  design load DL as defined in [2.3], exerted in the most unfavourable directions, with the most severe vertical location.

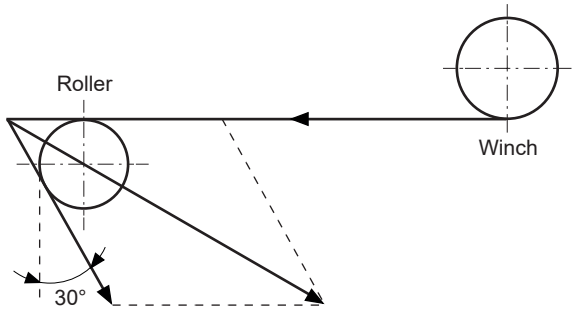
- in way of stern roller, including welds:

  design load DL as defined in [2.3], considering an anchor hanging underwater below the stern roller at a negative angle of 30° with respect to a vertical axis (see Fig 1).

- in way of handling and/or lifting appliances, if any, including welds:

  the maximum dynamic reactions exerted by lifting appliance pedestal, according to the lifting appliance certification.

Figure 1 : Angle of hanged anchor with respect to vertical axis



2.5 Anchor handling winch

2.5.1 The combined stress is not to exceed the following permissible stress depending on the design load, for both cases defined in [2.3]:

- for case 1:

  $\sigma_{VM} \leq R_e$

- for case 2:

  $\sigma_{VM} \leq 0,9\ R_e$

where:

R_e : Minimum specified yield stress of material, in N/mm^2

The emergency quick-release system is to be designed to:

- allow drum release in all operational modes, including emergency mode, in the shortest possible delay
- be activated locally at the winch and from a position at the bridge with full view and control of the operation
- operate even in dead ship condition
- be protected against unintentional operation.

A winch intended for functions of anchor handling and towing is to meet both the requirements of Ch 1, Sec 3, [2.7] and the requirements above.

Strength is to be checked on the basis of the calculations submitted, in particular the components which are exposed to the tension in the towline, such as the winch drums, drum shafts, brakes and support frame.

2.6 Anchor handling deck equipment other than winches

2.6.1 Strength of the deck equipment used for anchor handling, including guide pins and wire stopper, is to be checked under the maximum load on the wire equal to design load DL as defined in [2.3], exerted in the most unfavourable directions, with the most severe vertical location.

Stress levels in the anchor handling deck equipment are not to exceed the following permissible stresses:

- normal stress:

  $\sigma \leq 0,75\ R_e$

- shear stress:

  $\tau \leq 0,47\ R_e$

- equivalent stress:

  $\sigma_{VM} \leq 0,85\ R_e$

In case the yielding check of the structures is carried out by means of a three-dimensional finite element model, these permissible stress levels may be increased by 10 per cent.

Where necessary, buckling strength is to be checked.

2.7 Stern roller

2.7.1 The structure of the stern roller is to be checked under design load DL as defined in [2.3], considering an anchor hanging underwater below the stern roller at a negative angle of 30° with respect to a vertical axis (see Fig 1).

For strength purposes, design load DL as defined in [2.3] is to be considered in any transverse position on the stern roller, as allowed by the actual locations of the guide pins and the anchor handling deck equipment.

The bending, shearing and combined stresses are not to exceed the following permissible stresses:

- normal stress:
  $\sigma \leq 0,75\ R_e$
- shear stress:
  $\tau \leq 0,47\ R_e$
- equivalent stress:
  $\sigma_{VM} \leq 0,85\ R_e$

Where necessary, buckling strength is to be checked.

2.8 Wire

2.8.1 The minimum breaking strength of the wire is not to be less than the design load DL defined in [2.3] for the anchor handling winch.

The towline is to be protected from being damaged by chafing and abrasion. To this end, cargo rails, bulwarks, and all the elements supporting the towline are to be adequately rounded.

Strength of the wire attachment on the winch is to allow breaking in case the line is to be run out. Under normal operation, at least 3 turns of wire on the drum are considered.

2.9 Anchor handling arrangements

2.9.1 Stop pins or other design features meant to impede the movement of the wire further outboard are to be installed

2.9.2 The working deck is to be marked with contrasting colours or other identifiers such as guide pins, stop pins or similar easily identifiable points that identify operational zones for the line to aid operator observation.

Section 5 Testing

1 General

1.1 Load test

1.1.1 Load test is to be performed at the manufacturer workshop, for hoisting operation, and witnessed by the Society.

1.1.2 Winches are to be tested at design load DL, as defined in Ch 2, Sec 4, [2.3]. However, in case the winch is not of novel or particular design, it is sufficient to perform load test at the design bollard pull T_{BP}. In this case, it may be performed on board during commissioning trials and is to be witnessed by the Society.

1.2 Functional test

1.2.1 The tests are performed to check the proper:

- operation of the equipment within the specified limitations
- arrangement of the towline sectors and the towline paths, as shown on the arrangement drawing
- functioning under the normal operation modes
- functioning under the emergency operation modes, including the emergency release and the dead ship operations.

In particular, the emergency quick-release systems are to be function tested at the design bollard pull T_{BP}.

1.3 Operational tests

1.3.1 Prior to anchor handling operation, operational tests are to be performed by the crew in order to ensure the satisfactory operation of the winches and deck equipment, in particular the emergency quick-release system, as requested by the operational manual.

1.3.2 Records of the operational tests are to be kept on board and made available to the Society upon request.

CHAPTER 3
SUPPLY VESSELS

Section 1 General

Section 2 General Arrangement

Section 3 Stability

Section 4 Hull Structure

Section 5 Machinery and Cargo Systems

Section 6 Electrical Installations, Instrumentation and Automation

Section 7 Fire Prevention, Protection and Extinction

Section 1 General

1 General

1.1 Application

1.1.1 The present Chapter applies to ships defined as per [1.6.31] and [1.6.42], hereafter referred to as OSV(s).

OSV(s) means:

- well-stimulation vessels, and/or
- ships which are primarily engaged in the transport of stores, materials and equipment, including:
  - oil products with a flashpoint greater than 60°C, and/or
  - hazardous and noxious liquid substances,

  to, from and between offshore installations.

Attention is drawn to the Owner that compliance of this Chapter for a ship intended to carry oil product with a flashpoint equal to or less than 60°C is submitted to prior agreement by the Administration considering this ship as an OSV and not as an oil tanker, in particular regarding the statutory regulations dealing with the ship general arrangement.

1.1.2 Carriage of oil products

The requirements of the present Chapter regarding the carriage of oil products are to be in compliance with MARPOL Annex I, Regulation 2.2.

Note 1: When intended to carry less than 200 m^3 of non-flammable oil products only, supply vessels need not to comply with the specific requirements for the carriage of oil products.

1.1.3 Carriage of heated cargoes

For OSVs intended to carry cargoes heated at a temperature of 90°C or more, the design of the cargo tanks is subject to special consideration.

1.1.4 Carriage of hazardous and noxious goods in packaged form

The provisions in this Chapter do not regulate the transport of hazardous and noxious goods in packaged form.

1.1.5 Equivalents to the OSV Chemical Code

The IMO OSV Chemical Code chapter 1, paragraph 1.3 may allow equivalents to the provision of the Code. In the scope of the assignment of the additional service feature **HNLS** and/or **WELLSTIM** defined in [1.3], these equivalent provisions are to be transmitted to the Society for review.

1.2 IMO regulations

1.2.1 The requirements of the present Chapter are generally consistent with the following International Maritime Organisation (IMO) regulations:

- OSV Code – Code of safe practice for the carriage of cargoes and persons by offshore supply vessels adopted by IMO Resolution A.863(20), as amended by Resolution MSC 237(82).
- Offshore Supply Vessel Guidelines – Guidelines for the design and construction of offshore supply vessels adopted by IMO Resolution A.469(XII), as amended by Resolutions MSC 235(82) and MSC 335(90).
- IBC Code – IMO International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk, as amended.
- OSV Chemical Code – IMO OSV Chemical Code for the transport and handling of hazardous and noxious liquid substances in bulk on Offshore Support Vessels adopted by IMO Resolution A.1122(30).

1.2.2 The present Chapter does not cover Chapter 13 and Chapter 15 of the OSV Chemical Code (with the exception of sections 15.5.4 and 15.5.5) which are outside the scope of classification.

1.3 Classification notations

1.3.1 Service notation supply

Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **supply**, as defined in Pt A, Ch 1, Sec 2, [4.12.10].

Where applicable, the service notation **supply** is to be completed by the additional service feature **HNLS** (as defined in [1.3.2]) and/or **WELLSTIM** (as defined in [1.3.3])

1.3.2 Additional service feature HNLS

Ships granted with the service notation **supply** and intended to carry the following products:

- products which are listed in chapters 17 or 18 of the IBC Code and the latest edition of the MEPC.2/Circular (Provisional categorization of liquid substances in accordance with MARPOL Annex II and the IBC Code) and their related references to chapters 15 and 19; and/or
- oil-based/water-based mud containing mixtures of products listed in chapters 17 and 18 of the IBC Code and the MEPC.2/Circular; and/or
- liquid carbon dioxide (high purity and reclaimed quality) and liquid nitrogen; and/or
- contaminated backloads (see [1.6.4]),

are to be assigned with the additional service feature **HNLS** completed, where applicable, by:

one or several of the following notations subject to the products listed hereabove are considered:

-FP≤60°C when the ship may carry products with a flash point equal to or less than 60°C.

-toxic when the ship may carry toxic products (see [1.6.40])

-acids when the ship may carry acids (see [1.6.1])

-LG when the ship may carry liquid carbon dioxide and/or liquid nitrogen

1.3.3 Additional service feature WELLSTIM

The additional service feature **WELLSTIM** may be assigned to ships granted with the service notation **supply** when intended to carry products used in a blending (see [1.6.5]) or production process dedicated to the search and exploitation of seabed mineral resources, this process being installed on-board to facilitate such operations.

Where applicable, the additional service feature **WELLSTIM** is to be completed by one or several of the following notations: **-FP≤60°C**, **-toxic**, **-acids** and **-LG** as defined in [1.3.2].

1.4 Applicable rules

1.4.1 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B • Ch 3, Sec 2	• NR566 **(2)** • Ch 3, Sec 2
	L < 65 or 90 m **(1)**	• NR600 • Ch 3, Sec 2	• NR566 **(2)** • Ch 3, Sec 2
Hull	L ≥ 65 or 90 m **(1)**	• Part B • Ch 3, Sec 4	• Part B • Ch 3, Sec 4
	L < 65 or 90 m **(1)**	• NR600 • Ch 3, Sec 4	• NR600 • Ch 3, Sec 4
Stability		• Part B • Ch 3, Sec 3	• Part B • Ch 3, Sec 3
Machinery and cargo systems		• Part C • Ch 3, Sec 5	• NR566 **(2)** • Ch 3, Sec 5
Electrical installations and automation		• Part C • Ch 3, Sec 6	• NR566 **(2)** • Ch 3, Sec 6
Fire protection, detection and extinction		• Part C • Ch 3, Sec 7	• NR566 **(2)** • Ch 3, Sec 7

(1) Refer to the scope of application of NR600.

(2) For ships granted with **HNLS** and/or **WELLSTIM** service features, the limit of 500 GT does not apply for the specific requirements associated to these service features

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65m and Non Cargo Ships less than 90m.

Note 2: For ships granted with **HNLS** and/or **WELLSTIM** service features, in case of conflict, requirements mentioned in this Chapter shall prevail

1.5 Specific requirements

1.5.1 Ships assigned the additional service feature IPxxx or IPxxx-capable

Ships assigned the additional service feature **IPxxx** or **IPxxx-capable** are to comply with the following requirements in addition to the applicable requirements of this Chapter:

- Carriage of toxic products, low-flashpoint products or acids is not permitted when the total number of persons on board exceeds 60
- For the purpose of carrying industrial personnel, the areas and spaces where industrial personnel are not permitted to enter are to be clearly marked
- The arrangements for personnel transfer are to be located outside the cargo area
- The access to the arrangements for personnel transfer are to be, as far as practicable, located outside the cargo area.

1.6 Definitions

1.6.1 Acids

Acids are those products for which IBC 15.11 applies according to IBC Code Chapter 17, or the latest edition of the MEPC.2/Circ.

1.6.2 Accommodation spaces

Accommodation spaces are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces.

1.6.3 Administration

Administration means the Government of the State whose flag the vessel is entitled to fly.

1.6.4 Backload

Backload means contaminated bulk liquids, taken on board a vessel offshore, for transport either back to shore or to alternate offshore site.

1.6.5 Blending additives

Blending additives means small amounts of liquid substances used during blending of products or production processes of cargoes for use in the search and exploitation of seabed mineral resources on board vessels used to facilitate such operations.

1.6.6 Cargo area

Cargo area is that part of the offshore support vessel where:

a) a pollution hazard only substance having a flashpoint exceeding 60°C and not defined as toxic, is likely to be present and includes cargo tanks, portable tanks used as deck cargo tanks, slop tanks, cargo pump-rooms, pump-rooms adjacent to cargo tanks and enclosed spaces in which pipes containing cargoes are located. Areas on open deck are not considered part of the cargo area.

b) a safety hazard substance having a flashpoint exceeding 60°C and not defined as a toxic, is likely to be present and includes cargo tanks, portable tanks used as deck cargo tanks, slop tanks, cargo pump-rooms, pump-rooms adjacent to cargo tanks, hold spaces in which independent tanks are located, cofferdams surrounding integral tanks, enclosed spaces in which pipes containing cargoes are located and the following deck areas:

1) within 3 m of cargo tank installed on deck or portable tanks used as deck cargo tanks;

2) areas on open deck, or semi-enclosed spaces on deck, within 3 m of any cargo tank access outlet;

3) areas on open deck over an integral tank without an overlaying cofferdam plus the open deck area extending transversely and longitudinally for a distance of 3 m beyond each side of the tank;

4) areas on open deck, or semi-enclosed spaces on deck, within 3 m of cargo manifold valve, cargo valve, cargo pipe flange, except spaces within the 3 m zone that are separated by an enclosed bulkhead to the minimum height as given in item 6);

5) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo tank vent outlet intended for the passage of large volumes of vapour mixture during cargo loading, within a vertical cylinder of unlimited height and 3 m radius upon the centre of the outlet, and within a hemisphere of 3 m radius below the outlet;

6) areas on the open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2,4 m above the deck; and

7) compartments for cargo hoses.

c) *a substance having a flashpoint not exceeding 60°C, or defined as toxic or vapours of such cargo, is likely to be present and includes cargo tanks, portable tanks used as deck cargo tanks, slop tanks, cargo pump-rooms, pump-rooms adjacent to cargo tanks, hold spaces in which independent tanks are located, cofferdams surrounding integral tanks, enclosed spaces in which pipes containing cargoes are located and the following deck areas:*

1) *within 3 m of cargo tank installed on deck or portable tanks used as deck cargo tanks;*
2) *areas on open deck, or semi-enclosed spaces on deck, within 4,5 m of gas or vapour outlet, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;*
3) *areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading, within a vertical cylinder of unlimited height and 10 m radius centred upon the centre of the outlet, and within a hemisphere of 10 m radius below the outlet;*
4) *areas on open deck, or semi-enclosed spaces on deck, within 3 m of cargo pump-room entrances, cargo pump-room ventilation inlet, openings into cofferdams;*
5) *areas on the open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2,4 m above the deck;*
6) *compartments for cargo hoses; and*
7) *within the hose landing area.*

1.6.7 Cargo control station

Cargo control station means a location that is manned during cargo transfer operations for the purpose of directing or controlling the loading or unloading of cargo.

1.6.8 Cargo pump-room

Cargo pump-room is a space containing pumps and their accessories for the handling of the products.

1.6.9 Cargo tank

Cargo tank is the envelope designed to contain the cargo.

1.6.10 Cofferdam

Cofferdam is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

1.6.11 Control stations

Control stations are those spaces in which vessels' radio or main navigating equipment or the emergency source of power is located or where the fire-recording or fire-control equipment is centralized. This does not include special fire-control equipment which can be most practically located in the cargo area.

1.6.12 Dangerous goods

Dangerous goods mean the substances, materials and articles covered by the IMDG Code.

IMDG Code means the International Maritime Dangerous Goods Code (resolution MSC.122(75), as amended)

1.6.13 Deck spread

Deck spread means portable tanks, piping, equipment, processing equipment and control stations secured to the vessel by permanent means and used in the operation of the vessel.

1.6.14 Density

Density is the ratio of the mass to the volume of a product, expressed in terms of kilograms per cubic metre. This applies to liquids, gases and vapours.

1.6.15 Flammable liquid

A flammable liquid is any liquid having a flashpoint (closed cup test) not exceeding 60°C determined by an approved flashpoint apparatus.

Note 1: A liquid heated within 15°C of its flashpoint is also considered as a flammable liquid.

1.6.16 Flashpoint

Flashpoint is the temperature in degrees Celsius at which a product will give off enough flammable vapour to be ignited. Values given in the Chapter are those for a "closed cup test" determined by an approved flashpoint apparatus.

1.6.17 Fuel oil

Fuel oil means any oil used as fuel in connection with the propulsion and auxiliary machinery of the ship on which such oil is carried.

1.6.18 Gravity tank

Gravity tank means a tank having a design pressure not greater than 0,07 MPa gauge at the top of the tank. A gravity tank may be independent or integral. A gravity tank should be constructed and tested according to recognized standards, taking account of the temperature of carriage and relative density of the cargo.

1.6.19 Gas-safe area

Gas-safe area is an area which is not defined as hazardous.

1.6.20 Hazardous area

Hazardous area is an area in which an explosive atmosphere is or may be expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

1.6.21 Hold space

Hold space is the space enclosed by the vessels' structure in which an independent cargo tank is situated.

1.6.22 Hose landing area

Hose landing area means an area on the main deck, except those in compartments for cargo hoses, where cargo hoses of substances having a flashpoint not exceeding 60°C and/or defined as toxic are located during cargo transfer.

1.6.23 Independent

Independent means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems.

1.6.24 Independent tank

Independent tank means a cargo containment envelope which is not contiguous with, or part of, the hull structure.

An independent tank is built and installed so as to eliminate whenever possible (or in any event to minimize) its stressing as a result of stressing or motion of the adjacent hull structure. An independent tank is not essential to the structural completeness of the ship's hull.

1.6.25 Integral tank

Integral tank means a cargo containment envelope which forms part of the ship's hull and which may be stressed in the same manner and by the same loads which stress the contiguous hull structure and which is normally essential to the structural completeness of the ship's hull.

1.6.26 IGC Code

International Gas Carrier Code (IGC Code) means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (resolution MSC.5(48), as amended).

1.6.27 Low-flashpoint products

Low-flashpoint products means:

- noxious liquid substances with a flashpoint not exceeding 60°C
- oil with a flashpoint not exceeding 60°C, or
- liquefied gases defined by a "F" in Pt D, Ch 9, Sec 19, Tab 1, column "Vapour detection".

1.6.28 MARPOL

MARPOL means the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, as amended.

1.6.29 Noxious liquid substance

Noxious liquid substance means any substance indicated in the Pollution Category column of chapter 17 or 18 of the International Bulk Chemical Code, or the current MEPC.2/Circular or provisionally assessed under the requirements of regulation 6.3 of MARPOL Annex II as falling into categories X, Y or Z.

1.6.30 Offshore portable tank

Offshore portable tank means a portable tank specially designed for repeated use for transport of dangerous goods to, from and between offshore facilities. An offshore portable tank is designed and constructed in accordance with the Guidelines for the approval of containers handled in open seas (MSC/Circ.860)

1.6.31 Offshore support vessels

Offshore support vessels (OSVs) are:

a) multi-mission vessels which are primarily engaged in the transport of stores, materials and equipment to and from mobile offshore drilling units, fixed and floating platforms and other similar offshore installations; or

b) multi-mission vessels, including well-stimulation vessels, but excluding mobile offshore drilling units, derrick barges, pipe-laying barges and floating accommodation units, which are otherwise primarily engaged in supporting the work of offshore installations.

1.6.32 Oil product

Oil product means petroleum in any form including crude oil, sludge, oil refuse and refined products (other than the petrochemicals which are subject to the provisions of Annex II of MARPOL 73/78, as amended) and excludes fuel oil as defined in [1.6.17].

1.6.33 Open deck

Open deck is defined as an open or semi-enclosed space on cargo deck or inside of the cargo rail. Semi-enclosed spaces are those spaces that either:

a) are open at two ends; or

b) have an opening at one end, and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, the openings having a total area of at least 10% of the total area of the space sides.

1.6.34 Pollution hazard only substance

Pollution hazard only substance means a substance having an entry only of "P" in column d in chapter 17 of the IBC Code.

1.6.35 Portable tank

Portable tank means a multimodal tank used for the transport of dangerous goods.

1.6.36 Pump-room

Pump-room is a space, located in the cargo area, containing pumps and their accessories for the handling of ballast and oil fuel.

1.6.37 Safety hazard substance

Safety hazard substance means a substance having an entry of "S" or "S/P" in column d in chapter 17 of the International Bulk Chemical Code.

1.6.38 Separate

Separate means that a cargo piping system or cargo vent system, for example, is not connected to another cargo piping or cargo vent system.

The separation may be achieved by the use of design or operational methods. Operational methods are not to be used within a cargo tank and are to consist of one of the following types:

- removing of spool pieces or valves and blanking of pipe ends
- arrangement of two spectacle flanges in series, with provisions of detecting leakage into the pipe between the two spectacle flanges.

1.6.39 SOLAS

SOLAS means the International Convention for the Safety of Life at Sea, 1974, as amended.

1.6.40 Toxic products

Toxic products are those:

- for which IBC 15.12 applies according to IBC Code Chapter 17, or the latest edition of the MEPC.2/Circ, or
- defined by a "T" in Pt D, Ch 9, Sec 19, Tab 1column "Vapour detection".

1.6.41 Void space

Void space is an enclosed space in the cargo area external to a cargo tank, other than a hold space, ballast space, oil fuel tank, cargo pump-room, pump-room, or any space in normal use by personnel.

1.6.42 Well-stimulation vessel

Well-stimulation vessel means an offshore support vessel with specialized equipment and industrial personnel that deliver products and services directly into a well-head.

2 Documents to be submitted

2.1 General

2.1.1 The documents listed in Tab 2 are to be provided in addition to the documents listed in the applicable rules specified in [1.4].

Table 2 : Documents to be submitted

No.	Documents to be submitted	I/A **(1)**
Hull		
1.1	General arrangement	I
1.2	Access arrangement	A
1.3	Arrangement of entrances, air inlets and openings to accommodation service, machinery spaces and control stations	A
1.4	Capacity plan with clear indications of: • cargo tanks with nature and density of cargoes and indicating whether the product is flammable • fuel oil tanks • cofferdams adjacent to cargo tanks	I
1.5	Stowage of deck cargoes and lashing arrangement with location of lashing points and indication of design load	I
1.6	Connection of the cargo tanks with the hull structure	A
1.7	Structural reinforcements in way of load transmitting elements, such as winches, rollers, lifting appliances	A
Machinery		
2.1	Diagram of cargo piping system	A
2.2	Diagram of cargo tank venting system	A
2.3	Diagram of the cargo tank level gauging with overfill safety arrangement	A
2.4	Diagram of the bilge and ballast system serving spaces within the cargo area	A
2.5	Diagram of the bilge and ballast system serving spaces outside the cargo area	A
2.6	General layout of the cargo pump room with details of: • Bulkhead penetrations • Flammable vapours detections system • Bilge level monitoring devices • Ventilation.	A
2.7	Diagram of the cargo heating system, if any	A
2.8	Diagram of inert gas system with details of the inert gas plant, if any	A
2.9	Diagram showing deck tank arrangements: • portable tank information and details • sea fastening arrangement and calculations • deck arrangement and pipeline drawings • material safety data sheets of carried products	 I A A I
Electrical installations **(2)**		
3.1	Plan of hazardous area including location of all electrical equipment	A
3.2	Document giving details of types of cables and safety characteristics of the electrical equipment installed in hazardous area	A
Fire safety		
4.1	Fire extinguishing system in cargo area	A
4.2	Specification of fixed means of vapour detection	A

(1) A: To be submitted for approval; I: To be submitted for information.

(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

Section 2 General Arrangement

1 Compartment arrangement

1.1 General

1.1.1 Watertight integrity

The machinery spaces and other working and living spaces in the hull are to be separated from the other compartments by watertight bulkheads.

1.1.2 Afterpeak bulkhead

An afterpeak bulkhead is to be fitted and made watertight up to the freeboard deck. The afterpeak bulkhead may, however, be stepped below the freeboard deck, provided the degree of safety of the supply vessel as regards subdivision is not thereby diminished.

1.1.3 Location of cargo tanks

All cargo tanks are to be located aft of the collision bulkhead and forward of the aft peak.

1.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

1.2.1 With reference to OSV Chemical Code Chapter 2, section 2.1.5, the following requirements are, in particular, to be complied with:

a) Double bottoms:
Requirements mentioned in Pt B, Ch 2, Sec 2, [3] are to be referred to.

b) Collision bulkhead:
Requirements mentioned in Pt B, Ch 2, Sec 1, [3] are to be referred to.

c) After peak, machinery space and stern tubes:
Requirements mentioned in Pt B, Ch 2, Sec 1, [4] are to be referred to.

d) Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkhead:
Requirements mentioned in Pt B, Ch 2, Sec 1, [5] are to be referred to.

e) Openings in watertight bulkheads and internal decks:
Requirements mentioned in Pt B, Ch 2, Sec 1, [6.2] and Pt B, Ch 2, Sec 1, [6.3] are to be referred to.

f) Openings in the shell plating below the bulkhead deck:
Requirements mentioned in:
- Pt B, Ch 11, Sec 12, [2], Pt B, Ch 11, Sec 12, [3] and Pt B, Ch 11, Sec 12, [4], and
- Pt C, Ch 1, Sec 10, [8]

are to be referred to, taking into account Ch 3, Sec 5, [1.5.1].

1.2.2 Location of cargo tanks

Requirements mentioned in OSV Chemical Code Chapter 2, section 2.9.1 are to be referred to.

1.2.3 Cargo segregation

Requirements mentioned in OSV Chemical Code Chapter 3, section 3.1.1, 3.1.2.1, 3.1.2.2, 3.1.6 and 3.1.7 are to be referred to.

1.2.4 Accommodation, service space and control stations

Requirements mentioned in OSV Chemical Code Chapter 3, section 3.2 are to be referred to.

1.3 Compartment arrangement in way of oil product cargo tanks

1.3.1 Ships carrying oil products with a flashpoint more than 60°C

A cargo tank carrying exclusively oil products having a flashpoint exceeding 60°C (closed cup test) are to be segregated from accommodation spaces, drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, fuel oil tank, or other similar space. On-deck stowage of independent tanks or installation of independent tanks in otherwise empty hold spaces is to be considered as satisfactory.

1.3.2 Length of cargo tanks

The length of each cargo tank shall not exceed 10 metres or one of the values of Tab 1, as applicable, whichever is the greater.

Note 1: When the aggregate capacity of oil tanks is less than 200 m^3, this requirements might not be applied.

1.3.3 Slop tanks

Requirements mentioned in Pt D, Ch 7, Sec 2, [3.5.1] and Pt D, Ch 7, Sec 2, [3.6] are to be applied.

Note 1: When aggregate capacity of oil tanks does not exceed 1000 m^3, these requirements might not be applied.

Table 1 : Length of cargo tanks

Longitudinal bulkhead	Type of cargo tank	b_i/B **(1)**	Centreline bulkhead	Length (m)
No bulkhead	–	–	–	$(0,5\ b_i/B + 0,1)$ L **(2)**
Centreline bulkhead	–	–	–	$(0,25\ b_i/B + 0,15)$ L
Two or more bulkheads	Wing cargo tank	–	–	0,2 L
	Centre cargo tank	if $b_i/B > 1/5$	–	0,2 L
		if $b_i/B < 1/5$	No	$(0,5\ b_i/B + 0,1)$ L
			Yes	$(0,25\ b_i/B + 0,15)$ L

(1) Where b_i is the minimum distance from the side of the supply vessel to the outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centreline at the level corresponding to the assigned summer freeboard.

(2) Not to exceed 0,2 L.

2 Access arrangement and access to spaces

2.1 Access arrangement in way of cargo tanks for oil products

2.1.1 Direct access from open deck

Supply vessels are to be provided with the following:

a) Access to cargo tanks is to be direct from the open deck and such as to ensure their complete inspection except for access to cargo tanks in double-bottoms that may be through a cargo pump-room, pump-room, deep cofferdam, pipe tunnel or similar dry compartments, provided that the ventilation of these spaces complies with Ch 3, Sec 5, [6.1.1].

b) Access to cargo pumps does not need to be from the open deck provided that the access is independent of watertight doors.

2.1.2 Dimension of access openings

The following requirements are applicable for all the spaces referred to in [2.1.1]:

a) For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is no to be less than 600 mm by 600 mm.

b) For access through vertical openings, or manholes providing passage through the length and breath of the space, the minimum clear opening is not to be less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

c) Smaller dimensions may be approved by the Society in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

2.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

2.2.1 Access to spaces in the cargo area

Requirements mentioned in OSV Chemical Code Chapter 3, section 3.3 are to be referred to.

2.2.2 Additional requirements for ships granted with notations -FP≤60°C or -acids or -toxic

In addition to the requirements mentioned in [2.2.1], the following apply:

a) For cargo tanks segregation, requirements mentioned in OSV Chemical Code Chapter 4, sections 4.1.2 and 4.1.3, are to be referred to.

b) For the location of openings into accommodation, passageways, service and machinery spaces and control stations in relation to cargo piping and cargo vent systems, requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.7 are to be referred to.

c) For access to cargo tanks, cofferdams, void spaces, cargo pump-room, pump-room, empty tank, or other spaces adjacent to cargo tanks, requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.8 are to be referred to.

d) High walkways should not be located within the cargo area. Requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.9 are to be referred to.

2.2.3 Additional requirements for ships granted with notation -FP≤60°C

In addition to the requirements mentioned in [2.2.1] and [2.2.2], for location of entrances, openings into accommodation, service and machinery spaces and control stations, requirements mentioned in OSV Chemical Code Chapter 4, section 4.2.2 are to be referred to.

2.2.4 Additional requirements for ships granted with notation -acids

In addition to the requirements mentioned in [2.2.1] and [2.2.2], the special requirements mentioned in the IBC Code Chapter 15, section 15.11 are to be referred to.

2.2.5 Additional requirements for ships granted with notation -toxic

In addition to the requirements mentioned in [2.2.1] and [2.2.2], the following apply:

a) The special requirements mentioned in the IBC Code Chapter 15, section 15.12 are to be referred to.

b) For location of entrances, openings into accommodation, passageways, service and machinery spaces and control stations, requirements mentioned in OSV Chemical Code Chapter 4, sections 4.3.2, 4.3.3, 4.3.4, 4.3.5 and 4.3.6, are to be referred to.

c) For marking of cargo deck areas, requirements mentioned in OSV Chemical Code Chapter 15, section 15.5.5 are to be referred to.

3 Arrangement for hull and forecastle openings

3.1 General

3.1.1 Sidescuttles and windows

Sidescuttles and windows of opening type are, in general, accepted only in unexposed areas of the deckhouses located immediately above the forecastle and the areas above.

3.1.2 Sidescuttles of gas-safe areas facing hazardous areas

Sidescuttles of gas-safe areas facing hazardous areas, excluding those of non-opening type, are to be capable of ensuring an efficient gas-tight closure.

Warning plates are to be fitted on access doors to accommodation and service spaces facing the cargo area indicating that the doors and sidescuttles mentioned above are to be kept closed during cargo handling operations.

3.1.3 Freeing ports

The area of freeing ports is to be increased by 50% with respect to that determined according to Pt B, Ch 11, Sec 12, [6] or NR566, as applicable.

For ships operating in areas where icing is likely to occur, shutters may not be fitted.

3.1.4 Freeing ports through box-bulwarks

Where box-bulwarks the upper level of which extends to the forecastle deck are fitted in way of the loading area, the freeing ports are to pass through these box-bulwarks and their area is to be increased to take account of the height of the bulwarks.

3.1.5 Miscellaneous

Air pipes, ventilators, small hatchways, fans and control valves are to be located outside the loading area and protected from possible shifting of the deck cargo.

Section 3 Stability

1 General

1.1 Application

1.1.1 Every decked OSV of 24 metres and over is to comply with the provisions of present Section.

Note 1: The requirements of this Section are based on IMO Offshore Supply Vessel Guidelines amended by MSC 335(90).

1.1.2 The intact and damage stability of an OSV of less than 24 metres in length should be to the satisfaction of the Society.

1.2 Relaxation

1.2.1 Unless specified in [1.3], relaxation in the requirements of the present Section may be permitted by the Society for ships granted with navigation notation **coastal area**, provided the operating conditions are such as to render compliance with these requirements unreasonable or unnecessary.

1.3 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

1.3.1 No relaxation in the requirements of the present Section shall be accepted for ships assigned with the additional service features **HNLS** and/or **WELLSTIM**.

1.3.2 In addition to the requirements mentioned in this Section, the provisions of OSV Chemical Code Chapter 2, section 2.1, are to be applied.

Note 1: With reference to OSV Chemical Code Chapter 2, section 2.1.2, the stability of ships other than those carrying cargoes containing mixtures and individual products indicated in chapter 17 of the IBC Code and the latest edition of the MEPC.2/Circular will be subject to special consideration.

2 Intact stability

2.1 General

2.1.1 General stability criteria

The intact stability for the loading conditions defined in Pt B, Ch 3, App 2, [1.2.1] and Pt B, Ch 3, App 2, [1.2.13] with the assumptions in [2.1.5], is to be in compliance with the requirements of Pt B, Ch 3, Sec 2, [2.1] or, as an alternative, with the requirements of [2.1.2]. The additional criteria of [2.1.3] are also to be complied with.

2.1.2 Alternative stability criteria

The following equivalent criteria are recommended where the ship's characteristics render compliance with Pt B, Ch 3, Sec 2, [2.1] impracticable:

- *the area, in m·rad, under the curve of righting levers (GZ curve) may not be less than 0,070 up to an angle of 15° when the maximum righting lever (GZ) occurs at 15° and 0,055 up to an angle of 30° when the maximum righting lever (GZ) occurs at 30° or above. Where the maximum righting lever (GZ) occurs at angles of between 15° and 30°, the corresponding area "A", in m·rad, under the righting lever curve is to be:*

  $$A = 0{,}055 + 0{,}001 \cdot (30° - \theta_{max})$$

  where θ_{max} is the angle of heel, in degrees, at which the righting lever curve reaches its maximum
- *the area, in m·rad, under the righting lever curve (GZ curve) between the angles of heel of 30° and 40°, or between 30° and θ_f if this angle is less than 40°, may not be less than 0,03,* where θ_f is defined in Pt B, Ch 3, Sec 2, [2.1.2]
- *the righting lever (GZ), in m, is to be at least 0,20 at an angle of heel equal to or greater than 30°*
- *the maximum righting lever (GZ) is to occur at an angle of heel not less than 15°*
- *the initial transverse metacentric height (GM), in m, may not be less than 0,15 m.*

2.1.3 Additional criteria

A minimum freeboard at the stern of at least 0,005 L is to be maintained in all operating conditions.

2.1.4 Factors of influence

The stability criteria mentioned in [2.1.1] and [2.1.2] are minimum values; no maximum values are recommended. It is advisable to avoid excessive values, since these might lead to acceleration forces which could be prejudicial to the vessel, its complement, its equipment and the safe carriage of cargo.

Where anti-rolling devices are installed, the stability criteria indicated in [2.1.1] and [2.1.2] are to be maintained when the devices are in operation.

2.1.5 Assumptions for calculating loading conditions

If a vessel is fitted with cargo tanks, the fully loaded conditions of Pt B, Ch 3, App 2, [1.2.13] are to be modified, assuming first the cargo tanks full and then the cargo tanks empty.

If in any loading condition water ballast is necessary, additional diagrams are to be calculated, taking into account the water ballast, the quantity and disposition of which are to be stated in the stability information.

In all cases when deck cargo is carried, a realistic stowage weight is to be assumed and stated in the stability information, including the height of the cargo and its centre of gravity.

Where pipes are carried on deck, a quantity of trapped water equal to a certain percentage of the net volume of the pipe deck cargoes is to be assumed in and around the pipes. The net volume is to be taken as the internal volume of the pipes, plus the volume between the pipes. This percentage is 30 if the freeboard amidships is equal to or less than 0,015 L and 10 if the freeboard amidships is equal to or greater than 0,03 L. For intermediate values of the freeboard amidships, the percentage may be obtained by linear interpolation. In assessing the quantity of trapped water, the Society may take into account positive or negative sheer aft, actual trim and area of operation.

A vessel, when engaged in towing operations, may not carry deck cargo, except that a limited amount, properly secured, which would neither endanger the safe working of the crew nor impede the proper functioning of the towing equipment, may be accepted.

Allowance is to be made for the anticipated type of wire or rope on storage reels and wire on the winches when calculating loading conditions.

2.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

2.2.1 Requirements mentioned in the OSV Chemical Code Chapter 2, section 2.2, are to be referred to. In any case, requirements mentioned in the OSV Chemical Code shall prevail.

3 Damage stability

3.1 Damage stability when the additional class notation SDS is assigned

3.1.1 General

Taking into account, as initial conditions before flooding, the standard loading conditions as referred to in Pt B, Ch 3, App 2, [1.2.1] and Pt B, Ch 3, App 2, [1.2.13], the vessel is to comply with the damage stability criteria as specified in [3.1.8].

3.1.2 Damage dimensions

The assumed extent of damage of supply vessels is to be as indicated in Tab 1.

The extent of damage is to occur anywhere in the vessel's length between any transverse watertight bulkhead.

Table 1 : Extent of damage

Ship length	Longitudinal extent	Transverse extent **(1)**	Vertical extent **(2)**
L ≥ 80 m	1/3 $L^{2/3}$	B/20, or 760 mm **(3)**	Full depth
43 < L <80 m	3L/100 + 3	760 mm	
L ≤ 43 m	L/10		

(1) Measured inboard from the side of the vessel perpendicularly to the centreline at the level of the summer load waterline.
(2) From the underside of the cargo deck, or the continuation thereof.
(3) Whichever is the greater.

3.1.3 Consideration of transverse watertight bulkheads for flooding

For a vessel with length (L) less than 80 m, a transverse watertight bulkhead extending from the vessel's side to a distance inboard of 760 mm or more at the level of the summer load line joining longitudinal watertight bulkheads may be considered as a transverse watertight bulkhead for the purpose of the damage calculations.

For a vessel with length (L) from 80 m to 100 m, a transverse watertight bulkhead extending from the vessel's side to a distance inboard of B/20 or more (but not less than 760 mm) at the level of the summer load line joining longitudinal watertight bulkheads may be considered as a transverse watertight bulkhead for the purpose of the damage calculations.

Where a transverse watertight bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3,05 m, the double bottom or side tank adjacent to the stepped portion of the bulkhead is to be considered as flooded simultaneously.

If the distance between adjacent transverse watertight bulkheads or the distance between the transverse planes passing through the nearest stepped portions of the bulkheads is less than the longitudinal extent of damage given in [3.1.2], only one of these bulkheads should be regarded as effective for the purpose of the damage assumptions described in Tab 1.

3.1.4 Progressive flooding

If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable for each case of damage. The progressive flooding is to be considered in accordance with Pt B, Ch 3, Sec 3, [3.3].

3.1.5 Minor damage

If damage of a lesser extent than that specified in [3.1.2] results in a more severe condition, such lesser extent is to be assumed.

3.1.6 Permeability

The permeability of spaces assumed to be damaged is to be as indicated in Tab 2.

Table 2 : Values of permeability

Spaces	Permeability
Appropriated for stores	0,60
Occupied by accommodation	0,95
Occupied by machinery	0,85
Void spaces, empty tanks	0,95
Intended for dry cargo	0,95
Intended for liquids	**(1)**
(1) The permeability of tanks is to be consistent with the amount of liquid carried.	

3.1.7 Survival requirements

Compliance with the requirements of [3.1.8] is to be confirmed by calculations which take into consideration the design characteristics of the vessel, the arrangements, configuration and permeability of the damaged compartments and the distribution, specific gravities and free surface effect of liquids.

3.1.8 Damage stability criteria

a) *The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place.* The progressive flooding is to be considered in accordance with Pt B, Ch 3, Sec 3, [3.3].

b) *In the final stage of flooding, the angle of heel due to unsymmetrical flooding may not exceed 15°. This angle may be increased up to 17° if no deck immersion occurs.*

c) *The stability in the final stage of flooding is to be investigated and may be regarded as sufficient if the righting lever curve has at least a range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 100 mm within this range. Unprotected openings may not become immersed at an angle of heel within the prescribed minimum range of residual stability unless the space in question has been included as a floodable space in calculations for damage stability. Within this range, immersion of any of the openings referred to in item a) and any other openings capable of being closed weathertight may be authorized.*

Note 1: "other openings capable of being closed weathertight" do not include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship.

d) *The stability is to be sufficient during intermediate stages of flooding.* In this regard, the Society applies the same criteria relevant to the final stage of flooding also during the intermediate stages of flooding.

3.1.9 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

Requirements mentioned in the OSV Chemical Code sections 2.4, 2.5, 2.6, 2.7 and 2.8. are to be referred to. In any case, requirements mentioned in the OSV Chemical Code shall prevail.

Requirements mentioned in section 2.9.2 of the OSV Chemical Code are to be applied regarding the protrusion of suction wells installed inside cargo tanks for IBC Code ship types 2 and 3 products when affected compartments are determined flooded after a damage

For the application of these requirements, Tab 3 is to be used to consider together:

- ship type according to the quantity of products carried
- damage assumptions
- standard of damage.

Table 3 : Damage stability assumptions for ships granted with HNLS and/or WELLSTIM additional service features

Quantity of product carried, with reference to IBC Code		Ship length	Stability
type 1	type 2 + type 3		
≤ 150 m³	< 800 m³	> 100 m	• should be assumed to sustain damage described in section 2.6.2 of the OSV Chemical Code anywhere along the length between transverse watertight bulkheads, and • should also comply with SOLAS regulations II-1/6 to II-1/7-3 (probabilistic damage stability standard for a cargo ship).
		≤ 100 m	should be assumed to sustain damage described in section 2.6.2 of the OSV Chemical Code anywhere along the length between transverse watertight bulkheads.
≤ 150 m³	≥ 800 m³ and ≤ 1200 m³	> 100 m	• should be assumed to sustain damage described in section 2.6.2 of the OSV Chemical Code anywhere along the length, and • should also comply with SOLAS regulations II-1/6 to II-1/7-3 (probabilistic damage stability standard for a cargo ship).
		≤ 100 m	should be assumed to sustain damage described in section 2.6.2 of the OSV Chemical Code anywhere along the length.
≤ 150 m³	> 1200 m³	> 100 m	should be assumed to sustain damage described in section 2.6.1 of the OSV Chemical Code anywhere along the length.
		≤ 100 m	should be assumed to sustain damage described in section 2.6.1 of the OSV Chemical Code anywhere along the length except involving bulkheads bounding a machinery space of category A.
> 150 m³	any quantity	any length	should be assumed to sustain damage described in section 2.6.1 of the OSV Chemical Code anywhere along the length.

Section 4 Hull Structure

Symbols

k : Material factor for steel, defined in Pt B, Ch 4, Sec 1, [2.2]

b : Breadth of an elementary plate panel (EPP), in mm, as defined in Pt B, Ch 4, Sec 6, [2.1.1].

1 Structure design principles

1.1 General

1.1.1 For ships greater than 24 m in length, it is recommended that a double skin is provided to reinforce the protection of the main compartments in the event of contact with pontoons or platform piles.

1.2 Side structure exposed to bumping

1.2.1 Longitudinally framed side

In the whole area where the side of the ship is exposed to bumping, distribution frames are to be provided at mid-span, consisting of an intercostal web of the same height as the ordinary stiffeners, with a continuous face plate.

Within reinforced areas, scallop welding for all side ordinary stiffeners is forbidden.

1.2.2 Transversely framed side

In the whole area where the side of the ship is exposed to bumping, a distribution stringer is to be fitted at mid-span, consisting of an intercostal web of the same height as the ordinary stiffeners, with a continuous face plate.

Side frames are to be fitted with brackets at ends.

Within reinforced areas, scallop welding for all side ordinary stiffeners is forbidden.

1.2.3 Fenders

Efficient fenders, adequately supported by structural members, are to be fitted on the side, including the forecastle, on the full length of the areas exposed to contact.

1.3 Deck structure

1.3.1 Local reinforcements are to be fitted in way of specific areas which are subject to concentrated loads.

1.3.2 Exposed decks carrying heavy cargoes or pipes are to provide protection and means of fastening for the cargo, e.g. inside bulwarks, guide members, lashing points, etc.

1.4 Structure of cement tanks and mud compartments

1.4.1 Cargo tanks and hoppers intended to carry mud or cement are to be supported by structures which distribute the acting forces as evenly as possible on several primary supporting members.

1.5 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

1.5.1 Suction wells installed inside cargo tanks

When considering the size of suction wells installed inside the cargo tank, requirements of the OSV Chemical Code, Chapter 2, section 2.9.2 are to be referred to.

1.5.2 Portable tanks used as deck tanks

a) Requirements mentioned in OSV Chemical Code Chapter 5, section 5.2.2 are to be referred to regarding the allowable designs of these tanks.

b) Requirements mentioned in OSV Chemical Code Chapter 17, section 17.4.2 are to be referred to regarding the securing of the portable tanks to the deck.

1.6 Additional requirements for ships granted with notation -acids

1.6.1 In addition to the requirements mentioned in [1.5], the following apply:

a) The requirements in section 15.11 of the IBC Code are to be applied.

b) For acid spill protection, requirements mentioned in OSV Chemical Code Chapter 4, sections 4.4.2 and 4.4.6 are to be referred to.

2 Design loads

2.1 Dry uniform cargoes

2.1.1 Still water and inertial pressures

The still water and inertial pressures transmitted to the structure of the upper deck intended to carry loads are to be obtained, in kN/m^2, as specified in Pt B, Ch 5, Sec 6, [6.1], where the value of $P_{dl\text{-}s}$ is to be taken not less than 24 kN/m^2.

3 Hull scantlings

3.1 Plating

3.1.1 Minimum net thicknesses

The net thickness of the side and upper deck plating is to be not less than the values given in Tab 1.

Table 1 : Minimum net thickness of the side and upper deck plating

Plating	Minimum net thickness, in mm
Side below freeboard deck	The greater of: • $2,1 + 0,031\ L\ k^{0,5} + 0,0045\ b$ • $8\ k^{0,5}$
Side between freeboard deck and strength deck	The greater of: • $2,1 + 0,013\ L\ k^{0,5} + 0,0045\ b$ • $8\ k^{0,5}$
Upper deck	7,0

3.1.2 Strength deck plating

Within the cargo area, the thickness of strength deck plating is to be increased by 1,5 mm with respect to that determined according to Pt B, Ch 7, Sec 4.

However, the above increase in thickness by 1,5 mm may be omitted provided all the following conditions are fulfilled:

a) Wooden planking provide an efficient protection of the deck at the satisfaction of the society.

b) The welding of the steel fittings securing the wood protection is performed before coating application.

c) Full coating application is applied after item b) above.

3.2 Stiffeners

3.2.1 Longitudinally framed side exposed to bumping

In the whole area where the side of the supply vessel is exposed to bumping, the section modulus of stiffeners is to be increased by 15% with respect to that determined according to Pt B, Ch 7, Sec 5.

3.2.2 Transversely framed side exposed to bumping

In the whole area where the side of the supply vessel is exposed to bumping, the section modulus of stiffeners, i.e. side, tweendeck and superstructure frames, is to be increased by 25% with respect to that determined according to Pt B, Ch 7, Sec 5.

3.3 Primary supporting members

3.3.1 Distribution stringers

The section modulus of the distribution stringer required in [1.2.2] is to be at least twice that calculated in [3.2.2] for stiffeners.

3.3.2 Cement tanks and mud compartments

The net scantlings of the primary supporting members of cement tanks and mud compartments are to be calculated taking into account high stresses resulting from vertical and horizontal accelerations due to rolling and pitching.

Secondary moments due to the tendency of materials to tip over are to be considered by the Society on a case-by-case basis.

4 Other structure

4.1 Aft part

4.1.1 Rollers

At the transom, local reinforcements are to be fitted in way of rollers and other special equipment intended for cargo handling.

4.1.2 Structures in way of rollers

The structures in way of the stern rollers and those of the adjacent deck are considered by the Society on a case-by-case basis, taking into account the relevant loads which are to be specified by the Designer.

4.2 Superstructures and deckhouses

4.2.1 Deckhouses

Due to their location at the forward end of the supply vessel, deckhouses are to be reduced to essentials and special care is to be taken so that their scantlings and connections are sufficient to support wave loads.

4.2.2 Minimum net thicknesses

The net thickness of forecastle aft end plating and of plating of deckhouses located on the forecastle deck is to be not less than the values given in Tab 2.

Table 2 : Plating of forecastle aft end and of deckhouses located on the forecastle deck

Structure	Plating	Minimum net thickness, in mm
Forecastle	aft end	1,04 (5 + 0,01 L)
Deckhouses located on the forecastle deck	front	1,44 (4 + 0,01 L)
	sides	1,31 (4 + 0,01 L)
	aft end	1,22 (4 + 0,01 L)

4.2.3 Stiffeners

The net section modulus of stiffeners of the forecastle aft end and of deckhouses located on the forecastle deck is to be not less than the values obtained from Tab 3.

Stiffeners of the front of deckhouses located on the forecastle deck are to be fitted with brackets at their ends. Those of side and aft end bulkheads of deckhouses located on the forecastle deck are to be welded to decks at their ends.

Table 3 : Stiffeners of forecastle aft end and of deckhouses located on the forecastle deck

Structure	Stiffeners on	Net section modulus, in cm^3
Forecastle	aft end plating	3 times the value calculated according to Pt B, Ch 11, Sec 5, [3.3]
Deckhouses located on the forecastle deck	front plating	
	sides plating	0,75 times that of the forecastle tweendeck frames
	aft end plating	

4.3 Structure of cargo tanks

4.3.1 Scantling of cargo tanks is to be in compliance with the provisions of Part B, Chapter 7.

Refer to Ch 3, Sec 5, [3] to Ch 3, Sec 5, [6] for design details.

5 Hull outfitting

5.1 Rudders

5.1.1 Rudder stock scantlings

The rudder stock diameter is to be increased by 5% with respect to that determined according to Pt B, Ch 12, Sec 1, [4].

5.2 Bulwarks

5.2.1 Plating

In the case of a high bulwark, fitted with a face plate of large cross-sectional area, which contributes to the longitudinal strength, the thickness of the plating contributing to the longitudinal strength is to be not less than the value obtained according to Pt B, Ch 7, Sec 4.

5.2.2 Stays

The bulwark stays are to be strongly built with an attachment to the deck reinforced to take account of accidental shifting of deck cargo (e.g. pipes).

5.3 Equipment

5.3.1 Mooring lines

The mooring lines are given as a guidance, but are not required as a condition of classification.

The length of mooring lines may be calculated according to Pt B, Ch 12, App 2, [2].

However, in the case of supply vessels provided with devices enabling ample manoeuvring characteristics (e.g. supply vessels provided with two or more propellers, athwartship thrust propellers, etc.), the length of mooring lines, in m, may be reduced to (L + 20).

5.3.2 Chain locker

Chain lockers are to be arranged as gas-safe areas. Hull penetrations for chain cables and mooring lines are to be arranged outside the hazardous areas specified in Ch 3, Sec 1, [1.6.20].

Section 5 Machinery and Cargo Systems

1 Machinery systems

1.1 Cargo heating systems

1.1.1 Where provided, any cargo tank heating system is to comply with the provisions of Pt D, Ch 7, Sec 4, [2.6]

With reference to Ch 3, Sec 1, [1.6.15], particular attention to be provided to the maximum heating temperature of cargo tanks intended for the carriage of oil products.

1.2 Exhaust pipes

1.2.1 Exhaust outlets from diesel engines are to be provided with spark arresters.

1.3 Inert gas system

1.3.1 Where provided, nitrogen/inert gas systems fitted on the ship are to comply with the provision of Pt D, Ch 8, Sec 9, [2].

1.4 Other machinery systems

1.4.1 Fuel oil, lubricating oil tanks, foam forming liquid tanks, oil dispersant tanks and similar tanks which are located inside the cargo area may be served by pumps located outside the cargo area, provided that the piping is directly connected to the associated pump and does not run through cargo tanks.

1.5 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

1.5.1 Non cargo discharges below the freeboard deck

Requirements mentioned in Pt C, Ch 1, Sec 10, [8] and OSV Chemical Code section 2.3 are to be referred.

1.5.2 Pumps, ballast lines and vent lines serving ballast tanks

Requirements mentioned in OSV Chemical Code, Chapter 3, section 3.1.5 are to be referred to.

1.6 Additional requirements for ships granted with notations -FP≤60°C and/or -acids and/or -toxic

1.6.1 In addition to the requirements mentioned in [1.5], the following apply:

a) For discharge and filling arrangements for ballast or fresh water sited immediately adjacent to cargo tanks certified for products or residues of products, requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.5 are to be referred to.

b) For bilge pumping systems serving spaces where cargoes or residues of cargoes may occur, requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.6 are to be referred to.

c) For air intakes and openings into accommodation, passageways, service and machinery spaces and control stations in relation to cargo piping and cargo vent systems, requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.7 are to be referred to.

1.7 Additional requirements for ships granted with notation -FP≤60°C

1.7.1 In addition to the requirements mentioned in [1.5] and [1.6], for air inlets and openings to accommodation, service and machinery spaces and control stations, requirements mentioned in OSV Chemical Code Chapter 4, section 4.2.2 are to be referred to.

1.8 Additional requirements for ships granted with notation -toxic

1.8.1 In addition to the requirements mentioned in [1.5] and [1.6], the following apply:

a) The special requirements mentioned in the IBC Code Chapter 15, section 15.12 are to be referred to.

b) For air inlets and openings to accommodation, service and machinery spaces and control stations, requirements mentioned in OSV Chemical Code Chapter 4, sections 4.3.2, 4.3.3 and 4.3.4 are to be referred to.

1.9 Additional requirements for ships granted with notation -acids

1.9.1 In addition to the requirements mentioned in [1.5] and [1.6], the following apply:

a) For detection of leakage of cargo in adjacent spaces, requirements mentioned in IBC Code Chapter 15, section 15.11.7 are to be referred to.

b) For cargo pump room bilge pumping and drainage, requirements mentioned in IBC Code Chapter 15, section 15.11.8 are to be referred to.

2 Cargo piping design

2.1 Cargo separation

2.1.1 For cargo handling, a pumping and piping system independent from the other pumping and piping systems on board is to be provided.

2.1.2 The piping system serving the non-flammable oil product cargo tanks may be connected to the fuel oil pumping system in engine room, provided that:

- there are suitable means of separation between the branches serving the tanks dedicated for the cargo oil product tanks and the branches serving the fuel oil tanks
- mixing the two different kinds of oils does not jeopardize the intended use of neither the fuel oil nor the cargo.

2.2 Design and materials

2.2.1 Unless otherwise specified, materials for construction of tanks, piping, fittings and pumps are to be in accordance with Pt D, Ch 7, Sec 4, [3.3.2].

2.2.2 Unless otherwise specified, cargo piping is to be designed and constructed according to Pt D, Ch 7, Sec 4, [3.3.1].

2.3 Piping arrangement

2.3.1 The following requirements apply:

a) Cargo piping conveying non-flammable oil products, need not be located entirely within the cargo area provided that the separation requirements for accommodation spaces, drinking water and stores for human consumption are observed.

b) Control of discharge of oil products is to comply with Pt D, Ch 7, Sec 4, [5.3].

Note 1: This requirement might not be applied when aggregate capacity does not exceed 1000 m^3.

2.4 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

2.4.1 Segregation of cargo

Requirements mentioned in OSV Chemical Code Chapter 3, sections 3.1.2.2, 3.1.3 and 3.1.4, are to be referred to.

2.4.2 Piping scantling, fabrication, joining details, flange connections and testing

Requirements mentioned in OSV Chemical Code Chapter 6, sections 6.1, 6.2, 6.3 and 6.4, are to be referred to.

2.4.3 Piping arrangements

Requirements mentioned in OSV Chemical Code Chapter 6, section 6.5, are to be referred to.

2.4.4 Cargo transfer control system

Requirements mentioned in OSV Chemical Code Chapter 6, section 6.6, are to be referred to.

2.4.5 Ship's cargo hoses

Requirements mentioned in OSV Chemical Code Chapter 6, section 6.7, are to be referred to.

2.4.6 Mechanical ventilation in the cargo area

Requirements mentioned in the OSV Chemical Code Chapter 10 are to be referred to.

Note 1: Attention is drawn on the specific requirements to be applied as mentioned in the OSV Chemical Code sections 10.1.1, 10.1.2 and 10.1.3.

Note 2: Attention is drawn on the specific requirements to be applied mentioned in the OSV Chemical Code Chapter 10, section 10.3 for spaces normally not entered.

2.4.7 Pollution prevention - no discharge to the sea

Requirements mentioned in the OSV Chemical Code Chapter 12, section 12.2 are to be referred to.

2.5 Additional requirements for ships granted with notations -FP≤60°C and/or -acids and/or -toxic

2.5.1 In addition to the requirements mentioned in [2.4], for cargo piping location, requirements mentioned in OSV Chemical Code Chapter 4, section 4.1.4 are to be referred to.

3 Cargo tanks

3.1 Cargo oil tanks

3.1.1 Integral and independent gravity tanks are to be constructed and tested according to recognised standards taking into account the carriage temperature and the cargo relative density.

3.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

3.2.1 Tank type requirements for individual products

Requirements mentioned in OSV Chemical Code Chapter 5, section 5.2.1 are to be referred to.

3.2.2 Carriage of contaminated backloads

Requirements mentioned in OSV Chemical Code Chapter 16, section 16.4.2.1 are to be referred to.

4 Cargo pumping system

4.1 General

4.1.1 The delivery side of cargo pumps is to be fitted with relief valves discharging back to the suction side of the pumps (bypass) in closed circuit. Such relief valves may be omitted in the case of centrifugal pumps with a maximum delivery pressure not exceeding the design pressure of the piping, with the delivery valve closed.

4.1.2 Cargo pumps are to be monitored as required in Tab 1.

Table 1 : Monitoring of cargo pumps

Equipment - parameter	Alarm	Indication	Comments
Pump - discharge pressure	L	Local	• on the pump **(1)**, or • next to the unloading control station
Pump casing - temperature **(2)**	H		visual and audible, in cargo control room or pump control station
Bearings - temperature **(2)**	H		visual and audible, in cargo control room or pump control station
Bulkhead shaft gland - temperature **(2)**	H		visual and audible, in cargo control room or pump control station
(1) And next to the driving machine if located in a separate compartment. **(2)** Not required for supply vessels intended to carry pollution hazard only substances having a flashpoint above 60°C or oil products having a flashpoint above 60°C only.			

5 Cargo tank fittings

5.1 Level gauging systems and overflow control

5.1.1 Cargo oil tanks

For the cargo tanks intended to carry oil products having a flashpoint above 60°C, the gauging systems may be of the open type provided that the relevant provisions of Pt C, Ch 1, Sec 10, [9] and Pt C, Ch 1 Sec 10, [11] are complied with.

Each cargo tank is to be fitted with a level gauging system in compliance with Pt D, Ch 7, Sec 4, [4.4] and an overflow control system in compliance with Pt D, Ch 7, Sec 4, [4.5].

5.2 Cargo tank venting systems

5.2.1 General

Cargo tanks are to be provided with a venting system appropriate to the cargo being carried and these systems shall be independent of the air pipes and venting systems of all other compartments of the ship.

5.2.2 Cargo oil tanks

The following requirements apply:

a) general provisions of Pt C, Ch 1, Sec 10, [9] and Pt C, Ch 1, Sec 10, [11] are to be complied with

b) tank venting systems are to open to the atmosphere at a height of at least 760 mm above the weather deck

c) tanks may be fitted with venting systems of the open type provided with a flame screen.

5.3 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

5.3.1 Separated venting systems

Requirements mentioned in OSV Chemical Code Chapter 3, section 3.1.2.3] are to be referred to.

5.3.2 Cargo tank venting

Requirements mentioned in OSV Chemical Code Chapter 7, are to be referred to.

5.3.3 Venting of tanks carrying contaminated backloads

Requirements mentioned in OSV Chemical Code Chapter 16, section 16.4.2.2.1 are to be referred to.

5.3.4 Cargo tank indicators and overflow control

Requirements mentioned in OSV Chemical Code Chapter 11, sections 11.1, 11.2 and 11.3 are to be referred to.

5.4 Additional requirements for ships granted with notation -toxic

5.4.1 In addition to the requirements mentioned in [5.3], the following apply:

a) Special requirements in the section 15.12 of the IBC Code Chapter 15 apply.

b) For set point of the pressure vacuum valves, requirements mentioned in OSV Chemical Code Chapter 4, section 4.3.7 are to be referred to.

c) For alarms for pressure indication at cargo control station and cargo area, requirements mentioned in OSV Chemical Code Chapter 15, section 15.4.4 are to be referred to.

5.5 Additional requirements for ships granted with notation -acids

5.5.1 In addition to the requirements mentioned in [5.3], the following apply:

a) For spray shields, requirements mentioned in OSV Chemical Code Chapter 4, section 4.4.3 are to be referred to.

b) For loading manifolds (portable shield covers and drainage arrangements), requirements mentioned in OSV Chemical Code, section 4.4.4 are to be referred to.

c) For drainage arrangements, requirements mentioned in OSV Chemical Code section 4.4.5 are to be referred to.

6 Mechanical ventilation in the cargo area

6.1 Cargo pump-room ventilation

6.1.1 Ships carrying oil products

a) Cargo pump rooms are to be mechanically ventilated. The number of changes of air is to be at least 20 per hour, based upon the gross volume of the space.

b) Ventilation intakes are to be so arranged as to minimize the possibility of recycling hazardous vapours from ventilation discharge openings.

c) Ventilation ducts are not to be led through gas-safe spaces, cargo tanks or slop tanks.

6.2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

6.2.1 Mechanical ventilation in the cargo area

Requirements mentioned in the OSV Chemical Code Chapter 10 are to be referred to.

Note 1: Attention is drawn on the specific requirements to be applied mentioned in the OSV Chemical Code, sections 10.1.1, 10.1.2 and 10.1.3.

Note 2: Attention is drawn on the specific requirements to be applied mentioned in the OSV Chemical Code Chapter 10, section 10.3 for spaces normally not entered.

7 Discharging and loading of portable tanks on board

7.1 Ships granted with additional service features HNLS and/or WELLSTIM

7.1.1 Type of tank and quantity limitations

Requirements mentioned in the OSV Chemical Code Chapter 17, section 17.2 are to be referred to.

Note 1: When the product transported is not included in the list of products in Ch 3, Sec 1, [1.3.2], attention is drawn on requirements in OSV Chemical Code Chapter 17, section 17.2.2: carriage of such product is to be accepted by the Society and the quantity of such product able to be carried is limited.

7.1.2 Arrangement of deck spread

Requirements mentioned in the OSV Chemical Code Chapter 17, section 17.3 are to be referred to.

Arrangement of the deck spread are to be submitted, referring to the OSV Chemical Code Appendix 3, sections 4.1, 4.2 and attachments 3, 4, 5 and 6.

7.1.3 Portable tanks used as deck tanks

Requirements mentioned in the OSV Chemical Code Chapter 17, sections 17.4.4 and 17.4.6 are to be referred to.

8 Additional requirements for carriage of liquid carbon dioxide and liquid nitrogen

8.1 Ships granted with notation -LG

8.1.1 General

The provisions of this Article does not consider the carriage of other liquefied gases listed in chapter 19 of the IGC Code. When carriage of such liquefied gases are considered, this is to be handled on a case by case basis, referring to the OSV Chemical Code Chapter 18, section 18.12.

The Society may allow adjustments to specific requirements in the IGC Code regarding the cargo containment, materials of construction, vent system for cargo containment and cargo transfer, taking into account existing industry standards and practices, if it is as least as effective as that required by the IGC Code. In any case, these adjustments, if any, are to be submitted to the Administration.

8.1.2 Location of cargo tanks and ship survivability

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.1.4 are to be referred to.

8.1.3 Carriage requirements

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.1.5 are to be referred to.

8.1.4 Accommodation, service and machinery spaces an control stations

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.2 are to be referred to.

8.1.5 Cargo containment

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.3 are to be referred to.

Note 1: Attention is drawn to the specific requirement related to liquid nitrogen

8.1.6 Materials of construction

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.4 are to be referred to.

8.1.7 Vent system for cargo containment

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.5 are to be referred to.

8.1.8 Cargo transfer

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.6 are to be referred to.

8.1.9 Vapour detection

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.7 are to be referred to.

8.1.10 Gauging and level detection

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.8 are to be referred to.

8.1.11 Emergency shutdown system

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.9 are to be referred to.

8.1.12 Carriage on open deck

Requirements mentioned in the OSV Chemical Code Chapter 18, section 18.11 are to be referred to.

Section 6 Electrical Installations, Instrumentation and Automation

1 Hazardous location and types of equipment

1.1 General

1.1.1 OSVs are to comply with the requirements of Pt D, Ch 7, Sec 5.

1.1.2 Electrical equipment, cables and wiring shall not be installed in the hazardous location unless it conforms to IEC 60092-502.

2 Additional requirements for ships granted with HNLS and/or WELLSTIM additional service features

2.1 General

2.1.1 Requirements mentioned in OSV Chemical Code Chapter 8 are to be referred to.

Note 1: Specific attention should be drawn on the requirements mentioned in OSV Chemical Code, section 8.1.7.

2.1.2 Remote control for loading and unloading

Requirements mentioned in OSV Chemical Code Chapter 11, section 11.1.2 are to be referred to.

2.2 Additional requirements for ships granted with notations -FP≤60°C and/or -toxic

2.2.1 In addition to the requirements mentioned in [2.1], for vapour detection, requirements mentioned in OSV Chemical Code Chapter 11, section 11.4 are to be referred to.

2.3 Additional requirements for ships granted with notation -acid

2.3.1 In addition to the requirements mentioned in [2.1], the following apply:

a) For hydrogen risk, requirements mentioned in IBC Code Chapter 15, section 15.11.5 are to be referred to.

b) For detection of leakage of cargo in adjacent spaces, requirements mentioned in IBC Code Chapter 15, section 15.11.7 are to be referred to.

Section 7 Fire Prevention, Protection and Extinction

1 General

1.1 Application

1.1.1 Unless otherwise specified, this Section applies to ships intended to carry products as mentioned in Ch 3, Sec 1, [1.1]

1.1.2 For ships intended to carry only liquid identified as non-flammable and not covered by the OSV Chemical Code, the fire-fighting requirements are to be to the satisfaction of the Society.

2 Fire prevention and protection

2.1 Ships granted with additional service features HNLS and/or WELLSTIM

2.1.1 For ships granted with notation **-FP≤60°C**, with reference to OSV Chemical Code Chapter 4, section 4.2.2, doors to spaces not having access to accommodation, service and machinery spaces and control stations, such as cargo control stations and store-rooms, may be permitted within the deck area mentioned in OSV Chemical Code Chapter 1, Section 1.2.7.3, provided the boundaries of the spaces are insulated to A-60 standard.

3 Fire fighting

3.1 Ships carrying oil product

3.1.1 For ships of 500 gross tonnage and above, the requirements in Part C, Chapter 4 as they would apply to cargo ships of 2000 gross tonnage and over, are to be complied with.

In addition, the following requirements apply:

- Pt C, Ch 4, Sec 6, [1.2.4], item g)
- Pt D, Ch 7, Sec 6, [3.2] and Pt D, Ch 7, Sec 6, [3.3].

3.2 Ships granted with additional service features HNLS and/or WELLSTIM

3.2.1 Requirements mentioned in OSV Chemical Code Chapter 9 are to be referred to.

Note 1: OSV Chemical Code Chapter 9 requirements are referring both to SOLAS II-2 and the IBC Code Chapter 17. Attention is drawn on the OSV Chemical Code Chapter 9, [9.2] and [9.3] that provide specific requirements for the cargo pump-rooms and the cargo area.

Note 2: Attention is drawn on the OSV Chemical Code Chapter 9, sections 9.1.2, 9.1.3 and 9.1.4 about relaxation of requirements for ships carrying non-flammable and/or having a flashpoint equal or greater than 60°C.

4 Personnel protection

4.1 Ships carrying oil products

4.1.1 Fire-fighters outfits

Two additional fire-fighters outfits are to be provided.

4.2 Ships granted with additional service features HNLS and/or WELLSTIM

4.2.1 General

Requirements mentioned in OSV Chemical Code Chapter 14, sections 14.1, 14.2, 14.3 and 14.4 are to be referred to.

4.2.2 Carriage of contaminated backloads

Requirements mentioned in OSV Chemical Code Chapter 16, section 16.4.2.2, are to be referred to.

4.3 Additional requirements for ships granted with notation -LG

4.3.1 In addition to the requirements mentioned in [4.2] requirements mentioned in OSV Chemical Code Chapter 18, section 18.10, and consequently, in OSV Chemical Code Chapter 14, sections 14.3 and 14.4 are to be referred to.

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 4
FIRE FIGHTING SHIPS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Systems

Section 4 Fire Protection and Extinction

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **fire-fighting**, as defined in Pt A, Ch 1, Sec 2, [4.11.3].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 90 m	• Part B	• NR566
	L < 90 m	• NR600	• NR566
Hull	L ≥ 90 m	• Part B • Ch 4, Sec 2	• Part B • Ch 4, Sec 2
	L < 90 m	• NR600	• NR600
Stability		• Part B • Ch 4, Sec 2	• NR566 • Ch 4, Sec 2
Machinery and cargo systems		• Part C • Ch 4, Sec 3	• NR566 • Ch 4, Sec 3
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C • Ch 4, Sec 4	• NR566 • Ch 4, Sec 4
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT. NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.			

Section 2 Hull and Stability

1 Stability

1.1 Intact stability

1.1.1 General

The stability of the ship for the loading conditions defined in Pt B, Ch 3, App 2, [1.2.11] is to be in compliance with the requirements in Pt B, Ch 3, Sec 2.

1.1.2 Additional criteria

The loading conditions reported in the trim and stability booklet, with the exception of lightship, are also to be checked in order to investigate the ship's capability to support the effect of the reaction force of the water jet in the beam direction due to the monitors fitted on board.

A fire-fighting ship may be considered as having sufficient stability, according to the effect of the reaction force of the water jet in the beam direction due to the monitors fitted on board, if the heeling angle of static equilibrium θ_0, corresponding to the first intersection between heeling and righting arms (see Fig 1), is less than 5°.

The heeling arm may be calculated as follows:

$$b_h = \frac{\Sigma \cdot R_i \cdot h_i + S \cdot (T/2 - e)}{9{,}81 \cdot \Delta} \cdot \cos\theta$$

where:

b_h : Heeling arm, in m, relevant to the reaction force of the water jet of the monitors fitted on board, and to the effect of transversal manoeuvring thrusters. The monitors are assumed to be oriented in beam direction parallel to the sea surface, so as to consider the most severe situation

R_i : Reaction force, in kN, of the water jet of each monitor fitted on board (see Fig 2)

h_i : Vertical distance, in m, between the location of each monitor and half draught (see Fig 2)

S : Thrust, in kN, relevant to manoeuvring thruster(s), if applicable (see Fig 2)

e : Vertical distance, in m, between the manoeuvring thruster axis and keel (see Fig 2)

Δ : Displacement, in t, relevant to the loading condition under consideration

T : Draught, in m, corresponding to Δ (see Fig 2).

Figure 1 : Heeling and righting arm curves

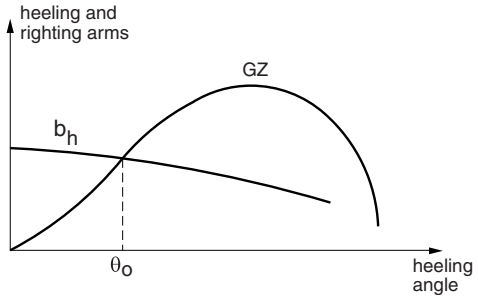
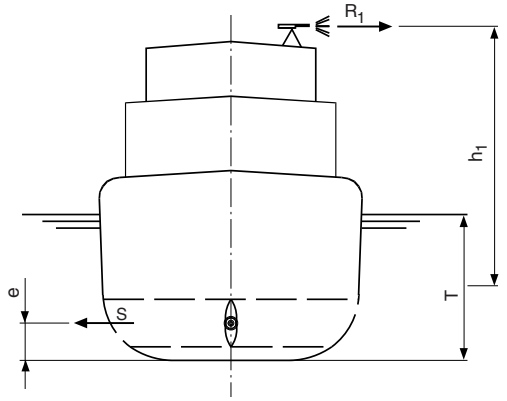


Figure 2 : Reaction force of water jet in the beam direction due to monitors



2 Structure design principles

2.1 Hull structure

2.1.1 The strengthening of the structure of the ships, where necessary to withstand the forces imposed by the fire-extinguishing systems when operating at their maximum capacity in all possible directions of use, are to be considered by the Society on a case-by-case basis.

2.2 Water and foam monitors

2.2.1 The seatings of the monitors are to be of adequate strength for all modes of operation.

3 Other structures

3.1 Arrangement for hull and superstructure openings

3.1.1 Deadlights and shutters are to be provided as requested by Ch 4, Sec 4, [2.2.1].

Section 3 Machinery and Systems

1 General

1.1 Application

1.1.1

a) This Section provides, for ships assigned the service notations **fire-fighting E**, **fire-fighting 1**, **fire-fighting 2**, and **fire-fighting 3**, specific requirements for:

- machinery systems
- fire-fighting systems installed on board the ship and intended for fighting of external fires.

b) The requirements related to the self-protection water-spraying systems fitted to fire-fighting ships assigned the additional service feature **water spraying** are given in Ch 4, Sec 4.

1.2 Documentation to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted.

2 Design of machinery systems

2.1 Manoeuvrability

2.1.1 General

a) The ratios between the main ship dimensions and the power of propulsion engines and of engines driving side thrusters are to be adequate and such as to ensure an effective manoeuvrability during fire-fighting operations.

b) The side thrusters and the main propulsion system are to be capable of maintaining the ship in position in still water and of withstanding the reaction forces of the water monitors even in the most unfavourable combination of operating conditions of such monitors, without requiring more than 80% of the above propulsive power, to prevent engine overload.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Description of the document **(2)**
1	I	General arrangement showing the disposition of all fire-fighting equipment
2	A	Details of all fire-fighting equipment such as pumps and monitors, including their capacity, range and trajectory of delivery
3	A	Schematic diagram of the water fire-fighting system
4	A	Plan of the water monitor seating arrangements
5	A	Diagram of local control and remote control system for water monitors
6	A	Schematic diagram of the fixed foam fire-extinguishing system
7	A	Plan of the foam monitor seating arrangements **(3)**
8	A	Diagram of local control and remote control system for foam monitors **(3)**
9	A	Specification and plan showing the location of fire-fighter's outfits and the location and capacity of the air compressor
10	A	Particulars of the means of keeping the ship in position during fire-fighting operations
11	I	Calculation of the required fuel oil capacity according to [2.2.1] **(4)**
12	I	Operating manual

(1) A: to be submitted for approval; I: to be submitted for information.

(2) Diagrams are also to include, where applicable:

- the (local and remote) control and monitoring systems and automation systems
- the instructions for the operation and maintenance of the piping system concerned (for information).

(3) For ships having the service notation **fire-fighting 3**.

(4) For ships having one of the following service notations: **fire-fighting 1**, **fire-fighting 2**, **fire-fighting 3**.

2.1.2 Power control system

An operating control system of the power supplied by the engines is to be provided, including:

- an alarm device operating at 80% of the maximum propulsive power available in free navigation, and
- an automatic reduction of power on reaching 100% of the above propulsive power,

to prevent engine overload.

Note 1: Such operating control system may not be required, at the discretion of the Society, in cases where the installed power is redundant.

2.2 Fuel oil capacity

2.2.1 All ships are to have fuel oil tanks whose capacity is to be sufficient for continuous fighting of fires whilst all the water monitors are operating for a period of time not less than:

- 24 hours in the case of ships having the service notation **fire-fighting 1**
- 96 hours in the case of ships having the service notation **fire-fighting 2** or **fire-fighting 3**.

This capacity is to be additional to that provided for the normal operation of the ship (propulsion, etc.).

Note 1: The determination of such required capacity is the responsibility of the Designer.

2.3 Scuppers

2.3.1 When the ship is protected by a water-spraying system, suitable scuppers or freeing ports are to be provided to ensure efficient drainage of water accumulating on deck surfaces when such system is in operation.

3 General requirements for fire-fighting systems

3.1 General

3.1.1 This Article applies to both water fire-extinguishing systems and fixed foam fire-extinguishing systems.

3.2 Independence of pumping and piping systems

3.2.1 The pumps and piping system serving the water and foam monitors are not to be used for other services except for the water-spraying system referred to in Ch 4, Sec 4 and the hose connections required for the portable fire-fighting equipment referred to in [6.2].

3.2.2 Where the water or foam monitor pumps are also used for the water-spraying system referred to in Ch 4, Sec 4 or for the hose connections required for the portable fire-fighting equipment referred to in [6.2]:

- it is to be possible to segregate each system from the others by means of valves, so that each system can be operated independently or simultaneously with the others, and
- the pump capacity is sufficient to serve all systems simultaneously.

3.3 Design and construction of piping systems

3.3.1 General

Fire-fighting piping systems are to comply with the provisions of Pt C, Ch 1, Sec 10.

3.3.2 Sea suctions

a) Sea suctions for fire-fighting pumps are not to be used for other purposes.

b) Sea suctions and associated sea chests are to be so arranged as to ensure a continuous and sufficient water supply to the fire-fighting pumps, not adversely affected by the ship motion or by water flow to or from bow thrusters, side thrusters, azimuth thrusters or main propellers.

c) Sea suctions are to be located as low as practicable to avoid:
   - clogging due to debris or ice
   - oil intake from the surface of the sea.

d) Sea water inlets are to be fitted with strainers having a free passage area of at least twice that of the sea suction valve. Efficient means are to be provided for clearing the strainers.

3.3.3 Pumps

a) Means are to be provided to avoid overheating of the fire-fighting pumps when they operate at low delivery rates.

b) The starting of fire-fighting pumps when sea water inlet valves are closed is either to be prevented by an interlock system or to trigger an audible and visual alarm.

c) It is to be demonstrated that the available net positive suction head is more than 1m above the net positive suction head leading to pump cavitation, i.e. $NPSH_A$ - 1m water column > $NPSH_R$.

3.3.4 Valves

a) If their nominal diameter exceeds 450 mm, sea water suction valves and water delivery valves are to be provided with a power actuation system as well as a manual operation device.

b) The sea water suction valve and water delivery valve and pump prime movers are to be operable from the same position.

3.3.5 Protection against corrosion

Means are to be provided to ensure adequate protection against:

- internal corrosion, for all piping from sea water inlets to water monitors
- external corrosion, for the lengths of piping exposed to the weather.

3.3.6 Piping arrangement

Suction lines are to be as short and straight as practicable.

3.4 Monitors

3.4.1 Design of monitors

a) Monitors are to be of an approved type.

b) Monitors are to be capable of withstanding the reaction forces of the water jet.

3.5 Monitor control

3.5.1 General

Water monitors and foam monitors are to be operated and controlled with a remote control system located in a common control station having adequate overall visibility.

3.5.2 Manual control

In addition to the remote control system, a local manual control is to be arranged for each monitor. It is to be possible to:

- disconnect the local manual control from the control station
- disconnect the remote control system, from a position close to each monitor, to allow the operation with the local manual control.

3.5.3 Valve control

The valve control is to be designed so as to prevent pressure hammering.

3.5.4 Control system

a) The control system is to comply with the relevant provisions of Pt C, Ch 3, Sec 1 and Pt C, Ch 3, Sec 2.

b) The control system is to be designed with a redundancy level such that lost function can be restored within 10 minutes.

c) In the case of a hydraulic or pneumatic control system, the control power units are to be duplicated.

3.5.5 Marking

All control and shut-off devices are to be clearly marked, both locally and in the control station.

4 Water fire-fighting system

4.1 Characteristics

4.1.1

a) For ships having the service notation **fire-fighting 1**, **fire-fighting 2** or **fire-fighting 3**, the number of pumps and monitors and their characteristics are to be in accordance with the requirements given in Tab 2.

b) For ships having the service notation **fire-fighting E**, the characteristics of the water fire-fighting system will be given special consideration by the Society.

4.2 Monitors

4.2.1 Monitors are to be so arranged as to allow an easy horizontal movement of at least 90° equally divided about the centreline of the ship. The allowed vertical angular movement is to be such that the height of throw required in Tab 2 can be achieved.

4.2.2 The monitors are to be located such that the water jet is free from obstacles, including ship's structure and equipment.

4.2.3 The monitors are to be capable of throwing a continuous full water jet without significant pulsations and compacted in such a way as to be concentrated on a limited surface.

4.2.4 At least two monitors are to be equipped with a device to make the dispersion of the water jet (spray jet) possible.

Table 2 : Number of pumps and monitors and their characteristics

Required characteristics	Service notations			
	fire-fighting 1	**fire-fighting 2**		**fire-fighting 3**
minimum number of water monitors	2	3	4	4
minimum discharge rate per monitor (m^3/h)	1200	2400	1800	2400
minimum number of fire-fighting pumps	1	2		2
minimum total pump capacity (m^3/h) **(1)**	2400	7200		9600
length of throw of each monitor (m) **(2)** **(4)**	120	150		150
height of throw of each monitor (m) **(3)** **(4)**	45	70		70

(1) Where the water monitor pumps are also used for the self-protection water-spraying system and / or the hose connections for portable fire-fighting, their capacity is to be sufficient to ensure the simultaneous operation of the three systems at the required performances.

(2) Measured horizontally from the monitor outlet to the mean impact area.

(3) Measured vertically from the sea level, the mean impact area being at a distance of at least 70 m from the nearest part of the ship.

(4) The length and height of throw are to be capable of being achieved with the required number of monitors operating simultaneously in the same direction.

4.3 Piping

4.3.1 The maximum design water velocity is not normally to exceed 4 m/s in the piping between pumps and water monitors. Higher velocity may however be accepted on a case-by-case basis and provided the concerned pipe length remains as short as possible.

5 Fixed foam fire-extinguishing system

5.1 General

5.1.1 Ships having the service notation **fire-fighting ship 3** are to be equipped with a fixed low expansion foam monitor system complying with the provisions of [3] and with those of this Article.

5.1.2 Ships having the service notation **fire-fighting 1**, **fire-fighting 2** or **fire-fighting E** are not required to be equipped with a fixed low expansion foam monitor system. When provided however, such system is to comply with the provisions of [3] and with those of this Article, except that some relaxations in these provisions may be accepted by the Society.

5.2 Characteristics

5.2.1 Foam expansion ratio

The foam expansion ratio is not to exceed 12.

5.2.2 Foam monitors

a) The ship is to be fitted with two foam monitors, each having a foam solution capacity not less than 300 m^3/h.

b) The height of throw is to be at least 50 m above the sea level, when both monitors are in operation at the maximum foam production rate.

5.2.3 Foam concentrate capacity

Sufficient foam concentrate is to be available for at least 30 min of simultaneous operation of both monitors at maximum capacity.

5.3 Arrangement

5.3.1 Foam generating system

The foam generating system is to be of a fixed type with separate foam concentrate tank, foam-mixing units and piping to the monitors.

5.3.2 Pumps

The pumps of the water monitor system may be used for supplying water to the foam monitor system. In such case, it may be necessary to reduce the pump water delivery pressure to ensure correct water pressure for maximum foam generation.

6 Portable fire-fighting equipment

6.1 Portable high expansion foam generator

6.1.1 Ships having the service notation **fire-fighting 2** or **fire-fighting 3** are to be equipped with a portable high expansion foam generator having a foam capacity not less than 100 m^3/min for fighting of external fires.

6.1.2 The total capacity of foam concentrate is to be sufficient for 30 min of continuous foam production. The foam concentrate is to be stored in portable tanks of about 20 litres capacity.

6.2 Hydrants and fire hoses

6.2.1 Hydrants

a) Hydrants are to be provided in accordance with Tab 3.

b) At least half of the required hydrants are to be arranged on the main weather deck.

c) Where hydrants are fed by the pumps serving the monitor supply lines, provision is to be made to reduce the water pressure at the hydrants to a value permitting safe handling of the hose and the nozzle by one man.

Table 3 : Number of hydrants

fire-fighting E	fire-fighting 1	fire-fighting 2	fire-fighting 3
4 at each side	4 at each side	8 at each side	8 at each side **(1)**
(1) May be increased to 10 hydrants at each side, depending on the ship's length.			

6.2.2 Fire hose boxes

a) At least one box containing fire hoses is to be provided for every two hydrants.

b) Each box is to contain two fire hoses complete with dual-purpose (spray/jet) nozzles.

6.2.3 Fire hoses

a) Fire hoses and associated nozzles are to be of a type approved by the Society.

b) Fire hoses are to be of 45 to 70 mm in diameter and generally are to be 20 m in length.

7 Fire-fighter's outfits

7.1 Number and characteristics

7.1.1 The ship is to be fitted with fire-fighter's outfits in accordance with Tab 4.

Note 1: The number of fire-fighter's outfits required in Tab 4 is the minimum total number of fire-fighter's outfits on-board. Fire-fighter's outfits provided for compliance with e.g. SOLAS II-2/10 may also be counted in this number.

Table 4 : Number of fire-fighter's outfits

fire-fighting E	fire-fighting 1	fire-fighting 2	fire-fighting 3
4	4	8	8

7.1.2 The air breathing apparatuses, protective clothing and electric safety lamps constituting parts of fire-fighter's outfits are to be of a type approved by the Society.

7.1.3 Breathing apparatuses are to be of the self-contained type. They are to have a capacity of at least 1200 litres of free air. At least one spare air bottle is to be provided for each apparatus.

7.1.4 The fire-fighter's outfits are to be stored in a safe position readily accessible from the open deck.

7.2 Compressed air system for breathing apparatuses

7.2.1 General

Ships are to be equipped with a high pressure air compressor complete with all fittings necessary for refilling the bottles of air breathing apparatuses. The compressor is to be located in a suitable sheltered location.

7.2.2 Capacity

The capacity of the compressor is to be sufficient to allow the refilling of the bottles of all air breathing apparatuses in no more than 30 min.

7.2.3 Accessories

a) The air suction of the compressor is to be fitted with a suitable filter.

b) The outlet of the compressor is to be fitted with oil separators and filters capable of preventing passage of oil droplets or vapours to the air bottles.

8 Electrical installations

8.1 General

8.1.1 The electrical installations are to allow the simultaneous use of all the electric equipment needed for fire-fighting operations.

8.2 Searchlight

8.2.1 A searchlight is to be available on each side of the vessel and operated from the navigation bridge. The searchlights are to be able to provide an illumination of 50 lux at a distance of 250 m.

9 Testing

9.1 General

9.1.1 The provisions of this Article are related to the certification, workshop and onboard tests to be carried out for:

- machinery systems
- fire-fighting systems.

They supplement those required in Part C, Chapter 1 for machinery systems.

9.2 Type testing

9.2.1 Water monitors

The following characteristics are to be tested for each type of water monitor and are to comply with the requirements given in Tab 2:

- discharge rate
- length of throw
- height of throw.

9.3 Workshop tests

9.3.1 Tests for material

a) Materials used for the housing of fire-fighting pumps are to be subjected to a tensile test at ambient temperature according to the relevant provisions of NR216 Materials and Welding.

b) Materials used for pipes, valves and other accessories are to be tested in accordance with the provisions of Pt C, Ch 1, Sec 10, [20.4].

9.3.2 Hydrostatic testing

After completion of manufacture and before installation on board, pipes, valves, accessories and pump housings are to be submitted to a hydrostatic test in accordance with the provisions of Pt C, Ch 1, Sec 10, [20.5].

9.4 On board tests

9.4.1 Fixed fire-fighting systems

a) After assembly on board, the water fire-fighting system and the fixed foam fire-extinguishing system are to be checked for leakage at normal operating pressure.

b) The water fire-fighting system and fixed foam fire-extinguishing system are to undergo an operational test on board the ship, to check their characteristics and performances.

9.4.2 Propulsion and manoeuvring systems

a) A test is to be performed to check the manoeuvring capability of the ship.

b) The capability of the side thrusters and of the main propulsion system to maintain the ship in position with all water monitors in service without requiring more than 80% of the propulsive power is to be demonstrated.

Section 4 Fire Protection and Extinction

1 General

1.1 Application

1.1.1 This Section provides, for ships assigned the service notations **fire-fighting 1**, **fire-fighting 2** and **fire-fighting 3**, specific requirements for:

- fire protection
- self-protection water-spraying system.

These requirements supplement those given in Part C, Chapter 4.

1.1.2 For ships assigned the service notation **fire-fighting E**, fire protection arrangements will be given special consideration by the Society.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Description of the document
1	A	Plan showing the structural fire division, including doors and other closing devices of openings in A and B class divisions
2	I	Fire test reports for insulating materials
3	A	Schematic diagram of the fixed self-protection water-spraying system
(1) A: to be submitted for approval; I: to be submitted for information		

2 Fire protection of exposed surfaces

2.1 Structural fire protection

2.1.1 On ships assigned the service notation **fire-fighting 1**, all exterior boundaries above the lightest operating waterline, including superstructures and exposed decks, are to be of steel and are to be internally insulated so as to form A-60 class divisions.

2.1.2 On ships assigned the service notation **fire-fighting 2** or **fire-fighting 3**, all exterior boundaries are to be of steel but they need not be insulated.

2.1.3 On ships assigned the additional service feature **water spraying**:

- the provisions of [2.1.1] need not apply, and
- aluminium may be accepted as an alternative to steel. No additional fire insulation is required in this case.

Note 1: The allowable arrangements for the external boundaries of fire-fighting ships are summarized in Tab 2 below in order to ease the reading.

Table 2 : Summary of additional requirements for external boundaries

Material of the external boundaries	**fire-fighting 1**	**fire-fighting 2** or **fire-fighting 3**
Steel	Additional requirement: • A-60 insulation, or • Self-protection water-spraying system complying with the provisions of Article [3]	No additional requirement
Aluminium	Additional requirement: Self-protection water-spraying system complying with the provisions of Article [3]	

2.2 Deadlights and shutters

2.2.1 On ships for which the additional service feature **water spraying** is not assigned, steel deadlights or external steel shutters are to be provided on all windows, sidescuttles and navigation lights, except for the windows of the navigation bridge.

3 Self-protection water-spraying system

3.1 General

3.1.1 The provisions of this Article apply to the self-protection water-spraying systems fitted to ships assigned the additional service feature **water spraying**.

3.2 Capacity

3.2.1 The capacity of the self-protection water-spraying system is to be not less than 10 l/min for each square metre of protected area. In the case of surfaces which are internally insulated, such as to constitute A-60 class divisions, a lower capacity may be accepted, provided it is not less than 5 l/min for each square metre of protected area.

3.3 Arrangement

3.3.1 Areas to be protected

The fixed self-protection water-spraying system is to provide protection for all vertical areas of the hull and superstructures as well as monitor foundations and other fire-fighting arrangements, and is to be fitted in such a way as not to impair the necessary visibility from the wheelhouse and from the station for remote control of water monitors, also during operation of spray nozzles.

3.3.2 Sections

The fixed self-protection water-spraying system may be divided into sections so that it is possible to isolate sections covering surfaces which are not exposed to radiant heat.

3.3.3 Spray nozzles

The number and location of spray nozzles are to be suitable to spread the sprayed water uniformly on areas to be protected.

3.4 Pumps

3.4.1 Use of pumps serving other systems

The following pumps may be used for the self-protection water-spraying system:

- fire pumps referred to in Pt C, Ch 4, Sec 6, [1.3]
- water monitor system pumps referred to in Ch 4, Sec 3, [4].

In this case, a shut-off valve is to be provided to segregate the systems concerned.

3.4.2 Capacity of the pumps

a) The pumps of the self-protection water-spraying system are to have a capacity sufficient to spray water at the required pressure from all spray nozzles of the system.

b) Where the pumps serving the self-protection water-spraying systems are also used for another service, their capacity is to be sufficient to ensure the simultaneous operation of both systems at the required performances.

3.5 Piping system and spray nozzles

3.5.1 General

Pipes are to be designed and manufactured according to the requirements of Pt C, Ch 1, Sec 10.

3.5.2 Protection against corrosion

Steel pipes are to be protected against corrosion, both internally and externally, by means of galvanising or equivalent method.

3.5.3 Drainage cocks

Suitable drainage cocks are to be arranged and precautions are to be taken in order to prevent clogging of spray nozzles by impurities contained in pipes, nozzles, valves and pumps.

CHAPTER 5
OIL RECOVERY SHIPS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Systems

Section 4 Electrical Installations

Section 5 Fire Protection, Detection and Extinction

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Rule Note are eligible for the assignment of service notation **oil recovery** as defined in Pt A, Ch 1, Sec 2, [4.11.4].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.3 Additional service feature OILTREAT

The additional service feature **OILTREAT** may be assigned to the ships designed and equipped to recover polluted water which is subjected to a chemical and/or a physical treatment, in order to separate the oil from the polluted water. The separated oil is to be stored and transported in dedicated tanks.

1.1.4 Additional service feature SECOND-LINE

The additional service feature **SECOND-LINE** may be assigned to the ships designed and equipped to recover polluted water in the event of spills of oils which have, at the time of recovery, a flash point exceeding 60°C (closed cup test).

This service feature is not to be assigned to oil recovery ships carrying heated recovered oils within 15°C of their flash point.

1.2 Definitions

1.2.1 Oil recovery ship

An oil recovery ship is a ship specially equipped with a fixed installation and/or a mobile equipment for the removal of oil from the sea surface and its retention on board, carriage and subsequent unloading.

1.2.2 Recovered oil

Recovered oil is the top layers of polluted water collected by means of skimmers, rotating disk, floating pumps or equivalent systems together with sweeping arms, booms or similar devices.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Ships less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Ch 5, Sec 2 • Part B	• Ch 5, Sec 2 • NR566
	L < 65 or 90 m **(1)**	• NR600	• Ch 5, Sec 2 • NR566
Hull	L ≥ 65 or 90 m **(1)**	• Ch 5, Sec 2 • Part B	• Ch 5, Sec 2 • Part B
	L < 65 or 90 m **(1)**	• NR600	• NR600
Stability		• Ch 5, Sec 2 • Part B	• Ch 5, Sec 2 • NR566
Machinery and cargo systems		• Ch 5, Sec 3 • Part C	• Ch 5, Sec 3 • NR566
Electrical installations		• Ch 5, Sec 4 • Part C	• Ch 5, Sec 4 • NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Ch 5, Sec 5 • Part C	• Ch 5, Sec 5 • NR566

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

1.2.3 Oil recovery tank

An oil recovery tank is a tank intended for the retention and the transportation of recovered oil.

For ships assigned with the additional service feature **OILTREAT**, the oil recovery tanks may be classified in two different categories:

- those intended for the retention of oil removed and separated from sea water, also named accumulation tanks
- those intended for the retention of polluted water only, also named settling tanks.

1.2.4 Oil recovery pump room

An oil recovery pump room is a space containing the pumps and their accessories for the handling of recovered oil.

1.2.5 Oil recovery area

The oil recovery area is the part of the ship that contains the oil recovery tanks, oil recovery pumps rooms, cofferdams, ballast or void spaces surrounding the integral tanks and hold spaces in which independent tanks are located, and the following deck areas:

- the deck area above the oil recovery tanks
- the deck area extending transversely and longitudinally from the oil recovery tanks over a distance of 3 m, when the rule length is greater than 50 m.

Note 1: Oil recovery area definition is not applicable to oil recovery ships assigned with the additional service feature **SECOND-LINE**.

1.2.6 Hazardous areas

The hazardous areas are the areas in which an explosive atmosphere is, or may be, expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

1.2.7 Gas-safe areas

The gas-safe areas are the gas areas which are not defined as hazardous.

Section 2 Hull and Stability

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Part B, the documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Description of the document
1	A	General arrangement
2	A	General arrangement of access and openings
3	I	Procedure and limiting conditions for recovering oil, oil recovery transfer, tank cleaning, gas freeing and ballasting
4	I	Specification of the oil removal operational test
5	I	General plan showing the location of tanks intended for the retention of oily residues and systems for their treatment
6	I	Plan of the system for treatment of oily residues and specification of all relevant apparatuses
7	A	Supporting structures of the system for treatment of oily residues
8	I	Operating manual
(1) A: to be submitted for approval; I: to be submitted for information		

1.2 General arrangement

1.2.1 Tank arrangement

a) Oil recovery tanks are to be separated from machinery spaces category A, propeller shaft tunnels, dry cargo spaces, accommodations, control stations and service spaces and from drinking water and stores for human consumption by means of a cofferdam or equivalent space. Fuel oil tanks, tanks for ballast water, tanks for liquids used for oil treatment, tanks for anti-pollution liquids, storerooms for oil removal equipment and pump-rooms are considered as spaces equivalent to a cofferdam.

When this cofferdam is impracticable, oil recovery tanks adjacent to the engine room may be accepted provided that:

- boundary bulkheads are accessible for inspection
- the boundary bulkheads are fitted continuously through joining structure to the top of the tank, where full penetration welding is to be carried out
- the tanks are to be pressure tested at each renewal survey.

b) Oil recovery tanks are to be located abaft the collision bulkhead.

c) For ships non-exclusively dedicated to oil recovery operations, the ship may use the following tanks as oil recovery tanks:

- tanks covered by the service notation **supply**, if designed for a cargo mass density of, at least, 1,025 t/m^3
- water ballast tanks
- fuel oil tanks
- hoppers spaces.

In all cases, the tanks and their associated equipment and piping are to comply with all the requirements for oil recovery tanks.

Fresh water tanks and tanks with a complex inner structure that can lead to obstruction can not be part of the oil recovery tanks.

d) Oil recovery ships assigned with the additional service feature **SECOND-LINE** do no need to comply with the arrangements referred to in item a), provided that the segregation requirements for accommodations, control stations, drinking water and stores for human consumption are observed.

1.2.2 Accommodation, control station, service and machinery spaces

a) Accommodation or service spaces, control stations or machinery spaces category A are to be located outside the oil recovery area.

Note 1: When, instead of a cofferdam, boundaries between oil recovery tanks and machinery spaces of category A are built as described in the second paragraph of [1.2.1], item a), the machinery spaces of category A may be located within the oil recovery area.

b) Unless they are spaced at least 7 m away from the oil recovery area entrances, air inlets and openings to accommodation, service and machinery spaces category A and control stations should not face the oil recovery area. Doors to spaces not having access to accommodation, service and machinery spaces and control stations, such as oil recovery control stations, storerooms or equipment rooms, may be permitted by the Society within the 7 m zone specified above, provided the boundaries of the spaces are insulated to A-60 standard.

c) When the additional service feature **SECOND-LINE** is assigned, the arrangement referred to in items a) and b) may be disregarded.

1.2.3 Access

a) Access hatches (at least 600 mm x 600 mm of clear opening) within the oil recovery area are to be direct from the open deck. Such access should be suitable for cleaning and gas-freeing.

b) For ships assigned with the additional service feature **SECOND-LINE**, the following requirements may apply instead of item a):

- Access to oil recovery tanks is to be direct from the open deck and such as to ensure their complete inspection, except for access to cargo tanks in double bottoms that may be through a cargo pump-room, pump-room, deep cofferdam, pipe tunnel or similar dry compartment, provided the ventilation of these spaces complies with Ch 5, Sec 5, [2.2]
- Access to oil recovery pump rooms does not need to be from the open deck, provided the access is independent of watertight doors.

1.2.4 Oil recovery tank construction

a) A cargo density of 1,025 t/m^3 is to be considered for calculating the internal pressures and forces in cargo tanks according to Pt B, Ch 5, Sec 6 or NR600 as applicable.

b) All tank openings and connections to the tank are to terminate above the weather deck and should be located in the tops of the tanks.

c) The structural design of the tanks should take into account the carriage temperature, and additional strength calculation may be required in case of risk of sloshing induced loads.

2 Stability

2.1 Intact stability

2.1.1 General

In addition to the standard loading conditions specified in Pt B, Ch 3, App 2, [1.2.1], the following loading cases are to be included in the trim and stability booklet for ships assigned with the service notation **oil recovery**:

- ship in the fully loaded departure to the oil recovery spot having all the oil recovery equipment installed on board
- ship in the worst anticipated operating during oil recovery operation; the worst operating condition regarding free surface effects when the equipment is fitted in the most unfavourable condition (for example, swiping arm extended).

3 Hull scantlings

3.1 Additional loads

3.1.1 For the checking of structures supporting oil recovery equipment, the reactions induced by this equipment during oil recovery operations may be calculated assuming that the oil recovery operations take place in moderate sea conditions (accelerations reduced by 10%).

3.1.2 If lifting appliances are used during oil recovery operations, the scantling of their supporting structures is to be checked according to Pt B, Ch 1, Sec 1, [1.2].

3.1.3 In case of oil collected in movable tanks fitted on the weather deck, the resulting reactions to be considered for deck scantling are to be calculated, as a rule, according to Pt B, Ch 5, Sec 6 or NR600 as applicable.

4 Construction and testing

4.1

4.1.1 Oil removal equipment

Tests are to be carried out according to a specification submitted by the Interested Party, in order to check the proper operation of the oil recovery equipment.

These tests may be performed during dry dock or sea trials.

Section 3 Machinery and Systems

1 General

1.1 Documents to be submitted

1.1.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Description of the document **(2)**
1	I	General plan of the system for oil recovery and specification of all relevant apparatuses
2	A	Schematic arrangement of recovered oil piping and pumping systems
3	A	Tank venting arrangement
4	A	Diagram of the bilge and ballast systems serving the spaces located in the oil recovery area
5	A	Specification of the anti-explosion devices (crankcase explosion relief valves, spark arresters) provided for diesel engines
6	A	Location and arrangement of sea chests for engine cooling and fire-fighting purposes
7	A	Diagram of the oil recovery cargo tank level gauging system with overfilling safety arrangement
8	A	Diagram of the cargo heating system, where applicable
(1) A: to be submitted for approval; I: to be submitted for information **(2)** Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.		

2 Machinery installation and piping system other than oil recovery system

2.1 Sea water cooling system

2.1.1 One of the suctions serving the sea water cooling system (see Pt C, Ch 1, Sec 10, [10.7.1]) is to be located in the lower part of the hull.

2.2 Water fire-extinguishing system

2.2.1 Sea suctions serving the fire water pumps are to be located as low as possible.

2.3 Exhaust gas systems

2.3.1

a) Exhaust lines from engines, gas turbines, boilers and incinerators are to be led outside any hazardous area (as defined in Ch 5, Sec 4) above the deck and are to be fitted with a spark arrester. The spark arrester is not required if the ship is assigned with the additional service feature **SECOND-LINE**.

b) Where the distance between the exhaust lines of engines and the hazardous areas is less than 3 m, the ducts are to be fitted in a position:

- near the waterline, if cooled by water injection, or
- below the waterline, in the other cases.

3 Pumping system, piping system and pump-rooms intended for recovered oil

3.1 Design of pumping and piping systems

3.1.1 General

The provisions of Pt D, Ch 7, Sec 4, [3] and Pt C, Ch 1, Sec 10 are to be complied with, as far as applicable.

3.2 Arrangement of piping systems

3.2.1

a) Piping systems for handling recovered oil are not to pass through:

- accommodation spaces
- service spaces
- control stations
- machinery spaces of category A except for ship assigned with the additional service feature **SECOND-LINE**.

b) Pumping and piping systems intended for recovered oil are to be independent from the other pumping and piping systems of the ship, except in the following cases:

- If sections of the cargo system covered by the service notation **supply** or if fuel oil tanks are used, means are to be provided to isolate the oil recovery system from any other system from which it may be connected. The connection between the cargo system and the recovered oil transfer piping may consist of movable pipe sections.
- If water ballast tanks are used as oil recovery tanks when the ship is in oil recovery mode, the water ballast piping is to be blanked-off at the nearest position at the tank before starting the oil recovery operation. The connection between the oil recovery piping and the water ballast tanks is to be done by means of detachable spool pieces.

c) Piping intended for recovered oil and located below the main deck may run from the tank it serves and penetrate tank bulkheads or boundaries common to longitudinally or transversely adjacent oil recovery tanks, ballast tanks, empty tanks, pump-rooms or oil recovery pump-rooms, provided that inside the tank it serves it is fitted with a stop-valve operable from the weather deck.

As an alternative, where an oil recovery tank is adjacent to an oil recovery pump-room, the stop valve operable from the weather deck may be situated on the tank bulkhead on the oil recovery pump-room side, provided an additional valve is fitted between the bulkhead valve and the oil recovery pump.

A totally enclosed hydraulically operated valve located outside the oil recovery tank may also be accepted, provided that the valve is:

- fitted on the bulkhead of the oil recovery tank it serves
- suitably protected against mechanical damage
- fitted at a distance from the shell as required for damage protection, and
- operable from the weather deck.

d) Transfer of recovered oil through hatches (by means of flexible hoses or movable piping) is not permitted except if the additional service feature **SECOND-LINE** is assigned.

3.3 Oil recovery pumps

3.3.1

a) Oil recovery pumps are to comply with the requirements of cargo pumps for **oil tanker, flash point > 60°C** (see Pt D, Ch 7, Sec 4, [3.2]).

b) Oil recovery pumps are to be capable of being remotely shutdown from a location which is manned during oil recovery operations and from at least one other location outside the oil recovery area.

c) If an oil recovery pump serves more than one tank, a stop valve is to be fitted in the line of each tank.

d) For ships non exclusively dedicated to oil recovery operation, the use of portable pumps or pumps serving cargo systems may be permitted, subject to special consideration by the Society.

3.4 Oil recovery pump-rooms

3.4.1

a) Pump-rooms containing the pumps for handling the recovered oil are to be provided with a fixed fire-extinguishing system suitable for machinery spaces of category A except if the ship is assigned with the additional service feature **SECOND-LINE**.

b) Means are to be provided to deal with drainage and any possible leakage from oil recovery pumps and valves in the oil recovery pump-room. Bilge pumping arrangement is to be situated entirely within the oil recovery area. The bilge system is to be operable from outside the oil recovery pump-room. Oil recovery pumps may also be used provided they are connected to the oil recovery pump-room bilge piping through a shut-off valve and a non-return valve arranged in series.

c) For ventilation of oil recovery transfer pump-rooms, see Ch 5, Sec 5, [2].

d) Oil recovery pump-rooms are to have no direct communication with machinery spaces of category A, except when the ship is assigned with the additional service feature **SECOND-LINE**.

4 Oil recovery tank fittings

4.1 Vent pipes

4.1.1

a) Vent pipes of oil recovery tanks are to lead to the open at least 2,4 m above the weather deck.

b) Vent pipes are to be located at a distance of at least 5,0 m measured horizontally from the nearest air intake or opening to accommodations, control stations, service and machinery spaces of category A and other gas-safe spaces and from ignition sources.

c) Openings of vent pipes are to be directed to open deck and fitted with:
- flameproof wire gauze made of corrosion resistant material easily removable for cleaning, and
- closing appliances complying with the provisions of Pt C, Ch 1, Sec 10, [9.1]

d) For ships non exclusively dedicated to oil recovery operations, portable vent pipes may be accepted.

4.2 Level gauging and overfilling control

4.2.1 Level gauging

Oil recovery tanks are to be fitted with sounding pipes or other level gauging devices of a type approved by the Society.

4.2.2 Overfilling control

a) Oil recovery tanks are to be fitted with a high level alarm or an overflow control system except if the oil recovery tank is an open hopper space.

b) The high level alarm is to be of a type approved by the Society and is to give an audible and visual alarm.

5 Heating systems

5.1

5.1.1 Heating systems fitted to oil recovery tanks are to comply with the provisions of Pt D, Ch 7, Sec 4, [2.6].

6 Additional requirements

6.1 Ships assigned with the additional service feature OILTREAT

6.1.1 When the separating system designed to reduce the oil content in the water being discharged into the sea is of a gravity type (single or in series):
- means for locating the oil/water interface in the oil recovery tanks are to be provided
- discharges of processed water from the separating process are to take place above waterline for visual control
- if chemical additives are added, the coating of the oil recovery tanks is to be compatible. The Shipyard is responsible for providing compatibility information to the ship operator and/or the master
- adequate means are to be provided for cleaning the oil recovery tanks.

6.1.2 Other types of separating system (e.g. gravity type coalescing, centrifugal separator, …) are to be reviewed on a case-by-case basis.

Section 4 Electrical Installations

1 General

1.1 Application

1.1.1 The requirements in this Section apply, in addition to those contained in Part C, Chapter 2.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, [2.1.1], the documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Description of the document
1	A	Plan of hazardous areas and location of electrical equipment
2	A	Document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas
(1) A: to be submitted for approval; I: to be submitted for information		

2 Design requirements

2.1 System of supply

2.1.1 The following systems of generation and distribution of electrical energy are acceptable:

a) Direct current:
- two-wire insulated

b) Alternating current:
- single-phase, two-wire insulated
- three-phase, three-wire insulated.

2.1.2 Earthed systems with hull return are not permitted, with the following exceptions to the satisfaction of the Society:

a) impressed current cathodic protective systems

b) limited and locally earthed systems, such as starting and ignition systems of internal combustion engines, provided that any possible resulting current does not flow directly through any hazardous area

c) insulation level monitoring devices, provided that the circulation current of the devices does not exceed 30 mA under the most unfavourable conditions.

2.1.3 Earthed systems without hull return are not permitted, with the following exceptions:

a) earthed intrinsically safe circuits and the following other systems to the satisfaction of the Society;

b) power supplies, control circuits and instrumentation circuits in non-hazardous areas where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions; or

c) earthed systems, provided that any possible resulting hull current does not flow directly through any hazardous area; or

d) isolating transformers or other adequate means, to be provided if the distribution system is extended to areas remote from the machinery space.

2.1.4 In insulated distribution systems, no current carrying part is to be earthed, other than:

a) through an insulation level monitoring device

b) through components used for the suppression of interference in radio circuits.

2.2 Earth detection

2.2.1 The devices intended to continuously monitor the insulation level of all distribution systems are also to monitor all circuits, other than intrinsically safe circuits, connected to apparatus in hazardous areas or passing through such areas. An audible and visual alarm is to be given, at a manned position, in the event of an abnormally low level of insulation.

3 Hazardous locations and types of equipment

3.1 Electrical equipment permitted in hazardous areas

3.1.1 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installation, hazardous areas are classified in zones (zone 0, zone 1 and zone 2), according to Pt C, Ch 2, Sec 1, [3.13.3]. The different spaces are to be classified according to Tab 2 or Tab 3, as applicable.

The types of electrical equipment permitted, depending on the zone where they are installed, are specified in Pt C, Ch 2, Sec 3, [10].

3.1.2 The explosion group and temperature class of electrical equipment of a certified safe type are to be at least IIA and T3.

3.2 Additional requirements for machinery installations in hazardous areas

3.2.1 Hazardous areas are not to contain:

- internal combustion engines
- steam turbines and steam piping with a steam temperature in excess of 200°C
- other piping systems and heat exchangers with a surface temperature exceeding 200°
- any other source of ignition.

Table 2 : Oil recovery ships - Space descriptions and hazardous area zones

Hazardous area	Spaces	
	No.	Description
Zone 0	1	Oil recovery tanks, pipes and equipment containing the recovered oil
Zone 1	2	Areas on open deck or semi-enclosed spaces on open deck within 3 m of any oil recovery tank outlet, oil recovery manifold valve, oil recovery valve, oil recovery pipe flange, oil recovery hatches
Zone 1	3	Cofferdams and enclosed or semi-enclosed spaces adjacent to or immediately above oil recovery tank which do not contain pipes, valves or other equipment for the handling of recovered oil unless separated by gas-tight boundaries and fitted with forced ventilation capable of giving at least 20 air changes per hour. An alarm on the navigation bridge is to be provided to indicate any loss of the required ventilation capacity. The alarm is to be initiated by fall-out of starter relay fan motor
Zone 1	4	For open hopper dredgers operating as oil recovery ships: the area above the hopper extended to the maximum breath of the ship with an unlimited height
Zone 1	5	Oil recovery pump-rooms
Zone 2	6	Enclosed or semi-enclosed spaces for the storage of floating pumps, associated hoses and equipment for the handling of recovered oil unless acceptable means are provided to drain or empty the equipment after completion of oil recovery operation
Zone 2	7	Double bottoms or duct keels located under oil recovery tanks unless separated by gas-tight boundaries and fitted with forced ventilation capable of giving at least 20 air changes per hour. An alarm on the navigation bridge is be provided to indicate any loss of the required ventilation capacity. The alarm is to be initiated by fall-out of starter relay fan motor
Zone 2	8	Enclosed or semi-enclosed spaces containing pipes, valves or other equipment for the handling of recovered oil unless made of entirely welded construction except for necessary flanged connections to valves, expansion joints, spool pieces and similar fittings or where required for coating, lining, fabrication, inspection or maintenance
Zone 2	9	Enclosed or semi-enclosed spaces containing pipes, valves or other equipment for the handling of recovered oil unless separated by gas-tight boundaries and fitted with forced ventilation capable of giving at least 20 air changes per hour. An alarm on the navigation bridge is to be provided to indicate any loss of the required ventilation capacity. The alarm is to be initiated by fall-out of starter relay fan motor.
Zone 2	10	Areas on open deck over all oil recovery tanks up to a height of 2,4 m above the deck

Table 3 : Oil recovery ships, second-line - Space descriptions and hazardous area zones

Hazardous area	Spaces	
	No.	Description
Zone 2	1	Oil recovery tanks, any pipe work of pressure relief or other venting system for oil recovery tanks, pipes and equipment containing recovered oil

3.3 Openings, access and ventilation conditions affecting the extent of hazardous areas

3.3.1 There are normally not to be access doors or other openings between a safe space, such as accommodation or service spaces, machinery spaces, control stations and similar spaces, and a hazardous area.

Access (other than access between oil recovery pump-rooms and machinery spaces category A) may, however, be accepted between such spaces and hazardous areas, provided that:

a) safe spaces are fitted with forced ventilation in order to maintain an overpressure therein

b) access doors are:

1) of a self-closing type and arranged to swing into the safer space, so that they are kept closed by the overpressure, with the self-closing device capable of shutting the doors against an inclination of 3,5° opposing closure, without hold-back hooks keeping them in an open position, or

2) gas-tight, kept closed during oil recovery operation until gas freeing is carried out, and provided with a warning plate (suitable instructions are given in the oil recovery manual).

Section 5 Fire Protection, Detection and Extinction

1 General

1.1 Documents to be submitted

1.1.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	A/I **(2)**	Description of the document **(1)**
1	A	Diagram of mechanical and natural ventilation with indication of inlets and outlets serving: • spaces within the oil recovery area • machinery spaces • accommodation spaces
2	A	Specification of flammable gas detectors and flash point measurement equipment
3	A	Drawing and specification of the fixed, if any, or movable fire-fighting system
(1) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems. **(2)** A: to be submitted for approval; I: to be submitted for information		

2 Mechanical ventilation in the oil recovery area

2.1 General

2.1.1 Spaces considered as hazardous are to have a ventilation system independent from those serving gas-safe spaces.

2.2 Ventilation of recovered oil pump rooms

2.2.1 Oil recovery pump rooms are to be provided with a mechanical ventilation system of the extraction type capable of giving at least 20 air changes per hour.

2.2.2 Ventilation intakes are to be so arranged as to minimise the possibility of recycling hazardous vapours from ventilation discharge openings.

2.2.3 Ventilation exhaust ducts are to discharge upwards to a safe area on the weather deck in locations at least 3,0 m from any ventilation intake and opening to accommodations, service and machinery spaces, control stations and other spaces outside the oil recovery area.

2.2.4 Protection screens of not more than 13 mm square mesh are to be fitted on ventilation duct intakes and outlets.

2.2.5 Ventilation fans are to be of non-sparking construction as per Pt C, Ch 4, Sec 1, [2.33].

2.2.6 The ventilation system is to be capable of being controlled from outside the oil recovery pump-room.

2.2.7 Provision is to be made to ventilate such spaces prior to entering the compartment and operating the equipment and a warning notice requiring the use of such a ventilation is to be placed outside the compartment.

2.2.8 Ventilation ducts are not to lead through accommodations, service and machinery spaces or other similar spaces.

2.3 Ventilation of enclosed spaces normally entered during oil recovery operation other than recovery oil pump rooms

2.3.1 Enclosed spaces normally entered within the oil recovery area are to be provided with a mechanical ventilation system of the extraction type capable of giving at least 8 air changes per hour.

2.3.2 Ventilation intakes are to be located at a distance of not less than 3,0 m from the ventilation outlets of oil recovery pump-rooms.

3 Fire protection and fighting

3.1 Vapor detector

3.1.1 At least one portable gas detection instrument capable of measuring flammable vapour concentrations in air and an equipment for oil flashpoint measurements are to be provided on board.

Alternatively, instead of a portable gas detection instrument, a fixed system may be accepted provided that the sample is drawn from a point within 6,0 m from the waterline.

3.2 Structural fire protection

3.2.1 Unless they are located at least 7,0 m from the nearest oil recovery area, exterior boundaries of the superstructures and deckhouses enclosing accommodations and including any overhanging decks which support such accommodations are to be insulated to A-60 standard for the whole of the portions which face the oil recovery areas up to the underside of the navigation bridge deck and for a distance of 3,0 m aft or forward of such areas.

Alternatively to A-60 insulation, a fixed water-spraying system capable of delivering water at a rate of 10 l/m^2/min may be accepted. This system is to comply with the requirements listed in Ch 4, Sec 4, [3], except that the only protected area is to be the exterior boundaries of the superstructures and deckhouses enclosing accommodations and including any overhanging decks which support such accommodations facing the oil recovery area.

3.2.2 Windows and sidescuttles fitted within 7,0 m from the nearest oil recovery area are to have the same fire integrity as the bulkhead in which they are fitted. If they have a lower fire rating because they are protected by the fixed water-spraying system mentioned in [3.2.1], windows and sidescuttles are to be fitted with inside covers of steel or other equivalent material having a thickness equal to the bulkhead in which they are fitted. Where they are not of the fixed type, they are to be such as to ensure an efficient gas-tight closure.

3.2.3 Ships assigned with the additional service feature **SECOND-LINE** do not need to comply with [3.2.1] and [3.2.2].

3.3 Fire-fighting

3.3.1 For the protection of the oil recovery area, the following fire-fighting equipment is to be provided near the working area:

- two dry powder fire extinguishers, each with a capacity of at least 50 kg or equivalent
- at least one portable foam extinguishing applicator complying with Pt C, Ch 4, Sec 15, [3.2.2].

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 6
CABLE-LAYING SHIPS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Systems

Section 4 Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **cable laying**, as defined in Pt A, Ch 1, Sec 2, [4.12.8].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B	• NR566
	L < 65 or 90 m **(1)**	• NR600	• NR566
Hull	L ≥ 65 or 90 m **(1)**	• Ch 6, Sec 2 • Part B	• Ch 6, Sec 2 • Part B
	L < 65 or 90 m **(1)**	• NR600	• NR600
Stability		• Ch 6, Sec 2 • Part B	• Ch 6, Sec 2 • NR566
Machinery and cargo systems		• Ch 6, Sec 3 • Part C	• Ch 6, Sec 3 • NR566
Electrical installations		• Part C	• NR566
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Ch 6, Sec 4 • Part C	• Ch 6, Sec 4 • NR566

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

Section 2 Hull and Stability

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships fitted, in general, with one or more continuous decks, suitable holds for the carriage of cables and superstructures extending for most of the ship's length.

The main characteristics of the ship may vary according to the service primarily performed which may be as follows:

- laying (and possibly burying) submarine cables on the sea bed
- hauling and repairing submarine cables.

1.2 Documents to be submitted

1.2.1 In addition to the documentation requested in Part B, the following documents are to be submitted for approval:

- Structural reinforcements in way of load transmitting elements, such as foundations and fastenings of the equipment to the ship structures.

2 Stability

2.1 Intact stability

2.1.1 General

The stability, the freeboard and the metacentric radius or roll period are to be such as to ensure:

- satisfactory seakeeping performance in working conditions
- a steady working platform in order to facilitate the performance of cable laying and/or repair operations.

Anti-roll tanks or bilge keels of adequate size may be fitted to meet the above requirements.

2.1.2 Tanks intended for liquid consumable

Special attention is to be paid to the arrangement of tanks intended to contain liquid consumables in order to prevent weight variations during service resulting in excessive changes in the ship's trim.

2.1.3 Intact stability criteria

The stability of the ship for the loading conditions in Pt B, Ch 3, App 2, [1.2.1] and for the (departure and arrival) loading conditions corresponding to the maximum draught is to be in compliance with the requirements in Pt B, Ch 3, Sec 2.

2.2 Damage stability for ships where the notation SDS has been required

2.2.1 Application

The requirements of this item apply to cable laying ships carrying less than 240 persons.

Damage stability criteria for cable laying ships carrying 240 persons and more are to be considered by the Society on a case-by-case basis.

2.2.2 General

Cable laying ships are to comply with the survival requirements specified in Pt B, Ch 3, App 3, where the required index R is to be considered as follows in Tab 1 and calculated according to [2.2.3].

Table 1 : Index R

Number of persons: Nb	Index R
Nb ≤ 60	0,8 R
60 < Nb < 240	Linear interpolation between 0,8 R and R **(1)**
(1) The required index is equal to R for Nb = 240	

2.2.3 Calculation of the required index

$$R = 1 - \frac{5000}{L_S + 2,5N + 15225}$$

where:

$$N = N_1 + 2N_2$$

N_1 : *Number of persons for whom lifeboats are provided*

N_2 : *Number of persons the ship is permittted to carry in excess of N_1.*

Where the conditions of service are such that compliance with R on the basis of $N = N_1 + 2\ N_2$ is impracticable and where the Society considers that a suitable reduced degree of hazard exists, a lesser value of N may be taken, but in no case less than $N = N_1 + N_2$. The reduced value of N is also to be subject to the agreement of the flag administration.

3 Hull scantlings

3.1 Cable tanks

3.1.1 The assessment of primary supporting members is to be made through direct calculations carried out according to Pt B, Ch 8, Sec 1, where the still water and wave loads are to be calculated for the most severe condition of use.

3.2 Connection of the machinery and equipment with the hull structure

3.2.1 The net scantlings of the structures in way of the connection between the hull structure and the machinery and equipment, constituting the laying or hauling line for submarine cables, are to be obtained through direct calculation to be carried out based on the service loads of such machinery and equipment, as specified by the Designer.

In calculating these above service loads, the Designer is to take into account the inertial loads induced by ship motions in the most severe condition of use.

4 Other structures

4.1 Fore part

4.1.1 In general, a high freeboard is needed in the forward area, where most repair work is carried out, in order to provide adequate safety and protection against sea waves.

5 Hull outfitting

5.1 Equipment

5.1.1 Hawse pipes

Hawse pipes are to be integrated into the hull structure in such a way that anchors do not interfere with the cable laying.

5.1.2 Sheaves

Where there is a risk that, in rough sea conditions, sheaves are subjected to wave impact loads, special solutions such as the provision of retractable type sheaves may be adopted.

Section 3 Machinery and Systems

1 General

1.1 Propulsion and manoeuvrability

1.1.1 The main propulsion systems of cable laying and/or repair ships are to be capable of:

a) maintaining an adequate speed during the transit condition

b) ensuring a satisfactory manoeuvrability at the speed assumed by the Designer for the performance of cable laying and/or repair operations.

1.2 Documents to be submitted

1.2.1 Tab 1 lists the documents which are to be submitted for information.

Table 1 : Documents to be submitted

No.	Document
1	General arrangement of the cable laying equipment
2	Design loads on all components of the cable laying equipment transferred to the ship structure
3	Structural plans of seating components of the cable laying equipment, including gears, pressure vessels, hydraulic systems, etc., as applicable, including details of the deck connection
4	Specification of the cable-laying equipment operation test

2 Arrangements for cable laying, hauling and repair

2.1 Typical machinery and equipment of cable laying ships

2.1.1 Cable laying ships, in relation to the special service to be performed, are generally to be provided with the following machinery and equipment:

a) a main windlass for cable hauling or laying, which generally consists of a drum with a horizontal axis (the surface of which is formed by a series of timed conveyors which fleet the cable axially across the face of the drum) housing the repeaters fitted throughout the cable length without damaging them (see Fig 1 (a))

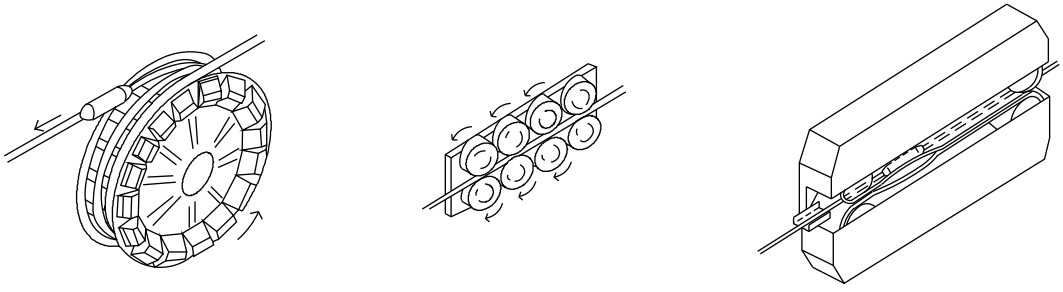
b) a linear tensioner working in conjunction with the main windlass and fitted between it and the cable tank, which maintains the due tension of the cable in relation to the cable type so as to allow effective cable hauling or laying. In order to permit the passage of repeaters, the tensioner may be of the type having either a series of double opposed rubber tyres (see Fig 1 (b)) or pressure-compensated opposed tracks (see Fig 1 (c)).

c) a dynamometer, normally fitted between the main windlass and the bow and stern sheaves, which continuously measures the force required to displace the cable under tension

d) one or more cable transporters, used to move the cable from the tank(s) and the tensioner.

All the above machinery and equipment form the “cable laying or hauling line”. More than one line may be fitted on board in the case of special service requirements.

Figure 1 : Cable handling machinery



(a) Fleeting cable drum

(b) Rubber tyre tensioner

(c) Track linear tensioner

2.2 Design of cable handling machinery and equipment

2.2.1 The scantlings of components of machinery and equipment listed in [2.1] and, more generally, of any other machinery and/or equipment to be used for the laying, hauling or repair of submarine cables are outside the scope of classification.

2.3 Safety

2.3.1 The requirements of this Chapter are based on the assumption that during cable handling all necessary safety measures are taken, due consideration being given to risks connected with the use of machinery and equipment dealt with in [2.1] and that such machinery and equipment are properly used by skilled personnel.

2.4 Testing of cable handling machinery and equipment

2.4.1 General

Machinery covered by [2.1] is to be tested in compliance with the following requirements, with the exception of prime movers and "hydraulic accumulator" type pressure vessels, which are to be tested in compliance with the applicable requirements of the various Sections of the Rules.

2.4.2 Testing of materials and components of the machinery

a) In general, testing is required for materials intended for shafts, gearing, pressure parts of pumps and hydraulic motors, and plates of foundations of welded construction.

b) As far as mechanical tests of materials are concerned, internal shop testing certificates submitted by the Manufacturer may be accepted by the Society at its discretion; in such cases, testing operations witnessed by the Surveyor may be limited to visual external inspection associated, where necessary, with non-destructive examinations and hardness tests.

2.4.3 Hydrostatic tests

Pressure parts are to be subjected to hydrostatic tests in accordance with the applicable requirements.

2.4.4 Tests on electrical components

The tests required in Part C, Chapter 2 of the Rules are to be carried out as applicable.

2.4.5 Running tests

a) Running tests of each individual piece of equipment are to be carried out whenever possible at the Manufacturer's works; as an alternative, the above tests may be performed on board during the trials required after installation of machinery.

b) On completion and subject to the result of the above tests, the inspection of components may be required, with dismantling where deemed necessary by the Surveyor in charge of the testing.

3 On board trials

3.1 Ship trials

3.1.1

a) Upon completion of construction, in addition to conventional sea trials, specific tests may be required at the Society's discretion in relation to the particular service for which the ship is intended or the particular characteristics of machinery and equipment fitted on board and according to a test specification submitted by the interested party.

b) In particular, as far as propulsion and steering systems are concerned, tests may be required to check the manoeuvring capability and the speed of the ship whilst operating with only directional propellers or active rudders or a combination thereof.

c) In the case of ships mainly intended for repair of submarine cables, a check of manoeuvring capability whilst running astern or a complete overturning trial may be required to be carried out using the rudder, active rudders or side thrusters only.

d) In the case of ships provided with a dynamic positioning system, tests to check the capability of holding the desired position or heading are requested.

3.2 Equipment trials

3.2.1

a) As far as arrangements for the cable laying, hauling and/or repair lines are concerned, tests are to be carried out to verify the proper operation of all relevant machinery and equipment, by means of the actual hauling and laying of submarine cables, plain or with repeaters, at different ship speeds and, if necessary, in different sea and weather conditions.

b) Special attention is to be paid during such tests so as to prevent cables being forced to reach their minimum allowed bending radius, both inside and outside the ship.

Section 4 Fire Protection

1 Cable tanks

1.1 Means for fire fighting

1.1.1 Depending on any special requirements of the Manufacturers of cables, cable tanks may also be required to be protected by a fixed pressure water-spraying or automatic sprinkler fire-extinguishing system.

CHAPTER 7
DIVING SUPPORT VESSELS

Section 1 General

Section 2 General Arrangement

Section 3 Structural Assessment

Section 4 Machinery and Systems

Section 5 Safety Features

Section 6 Specific Requirements for Ships Assigned with the Service Notation diving support-capable

Section 7 Initial Inspection and Testing

Section 1 General

1 General

1.1 Application

1.1.1 Ships intended to support diving operations and complying with the present Chapter are eligible for the assignment of one of the following service notations as defined in Pt A, Ch 1, Sec 2, [4.11.5]:

- **diving support-integrated** when the vessel is fitted with permanently installed diving systems
- **diving support-portable**, when the vessel is fitted with a non-permanent diving system which is installed and operational
- **diving support-capable**, when the vessel is able to be fitted with a non-permanent diving system and the diving equipment is not installed.

Note 1: For non-permanent diving systems, the service notation **diving support-capable** is to be replaced by **diving support-portable** before conducting any diving operations (see Ch 7, Sec 6).

1.1.2 One of the following additional service features is to be added to service notations **diving support-integrated** and **diving support-portable**:

- **DD** when the diving system installed onboard is a deep diving system (or saturation system) as defined in [2.1.2]
- **SD** when the diving system installed onboard is a shallow diving system (or surface supplied diving system) as defined in [2.1.1].

Note 1: Bounce diving system as defined in [2.1.3] are considered as a shallow diving system for the purpose of this Chapter.

1.1.3 The present Chapter does not apply to the classification of diving systems which are covered by NR610, as detailed in [2.2].

1.1.4 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1 and specific requirements for initial inspection and testing as per Ch 7, Sec 7.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B • Ch 7, Sec 2 **(2)**	• NR566 • Ch 7, Sec 2 **(2)**
	L < 65 or 90 m **(1)**	• NR600 • Ch 7, Sec 2 **(2)**	• NR566 • Ch 7, Sec 2 **(2)**
Stability		• Part B	• NR566
Structural assessment	L ≥ 65 or 90 m **(1)**	• Part B • Ch 7, Sec 3 **(2)**	• Part B • Ch 7, Sec 3 **(2)**
	L < 65 or 90 m **(1)**	• NR600 • Ch 7, Sec 3 **(2)**	• NR600 • Ch 7, Sec 3 **(2)**
Machinery and systems		• Part C • Ch 7, Sec 4 **(2)**	• NR566 • Ch 7, Sec 4 **(2)**
Electrical installations and automation		• Part C • Ch 7, Sec 4 **(2)**	• NR566 • Ch 7, Sec 4 **(2)**
Safety features		• Part C • Ch 7, Sec 5 **(2)**	• NR566 • Ch 7, Sec 5 **(2)**

(1) Refer to the scope of application of NR600.
(2) Or Ch 7, Sec 6 if the service notation **diving support-capable** is assigned.
Note 1:
NR566 : Hull Arrangement, Stability and Systems for Ships less than 500 GT.
NR600 : Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

1.2 Scope

1.2.1 The present Chapter addresses the requirements regarding the installations on the supporting ship providing the diving system with auxiliary functions such as: fire safety, electrical power supply, communication means, breathing gas storage, ventilation, structural foundations, station keeping capabilities, etc.

1.2.2 The present Chapter includes the provisions of IMO Code of Safety for Diving Systems as applicable to the interface between the diving system and the supporting ship.

Note 1: Attention is drawn to the fact that IMO Code of Safety for Diving Systems also covers the diving system itself.

These requirements are reproduced in Italic type. In reproducing the text, the word "Administration" is replaced by the word "Society".

2 Diving system

2.1 Description

2.1.1 Shallow or surface supplied diving system

A surface supplied diving system is a system where interventions by divers are performed at such depth and durations that the descent onto the seabed, the work and the decompression are carried out in the water (without resorting to the use of a closed diving bell).

The breathing gas is supplied from the supporting vessel through an umbilical.

The breathing gas may be:

- pure compressed air, or
- mixed gas with enriched oxygen or helium.

The surface supplied diving installation generally includes as the case may be:

- means of getting into water
- means to recover the divers
- a decompression chamber
- means adapted to the diving method used.

2.1.2 Deep or saturation diving system

A saturation diving system is a system where the divers live in a pressurized environment which may be maintained for several days or weeks. Divers are generally decompressed to surface pressure only once, at the end of their tour of duty.

2.1.3 Bounce diving system

For the purpose of the present Chapter, a bounce diving system, as defined in [3.2.2], is considered as a shallow diving system.

2.1.4 Components of the diving system

Diving systems generally include, but are not limited to, the items listed in Tab 2.

Table 2 : List of diving equipment

Items	Deep diving	Shallow diving
Submersible compression chamber (closed diving bell)	X	
Wet diving bell or diver basket		X
Deck decompression chamber	X	X
Deck decompression chamber control panel	X	X
Hyperbaric evacuation system	X	
Breathing supply system	X	X
Handling systems for the diving bell	X	X
Diving control stand	X	X
Clamping and under pressure transfer system	X	
Devices for controlling the atmosphere	X	X
Devices for the recovery and the purification of breathing gases	X	X
Means of production of hot water	X	X

2.2 Classification of the diving system

2.2.1 The diving system is to be classed and compliant with NR 610 Rules for the Classification of Diving Systems, or with the rules of a recognized Classification Society.

As an alternative, a recognized diving system certificate may be accepted, subject to the Society agreement.

2.2.2 Classification of the diving support ship and classification of the diving system are independent.

3 References

3.1 Acronyms

3.1.1 The following acronyms are used:

DDC : Deck decompression chamber (see [3.2.5])

HRU : Hyperbaric rescue unit (see [3.2.11])

LARS : Launch and recovery system (see [3.2.12])

MSW : Metres of sea water (see [3.2.15])

SDC : Submersible diving chamber (see [3.2.4])

SPHL : Self-propelled hyperbaric lifeboat (see [3.2.11]).

3.2 Definitions

3.2.1 Bottle

Pressure container for the storage and transport of gases under pressure. Also called gas cylinders.

3.2.2 Bounce diving system

A bounce diving system is a system using a closed diving bell and where the divers are decompressed on-board in a deck decompression chamber after each dive.

3.2.3 Breathing gas

All gases and mixtures of gases which are used for breathing during diving operations.

3.2.4 Closed diving bell / submersible diving chamber

Manned underwater compression chamber, including its fitted equipment, for transfer of diving personnel under pressure between the work location and the deck chambers.

Also known as a personnel transfer capsule (PTC) or submersible compression chamber or submersible diving chamber (SDC).

3.2.5 Deck decompression chamber (DDC)

Pressure vessel for human occupancy which does not go under water and may be used as a living chamber during saturation diving, diver decompression or treatment of decompression illness. Also called compression chamber, recompression chamber, deck chamber or surface compression chamber.

3.2.6 Depth

Water depth or equivalent pressure to which the diver is exposed at any time during a dive or inside a surface compression chamber or a diving bell.

3.2.7 Diving basket

Man-riding equipment used for transfer of diving personnel at ambient sea pressure between the work location and the diving support ship.

3.2.8 Hazardous areas

Those locations in which an explosive gas-air mixture is:

- continuously present, or present for long periods (zone 0)
- likely to occur in normal operation (zone 1)
- not likely to occur and, if it happens, only existing for a short time (zone 2).

3.2.9 Hyperbaric evacuation system (HES)

The whole plant and equipment necessary for the evacuation of divers in saturation from a deck decompression chamber to the Hyperbaric Reception Facility (HRF) where decompression can be carried out. The main components of a hyperbaric evacuation system include the Hyperbaric Rescue Unit (HRU), its handling system, the Hyperbaric Reception Facility and the evacuation procedures.

3.2.10 Hyperbaric reception facility (HRF)

Normally a shore based facility (but could be installed offshore) which is capable of accepting a HRU and mating it to a decompression chamber such that the evacuated occupants can be transferred into that chamber and safely decompressed.

3.2.11 Hyperbaric rescue unit (HRU)

Floating unit used to evacuate divers under pressure safely from a ship or a floating structure to a location where decompression can be carried out.

It may be a Hyperbaric Rescue Chamber (HRC) or a Self-Propelled Hyperbaric Lifeboat (SPHL). Also known as Hyperbaric Evacuation Unit (HEU).

3.2.12 Launch and recovery system (LARS)

Plant and equipment necessary for raising, lowering and transporting the diving bell, and/or diving basket, between the work location and the surface compression chamber.

3.2.13 Life support system

Gas supply, breathing gas system, decompression equipment, environmental control system and equipment required to provide a safe environment for the diving crew in the diving bell and the surface compression chamber under all ranges of pressure and conditions they may be exposed to during diving operations.

3.2.14 Maximum operating depth

Depth in metres of seawater equivalent to the maximum pressure for which the diving system is designed to operate.

3.2.15 Metres of sea water (MSW)

Metres of sea water are sometimes used to express a water depth equivalent to a pressure. For the purpose of the design and testing of pressure vessels, the values in MSW are to be converted into pressure units.

3.2.16 Portable diving systems

Portable equipment not remaining onboard but installed periodically for the purpose of specific works related to diving.

3.2.17 Pressure vessel

Container capable of withstanding an internal maximum working pressure greater than or equal to 1 bar.

3.2.18 Umbilical

Link between the diving support ship and the diving bell, or link between the diving bell and divers

It may contain surveillance, communication and power supply cables, breathing gas and hot water hoses.

3.2.19 Wet diving bell / open diving bell

Bell with a closed top section, capable of containing a dry gaseous atmosphere to provide a refuge for the divers. It is not a pressure vessel. Also called an open bell.

3.3 Reference rules and regulations

3.3.1 The requirements of the present Chapter are generally consistent with the following rules and regulations:

- IMO - Code of Safety for Diving System:
  IMO - Code of Safety for Diving Systems means the Code of Safety adopted by IMO Resolution A.831(19), as amended.
- IMO - Guidelines and Specifications for Hyperbaric Evacuation Systems:
  IMO Guidelines and Specifications for Hyperbaric Evacuation Systems adopted by Resolution A.692(17).
- IMCA publications:
  International Marine Contractors Association (IMCA) is the editor of various publications providing guidelines for commercial diving and dynamic positioning operations. The following IMCA publications are referenced within the present Chapter:
  - IMCA D 014 - IMCA international code of practice for offshore diving
  - IMCA D 018 - Code of practice on the initial and periodic examination, testing and certification of diving plant and equipment
  - IMCA D 039 - FMEA guide for diving systems
  - IMCA D 052 - Guidance on hyperbaric evacuation systems
  - IMCA AODC 055 - Protection of water intake points for diver safety.

4 Documents to be submitted

4.1 General

4.1.1 The documents listed in Tab 3 are to be submitted.

4.2 Diving system documentation

4.2.1 Specification

The diving system specification is to include:

- the description of the system

- a design basis including:
  - maximum operating depth (and equivalent design pressure)
  - maximum operating time
  - maximum number of divers in water and in the DDC
  - maximum time of occupancy expected in the DDC
  - maximum operational wave height
  - minimum and maximum sea and air temperature
  - safety concept.
- the list of diving equipment with reference and name of the manufacturer.

4.2.2 Operating manual

The manufacturer of the diving equipment is to provide an operating manual with detailed information on the method to use the decompression system.

- the user instructions to operate the system
- operational limitations
- evacuation procedure

Table 3 : Documents to be submitted

No.	Documents to be submitted	I/A **(1)**
1	Diving system documentation **(2)**: • diving system certificates • specification (see [4.2.1]) • operating manual (see [4.2.2]) • equipment and certificate register (see [4.2.3]) • service record book (see [4.2.4]) • FMEA (see [4.2.5]) and critical spare parts list • planned maintenance system (see [4.2.6])	I
2	General arrangement of the ship showing the diving system arrangement and including the: • locations of equipment • location of breathing gas storage • hazardous zone and hazardous substances locations • interface with the piping arrangement, electrical installations, etc.	A
Structural assessment		
3	Structural arrangement showing the interface between diving equipment and hull structure	A
4	Description of the seafastening, if any	I
Electrical installations		
5	General arrangement showing location of electrical installations	I
6	Description of electrical arrangement principles, failure scenarios, redundancy principles, emergency arrangement, etc.	I
7	Single line distribution diagram and detailed diagram of the whole installation	A
8	General arrangement of the diving control room	A
9	Descriptions and details of any communication means as required by the Rules, including single line diagram	A
10	Description and details of the lighting arrangement around the diving system	A
Safety features		
11	Fire protection documentation with definition of the spaces which enclose or surround the diving system items and details of the passive fire protection	A
12	Fire-fighting equipment details	A
13	Fire detection and alarm equipment details	A
14	Breathing gas arrangement details, including piping diagram	A
15	General arrangement showing the hyperbaric evacuation means	A

(1) A : To be submitted for approval; I : To be submitted for information

(2) Except when not available in case of service notation **diving support-capable**.

4.2.3 Equipment and certificate register

An equipment and certificate register as defined in IMCA D014 is to be kept on-board.

4.2.4 Service record book

The Owner is to establish and maintain a service record book of the diving system which is to be submitted to the Society for in-service inspections.

The service record book is to contain all service and maintenance operations.

The service record book is to be available on-board.

4.2.5 Failure modes and effects analysis (FMEA)

A failure modes and effects analysis (FMEA) of the diving installation is to be conducted at an early stage of the new built projects or when a portable diving system is to be installed on-board.

The FMEA should identify the critical components for which spare parts should be provided.

It is recommended to update the FMEA for each modification of the diving system.

Note 1: A guidance to conduct to FMEA is proposed in the document IMCA D039 - FMEA guide for diving systems.

4.2.6 Planned maintenance system (PMS)

A planned maintenance system (PMS), as defined in IMCA D 018, should be submitted to the Society.

The PMS should include the requirements for the periodic examinations and testing.

The PMS should ensure the traceability of the maintenance works carried out and the routine replacement of the components on the diving plant.

The PMS is to include the identification markings of the diving equipment.

Section 2 General Arrangement

1 General arrangement

1.1 Diving system arrangements

1.1.1 *The diving system and breathing gas facilities should be arranged in spaces or locations which are adequately ventilated and provided with suitable electric lighting.*

1.1.2 *When any part of the diving system is sited on open deck, particular consideration should be given to providing reasonable protection from the sea, icing, heat or any damage which may result from other activities on board the ship or floating structure.*

1.1.3 *Diving systems are not to be located closed to ventilation outlets and exhausts from machinery spaces or galleys.*

Note 1: In general, a minimum distance of 6 metres between ventilation outlets or exhausts defined above, and diving system ventilation inlets is considered sufficient.

1.1.4 The diving system arrangement is to comply with the safety features requirements in Ch 7, Sec 5.

1.2 Machinery spaces

1.2.1 *The diving system and breathing gas storage facilities shall not be located in machinery spaces if the machinery is not associated with the diving system.*

1.3 Hazardous areas

1.3.1 As far as practicable, diving systems should not be located in hazardous areas.

1.3.2 Where, due to the requirements of diving operations, the diving equipment is located in hazardous areas zone 1 or zone 2, it has to comply with the requirements for such equipment in hazardous areas, as defined Part C, Chapter 4

1.3.3 *In any case, diving equipment are not permitted in hazardous areas designated as zone 0.*

1.4 Breathing gas storage

1.4.1 Particular requirements apply to the storage of the breathing gas, as specified in Ch 7, Sec 5.

1.5 Location of deck decompression chamber

1.5.1 It is recommended to install deck decompression chambers in the longitudinal direction to limit the effect of rolling motion on the divers.

1.5.2 The deck decompression chamber of a surface supplied diving system is to be close to the location where the diver is getting out of the water and and easily accessible without any trip hazards.

1.6 Diving operations

1.6.1 The diving system is to be located in such a way that diving operations are not affected by thrusters, propellers or mooring lines.

1.6.2 The diving operation arrangement should ensure that all deployed umbilicals are physically prevented from coming into contact with any hazard such as thrusters or seawater inlets.

2 Access arrangement

2.1 General

2.1.1 There is to be a sufficient level of access available around the diving system in order to allow operational personnel to safely and efficiently carry out their duties.

2.2 Means of evacuation

2.2.1 An hyperbaric evacuation system is to be provided for units granted with the additional service feature **DD**, as specified in Ch 7, Sec 5.

Section 3 Structural Assessment

1 Diving equipment foundations

1.1 General

1.1.1 *Provision should be made to ensure that the diving system and auxiliary equipment are securely fastened to the ship or floating structure and that adjacent equipment is similarly secured. Consideration should be given to the relative movement between the components of the system. In addition, the fastening arrangements should be able to meet any required survival conditions of the ship or floating structure.*

1.1.2 Diving equipment are to be permanently secured to the ship primary structure by means of welding or bolting. Normally, a lashing arrangement is considered as not sufficient.

1.1.3 The fastening arrangement of the pressure vessel has to allow volume variations due to internal pressure variations.

1.2 Design loads

1.2.1 The deadweight and the maximum operational loads of the diving equipment are to be provided (maximum number of persons, stores and equipment).

1.2.2 The design loads of pressure vessels for human occupancy are to be especially considered if hydro testing is to be made onboard.

1.3 Allowable deflection

1.3.1 The deflection of the deck in way of the deck decompression chamber are to be within the allowable limits set by the equipment manufacturer, if any.

2 Launching system foundations

2.1 General

2.1.1 The foundations of the launching appliance are to comply with Pt B, Ch 1, Sec 1, [1.2].

Section 4 Machinery and Systems

1 Sea inlets

1.1 General

1.1.1 Special considerations are to govern the design of sea inlets fitted in the hull of the ship, in order to protect the divers and the unit seawater systems.

Note 1: Recommendations are provided in IMCA AODC 055.

1.1.2 Water current in the immediate vicinity of the sea inlet is not to exceed 0,5 m/sec.

1.1.3 The mesh or aperture size of any protective structure is to be such as to prevent any part of the diver or his equipment from being drawn into the intake.

1.1.4 The maximum mesh size, or the maximum size of any opening if not a mesh-type construction, is not to exceed an area of 400 cm^2, equivalent to a square of 20 cm x 20 cm or a rectangle of 28 cm x 14 cm.

2 Position keeping

2.1 General

2.1.1 Ships covered by the present Chapter are to be able to safely maintain their position during diving operations. This may be achieved with a passive mooring or a dynamic positioning system complying with [2.2].

2.2 Dynamic positioning

2.2.1 When a diving support unit is fitted with a dynamic positioning system used during diving operations, the dynamic positioning system is to comply with IMO class 2 requirements.

In this case, the diving support unit is to be granted with the additional class notation **DYNAPOS AM/AT**, completed by one of the following symbols:

- **R**, when the dynamic positioning is provided with redundancy means. In this case, IMO class 2 equipment is to be used.
- **RS**, when, in addition to symbol **R**, the redundancy is achieved using two systems or alternative means of performing a function physically separated. In this case, IMO class 3 equipment is to be used.

2.2.2 The dynamic positioning control stand and the diving control room are to have 2-way communication means and a manually operated alarm.

3 Electrical installations

3.1 General

3.1.1 *All electrical equipment and installations, including power supply arrangements, should be designed for the environment in which they will operate in order to minimize the risk of fire, explosion, electrical shock and emission of toxic gases to personnel, as well as galvanic corrosion of the deck decompression chamber or diving bell.*

3.1.2 Electrical installations of the diving system are to be considered as secondary essential services according to Pt C, Ch 2, Sec 1.

3.1.3 Main and automatic emergency lightings are to be provided in spaces containing diving equipment.

3.1.4 Electrical wires are to be separated from piping installations carrying breathing gas.

3.2 Electrical power supply

3.2.1 *In the event of failure of the main source of electrical power supply to the diving system, an independent source of electrical power is to be available for the safe termination of the diving operation. It is admissible to use the unit's emergency source of electrical power as an emergency source of electrical power if it has sufficient electrical power capacity to supply the diving system and the emergency load for the vessel at the same time.*

3.2.2 *The alternative source of electrical power is to be located outside the machinery casings to ensure its functioning in the event of fire or other casualty causing failure to the main electrical installation.*

3.2.3 As a minimum, the emergency source of power is to be of sufficient capacity to supply:

- the life support system (analysis and regeneration)
- the emergency communication system
- the emergency lighting in the deck decompression chamber, the diving bell and the diving control room
- the LARS
- the handling system required for emergency launching of the means of hyperbaric evacuation
- the emergency systems in the diving control room.

3.2.4 The emergency source of power is to be capable of supplying the systems specified in [3.2.3] for a period in compliance with the National Authorities' regulations, as relevant, and in any case not less than 18 hours.

3.2.5 When switching from the main source of power to the emergency source of power, an audible and visible alarm is to be actuated in the diving control room with the indication of the source of power connected.

4 Diving control station

4.1 General

4.1.1 *The diving system should be so arranged as to ensure that centralized control of the safe operation of the system can be maintained under all weather conditions.*

4.1.2 The diving control station is to provide control of diving operations and of hyperbaric chambers.

These functions may be separated in 2 distinct control rooms with suitable means of communication.

4.2 Communication and relocation system

4.2.1 The communication system should be arranged for direct 2-way communication between the diving control station(s) and:

- the deck decompression chamber control stand, when relevant
- the divers in water
- the diving bell
- each compartment of the deck decompression chamber
- the handling system operating position
- the dynamic positioning control stand
- the bridge
- the hyperbaric evacuation system launch point
- inside the hyperbaric evacuation system.

4.2.2 *Alternative means of communication with divers in the deck decompression chamber and submersible compression chamber should be available in case of emergency.*

4.2.3 *Each deck decompression chamber and submersible compression chamber should be connected to a speech unscrambler when used with gas systems, including helium.*

5 Diver heating system

5.1 Oil fired heaters

5.1.1 When diver heating system includes oil fired heaters, they are to be located such that they present no risk to the dive system in the event of fire.

5.1.2 The local tank is to be fitted with an overflow system with a capacity greater than the filling supply system (i.e. capable of allowing a rate of overflow greater than the filling rate).

5.1.3 The overflow system is to dump to a safe area.

Section 5 Safety Features

1 Fire safety

1.1 Personnel protection

1.1.1 As a minimum, the following fire protection equipment is to be provided in the diving control room for all persons required for the safe operation of the diving equipment, in addition to individual equipment required by the SOLAS Convention:

- emergency breathing masks
- fire-fighter's outfits.

1.2 Structural fire protection

1.2.1 All materials and equipment used in connection with the diving system should be, as far as practicable, of fire-retardant type in order to minimize the risk of fire and sources of ignition.

1.2.2 Enclosed spaces in which the diving system or its auxiliary equipment is located are to be provided with structural fire protection A-60 with adjacent spaces.

These enclosed spaces may be subdivided into several compartments containing diving equipment and separated with A-0 bulkheads.

1.2.3 Doors located in bulkheads forming boundaries with adjacent spaces are to be of self-closing type.

1.2.4 Piping and cables included in the diving system are to be routed in ducts having the same fire protection than the space containing the diving equipment.

1.3 Detection and alarm

1.3.1 *Interior spaces containing diving equipment such as deck decompression chambers, submersible compression chambers, gas storage, compressors and control stands are to be provided with an automatic fire detection and alarm system.*

1.3.2 The fire detection and alarm system referred to in [1.3.1] is to be independent of those of the other spaces.

1.3.3 The fire detection panel is to be located in the ship control station and repeated in the engine control room and diving control station(s).

1.4 Fire-fighting equipment

1.4.1 *Interior spaces containing diving equipment such as deck compression chambers, submersible compression chambers, breathing gas storage, compressors and control stands are to be provided with a a fixed fire-extinguishing system* suitable for machinery spaces of category A.

The fixed fire-extinguishing system is to be:

- either a manually actuated water-spraying system complying with Pt C, Ch 4, Sec 15, [6],
- or a fixed gas fire-extinguishing system using a non-toxic gas, subject to the Society approval.

1.4.2 *When pressure vessels (including gas cylinders) are situated in enclosed spaces, a manually actuated water-spray system having an application rate of 10 litres per minute per square metre of the horizontal projected area is to be provided to cool and protect such pressure vessels in the event of an external fire.*

Alternative means using water mist may be provided subject to the Society approval.

1.4.3 Means for cooling windows of pressure vessels for human occupancy are to be provided.

1.4.4 *When pressure vessels are situated on open decks, fire hoses may be considered as providing the necessary protection.*

1.4.5 *Portable fire extinguishers of approved types and designs are to be distributed throughout the space containing the diving system.*

1.4.6 *One of the portable fire-extinguishers is to be stowed near the entrance to that space.*

2 Breathing gas system

2.1 Storage on board

2.1.1 *Breathing gas storage and associated equipment should not be located in a machinery space not associated with the diving system.*

2.1.2 As a rule, breathing gas should be stored on an open deck.

2.1.3 If the breathing gas is located in an enclosed space, the following is to be provided:

- a forced ventilation system as defined in [3]
- a type approved continuous monitoring system of the oxygen content in the ambient air
- a type approved audio-visible oxygen alarm (low-high) is to be installed at a manned control station
- any relief valve or bursting disc is to be piped to dump overboard and not into the enclosed space
- the enclosed space is to be gas-tight
- if lighting is provided in the enclosed space containing the breathing gas, it is to be of an approved safe type for operation in the gases likely to be encountered
- signboards as defined in [2.5].

2.1.4 *Breathing gas should not be stored near flammable substances.*

2.1.5 *Any gas mixture containing more than 25% oxygen by volume will need to be handled like pure oxygen.*

2.2 Piping

2.2.1 Piping containing breathing gas under high pressure is not to be arranged inside the accommodation spaces, machinery spaces or hazardous areas.

2.2.2 Piping systems containing flammable substances are not to be arranged in the same area as piping systems containing breathing gas.

2.2.3 *Flexible hoses, except for umbilicals, should be reduced to a minimum.*

2.2.4 *Exhaust lines should be fitted with an anti-suction device on the inlet side.*

2.2.5 *Gases vented from the diving system should be vented into the open air away from sources of ignition, personnel or any area where the presence of those gases could be hazardous.*

2.2.6 *All high-pressure piping is to be protected against mechanical damage.*

Note 1: Generally piping is considered under high pressure between cylinders or compressors and pressure reducing devices.

2.2.7 Piping carrying breathing gas is to be kept away from electrical cables.

2.3 Oxygen installation

2.3.1 A recognized standard is to be applied for the design of the oxygen installation and submitted to the Society for approval.

2.3.2 *Any material used in a plant which is intended to carry oxygen is to be compatible with oxygen at working pressure and flow rate.*

2.3.3 *The use of high-pressure oxygen piping is to be minimized by the fitting of pressure reducing devices, as close as practicable to the storage cylinders.*

2.3.4 Means of protection against overpressure are to be provided in accordance with Pt C, Ch 1, Sec 10, [2]

2.3.5 *Hoses for oxygen are to be of fire-retardant construction and type-approved.*

2.3.6 Any materials used in a plant which is intended to carry oxygen is to be cleaned of hydrocarbons and debris to avoid explosions. Formal cleaning procedures for such equipment are to be developed and implemented.

2.4 Colour code

2.4.1 *For piping systems and gas storage bottles/pressure vessels, the colour codes defined in Tab 1 are to be used.*

In addition, each bottle/pressure vessel is to be marked with the name and symbol of the gases it contains. The marking and colour coding of the gas storage bottles is to be visible from the valve end.

Table 1 : Colour code

Name	Symbol	Colour code
Oxygen	O_2	white
Nitrogen	N_2	black
Air	Air	white and black
Carbon dioxide	CO_2	grey
Helium	He	brown
Oxygen-helium mix gas	O_2-He	white and brown

2.5 Signboards

2.5.1 As a minimum, the following signboards are to be displayed in the storage room containing breathing gas:

- NO SMOKING
- diagram of the breathing gas plant.

3 Ventilation

3.1 General

3.1.1 Enclosed spaces containing the diving equipment are to have a forced ventilation with a rate of 8 air changes per hour with an independent system. The air intake is to be located in a non-hazardous area.

3.1.2 Ventilation fans are to be of non-sparking construction complying with Pt C, Ch 4, Sec 1.

4 Means of evacuation of the divers in saturation

4.1 Application

4.1.1 Ships assigned the additional service feature **DD** are to be provided with an hyperbaric evacuation system.

4.2 Hyperbaric evacuation system

4.2.1 *An evacuation system is to be provided having sufficient capacity to evacuate all divers under pressure in the event of the ship having to be abandoned.*

4.2.2 *The hyperbaric evacuation system is to comply with the IMO "Guidelines and Specifications for Hyperbaric Evacuation Systems", adopted by resolution A.692(17).*

4.3 Launching arrangement

4.3.1 The hyperbaric evacuation system launching arrangement is to be manufactured, inspected and tested according to SOLAS and IMO International Life-Saving Appliances Code (LSA Code) requirements, as far as practicable.

Section 6 Specific Requirements for Ships Assigned with the Service Notation diving support-capable

1 General

1.1 Application

1.1.1 The present Section provides requirements for ships intended to be fitted with non-permanent diving systems.

1.1.2 Ships complying with the present Section are eligible for the assignment of the service notation **diving support-capable** defined in Ch 7, Sec 1, [1.1.1].

1.1.3 Provisions and margins for the diving system are to be considered in the design of the supporting ship. The documents to be submitted are listed in [1.2].

1.1.4 The service notation **diving support-capable** apply when the diving system is not installed on board.

1.1.5 When the diving system is installed on board and before diving operations, the service notation **diving support-portable** is to be activated in replacement of **diving support-capable**, as detailed in [1.3].

1.2 Documents to be submitted

1.2.1 General

The documents listed in Tab 1 are to be provided, as a minimum. Any additional information deemed necessary may be required by the Society.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents to be submitted
1.1	I	Diving operational restrictions (Maximum MSW, limiting environmental conditions, …)
1.2	I	Provisional characteristics of the diving system: • list of equipment • mass estimated • overall dimensions and arrangement • electrical consumers list • quantity of divers
1.3	A	General arrangement of the ship showing the provisions for diving system arrangement and including the: • locations of equipment • location of breathing gas storage • hazardous zones and hazardous substances locations • interface with the piping arrangements, electrical installations, etc.
1.4	I	Description of the interface between the diving system and the supporting ship as detailed in [1.2.2]
Structural assessment		
2.1	A	Structural arrangement showing the interface between diving equipment and hull structure
Electrical installations		
3.1	I	Description of electrical arrangement principles, when relevant
3.2	A	Electrical balance of the ship considering the diving system
Safety features		
4.1	A	Fire protection documentation with definition of the spaces which enclose or surround the diving system items and details of the passive fire protection, when relevant **(2)**
4.2	A	Fire-fighting equipment details
4.3	A	Fire detection and alarm equipment details, when relevant
4.4	A	Breathing gas arrangement details including piping diagram, when relevant
(1) A: to be submitted for approval; I: to be submitted for information. **(2)** Not applicable to open deck		

1.2.2 Description of the interface between the diving system and the supporting ship

A description of the interface with the supporting ship is to be provided, including the modifications to be made on the ship where necessary.

The description is to include:

- the electrical power supply
- the fresh water supply
- the sea water supply
- the means for fire fighting, when provided by the ship
- the means of communication and alarms between the bridge of the ship and:
  - the diving control station,
  - the life support control station,
  - the LARS control stand.

1.3 Activation of service notation diving support-portable

1.3.1 Before any diving operation being conducted, the service notation **diving support-portable** is to be activated. For this purpose, the following requirements are to be complied with:

- documents defined in Ch 7, Sec 1, [4] are to be submitted for information or approval, including a recognized certificate of the diving system, as per Ch 7, Sec 1, [2]
- a survey of the diving system is to be conducted after the installation of the diving equipment on board, as defined in Ch 7, Sec 7, [1.2].

1.3.2 When the requirements of [1.3.1] are fulfilled, the class certificate of the supporting ship is re-issued with the service notation **diving support-portable**, in replacement of **diving support-capable**.

Note 1: Normally, a minimum of 4 weeks is to be scheduled between the submission of the documents to the Society and the diving operations.

2 General arrangement

2.1 General

2.1.1 Applicable requirements of Ch 7, Sec 2 are to be complied with, based on the provisional characteristics of the diving system.

3 Structural assessment

3.1 General

3.1.1 Requirements of Ch 7, Sec 3 are to be complied with, based on the provisional characteristics of the diving equipment.

4 Machinery and systems

4.1 Position keeping

4.1.1 Requirements of Ch 7, Sec 4, [2] are to be complied with.

4.2 Sea inlets

4.2.1 Relevant requirements of Ch 7, Sec 4, [1] are to be complied with.

5 Electrical installations and automations

5.1 Electrical power supply

5.1.1 When the electrical power is supplied by the supporting ship, applicable requirements of Ch 7, Sec 4, [3] are to be complied with.

6 Safety features

6.1 Fire safety

6.1.1 When a part of the diving system is located in an enclosed space inside the supporting ship, applicable requirements of Ch 7, Sec 5, [1] are to be complied with.

6.2 Breathing gas facilities

6.2.1 Applicable requirements of Ch 7, Sec 5, [2] are to be complied with, based on the provisional characteristics of the diving system.

6.3 Ventilation

6.3.1 When a part of the diving system is located in an enclosed space inside the supporting ship, applicable requirements of Ch 7, Sec 5, [3] are to be complied with.

Section 7 Initial Inspection and Testing

1 General

1.1 Application

1.1.1 The present Section provides requirements for initial inspection and testing of the diving equipment when first installed on-board or after re-installation on a supporting ship.

1.1.2 Upon the installation of the diving system on-board and in addition to conventional sea trials, specific inspection and testing in relation to the particular service for which the ship is intended are required.

1.1.3 These tests are to be conducted according to an inspection and testing specification to be submitted to the Society by the party applying for classification.

The Society is to be duly informed of the time and place of the commissioning tests of the diving system.

1.1.4 The commissioning procedures of the diving system should be approved by the certifying authority of the diving system.

1.1.5 The inspection and testing requirements of the present Section are provided as a minimum and in addition to the requirements of the rules or standards referred to in the diving system certificate.

Any additional testing may be required to the satisfaction of the attending Surveyor.

1.1.6 The Factory Acceptance Tests (FAT) of the diving equipment are not in the scope of the present Chapter.

1.2 Non-permanent diving system

1.2.1 Non-permanent diving systems should meet inspection and testing requirements defined in [2] after each installation on-board.

1.2.2 Upon satisfactory completion of [1.2.1], the service notation **diving support-portable** may be activated as defined in Ch 7, Sec 6, [1.3].

2 On-board testing

2.1 Diving installations

2.1.1 The inspection and testing of the diving installation should include, as a minimum:

a) Verification of the presence on-board of the following documents:
   - Diving system specification, as defined in Ch 7, Sec 1, [4.2.1]
   - Operating manual, as defined in Ch 7, Sec 1, [4.2.2]
   - Equipment and certificate register, as defined in Ch 7, Sec 1, [4.2.3]
   - Planned maintenance system, as defined in Ch 7, Sec 1, [4.2.6].

b) Verification of the structural arrangement and scantling of the foundations of pressure vessels and bell handling system

c) Verification of the sea fastening arrangement of the diving equipment. If the sea fastening requires any welded fixtures then there is to be Non Destructive Testing reports available confirming these welds were satisfactorily tested

d) Functional testing of the main source of electrical power, emergency source of electrical power and switching from one to the other. Verification of the satisfactory operation of the alarms and indications

e) General examination of the electrical cabling

f) Functional testing of the main and alternative two-way communication system at the dive location, i.e. between divers, chambers, control rooms, launch point and other important locations

g) Testing of the breathing gas installations:
   1) general examination of the storage of the gas cylinders
   2) verification of cleanliness of the breathing gas piping system according to the approved procedure
   3) testing of the gas-tightness of all sealing devices of the enclosed spaces for breathing gas storage
   4) confirmation of the proper operation of the forced ventilation of the enclosed spaces for gas storage
   5) verification of the means for the protection against overpressure of the oxygen installation
   6) verification of the alarms of oxygen-measuring equipment
   7) verification of the signboards in the area containing the gas cylinders.

h) General examination of the automatic fire detection and alarm system

i) Verification of the suitable fixed fire-extinguishing system intended for interior spaces containing diving equipment

j) Confirmation that the fire fighters' outfits, including their self-contained compressed air breathing apparatus, two-way portable communication apparatus and emergency breathing mask, are complete and in good condition and that the cylinders, including the spare cylinders, of any required self-contained breathing apparatus are suitably charged

k) Functional testing of the self closing systems of the doors located in the bulkheads forming boundaries with the adjacent spaces

l) General examination of the visible parts of the items forming the structural fire protection, such as bulkheads, decks, doors and trunks, due attention being given to their integrity and that of the insulating material.

2.1.2 As a rule, all the connections between the supporting ship and the diving installation are to be presented for examination by the Surveyor.

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 8
LIFTING UNITS

Section 1 General

Section 2 General Arrangement

Section 3 Stability and Subdivision

Section 4 Structural Assessment

Section 5 Machinery and Systems

Section 6 Initial Inspection and Testing

Section 7 Self-Elevating Ships

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the present Chapter are eligible for the assignment of the service notation **lifting** as defined in Pt A, Ch 1, Sec 2, [4.12.6].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1 and specific requirements for initial inspection and testing as detailed in Ch 8, Sec 6.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B • Ch 8, Sec 2	• NR566 • Ch 8, Sec 2
	L < 65 or 90 m **(1)**	• NR600 • Ch 8, Sec 2	• NR566 • Ch 8, Sec 2
Stability		• Part B • Ch 8, Sec 3	• NR566 • Ch 8, Sec 3
Structural assessment	L ≥ 65 or 90 m **(1)**	• Part B • Ch 8, Sec 4	• Part B • Ch 8, Sec 4
	L < 65 or 90 m **(1)**	• NR600 • Ch 8, Sec 4	• NR600 • Ch 8, Sec 4
Machinery and systems		• Part C • Ch 8, Sec 5	• NR566 • Ch 8, Sec 5
Electrical installations and automation		• Part C • Ch 8, Sec 5	• NR566 • Ch 8, Sec 5
Fire protection, detection and extinction		• Part C	• NR566

(1) Refer to the scope of application of NR600.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

1.1.3 The lifting appliance is to be certified as required in [2.1].

1.1.4 Ships fitted with legs for self-elevating purposes

When the vessel is fitted with legs for self-elevating purpose, the additional service feature self-elevating is to be assigned in accordance with Pt A, Ch 1, Sec 2, [4.12] and the requirements of Ch 8, Sec 7 are to be complied with.

1.2 Scope

1.2.1 The present Chapter addresses the requirements regarding the installations on the ship providing the lifting equipment with auxiliary functions (power supply, communication means, station keeping capabilities etc.), the stability criteria for lifting operations and the requirements for the structural assessment of the foundations of the lifting equipment.

1.2.2 Specific requirements for ships fitted with legs for self-elevating purposes are also addressed in Ch 8, Sec 7.

2 Lifting equipment

2.1 Certification of the lifting equipment

2.1.1 The lifting equipment is to be certified and included within the scope of classification by assigning to the lifting unit the additional class notation **ALM** or **OHS**, as defined in Pt A, Ch 1, Sec 2, [6.12] and Pt A, Ch 1, Sec 2, [6.25.6] respectively.

3 References

3.1 Acronyms

3.1.1 The following acronyms are used:

DAF : Dynamic amplification factor (see [3.2.1])

MBL : Minimum breaking load (see [3.2.4])

RP : Rated line pull (see [3.2.6])

SWL : Safe working load (see [3.2.7])

WLL : Working load limit (see [3.2.9]).

3.2 Definitions

3.2.1 Dynamic amplification factor (DAF)

The dynamic amplification factor (DAF) is applied on the static hook load to account for the effect of the external forces due to vessel motions and accelerations, the self motion of the lifting appliance, and the dynamic effects due to lifting in water in case of subsea lifting.

3.2.2 Geometrical limit

The geometrical limit is the configuration of the lifting appliance for which the SWL is defined.

It is possible to specify several SWL corresponding to different geometrical limits.

3.2.3 Handling system

A handling system means any system intended to lifting or pulling of a load.

3.2.4 Minimum breaking load (MBL)

The minimum breaking load of chain, wire ropes and fibre ropes are provided by the manufacturer in accordance with NR216 Materials and Welding.

3.2.5 Nominal pulling load

The nominal pulling load of a handling system is defined as the maximum load which may be pulled by the system in a safe manner, in kN.

When the handling system is a lifting appliance, the nominal pulling load is equivalent to the Safe Working Load.

3.2.6 Rated line pull (RP)

The rated line pull (RP) of a winch is the maximum rope tension, in kN, that the winch can haul at the relevant layer, in normal service condition, when the drum rotates at its maximum service speed.

3.2.7 Safe working load (SWL)

The safe working load (SWL), in kN, is defined as the maximum static load which may be lifted vertically by the appliance under normal use and within its geometrical limits.

3.2.8 Static Load

The static load, in kN, corresponds to the sum of the static mass of the lifted cargo and its rigging, times the gravity acceleration.

3.2.9 Working load limit (WLL)

The working load limit (WLL), in kN, is defined as the maximum load that a lifting accessory (loose gear) is certified to withstand under normal use and in a given configuration.

4 Documents to be submitted

4.1 General

4.1.1 The documents listed in Tab 2 are to be provided, as a minimum.

4.2 Lifting equipment documentation

4.2.1 Operating manual

The operating manual is to contain the user documentation required by the technical standard the lifting equipment is complying to.

In particular, the operating manual is to contain full information concerning:

- the crane utilization chart, taking into account the stability and structural limitations for each relevant wind and sea state

- all limitations during normal and emergency operations:
  - maximum wind and sea state
  - maximum heel and trim
  - design temperature
  - braking systems
- the description of the equipment
- the design technical standard
- the mass and location of centre of gravity of the main components of the lifting equipment
- all safety devices, including overload protection system, when relevant
- the description of the motion compensation system, when relevant
- the user instructions to operate, erect, dismantle and transport the system
- the factory acceptance tests specification
- the inspection and testing programme of the equipment when installed on-board
- the testing specification of the emergency lowering system for personnel transfer, when relevant
- the diagrams of electrical, hydraulic and pneumatic systems and equipment
- the materials used in construction, welding procedures and extent of non-destructive testing

Note 1: The party applying for classification may also refer to the IMO MODU Code Chapter 12 for the description of the manual content.

4.2.2 Calculation notes

Calculation notes including the items listed below are to be provided for information:

- loading conditions and design loads applied on the lifting equipment
- loads lowering in the foundations
- structural assessment of the connecting bolts between the lifting equipment and its foundations.

Table 2 : Documents to be submitted

No.	Documents to be submitted	I/A **(1)**
1	Lifting operational restrictions (lifting diagram, limiting environmental conditions, …)	I
2	Lifting appliance documentation: • operating manual (see [4.2.1]) • calculation notes (see [4.2.2])	I
3	General arrangement of the ship showing the lifting equipment position during transit and lifting operations	A
4	General arrangement of the lifting equipment showing the control stations	I
Stability		
5	Loading conditions during transit and lifting operations	A
6	Trim and stability booklet as defined in Ch 8, Sec 3	A
Structural assessment		
7	Structural arrangement showing the foundations of the lifting equipment and the hull structure reinforcements	A
8	Scantlings and steel grades of the connecting bolts between the lifting equipment and its foundations	I
9	Structural arrangement of the supporting and locking devices used for transit conditions	A
10	Material specification of the foundations of the lifting equipment	A
11	Cargo securing manual and lashing arrangement **(2)**	A
12	Welding procedure, welding book of the foundation	A
Machinery		
13	Ballast system diagram when counter ballast is used	A
14	Description of the hydraulic installations of the lifting equipment	A
Electrical installations		
15	General arrangement showing location of electrical installations of the lifting equipment	I
16	Description of electrical arrangement principles, failure scenarios, redundancy principles, emergency arrangement, etc.	I
17	Description of the power supply and control systems of the lifting equipment	A

(1) A : To be submitted for approval; I : To be submitted for information
(2) For mobile lifting appliance

Section 2 General Arrangement

1 General

1.1 Location of lifting appliances

1.1.1 *Lifting appliances should be so located and protected as to reduce to a minimum any danger to personnel, due regard being paid to moving parts or other hazards. Adequate provisions should be made to facilitate cleaning, inspection and maintenance.*

1.2 Position of the crane during navigation

1.2.1 When the lifting appliance is a crane, it is to be possible and to secure it during transit.

Section 3 Stability and Subdivision

Symbols

LCG : Longitudinal centre of gravity
TCG : Transversal centre of gravity
VCG : Vertical centre of gravity.

1 General

1.1 Application

1.1.1 *The provisions of this Section are to be applied to operations involving the lifting of the ship's own structures or for lifts in which the maximum heeling moment due to the lift is greater than that given in the following:*

$$M_L = 0,67 \cdot \Delta \cdot GM \cdot \left(\frac{f}{B}\right)$$

Where:

M_L : *Threshold value for the heeling moment, in t.m, induced by the lifting equipment and load in the lifting equipment.*

GM : *Initial metacentric height, in m, with free surface correction, including the effect of the lifting equipment and load in the lifting equipment.*

f : *Minimum freeboard, in m, measured from the upper side of the weather deck to the waterline.*

B : *Moulded breadth of the ship, in m.*

Δ : *Displacement of the ship, including the lift load, in t.*

The stability criteria of this Section also apply to ships which are engaged in lifting operations where no transverse heeling moment is induced and the increase of the ship's vertical centre of gravity (VCG) due to the lifted weight is greater than 1%.

The calculations are to be completed at the most unfavourable loading conditions for which the lifting equipment shall be used.

1.1.2 This Section provides additional stability criteria to be met during lifting operations in exposed or in non-exposed waters.

1.2 Definitions

1.2.1 Exposed/non-exposed waters

For the purpose of this Section, waters that are not exposed are those where the environmental impact on the lifting operation is negligible. Otherwise, waters are to be considered exposed. In general, waters that are not exposed are calm stretches of water, i.e. estuaries, roadsteads, bays, lagoons; where the wind fetch is six nautical miles or less.

Note 1: Wind fetch is an unobstructed horizontal distance over which the wind can travel over water in a straight direction.

1.3 Loading conditions

1.3.1 *The stability criteria stated in this Section shall be satisfied for all loading conditions intended for lifting and with the hook load at the most unfavourable positions. For each loading condition, the weight and centre of gravity of the load being lifted, the lifting appliance, and counter ballast, if any, should be included. The most unfavourable position may be obtained from the load chart and is chosen at the position where the total of the transverse and vertical moment is the greatest. Additional loading conditions corresponding to various boom positions and counter ballast with different filling level, if applicable, may need to be checked.*

1.3.2 *In lifting operations involving a lifting appliance such as a crane, derrick, sheerlegs or any other similar lifting device:*

- *the magnitude of the lifted load (P_L) shall be the maximum allowed static load at a given outreach of the lifting appliance*
- *the transverse distance (y) is the transverse distance between the point at which the vertical load is applied to the lifting appliance and the ship centreline in the upright position*
- *the vertical height of the load (KG_{load}) is taken as the vertical distance from the point at which the vertical load is applied to the lifting appliance to the baseline in the upright position*
- *the change of centre of gravity of the lifting appliance(s) need to be taken into account.*

1.3.3 *In lifting operations not involving a lifting appliance consisting of a crane, derrick, sheerlegs, a-frame or similar, which involve lifting of fully or partially submerged objects over rollers or strong points at or near a deck-level:*

- *the magnitude of the lifted load (P_L) shall be the winch brake holding load*
- *the transverse distance (y) is the transverse distance between the point at which the vertical load is applied to the ship and the ship centreline in the upright position*

- *the vertical height of the load (KG_{load}) is taken as the vertical distance from the point at which the vertical load is applied to the ship to the baseline in the upright position.*

1.3.4 Allowance is to be made for the anticipated type of wire or rope on storage reels and wire on the winches when calculating loading conditions.

1.4 Trim and stability booklet

1.4.1 *Loading conditions reflecting the operational limitations of the ship, while engaged in lifting shall be included in the stability booklet.*

Use of counter ballast, if applicable, shall be clearly documented, and the adequacy of the ships stability in the event of the sudden loss of the hook load shall be demonstrated.

1.4.2 *The following information is to be included in the trim and stability booklet in addition to the information required in Part B, Chapter 3:*

a) Maximum heeling moment for each direction of lift/inclination as a function of the counter-ballast heeling moment, if used, the draught, and vertical centre of gravity.

b) Where fixed counter ballast is used the following information shall be included:
- *mass of the fixed counter ballast*
- *centre of gravity (LCG, TCG, VCG) of the fixed counter ballast.*

c) Loading conditions over the range of draughts for which lifting operations may be conducted with the maximum vertical load of the lift. Where applicable, righting lever curves for both before and after load drop should be presented for each loading condition.

d) Limitations on cranes operation including permissible heel angles.

e) Operational limitations, such as:
- *maximum safe working load (SWL)*
- *maximum radius of operation of all derricks and lifting appliances*
- *maximum load moment*
- *environmental condition affecting the stability of the ship.*

f) Instructions related to normal operations, including use of counter-ballast.

g) Instructions such as ballasting/de-ballasting procedures to righting the ship following an accidental load drop.

h) Identification of critical down-flooding openings.

i) Recommendations on the use of roll reduction systems.

j) Drawing of the crane showing the weight and centre of gravity, including heel/trim limitations established by the crane manufacturer.

k) A crane load chart, with appropriate de-ratings for wave height.

l) Load chart for lifting operations covering the range of operational draughts related to lifting and including a summary of the stability results.

m) A crane specification manual provided by the manufacturer shall be submitted separately for information.

n) The lifting appliance load, radius, boom angle limit table, including identification of offlead and sidelead angle limits and slewing angle range limits and reference to the ship's centreline.

o) A table that relates the ship trim and heel to the load, radius, slewing angle and limits, and the offlead and sidelead limits.

p) Procedures for calculating the offlead and sidelead angles and the ship VCG with the load applied.

q) If installed, data associated with a Load Moment Indicator system and metrics included in the system.

r) If lifting appliance (crane) offlead and sidelead determine the maximum ship equilibrium angle, the stability booklet should include a note identifying the lifting appliance as the stability limiting factor during lifting operations.

s) Information regarding the deployment of (stability) pontoons to assist a lifting operation, if fitted.

The information listed above may be included in other ship specific documentation on board the ship. In that case, a reference to these documents shall be included in the stability booklet.

1.5 Model tests or direct calculations

1.5.1 *Model tests or direct calculations, performed in accordance with a methodology acceptable to the Society, that demonstrate the survivability of the ship after sudden loss of hook load, may be allowed as an alternative to complying with the requirements of [2.3] or [3.2.3], provided that:*
- *the effects of wind and waves are taken into account, and*
- *the maximum dynamic roll amplitude of the ship after loss of load will not cause immersion of unprotected openings.*

1.6 Operational procedures against capsizing

1.6.1 *Ships should avoid resonant roll conditions when engaged in lifting operations.*

1.7 Guidance on wind force

1.7.1 The curves of wind heeling moments may be drawn for wind forces calculated by the following formula:

$F = 0,5\ C_S\ C_H\ P\ V^2\ A$

where:

F : Wind force, in N

C_S : Shape coefficient depending on the shape of the structural member exposed to the wind (refer to Tab 1)

C_H : Height coefficient depending on the height above sea level of the structural member exposed to wind (refer to Tab 2)

P : Air specific mass (1,222 kg/m^3)

V : Wind speed, in m/s

A : Projected area of the exposed surface of the structural member in either the upright or the heeled condition, in m^2.

Table 1 : Shape coefficient C_s

Shape	C_S
Spherical	0,40
Cylindrical	0,50
Large flat surface (hull, deckhouse, smooth underdeck areas)	1,00
Drilling derrick	1,25
Wires	1,20
Exposed beams and girders under deck	1,30
Small parts	1,40
Isolated shapes (crane, beam, etc.)	1,50
Clustered deckhouses or similar structures	1,10

Table 2 : Height coefficient C_H

Height above sea level, in m	C_H
0 - 15,3	1,00
15,3 - 30,5	1,10
30,5 - 46,0	1,20
46,0 - 61,0	1,30
61,0 - 76,0	1,37
76,0 - 91,5	1,43
91,5 - 106,5	1,48
106,5 - 122,0	1,52
122,0 - 137,0	1,56

Height above sea level, in m	C_H
137,0 - 152,5	1,60
152,5 - 167,5	1,63
167,5 - 183,0	1,67
183,0 - 198,0	1,70
198,0 - 213,5	1,72
213,5 - 228,5	1,75
228,5 - 244,0	1,77
244,0 - 259,0	1,79
above 259	1,80

1.7.2 Wind forces are to be considered in the transversal direction relative to the ship axis and the value of the wind speed is to be taken as follows:

a) In general, a minimum wind speed of 10 m/s (20 knots) is to be used for normal working conditions.

b) When the ship is limited in operation, the maximum wind velocity is to be clearly stated in the crane utilization manual.

1.7.3 In calculating the projected areas to the vertical plane, the area of surfaces exposed to wind due to heel or trim such as under decks surfaces, etc., are to be included using the appropriate shape factor. Open truss work may be approximated by taking 30% of the projected block area of both the front and back section, i.e., 60% of the projected area of one side. In the case of columns, the projected areas of all columns is to be included.

1.7.4 The lever for the wind heeling moment is to be taken vertically from the centre of the lateral resistance or, if available, the centre of hydrodynamic pressure, of the underwater body to the centre of pressure of the areas subject to wind loading. When the installation is fitted with dynamic positioning system, the thrusters effect in [1.7.7] is to be considered.

1.7.5 The curve of wind heeling moments may be assumed to vary as the cosine function of ship heel (see Fig 1).

1.7.6 Wind heeling moments derived from wind tunnel tests on a representative model of the ship may be considered as alternatives to the method given in [1.7.1] to [1.7.5]. Such heeling moment determination is to include lift and drag effects at various applicable heel angles.

1.7.7 Thrusters effect

When deemed necessary, for ships on which dynamic positioning is installed, the thrusters negative effect on stability is to be taken into account.

2 Intact stability

2.1 General stability criteria

2.1.1 The stability criteria included herein, or the criteria contained in [2.2], [2.3] or [3], as applicable, is to be satisfied for all loading conditions intended for lifting with the lifting appliance and its load at the most unfavourable positions.

For the purpose of this Section, the lifting appliance, its load(s) and their centre of gravity (COG) should be included in the displacement and centre of gravity of the ship, in which case no external heeling moment/heeling lever is applied.

2.1.2 For the loading conditions stated in [1.3], the following intact stability criteria are to be complied with:

a) the equilibrium heeling angle φ_1 shall not be greater than the maximum static heeling angle for which the lifting device is designed and which has been considered in the approval of the loading gear.

b) during lifting operations in non-exposed waters, the minimum distance between the water level and the highest continuous deck enclosing the watertight hull, taking into account trim and heel at any position along the length of the ship, shall not be less than 0,50 m.

c) during lifting operations in exposed waters, the residual freeboard shall not be less than 1,00 m or 75% of the highest significant wave height H_S, in (m), encountered during the operation, whichever is greater.

2.2 Lifting operations conducted under environmental and operational limitations

2.2.1 *For lifting conditions carried out within clearly defined limitations set forth in a), the intact criteria set forth in b) may be applied instead of the criteria included in [2.1]:*

a) The limits of the environmental conditions should specify at least the following:

- *the maximum significant wave height*
- *the maximum wind speed (1 minute sustained at 10 m above sea level), see guidance in [1.7]*

The limits of the operational conditions should specify at least the following:

- *the maximum duration of the lift*
- *limitations in ship speed*
- *limitations in traffic/traffic control*

b) The following stability criteria apply with the lifted load is at the most unfavourable position:

- *the corner of the highest continuous deck enclosing the watertight hull shall not be submerged*
- $A_{RL} \geq 1,40 \times A_{HL}$

  Where:

  A_{RL} : *The area under the net righting lever curve, corrected for crane heeling moment and for the righting moment provided by the counter ballast, if applicable, extending from the angle φ_1 to the angle φ_2, see Fig 1*

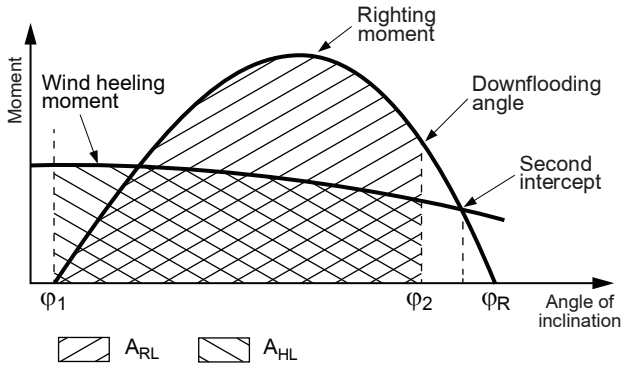
  A_{HL} : *The area below the wind heeling lever curve due to the wind force applied to the ship at the maximum wind speed specified in a), see Fig 1*

  φ_1 : *Equilibrium heeling angle*

  φ_2 : *The lesser between the angle of down flooding (φ_F), the angle of vanishing stability (φ_R), and the second intersection of the righting lever curve with the wind heeling lever curve.*

c) The area under the net righting lever curve from the equilibrium heel angle, φ_1, to the down flooding angle, φ_F, or 20°, whichever is less, shall be at least 0,03 m rad.

Figure 1 : Intact criteria under Environmental and Operational limitations



2.3 Intact stability criteria in the event of sudden loss of the lifted load

2.3.1 *A ship engaged in a lifting operation and using counter ballasting should be able to withstand the sudden loss of the hook load, considering the most unfavourable point at which the hook load may be applied to the ship (i.e. largest heeling moment).*

In this case, the following intact stability criteria are to be complied with in addition to those in [2.1] and [2.2].

2.3.2 *For this purpose, the area on the side of the ship opposite to the lift (Area 2) is to be greater than the residual area on the side of the lift (Area 1), as shown in Fig 2, by an amount given by the following:*

- *Area 2 > 1,4 × Area 1, for lifting operations in waters that are exposed*
- *Area 2 > 1,0 × Area 1, for lifting operations in waters that are not exposed*

Where:

GZ_1 : *Net righting lever (GZ) curve for the condition before loss of crane load, corrected for crane heeling moment and for the righting moment provided by the counter ballast if applicable.*

GZ_2 : *Net righting lever (GZ) curve for the condition after loss of crane load, corrected for the transverse moment provided by the counter ballast if applicable.*

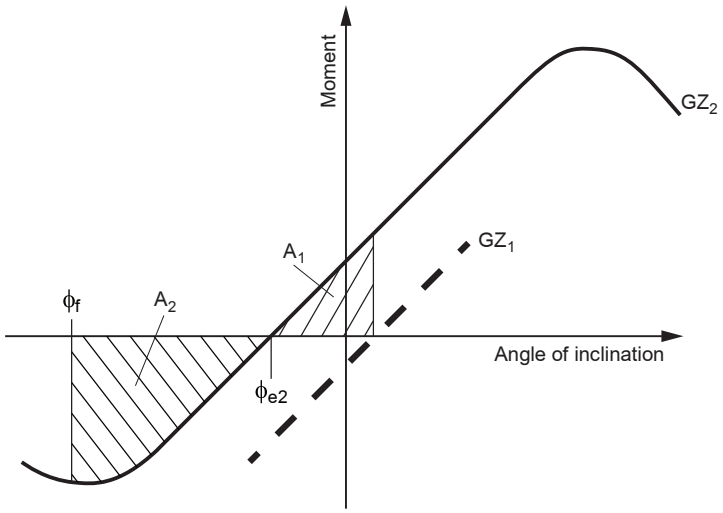
φ_{e2} : *The angle of static equilibrium after loss of crane load.*

φ_f : *The angle of down-flooding or the heel angle corresponding to the second intersection between heeling and righting arm curves, whichever is less.*

The term "net righting lever" means that the calculation of the GZ curve includes the ship's true transverse centre of gravity as function of the angle of heel.

Note 1: When, after the loss of the lifted load, the ship still heels to the side of the lift, there is no need to comply with above criteria.

Figure 2 : Righting moment curve after sudden loss of load



3 Intact stability - alternative method

3.1 General

3.1.1 *The criteria in this Article may be applied to a ship engaged in a lifting operation, as an alternative to the criteria in [2.1] to [2.3], as applicable.*

For the purpose of this section and the alternative stability criteria set out in [3.2], the lifted load which causes the ship to heel is translated for the purpose of stability calculation to a heeling moment/heeling lever which is applied on the righting lever curve of the ship.

3.1.2 *The heeling moment applied to the ship due to a lift and the associated heeling lever should be calculated using the following formulae:*

$HM_\varphi = P_L \cdot y \cdot \cos\varphi$

$HL_\varphi = HM_\varphi / \Delta$

where:

HM_φ : *heeling moment, in t.m, due to the lift at* φ

P_L : *vertical load, in t, of the lift, as defined in [1.4.2]*

y : *transverse distance, in m, of the lift, metres, as defined in [1.4.2]*

φ : *angle of heel*

HL_φ : *heeling lever, in m, due to the lift at* φ

Δ : *displacement, in t, of the ship with the load of the lift.*

3.2 Alternative stability criteria

3.2.1 *The equilibrium heel angle* φ_e *referred to in this Article means the angle of first intersection between the righting lever curve and the heeling lever curve.*

3.2.2 *During the lifting operation, the following stability criteria apply:*

a) *the residual righting area below the righting lever and above the heeling lever curve between* φ_e *and the lesser of 40° or the angle of the maximum residual righting lever should not be less than:*
   - *0,080 m rad, if lifting operations are performed in waters that are exposed, or*
   - *0,053 m rad, if lifting operations are performed in waters that are not exposed.*

b) *in addition, the equilibrium angle is to be limited to the lesser of the following:*
   - *10 degrees*
   - *the angle of immersion of the highest continuous deck enclosing the watertight hull*
   - *the lifting appliance allowable value of trim/heel (data to be derived from sidelead and offlead allowable values obtained from manufacturer).*

3.2.3 *For application of the criteria contained in [2.3] involving the sudden loss of load of the lift in which counter-ballast is used, the heeling levers that include the counter-ballast should be calculated using the following formulae (see Fig 3):*

$$CHL_1 = \frac{(P_L \cdot y - CBM)}{\Delta} \cos\varphi$$

$$CBHL_2 = \frac{CBM \cdot \cos\varphi}{\Delta - P_L}$$

Where:

CBM : *the heeling moment, in t.m, due to the counter-ballast*

CHL_1 : *combined heeling lever, in m, due to the load of the lift and the counter-ballast heeling moment at the displacement corresponding to the ship with the load of the lift*

$CBHL_2$: *heeling lever, in m, due to the counter-ballast heeling moment at the displacement corresponding to the ship without the load of the lift.*

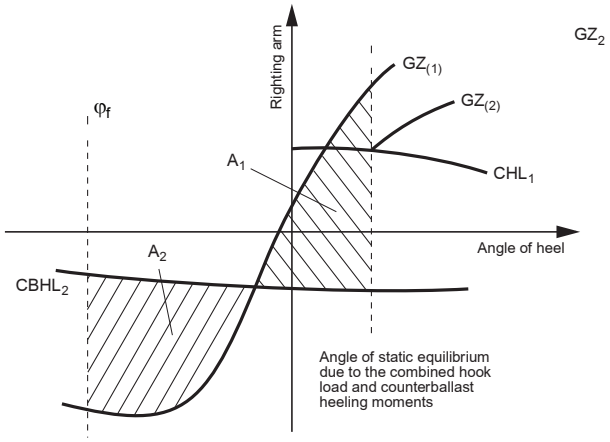
For this purpose, the area on the side of the ship opposite from the lift (Area 2) in Fig 3 should be greater than the residual area on the side of the lift (Area 1) by an amount given by the following:

Area 2 – Area 1 > K

where

- *K = 0,037 m.rad, for a lifting operation in waters that are exposed, and*
- *K = 0,0 m.rad, for a lifting operation in waters that are not exposed.*

Figure 3 : Alternative criteria - sudden loss of load



4 Additional intact stability criteria for crane overload test

4.1 General

4.1.1 Intact stability check during crane overload testing may be deemed necessary.

As guidance, ships which have onboard cranes of significant size compared to the ship general particulars or/and in case the intact stability particulars during normal crane operations are deemed marginal, the residual intact stability during crane overload test is to be checked and is in principle not to be less than that required by [2.1] and [2.3] as applicable.

5 Alternative damage stability for lifting operations for ships where additional class notation SDS is assigned

5.1 Application

5.1.1 The damage stability criteria specified in this Article may apply to ships operating within a field such as a windfarm and within the limiting conditions as defined in [5.1.2], in lieu of the damage stability criteria applicable as per Pt B, Ch 3, Sec 3, subject to Society agreement.

5.1.2 These alternative damage stability criteria may be applied when the following conditions are satisfied:

- the ship is operating in an area subject to fully controlled traffic (e.g. wind farm)
- maximum wave significant height and wind speed is limited

5.2 Data to be submitted

5.2.1 The following data are to be submitted:

- limits of the environmental conditions:
  - the maximum significant wave height
  - the maximum wind speed (1 minute sustained at 10 m above sea level)
- limits of the operational conditions:
  - the maximum duration of the lift
  - limitations in ship speed
  - limitations in traffic/traffic control

5.3 Extent of damage

5.3.1 The following extent of damage is to be assumed to occur between effective watertight bulkheads:

a) vertical extent: from the baseline upwards without limit

b) horizontal penetration measured inboard from the side of the ship perpendicularly to the centreline at the summer load waterline level: 1,5 m.

5.3.2 The distance between effective watertight bulkheads or their nearest stepped portions which are positioned within the assumed extent of horizontal penetration are not to be less than 3 m; where there is a lesser distance, one or more of the adjacent bulkheads are to be disregarded.

5.3.3 Where damage of a lesser extent than defined in [5.3.1] results in a more severe condition, such lesser extent is to be assumed.

5.3.4 All piping, ventilation systems, trunks, etc., within the extent of damage referred to in [5.3.1] are to be assumed to be damaged. Positive means of closure are to be provided at watertight boundaries to prevent the progressive flooding of other spaces which are not managed.

5.4 Alternative damage stability criteria

5.4.1 The following stability criteria in the final stage of flooding are to be complied with:

- the final waterline is to be below the lower edge of any opening through which progressive flooding may occur.
- the equilibrium heeling angle is to be less than 15 degrees, or 17 degrees if no deck immersion occurs
- the righting lever curve is to have a range of positive stability of at least 16° and the GZ max is not to be less than 0.12 m within this range
- unprotected openings are not to become immersed within the prescribed minimum range of positive stability unless the space in question has been included as a floodable space in calculations for damage stability.

Section 4 Structural Assessment

1 General

1.1 Application

1.1.1 This Section provides requirements for the structural assessment of the foundations of the lifting equipment, the devices for stowage during transit and the connecting bolts between the lifting equipment and the foundations.

1.1.2 In addition, when the lifting operations are inducing significant hull girder stresses, the hull girder loads due to the lifting operations are to be considered in the hull scantling verification, as specified in Article [4].

2 Structural design principles

2.1 General

2.1.1 The foundations of the lifting equipment are considered as integral part of hull.

2.1.2 The foundations means the structural elements permanently connected by welding to the hull (for instance crane pedestals, masts, derrick seatings, etc...) to the exclusion of the cranes themselves, derrick booms, ropes, rigging accessories, slewing rings and, generally, any dismountable parts.

2.1.3 In general, ships performing lifting operations are to be longitudinally framed.

2.2 Materials

2.2.1 Structural category and steel grades for the foundations of the lifting equipment

The steel grade of the structural elements of the foundation is to comply with Pt B, Ch 4, Sec 1, taking into account the structural categories given in Tab 1.

Table 1 : Guidance for structural categories

Category / Class	Structural elements
Secondary / Class I	crane resting support
Primary / Class II	crane pedestal and its foundation
Special / Class III	insert plate of deck plating in way of crane pedestal

2.3 Crane pedestal

2.3.1 In general, crane pedestal is to be continuous through the deck.

In this case, the pedestal is to be checked against through thickness stress in accordance with Pt B, Ch 4, Sec 1, [2.6].

2.3.2 If the pedestal is interrupted on deck, the continuous deck plate is to be made of Grade Z steel quality in way of the crane pedestal.

2.4 Mobile lifting equipment

2.4.1 When the lifting equipment is fastened on deck with a lashing arrangement, the description of the sea fastening is to be submitted.

2.4.2 A cargo securing manual, as defined in NI429, Guidelines for the Preparation of the Cargo Securing Manual, is to be submitted.

2.5 Devices for equipment stowage

2.5.1 The structure of the locking device used for the stowage of the lifting equipment during transit is to comply with the relevant provisions of Part B.

Environmental loads during transit are to be considered.

2.5.2 The hull is to be strengthened in way of the crane stowage device.

3 Design loads

3.1 General

3.1.1 The design loads defined in [3.2] to [3.6] are to be provided by the Interested Party.

3.2 Hull girder loads

3.2.1 Still water loads

The still water bending moment and shear forces due to lifting operations are to be added to the moment and shear forces due to the ship weight distribution.

3.2.2 Wave loads

The wave hull girder loads corresponding to the maximum sea state defined in the operational limitations of the lifting equipment are to be obtained through an hydrodynamic analysis.

When an hydrodynamic analysis is not performed, the wave hull girder loads are to be evaluated through assumptions to be defined in agreement with the Society.

3.2.3 Torsional moment

When deemed necessary, the hull girder strength is to be checked against torsion.

3.3 Loading conditions

3.3.1 The loading conditions and associated design loads to be considered for the calculation of the foundations are given in Tab 2.

Table 2 : Guidance for the design loading conditions

Loading condition	Load case	Design loads		Environmental load	Basic allowable stress factor **(1)**
		hoisting load	Hull girder loads		
Transit	Design	none	still water + wave	extreme situation	**(2)**
Operating - static	Static	SWL	still water only	none	α = 0,6
Operating - dynamic	Design	SWL x DAF	still water + wave	operating conditions	α = 0,8
Accidental situation	Accidental	Maximum holding load	still water + wave	accidental situation	α = 1,0
Testing condition	Testing	Overload test	still water only	none	α = 0,9

(1) Factor α is given in this Table as an indication of safety level for each design loading condition.
(2) Structural assessment is to comply with Part B, Chapter 7.

3.4 Load cases

3.4.1 The foundations of the lifting appliance and the stowage device are to be designed for at least the load cases defined in [3.4.2] to [3.4.5].

3.4.2 Load cases 1 “static” (still water)

These load cases refer to the most unfavourable combinations of the fixed and operational loads.

The most severe arrangement of operational loads, in particular with respect to moving equipment and dynamic operational loads, is to be considered.

For these load cases no environmental load is taken into account.

3.4.3 Load cases 2 “design” (with environment)

These load cases refer to the most unfavourable combinations of the fixed, operational and environmental loads, including:

- the extreme (severe storm) environmental loads with fixed and associated operational loads
- environmental loads specified by the Operating Manual as constituting limits for a condition of operation of the unit or for the operation of a particular equipment or system, with corresponding fixed and operational loads.

3.4.4 Load cases 3 “accidental”

The accidental loads are to be combined with the fixed, operational and associated environmental loads corresponding to the nature of each accidental load.

3.4.5 Load cases 4 “testing”

Testing loads are to be considered for the design of structures being tested and of the structures supporting the items to be tested, and also, as necessary, for design of overall structure.

3.5 Lifting loads

3.5.1 Vertical loads

As a minimum, the following vertical loads, referring to the coordinate system of the ship, are to be considered:

- the maximum static load equal to the Safe Working Load (SWL) in calm sea, within the geometrical limits of the crane utilisation chart
- the maximum dynamic hoisting loads equal to the maximum Dynamic Amplification Factor (DAF) times the SWL associated with the most severe sea state allowed, within the geometrical limits of the crane utilisation chart
- the maximum holding load corresponding to either the maximum brake capacity or the overload release value

Note 1: The foundation of the lifting equipment is to withstand the design overload value referred to in the rules for certification applicable to the lifting equipment.

- the overload test value of the lifting equipment.

3.5.2 Horizontal loads

Horizontal loads, referring to the coordinate system of the ship, due to lifting operations are to be accounted for in the structural assessment of the foundation.

3.5.3 Dynamic amplification factor

Dynamic amplification factors are applied on static loads to account for the effect of:

a) lifting equipment self-motions

b) ship motions and accelerations.

The dynamic amplification factors are to be based on the technical standard used for the certification of the lifting equipment.

Additional requirements applicable to subsea lifting are to be complied with, when relevant.

3.5.4 Boom configuration

The design loads are to be applied at the most unfavourable positions of the crane boom within the geometrical limits of the crane utilisation chart.

3.6 Environmental loads

3.6.1 The environmental loads include:

- wind loads acting on the crane and the lifted cargo, as specified in [3.6.2]
- the ship acceleration and motion corresponding to the allowable sea state for a given operation (DAF) as defined in [3.5.3]
- the hull girder wave loads corresponding to the allowable sea state for a given operational limitation, as specified in [3.2.2].

3.6.2 Wind loads

The wind velocity to consider for structural assessment of the foundation are given in Tab 3.

Note 1: the design wind velocity corresponds to an average velocity over 1 minute and taken at 10 m above sea level.

The wind loads acting on the lifted cargo are also to be considered.

Table 3 : Wind velocity

Condition of operation	Wind velocity
Transit	51,5 m/s
Operating	20 m/s or from lifting equipment operating manual, whichever is the greatest

4 Hull girder strength

4.1 Principles

4.1.1 The hull girder strength is to be checked in accordance with Pt B, Ch 6, Sec 1 with the loads due to lifting operations defined in [3.2].

4.2 Hull girder stress

4.2.1 General

The stresses due to hull girder loads are to be considered in the longitudinal members of the lifting equipment foundations.

5 Allowable stress

5.1 General

5.1.1 For lifting conditions, the foundations of the lifting equipment are to comply with allowable stress criteria defined in the present Article.

5.1.2 Allowable stress for transit conditions are to be taken as per the rules applicable to the hull in Part B.

5.2 Criteria

5.2.1 The equivalent stress σ_{VM} is not to exceed the allowable stress σ_{perm}, for the loading condition considered, according to the following formula:

$\sigma_{VM} \leq \sigma_{perm}$

where:

σ_{perm} : Allowable stress, given by:

$\sigma_{perm} = 1,1\ \alpha\ R_f$

α : Basic allowable stress factor defined in [5.3].

R_f : Material reference stress defined in [5.4]

σ_{VM} : Equivalent stress defined in [5.5]

5.2.2 When the stresses are obtained through a fine mesh Finite Element Model, the Society may give consideration to small hot spot areas not satisfying above stress criteria, providing that the following criteria are fulfilled:

- Equivalent Von Mises stress σ_{VM} at the centroid of elements of a peak stress region of no more than 2t x 2t, with t being the thickness of the elements, is to comply with the following criteria:

  $\sigma_{VM} \leq 1,3\ \alpha\ R_f$
- outside the peak stress region of 2t x 2t, the Von Mises stress is to comply with [5.2.1]
- a plastic stress redistribution should be demonstrated to the satisfaction of the Society or obvious from engineering judgement.

5.3 Basic allowable stress factor

5.3.1 The basic allowable stress factor α is to be taken as follows:

a) In general:
   - for load case 1 (“static”):

     $\alpha = 0,6$
   - for load case 2 (“design”):

     $\alpha = 0,8$
   - for load case 3 (“accidental”):

     $\alpha = 1,0$

b) For specific calculations:
   - for load case 4 (“testing”):

     $\alpha = 0,9$

Note 1: The definitions of the above load cases are provided in Article [3].

5.4 Material strength

5.4.1 The reference stress of material, R_f, is defined by:

$$R_f = \min\left(R_{eG}, \frac{R}{1,2}\right)$$

where:

R_{eG} : Minimum specified yield stress of the material

R : Tensile strength of the material.

5.4.2 For hull steels, as defined in NR216 Materials and Welding, R_f is equal to the minimum specified yield strength of steel.

5.4.3 For light alloy materials (aluminium), when used in non-welded constructions, R_f is to be defined taking into account the material properties in the specified condition of delivery. For welded aluminium, R_f is to be taken based on R_{eG} in the annealed condition (refer to NR216 Materials and Welding).

5.5 Equivalent stress

5.5.1 For uniaxial stress condition (e.g. obtained by beam calculation), the following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

Above stresses are the result of the addition of overall stresses and grillage stresses.

5.5.2 For biaxial stress condition (e.g. obtained by finite element calculation with plate elements), the following stress components are to be calculated at the centroid of the mid-plane layer of each element:

- the normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

The stresses in the element under study, include the effects of both overall and local loads.

6 Buckling

6.1 General

6.1.1 As possible, the risk of instability (buckling) of structural elements is to be avoided or minimised by adequate structural arrangement (e.g. by avoiding large unstiffened panels or members with high slenderness, by the proper orientation of stiffeners with respect to direction of compressive stresses, etc.) and by detailing (e.g. by providing lateral restraint by tripping brackets, or additional members).

6.1.2 The buckling strength of structural elements is to be ascertained considering the most unfavourable combinations of loads likely to occur, with respect to possible modes of failure.

6.1.3 For unstiffened or ring-stiffened cylindrical shells, both local buckling and overall buckling modes are to be considered for buckling strength assessment.

6.1.4 For stiffened panels, buckling check is to be performed in accordance with NR615 Buckling Assessment of Plated Structures.

The buckling of tubular members is to be checked according to recognized codes or standards.

6.2 Buckling strength criteria

6.2.1 The buckling strength of structural elements is to be ascertained for the effect of stresses resulting from:

- compression induced by axial loads
- compression induced by bending in flanges and web of members
- shear
- external pressure
- localised compression loads.

6.2.2 The buckling capacity of structural elements for each failure mode is to be evaluated following recognised techniques, taking into account:

- potential overall and local failure mode(s)
- due allowance for the manufacturing and/or construction tolerances and residual stresses
- interaction of buckling with yielding
- when relevant, the interaction between overall and local buckling.

6.2.3 The buckling utilisation factor η of a structural element subject to lifting induced stresses is to satisfy the following criterion:

$\eta \leq \eta_{ALL}$

with:

$\eta_{ALL} = \alpha$

α : Basic allowable stress factor defined in [5.3.1].

The buckling utilisation factor η of the structural member is defined as the highest value of the ratio between the applied loads and the corresponding ultimate capacity or buckling strength obtained for the different buckling modes.

7 Fatigue

7.1 General

7.1.1 Structural details located between the connection flange with the lifting equipment and the strength deck are to be checked in accordance with NI 611 Guidelines for Fatigue Assessment of Ships and Offshore Units.

7.1.2 The justification of the long term distribution of fluctuating stress is to be provided.

Note 1: In the absence of data on loading conditions, assumptions may be taken from a recognized standard, e.g. API SPEC 2C Specification for Offshore Pedestal-mounted Cranes.

8 Welding

8.1 Welding

8.1.1 As a rule, full penetration welding is to be provided between crane pedestal and deck plate.

Section 5 Machinery and Systems

1 General

1.1 Essential service

1.1.1 Electrical installations related to the lifting equipment are to be considered as essential services according to Part C, Chapter 2.

1.2 Hazardous areas

1.2.1 As far as practicable, electrical installations intended for the lifting equipment should not be located in hazardous areas.

1.2.2 Where, due to the operational requirements, some electrical equipment is located in hazardous areas zone 1 or zone 2, it has to comply with the requirements for such equipment in hazardous areas, as defined in Pt C, Ch 2, Sec 1.

2 Position keeping

2.1 General

2.1.1 Vessels granted with the service notation **lifting** are to be able to safely maintain their position during lifting operations. This may be achieved with a passive mooring or a dynamic positioning system in accordance with [2.2].

2.2 Dynamic positioning

2.2.1 When the unit is fitted with a dynamic positioning system, it may be assigned the additional class notation **DYNAPOS** defined in Part A of the classification rules used for the supporting unit.

In this case, lifting units are to be granted with the additional class notation **DYNAPOS AM/AT**, completed by one of the following symbols:

- **R**, when the dynamic positioning is provided with redundancy means. In this case, IMO class 2 equipment is to be used.
- **RS**, when, in addition to symbol **R**, the redundancy is achieved using two systems or alternative means of performing a function physically separated. In this case, IMO class 3 equipment is to be used.

3 Power supply

3.1 General

3.1.1 When the ship main power plant is used to supply the lifting equipment, it shall have sufficient power to run simultaneously:

- the lifting equipment at its maximum rated load and nominal hook velocity
- the essential services
- the dynamic positioning system, when relevant
- the ballast system, when relevant.

3.1.2 The description of the power supply is to be submitted.

4 Lifting equipment controls

4.1 General

4.1.1 The commands on the lifting equipment operating position are to comply with NR526 or another recognized standard.

4.2 Overload prevention

4.2.1 *Each lifting appliance should be fitted, to the satisfaction of the Society, with a safety device to give the operator a continuous indication of hook load and rated load for each radius. The indicator should give a clear and continuous warning when approaching the rated capacity of the crane.*

4.3 Emergency system

4.3.1 Emergency lowering system and emergency stops are to comply with the requirements of the NR526 Certification of lifting appliances onboard ships and offshore units, or another recognized standard.

4.4 Communication means

4.4.1 The communication system is to be arranged for direct 2-way communication between the lifting equipment operating position and:

- the bridge or command centre of the supporting unit
- the dynamic positioning control stand.

Section 6 Initial Inspection and Testing

1 General

1.1 Application

1.1.1 The present Section provides requirements for inspection and testing of the lifting installations when first installed onboard or after re-installation.

1.1.2 The inspection and testing requirements of the present Section are provided as a minimum and in addition to the requirements of the rules or standards referred to in the lifting equipment certificate.

Any additional testing may be required to the satisfaction of the attending Surveyor.

1.1.3 These tests are to be conducted according to an inspection and testing specification which is to be submitted to the Society by the interested party.

The Society is to be duly informed of the time and place of the commissioning tests of the lifting equipment.

1.1.4 The specification of the commissioning tests of the lifting equipment should be approved by the certifying authority of the equipment.

2 Onboard testing

2.1 Lifting installations

2.1.1 Before putting into service, the inspection and testing of the lifting equipment is to include, as a minimum:

a) Verification of the presence onboard of the operating manual as defined in Ch 8, Sec 1.

b) Inspection of the structural arrangement and scantling of the foundations of the lifting equipment

c) General examination of the electrical cabling

d) Functional testing of the main and alternative two-way communication system at the lifting operating position.

e) Testing of the hydraulic installations

f) Load tests in accordance with the rules and standards referred to in the lifting equipment certificate:
   - Functional tests
   - Overload tests.

2.1.2 As a rule, all the connections between the supporting unit and the lifting equipment are to be presented for examination by the Surveyor.

Section 7 Self-Elevating Ships

1 General

1.1 Application

1.1.1 The present Section is applicable to ships or barges fitted with legs and capable of being lowered to the sea bed and of raising the hull above the sea level, hereafter defined as self-elevating ships (see [3.1]).

The present Section addresses the requirements regarding structural assessment of the hull in elevated position, the elevating system and the specific fire safety features.

1.1.2 Self-elevating ships complying with the requirements of this Section are eligible for the assignment of the additional service feature **self elevating** to complete the service notations assigned to the ship as defined in Pt A, Ch 1, Sec 2, [4.12].

1.1.3 The Party applying for classification is to provide the most unfavourable environmental conditions for which the self-elevating ship is designed, as stipulated in Article [6]. These conditions are to be reported in the Design Criteria Statement defined in [2.2].

All changes of the stipulated environmental conditions are to be submitted to the examination of the Society and the design criteria statement may be modified accordingly after approval of the design for the new conditions and, if applicable, execution of the necessary reinforcements.

1.2 Applicable rules and regulations

1.2.1 In addition to the requirements that ships are to comply with for granting a service notation defined in Pt A, Ch 1, Sec 2, [4.12], ships assigned with the additional service feature **self elevating** are to comply with:

- the requirements for hull structure listed in [1.2.2], taking into account the specific structural requirements for elevated position
- the requirements for machinery, electrical installations, and automation listed in [1.2.2], taking into account the specific requirements for jacking system
- the requirements for fire safety listed in Article [9].

1.2.2 Self-elevating ships are to comply with the relevant requirements of NR534, as specified in:

- Article [5] for structure design principles
- Article [6] for design and environmental conditions
- Article [7] for structural analysis, in elevated position (see [7.1]) or transit and installations conditions (see [7.2])
- Article [8] for jacking system
- Article [10] for construction survey.

Note 1: NR534 Rules for the classification of self elevating units - jackups and liftboats, as amended.

1.2.3 The attention is drawn to certain national or international regulations that may be required by the Administration.

Note 1: e.g. IMO MODU Code (IMO Resolution A.1023(26) - Code for the construction and equipment of mobile offshore drilling unit) applicable to self-elevating units.

2 Classification principles

2.1 Classification limits

2.1.1 Site conditions

It is incumbent to the owner or operator:

- to perform the necessary investigations, including environmental and geotechnical surveys, prior to operating the unit at a given site
- to ascertain that the actual conditions met at the contemplated operating site remain on the safety side when compared to the design data and assumptions (particularly those listed in the design criteria statement, as defined in [2.2]). Such site assessment is not part of the classification.

Classification does not cover the following items:

- assessment of sea bottom conditions and geotechnical investigations
- prediction of footing penetration during preloading

- the stability of the foundation after preloading
- assessment of the possible sea floor movement.

2.1.2 Operating procedures

Classification does not cover the procedures to be used for the unit positioning, leg jacking (lowering or elevating), preloading, jetting and other procedures related to operations.

It is the responsibility of the owner operator to ascertain that the said procedures and their implementation satisfy the design criteria of the ship and the design of the related equipment.

2.2 Design criteria statement

2.2.1 Classification is based upon the design data or assumptions specified by the party applying for classification in accordance with [1.1.3].

A design criteria statement is to list the service(s) performed by the ship and the design conditions and other assumptions on the basis of which class is assigned.

The design criteria statement is issued by the Society, based on the information provided by the party applying for classification.

The design criteria statement is to be incorporated in the operating manual (see [4.2]).

2.2.2 The description of the most unfavourable environmental conditions for which the ship is designed to operate in elevated position, as defined in [1.1.3] is to be included in the design criteria statement as per Article [6].

3 Definitions

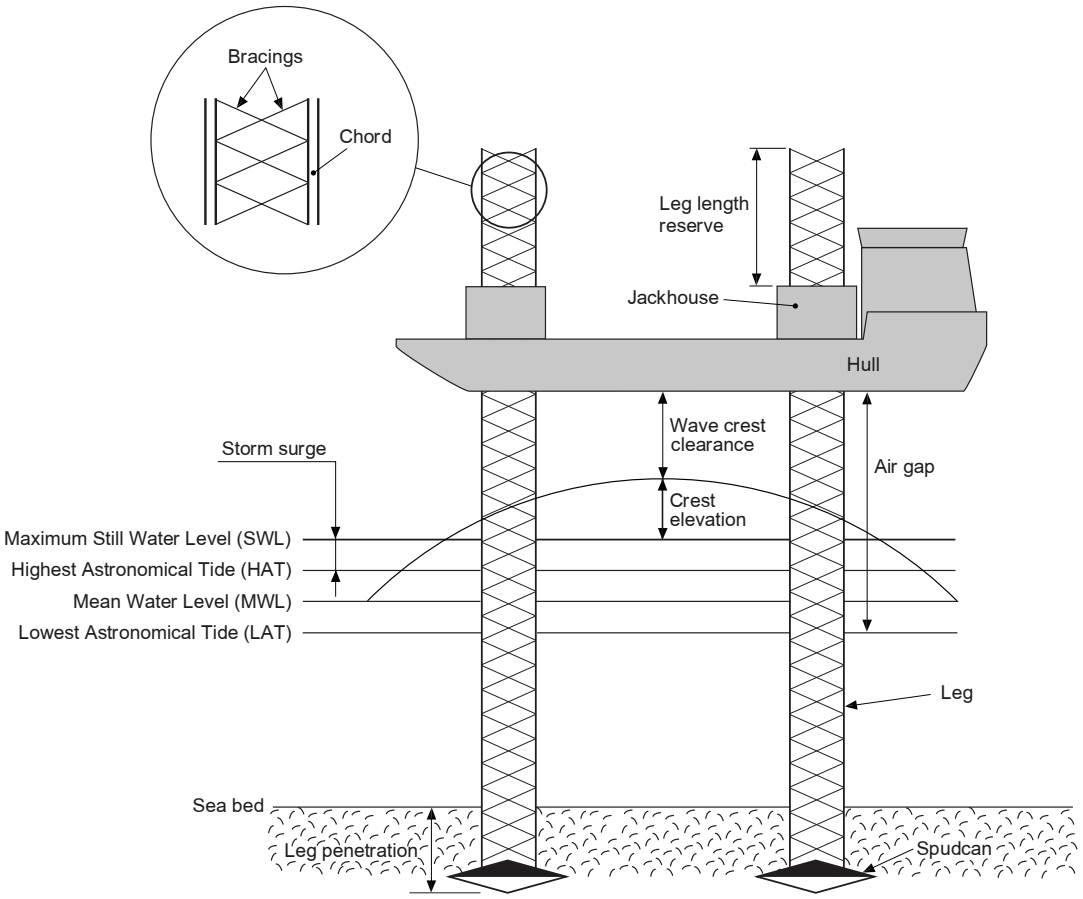
3.1 Self-elevating ship

3.1.1 A self-elevating ship is a ship or a barge fitted with legs and capable of being lowered to the sea bed and of raising the hull above the sea level (see Fig 1).

The legs may be:

- of a shell or truss type
- equipped with a lower mat, a spudcan, a gravity-based structure or with footings designed to penetrate the sea bed
- vertical or slanted.

Figure 1 : Self-elevating ship



3.2 Modes of operation

3.2.1 A self-elevating ship is designed to resist to the loads occurring during working, survival, transit, installation and retrieval modes:

- working mode: the ship is on location, supported on the sea bed to operate, and combined environmental and operational loading are within the appropriate design limits established for such operations
- survival mode: the ship is on location, supported on the sea bed and may be subjected to the most severe environmental loading for which it is designed
- transit mode: the ship moves from one location to another within the appropriate limits the ship is designed to
- installation mode: period when the ship is firstly lowering legs to the sea bed, secondly elevating hull at the required elevation above the sea level, and then preloading the legs to the extreme loading
- retrieval mode: period when the ship is lowering the hull and then elevating legs to be ready for transit mode.

3.3 Water levels, crest elevation and water depth

3.3.1 The reference water levels and crest elevation are defined as follows in the present Section (see Fig 1):

- mean water level (MWL): mean level between the highest astronomical tide (HAT) and the lowest astronomical tide (LAT)
- astronomical tidal range: range between the highest astronomical tide (HAT) and the lowest astronomical tide (LAT)
- maximum still water level (SWL): level at the highest astronomical tide (HAT) including storm surge
- crest elevation: height of wave crest above the SWL.

3.3.2 Except otherwise specified, the reference water depth to be considered is the distance between the sea bed and the SWL.

3.4 Configuration of a self-elevating unit in elevated position

3.4.1 The configuration of a self-elevating ship in elevated position is to be defined based on the site data associated with the ship's services, as specified in accordance with [1.1.3].

3.4.2 The configuration is defined with the following parameters (see Fig 1):

- leg penetration length: the leg penetration length is the maximum leg penetration into the sea bed, including the spudcan if any
- leg length reserve: the leg length reserve is the reserve above the upper guide to avoid any soil settlement or punch through and to provide a contingency in case the penetration exceeds the predicted one
- air gap: the air gap is defined as the distance between the underside of the hull and the lowest astronomical tide (LAT)
- wave crest clearance: the wave crest clearance is defined as the distance between the highest wave crest and the underside of the hull.

4 Documents to be submitted

4.1 General

4.1.1 Documents listed in Tab 1 are to be submitted for approval or information.

4.2 Operating manual

4.2.1 An operating manual, including instructions regarding the safe operation of the ship and of the elevating systems is to be placed on board.

The operating manual is to be, at all times, made available to all concerned. A copy of the operating manual is to be retained ashore by the owner of the ship or by his representatives.

The operating manual is to incorporate a dedicated section containing all the information relating to classification, particularly the environmental, loading and other design criteria, as well as the classification restrictions. The operating manual of a self-elevating ship is also to stipulate the instructions related to the transit conditions, the preloading and the emergency procedures in case of punch through.

It is the responsibility of the party applying for classification to prepare the contents of the operating manual.

4.2.2 The operating manual is to be submitted to the Society for review, this review being limited to check that the classification related material as mentioned above is consistent with the data given in the design criteria statement defined in [2.2].

4.2.3 The operating manual is to include the following information, where applicable:

- design limitations:
  - during transit (leg arrangement, rig and other equipment sea fastening)
  - during installation (leg lowering, preloading)

- on site
- during retrieval (hull lowering, leg retrieval)

- emergency procedures in case of punch through
- preload procedure
- or normal operation, information regarding the preparation of the ship to avoid structural damage during the setting or retraction of legs on or from the seabed, or during extreme weather conditions while in transit, including the positioning and securing of legs
- jacking gear main loading capacity in operating conditions
- maximum loading capacity in case of engaged fixation system
- design criteria statement including the classification restrictions, if any.

Table 1 : Documents to be submitted

No.	Document	A/I **(1)**
1	Operating manual as defined in [4.2]	A
2	Descriptions of the environmental loads including forces and moments from wind, waves, currents, ice, snow, earthquakes, as applicable as per [6.1]	I
3	Structural analysis of the unit in elevated position	I
4	Calculations of the unit resistance against overturning while resting on the sea bed in elevated position	I
5	Leg strength calculation in floating condition	I
6	Local strength calculations of: • legs • leg/hull connection • spudcans or bottom mat, if relevant • leg/spudcan or leg/mat connection, if relevant	I
7	Fatigue calculations of structural details, when relevant	I
8	Calculations of jacking systems and, if any, fixation systems	I
9	Calculations of segregation of loads between jacking and fixation systems, if relevant	I
10	General arrangement in elevated position	I
11	Drawings of the legs including: • for lattice legs: racks, chords, bracings and their connections • for shell type legs: shell plating, stiffeners, stringers, struts, connections of racks with shell plating and supporting leg rack members, potential openings, where relevant	A
12	Detailed drawings of the racks, if any, including their arrangement in transit and elevating conditions	A
13	Drawings of the footings (spudcans) or mats	A
14	Drawing of the leghouses and their attachments with the hull	A
15	Description of the jacking system as required in NR534, Section 10	**(2)**
16	Arrangement of the fire-fighting system in elevated position	A

(1) A : To be submitted for approval; I : To be submitted for information
(2) As per NR534, Sec 10, Tab 1

5 Structure design principles

5.1 General

5.1.1 The structure design principles applicable for the legs, the leghouses and the spudcans or bottom mat are to be in accordance with NR534, Section 2.

6 Design conditions

6.1 General

6.1.1 The design conditions applicable for the design of the legs, the leghouses, the spudcans or bottom mat and the elevating system, are to be in accordance with NR534, Section 3 as amended by [6.2] for elevated configuration, [6.3] for transit configuration and [6.4] for installation conditions.

6.2 Design conditions in elevated configuration

6.2.1 The most unfavourable wave, current and wind loads to be considered in elevated configuration are to be provided for both working and survival modes.

The area of operation and the description of sea state are to be provided in accordance with NR534, Section 4.

6.2.2 Environmental loads to be considered for accidental conditions such as a broken bracing on a lattice leg may be specially considered subject to the agreement of the Society.

6.3 Transit conditions

6.3.1 Simplified approach

The structural assessment of the legs, the leghouses, the spudcans or bottom mat and the elevating system in transit conditions, is to be based on the motions and accelerations derived from Part B, Chapter 5.

The greatest transversal and longitudinal metacentric heights (GMt ad GML) are to be taken from the trim and stability booklet for the calculation of the roll and pitch motions and accelerations.

Note 1: When the condition L/B > 5 is not met, a direct assessment of the environmental loads as per [6.3.2] is recommended.

6.3.2 Direct calculation approach

Subject to the agreement of the Society, specific environmental conditions may be considered for the structural assessment of the legs, the leghouses and the spud cans or bottom mat in transit conditions.

In that case, a hydrodynamic analysis is to be performed in accordance with NR534, Appendix 1.

6.4 Installation conditions

6.4.1 The impact loads during installation are to be taken into account as per NR534, Sec 6, [5].

7 Structural analysis

7.1 Structural analysis in elevated position

7.1.1 The structural analysis in elevated position of the legs, the leghouses, the spudcans or bottom mat, the elevating system and the hull, are to be conducted in accordance with NR534, Section 5, considering the wave and wind loads defined in [6.2].

7.1.2 When the self-elevating ship is fitted with lifting appliances intended to be used in elevated position, the lifting loads, defined in Sec 4, [5] are to be taken into consideration for the structural assessment of the elevated hull, the legs and the leghouses.

7.1.3 When fatigue calculations are to be submitted in accordance with NR534, Sec 5, [6.5], the damage ratio criteria are to be selected among the ones applicable to the details accessible for dry inspection.

7.2 Structural analysis in transit conditions and installations conditions

7.2.1 The legs, the leghouses, the spudcans or bottom mat and the self-elevating system are to be designed to sustain the loads induced by the ship motions and accelerations in transit considering the design loads defined in [6.3] and the loads induced by impact, preloading and punch through during installation phase.

7.2.2 The leg structure is to be examined in transit according to the inertia and wind loads distributed along the legs.

7.2.3 The forces and moments induced by the legs are to be considered for the verification of local reinforcements in way of the guides.

7.2.4 The structural assessment to be performed on the legs, the leghouses and the spudcans or bottom mat, are described in NR534, Sec 6, [3], exclusive of the hull and superstructure design requirements.

7.2.5 Spudcans and bottom mat scantling is also to comply with requirements from NR534, Sec 6, [7.2].

8 Jacking system

8.1 General

8.1.1 The design and construction of the jacking system is to comply with the requirements of NR534, Section 10.

8.2 Electricity and automation

8.2.1 The jacking system is to be considered as an essential service.

9 Fire and safety

9.1 Firefighting water supply

9.1.1 At least two water supply sources (sea chests, valves, strainers and pipes) are to be provided and be so arranged that one supply source failure will not put all supply sources out of action.

The following additional fire water supply measures are to be provided:

- in elevated position, water is to be supplied from sea water main filled by at least two submersible pumping systems. One system failure is not to put the other system(s) out of function
- water is to be available while the ship is lifting or lowering. The water stored is to be not less than 40 m^3 plus the engines cooling water consumptions before the ship is lifting or lowering. Alternatively, water may be supplied from buffer tank(s) in which the sea water stored is not less than the quantity mentioned above.

10 Construction survey

10.1 Self-elevating system

10.1.1 The construction survey of the self-elevating system, the legs, the leghouses and the spudcans or the bottom mat is performed in accordance with NR534, Section 9.

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 9
SEMI-SUBMERSIBLE CARGO SHIPS

Section 1 General

Section 2 General Arrangement

Section 3 Stability, Subdivision and Load Line

Section 4 Hull Structure

Section 5 Machinery and Systems

Section 6 Electrical Installations and Controls

Section 7 Safety Features

Section 8 Initial Inspection and Testing

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the present Chapter are eligible for the assignment of the service notation **semi-submersible cargo ships**, as defined in Pt A, Ch 1, Sec 2, [4.2.9].

The service notation **semi-submersible cargo ship** is to be completed by:

- the additional service feature **heavycargo [AREA1, X1 kN/m² - AREA2, X2 kN/m² - ...]** as defined in Pt A, Ch 1, Sec 2, [4.16.11]
- one of the additional class notations **LI-HG-S2** or **LI-HG-S3**, as defined in Pt A, Ch 1, Sec 2, [6.16.1], in compliance with Ch 9, Sec 3, [1].
- the additional class notation **SDS**, as defined in Pt A, Ch 1, Sec 2, [6.17.1], in compliance with the damage stability requirements specified in Ch 9, Sec 3.

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1 and specific requirements for initial inspection and testing as defined in Ch 9, Sec 8.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 m	• Part B • Ch 9, Sec 2	• NR566 • Ch 9, Sec 2
	L < 65 m	• NR600 • Ch 9, Sec 2	• NR566 • Ch 9, Sec 2
Stability		• Part B • Ch 9, Sec 3	• NR566 • Ch 9, Sec 3
Structural assessment	L ≥ 65 m	• Part B • Ch 9, Sec 4	• Part B • Ch 9, Sec 4
	L < 65 m	• NR600 • Ch 9, Sec 4	• NR600 • Ch 9, Sec 4
Machinery and systems		• Part C • Ch 9, Sec 5	• NR566 • Ch 9, Sec 5
Electrical installations and automation		• Part C • Ch 9, Sec 6	• NR566 • Ch 9, Sec 6
Safety features		• Part C • Ch 9, Sec 7	• NR566 • Ch 9, Sec 7
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT. NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m			

1.2 Scope

1.2.1 General

This Chapter addresses specific requirements to:

- load line and stability criteria for transit and temporary submerged conditions
- ballast system and auxiliary equipment
- structural assessment of the hull in the temporary submerged conditions
- electrical installations
- safety features
- sea trials.

1.2.2 Submerged conditions

a) Stability:

The stability verification required in this Chapter is limited to the assumptions made on some typical floating cargoes as mentioned in the stability booklet.

As a rule, the stability and buoyancy are to be checked before any submersion operation with the actual description of the floating cargo, as specified in Ch 9, Sec 3.

b) Bottom contact:

For units requiring sea bottom contact when submerging, the soil is to be surveyed to obtain information on the character of the soil and to localize obstacles possibly present.

c) Environmental conditions:

Limitations on the environmental conditions (waves, wind and current) to carry out the submersion procedure in a safe and controllable manner, taking into account the actual behaviour of the ship and the floating cargo, are under the responsibility of the operator of the ship.

1.3 Definitions

1.3.1 Transit condition

Transit condition means all ship movements from one geographical location to another.

1.3.2 Temporary submerged condition

Temporary submerged condition means any situation where the semi-submersible cargo ship has its cargo deck under the sea surface.

1.3.3 Maximum submerged draft

The maximum submerged draft is the distance, in m, measured vertically from the moulded base line to the uppermost considered waterlines in temporary submerged conditions at the relevant longitudinal position.

The maximum submerged draft may be:

- the maximum submerged draft at midship taking into account to the uppermost considered waterline with no trim, or
- the maximum submerged draft at fore end (FE) taking into account the maximum negative trim of the ship, or
- the maximum submerged draft at aft end (AE) taking into account the maximum positive trim of the ship.

1.3.4 Cargo deck

The cargo deck is the deck on which the floating cargo is being transported. It is generally equivalent to the freeboard deck as defined in the International Convention on Load Lines 1966, as amended.

1.3.5 Central ballast control station

The central ballast control station is a control station from which the submersion operations are performed.

2 Documents to be submitted

2.1 General

2.1.1 The documents listed in Tab 2 are to be submitted.

Relevant additional drawings and calculation notes may be requested by the Society in complement to the hereafter mentioned documents.

2.2 Submersion operating manual

2.2.1 A submersion operating manual including the following is to be submitted:

- stability assessment method
- procedure for ballast operations including the filling sequence and the designation of the pumps and tanks used simultaneously
- definition of the ballast capacity with respect to associated type of operation (float-on/float-off or load-on/load-off) and for the different failure modes defined in Ch 9, Sec 5, [2.2]
- commissioning procedure
- contingency plan.

Table 2 : Document to be submitted

No.	Documents to be submitted	I/A **(1)**
1.1	General arrangement showing the maximum submerged draft	I
1.2	Submersion operating manual	I
Stability		
2.1	Trim and stability booklet	A
2.2	Loading instrument certification booklet	A
2.3	Loading instrument operating procedure when cargo is considered buoyant (see Ch 9, Sec 3)	I
2.4	Justification of the reserve buoyancy	I
Structure		
3.1	Justification of the hull girder loads in limited environmental conditions, when relevant	I
3.2	Description of the connection of the buoyancy casings on deck	A
3.3	Fatigue calculations, when relevant	A
Machinery and systems		
4.1	Description of the ballast system (single line diagram, specifications, failure modes etc.)	A
4.2	Owner performance request of the ballast system, if any, for each failure mode	I
4.3	Ballast system FMEA	I
4.4	Planned Maintenance System of the ballast system	I
4.5	Overflow tank drainage capacity calculations	I
4.6	Arrangement for hydraulic and pneumatic controlled valves	A
Electrical installations		
5.1	Description of electrical arrangement principles, failure scenarios, redundancy principles, emergency arrangement, etc.	A
5.2	Power supply and control system diagrams of the ballast system	A
5.3	Description of the draft gauging system	I
5.4	Description of the ballast tanks gauging system	I
Safety features		
6.1	Drawing showing the means of escape	A
6.2	Description of the means of fire-fighting for the open deck	A
6.3	Description of the arrangements for life-saving appliances	I
(1) A : To be submitted for approval; I : To be submitted for information		

Section 2 General Arrangement

1 General

1.1 Draft marks

1.1.1 Accurate draft marks are to be positioned on the hull and casings in order to remain visible in temporary submerged conditions and with the maximum trim.

The draft marks and gauges are to be positioned sufficiently at the ends of the ship in order that the trim can be read accurately.

As a rule, the draft scales are to extend above the maximum submerged draft with a height equal to:

- 1,0 m, or
- 0,75L / 100,

whichever is the greater

Draft marks above the summer load line should be highly visible with indicating figures 0,5 m in height, 0,5 m apart.

1.1.2 The maximum submerged draft is to be clearly indicated with a mark near each draft scale.

1.1.3 In addition to the above, automatic draft gauges and alarms are to be provided as defined in Ch 9, Sec 6.

2 Ballast system arrangement

2.1 General

2.1.1 Requirements for the ballast system are given in Ch 9, Sec 5.

2.1.2 Special arrangement to reduce the air entrapped in the ballast tanks are to be considered.

2.2 Central ballast control station

2.2.1 A central ballast control station is to be provided.

2.2.2 The central ballast control station is to be located above the maximum submerged draft and in a space not within the assumed extent of damage referred to in Ch 9, Sec 3, [6].

2.2.3 The central ballast control station is to contain all means necessary to conduct the submersion operation as defined in Ch 9, Sec 5.

Section 3 Stability, Subdivision and Load Line

1 General

1.1 Loading instrument

1.1.1 General

A loading instrument is to be provided on-board and accessible from the central ballast control station.

The loading instrument is to comply with Pt B, Ch 1, Sec 5, according to the assigned additional class notation **LI-HG-S2** or **LI-HG-S3**, and also with the additional requirements of the present Section.

Note 1: When the loading instrument allows the definition of a buoyant cargo and/or damage cases, the approval is to be specially considered.

1.1.2 Ballast gauging system

It is recommended that the loading instrument be connected to the ballast tank monitoring system so as to check the stability using the actual filling level values.

1.1.3 Transit conditions

When the cargo is considered buoyant in transit conditions, a procedure describing the input of the new set of data into the loading instrument is to be submitted.

The procedure should include the definition of the new buoyant volume and of the new damage cases under the provisions of [4.2].

1.1.4 Temporary submerged conditions

The loading instrument should be able to perform simulations of the ballast loading sequence and to check the stability criteria for the intermediate conditions during submersion operation.

The loading instrument is to be able to perform stability verification up to the maximum submerged draft and the maximum trim.

1.2 Stability verification in temporary submerged conditions

1.2.1 In addition to the typical loading conditions assumed for the temporary submerged condition in the trim and stability booklet defined in [2.2], specific stability calculations are to be performed before any submersion operation.

A description of the method used for the assessment of stability in the temporary submerged conditions is to be submitted to the Society.

1.3 Submersion procedure

1.3.1 A detailed procedure of the ballasting operation during submersion operation is to be submitted to the Society for the typical loading conditions assumed in the trim and stability booklet.

The procedure should include the sequence of ballast tank filling and stability verification for several intermediate stages.

2 Loading conditions

2.1 Transit conditions

2.1.1 The trim and stability booklet is to include the loading conditions specified in Part B, Chapter 3 for the transit conditions.

Loading conditions with typical cargoes are to be submitted, including the full draft condition.

The windage area of the deck cargo is to be considered.

Buoyancy of the deck cargo may be considered subject to the provisions detailed in Articles [3] and [4].

2.2 Temporary submerged conditions

2.2.1 The trim and stability booklet is to include the following temporary submerged conditions:

- no cargo on deck
- typical loading conditions including buoyant cargo(es) on deck.

The loading conditions are to include initial transit draft and maximum submerged draft with several intermediate stages.

Several trim values are to be considered, including maximum trim.

The free surface effect resulting from partial filling of the ballast tanks is to be considered.

The buoyant volume of the cargo is to be included in the hydrostatic calculations.

Note 1: The stability in temporary submerged conditions is to be checked before any loading or unloading operation.

3 Intact stability in transit conditions

3.1 General

3.1.1 The intact stability in transit condition is to comply with the requirements of Part B, Chapter 3.

3.2 Buoyancy of the cargo

3.2.1 Buoyancy of the cargo may be considered in the stability calculations, on case-by-case basis.

Note 1: Special agreement from the Administration should be granted.

The buoyancy and the watertight integrity of the cargo is to be documented.

3.2.2 For any loading condition involving the buoyancy of the deck cargo, stability calculations with the buoyancy data are to be performed prior to the operation.

3.2.3 Lift-off of buoyant cargo

When the cargo is considered buoyant, assessment of the lift-off of the cargo at heel is to be submitted.

The cargo should not lift-off at an angle of heel less than 20°.

Note 1: Lift-off occurs when the cargo is partially floating, i.e. the tilting moment due to hydrostatic pressure on the cargo is higher than the moment due to gravity.

4 Damage stability in transit conditions

4.1 General

4.1.1 For assignement of the additional class notation **SDS**, semisubmersible cargo ships are to comply with the applicable requirements of Pt B, Ch 3, Sec 3 taking into account the provisions of:

- [4.2] for the buoyancy of cargo
- [4.3] for type B freeboard
- [4.4] for reduced freeboard.

4.2 Buoyancy of the cargo

4.2.1 Buoyancy of the cargo may be considered in the stability calculations on case-by-case basis.

Note 1: Special agreement from the Administration should be granted.

The buoyancy and the watertight integrity of the cargo is to be documented.

4.2.2 For any loading condition involving the buoyancy of the deck cargo, stability calculations with the buoyancy data are to be performed prior to the operation.

4.3 Type B freeboard

4.3.1 For ships with type B freeboard, damage stability is to comply with the requirements of Pt B, Ch 3, Sec 3 as applicable to cargo ships..

Note 1: When the criteria on the maximum allowable vertical centre of gravity (KG) are not met, compliance with Pt B, Ch 3, App 4 may be considered as an alternative subject to acceptance by the Society. Special agreement from the Administration should also be granted.

Note 2: When the buoyancy of the cargo is taken into account, the damage stability is to comply with the requirements of Pt B, Ch 3, App 4 and the provisions specified in [4.2].

4.4 Type B-60 and B-100 freeboard

4.4.1 For ships which have been assigned reduced freeboard as permitted by Regulation 27 of the International Convention on Load Lines, damage stability is to comply with the requirements specified in Pt B, Ch 3, App 4, taking into account [4.4.2], [4.4.3] and the provisions of IACS UI LL65.

Therefore, compliance with the requirements in [4.3.1] is not required.

Note 1: Note 1: When the buoyancy of the cargo is taken into account, the damage stability is to comply with the provisions specified in [4.2].

4.4.2 Extent of damage

Units with a type B-60 freeboard are to comply with the requirements of ICLL for one compartment damaged.

Units with a type B-100 freeboard are to comply with the requirements of ICLL for two compartments damaged.

4.4.3 Extent of damage with protruding cargo

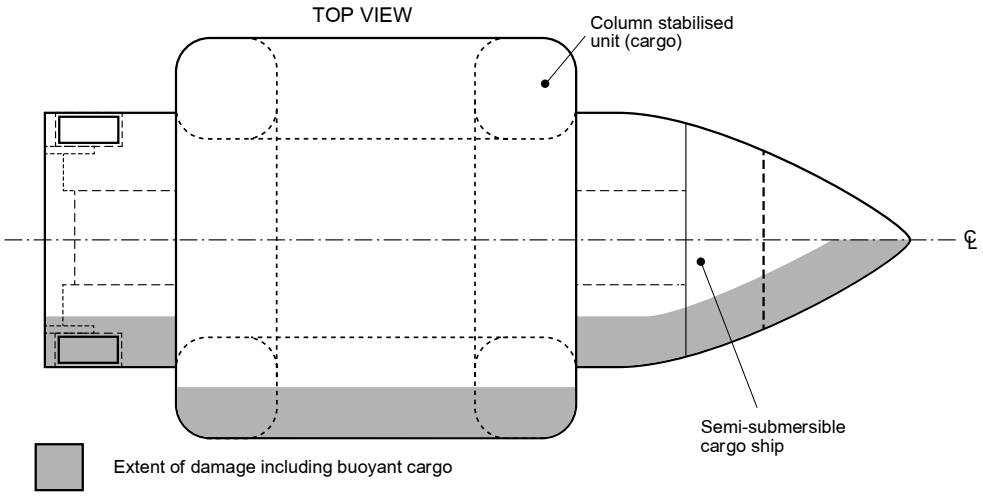
When the cargo is considered buoyant and is protruding from the side shell of the ship, the transversal penetration may include the cargo overhang as shown in Fig 1.

In that case, the cargo is considered part of the hull providing the vertical distance between the cargo and the sea level is small, typically less than 4,5 m, and the cargo structure is considered strong enough.

The transverse extent of damage is to be in accordance with ICLL, measured inboard from the side of the ship or from the side of the cargo, on a line perpendicular to the ship's centreline, whichever is the farthest.

Note 1: In specific cases, the definition of the extent of damage may need to be supported by a collision analysis in order to assess the effective protection of the hull provided by the cargo.

Figure 1 : Extent of damage with protruding buoyant cargo



5 Intact stability in temporary submerged conditions

5.1 Criteria

5.1.1 The intact stability in temporary submerged conditions is to be checked with the following criteria:

a) The metacentric height GM is to be not less than 0,30 m

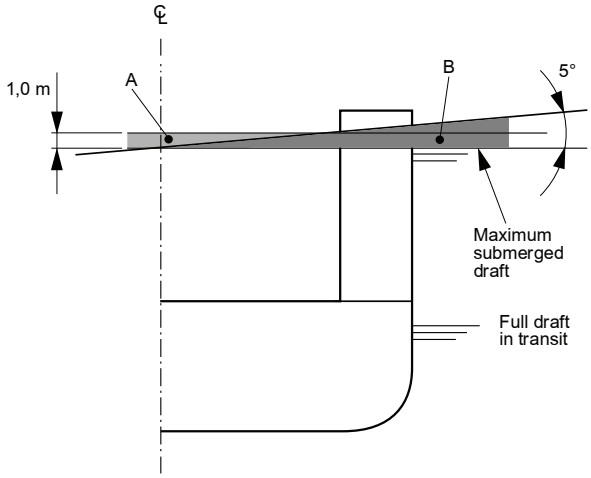
b) The range of stability is to be positive over a range of at least 15°

c) Within the range of GZ curve of 15°, the GZ lever maximum is to be not less than 0,10 m

d) The maximum GZ value shall not occur at an angle of heel less than 10°

e) In equilibrium condition, the distance between the waterline and any weathertight opening through which progressive flooding can occur is to be at least 1,0 m or, with a heel angle of 5°, the weathertight opening is to be above the waterline, whichever is the greatest (see Fig 2).

Figure 2 : Zone of weathertight integrity



A : 1.0m - Zone of weathertightness

B : 5 degrees - Zone of weathertightness

6 Damage stability in temporary submerged conditions

6.1 General

6.1.1 For the assignment of the additional class notation **SDS**, the requirements of the present Article are to be complied with in lieu of Pt B, Ch 3, Sec 3.

6.1.2 Damage stability during temporary submerged conditions as a result of a collision with the cargo or flooding due to a failure of the water ballast system is to be considered.

6.2 Extent of damage

6.2.1 Horizontal penetration

A one-compartment extent of damage is to be assumed on vertical surface adjacent to the exposed deck with:

- longitudinal/ transversal extent of 5,00 m

Note 1: One-compartment extent with a damage length of 5 m imply that a watertight bulkhead may be considered to remain intact provided that the distance with adjacent bulkheads exceeds 5m.

- penetration of 0,76 m
- vertical extent 3,0 m occurring at any level between the exposed deck and 5 m above the maximum submerged draft.

This includes all sides of casings, superstructure bulkheads and hull surface adjacent to the exposed deck within a distance of 2,5 m measured from the superstructure bulkhead.

6.2.2 Vertical penetration

A one-compartment extent of damage is to be assumed on the exposed deck with:

- longitudinal extent of 5,00 m
- transversal extent of 5,00 m
- vertical penetration of 0,76 m.

Note 1: One-compartment extent with a damage length of 5 m imply that a watertight bulkhead may be considered to remain intact provided that the distance with adjacent bulkheads exceeds 5 m.

6.3 Compartment permeability

6.3.1 The permeability of damaged compartments (voids and water ballast) is to be taken as 0,95. The permeability of machinery spaces is to be taken as 0,85.

6.4 Damage criteria

6.4.1 The following damage stability criteria are to be complied with:

a) The final waterline after flooding is to be below any non-watertight opening through which progressive flooding may take place

b) The equilibrium angle is not to exceed 15° of heel

c) The righting lever curve is to have a positive range of at least 7° beyond the equilibrium angle

d) The maximum righting lever is to be at least 0,05 m within the range of positive stability.

6.5 Intermediate stage of flooding

6.5.1 Damage stability at intermediate stages of flooding is to be verified.

7 Temporary submersion

7.1 International Load Line Certificate

7.1.1 Attention is drawn to the temporary submerged condition, for which an exemption with regard to the provisions of ICLL Article 6 should be granted by the Administration.

7.2 Reserve buoyancy

7.2.1 Criteria

The reserve buoyancy at maximum submerged draft is to be assessed.

The reserve buoyancy volume, i.e. the volume with weathertight integrity above the maximum submerged waterline, is to be at least 4,5% higher than the submerged volume.

The reserve buoyancy ratios of the fore end and aft end structures considered separately are to be at least 1,5% higher than the submerged volume.

7.2.2 Alternative

As an alternative to the reserve buoyancy criteria, the ship is to provide sufficient buoyancy and stability at the maximum submerged draft in order to withstand the accidental flooding of any watertight compartment wholly or partially below the waterline in submerged conditions, which is a ballast pump room or a room containing ballast system piping, in compliance with the following criteria:

a) the angle of inclination after flooding should not be greater than 25°

b) any opening below the final waterline should be made watertight

c) a range of positive stability should be provided, beyond the calculated angle of inclination in these conditions, of at least 7°

7.3 Watertight openings

7.3.1 Openings which could be submerged during temporary submerged conditions are to be closed with two effective watertight means to maintain the watertight integrity if one means fails.

The fitting of a second door or hatch of equivalent strength and watertightness is an acceptable arrangement.

A leakage detection device shall be provided in the compartment between the two doors. Drainage of this compartment to the bilges, controlled by a readily accessible screw-down valve, is to be arranged. The outer door is to open outwards.

7.4 Openings

7.4.1 Openings which are to remain open during the temporary submerged conditions, such as the engine room air intakes, are to be provided with remote controlled quick-closing appliances.

Section 4 Hull Structure

Symbols

T_S : Maximum submerged draft, in m, defined in Ch 9, Sec 1, [1.3.3]

H_S : Wave parameter defined in Pt B, Ch 5, Sec 3, calculated using:

- the coefficients given in Tab 1
- the reference length L_{ref} calculated with α and f_α values as defined in Pt B, Ch 5, Sec 3 or Pt B, Ch 5, Sec 4, as applicable

n_S : Navigation coefficient for the temporary submerged conditions, as defined in Pt B, Ch 5, Sec 3, [1.1.2], using H_S instead of H.

1 General

1.1 Application

1.1.1 This Section provides specific requirements for:

- structural assessment of semi-submersible cargo ships in temporary submerged conditions
- ballast tanks pressure when using overflow tanks.

1.2 Internal ballast pressure when using overflow tanks

1.2.1 In order to limit the pressure head in the tanks, the cargo ship may be fitted with an overflow system.

When overflow tanks complying with the relevant provisions of Ch 9, Sec 5 are installed, the pressure head may be taken at the top of the overflow tank instead of the top of the air pipe.

2 Loading conditions

2.1 General

2.1.1 In addition to the design load scenarios defined in Pt B, Ch 5, Sec 7, the structural assessment is to be performed against temporary submerged scenario considering draught T_S and the navigation coefficient n_S.

2.1.2 As a minimum, the loading conditions during temporary submerged conditions defined in Tab 1 are to be considered.

Note 1: As an alternative to the rule-based formulae, a direct hydrodynamic analysis may be performed in order to obtain the design wave loads.

Table 1 : Wave parameter H_S coefficients

Loading condition	Assessment	A_0	A_1	e_1	A_2	e_2	L_c
Temporary submerged conditions in sheltered area	Strength	0,25	1,63	2,25	0,18	1,55	155
	Fatigue	0,1	1,91	2,13	0,51	1,56	233
Temporary submerged conditions in harbour	Strength	0,16	1,65	2,28	0,17	1,44	127
	Fatigue	0,07	2,0	2,22	0,49	1,43	206

3 Design loads

3.1 Vertical wave bending moments

3.1.1 The vertical wave bending moments during temporary submerged conditions $M_{wv\text{-}h,S}$ and $M_{wv\text{-}s,S}$ at any hull transverse section are to be obtained, in kN·m, according to Pt B, Ch 5, Sec 4, [3.1.1], replacing n by n_S:

3.2 Horizontal wave bending moments

3.2.1 The horizontal wave bending moment during temporary submerged conditions $M_{wh,S}$ at any hull transverse section is to be obtained, in kN·m, according to Pt B, Ch 5, Sec 4, [3.3.1], replacing H by H_S and T_{LC} by T_S.

3.3 Vertical wave shear forces

3.3.1 The vertical wave shear forces during temporary submerged conditions $Q_{wv\text{-}pos,S}$ and $Q_{wv\text{-}neg,S}$ at any hull transverse section are to be obtained, in kN, according to Pt B, Ch 5, Sec 4, [3.2.1], replacing n by n_S:

3.4 Still water and dynamic pressures

3.4.1 External boundaries

For temporarily submerged conditions, the hydrostatic and hydrodynamic pressures at any point of the hull are to be the calculated according to Pt B, Ch 5, Sec 5, [1] considering the wave parameter H_S.

3.4.2 Watertight boundaries

The static pressure P_{fs}, in kN/m^2 acting on structural watertight elements defined as per the Internal Watertight Plan and located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding is to be based on the deepest equilibrium waterline in damaged transit or damaged temporary submerged conditions.

3.4.3 Internal pressure

In order to limit the pressure head in the tanks, the cargo ship may be fitted with an overflow system.

When overflow tanks complying with the relevant provisions of Ch 9, Sec 5 are installed, the pressure head may be taken at the top of the overflow tank instead of the top of the air pipe.

4 Hull girder strength

4.1 General

4.1.1 The hull girder strength is to be checked in temporary submerged conditions with the hull girder loads defined in [3].

Note 1: Due to the low depth of the hull girder, special attention is to be paid to the requirement regarding the moment of inertia. This requirement is to be satisfied over a minimum length of 0,25 L in the midship area.

5 Hull scantlings

5.1 General

5.1.1 Hull scantlings are to be checked in temporary submerged conditions with the design loads defined in [3].

Where intermediate situations are considered more severe due to specific loading conditions of the cargo ship, the scantlings are to be determined according to the most severe situation.

6 Connection of the buoyancy casings

6.1 General

6.1.1 The scantlings of the structures in way of the connection between the hull structure and the buoyancy casings are to be obtained through direct calculations.

6.2 Design loads

6.2.1 Still water loads

Static pressures are to be calculated taking into account the maximum draught at the location of the buoyancy casing.

6.2.2 Wave loads

Hydrodynamic pressures at any point of the hull is to be the calculated according to Pt B, Ch 5, Sec 5, [1] considering the wave parameter H_S.

Note 1: As an alternative to the rule-based formulae, a direct hydrodynamic analysis may be performed in order to obtain the design wave loads.

6.3 Strength criteria

6.3.1 The local stresses in the elements of the buoyancy casings and in connections with the hull structure are to satisfy the following conditions:

$\sigma \leq 0,8R_y$

$\tau \leq 0,4R_y$

7 Fatigue strength assessment

7.1 General

7.1.1 Fatigue assessment may be required on ships less than 150m in length if deemed necessary by the Society.

7.1.2 The fatigue life and sea conditions of the ship are to be specified by the Owner, and to be indicated on the midship section drawing.

7.1.3 Fatigue calculations are to be provided to the Society for review.

Section 5 Machinery and Systems

1 General

1.1 Sea pressure

1.1.1 Any equipment on the hull and submitted to the sea pressure is to withstand the pressure due to the maximum submerged draft.

2 Ballast system

2.1 Failure modes and effects analysis

2.1.1 A failure modes and effects analysis (FMEA) is to be performed regarding the ballast system, including its control and monitoring systems.

2.1.2 The FMEA is to address the ballast functions with reference to the different modes of operation defined in [2.2], and regarding float-on / float-off or load-on / load-off operations.

2.1.3 The FMEA method described in Pt F, Ch 2, App 1 may be used as a guidance.

2.2 Failure modes

2.2.1 The ballast system is to be designed in order to meet the safety principles defined in [2.4] in the following failure modes:

- Normal conditions, refer to [2.3.1]
- Degraded conditions, refer to [2.3.2]
- Emergency conditions, refer to [2.3.3].

2.3 Definitions

2.3.1 Normal ballast functions

The normal ballast functions means the design ballast capacity, control and monitoring functions allowing to perform ballasting and de-ballasting procedure of the semi-submersible cargo ship in the intended manner regarding float-on / float-off or load-on / load-off operations.

2.3.2 Degraded ballast functions

The degraded ballast functions means the ballast capacity, control and monitoring functions which remain available in case of a single failure on any active component of the ballast system, as defined in [2.3.4].

The degraded ballast functions are to be defined by the Owner and addressed in the FMEA.

2.3.3 Emergency ballast functions

The emergency ballast functions means the ballast capacity, control and monitoring functions available in case of main source of electrical power failure.

The emergency ballast functions are to be defined by the Owner and addressed in the FMEA.

2.3.4 Active component of the ballast system

An active component of the ballast system means any component of the ballast system which is not a pipe, an electrical cable, a manually controlled valve or a tank.

Active components include the machinery items (pumps, remote controlled valves, filters, etc.) and the control system items (gauges, sensors, switchboards).

2.4 Safety principles

2.4.1 Degraded conditions

Any single failure on an active component in the ballast system is not to lead to a situation where the degraded ballast functions are not met or to unintended flooding.

Note 1: Duplicate of components of the ballast control system may be required.

2.4.2 Emergency conditions

Failure of the main source of electrical power is not to lead to a situation where the emergency ballast functions are not met or to unintended flooding.

2.5 Air pipes

2.5.1 General

Effective means to reduce the air entrapped in the ballast tanks while filling up are to be provided, such as:

- sufficient air holes in tank internal structures, and
- air pipe connected to the highest point during the ballast operations.

Note 1: If the venting system requires operational restrictions (i.e. no trim by the bow when submersing), this should be specifically noted in the submersion operating manual.

2.5.2 Valves

Installation of valves on ballast tank air pipes may be accepted, subject to the following conditions:

- the layout of the air pipe system and of the control and supply systems is to be of fail-safe design. In this design, both the risk of flooding and pressurisation are to be taken into account
- an interlock system is provided between filling tank lines and air vent valves.

2.6 Overflow tanks

2.6.1 General

When overflow tanks are fitted to reduce tank pressures in case of overfilling, means are to be provided to drain the overflow tank with sufficient capacity to allow uninterrupted ballasting in normal conditions.

2.6.2 Design pressure and alarms

The design head of pressure considered for the ballast tanks structural assessment may be taken as the overflow tank top level, instead of the top of the air pipe, providing that the following alarms are fitted:

- High level alarm or overflow alarm
- High-High level alarm at max 98% level with shut-down of ballast pumps.

2.6.3 Overflow tank capacity

The overflow tanks are to have a capacity $V_{overflow}$, in m3, not less than:

$$V_{overflow} = \frac{T_{filling}}{60} \times (Q_{normal} - Q_{draintotal} + Q_{drainpump})$$

Where:

$T_{filling}$: Filling time, in minute, to be taken the lesser of:

- 10 min, or
- time matching the design ballast philosophy, or
- when alarms in compliance with [2.6.2] and an automatic draining system are provided, the greatest of:
  - the time elapsed before the drain system is switched on, and
  - 3 min.

Q_{normal} : Ballast rate in normal conditions, in m^3/hr

$Q_{draintotal}$: Total drain pump rate, in m^3/hr

$Q_{drainpump}$: Rate of the largest drain pump, in m^3/hr.

Note 1: The rate of the largest pump is considered in order to cope with the single failure of a drain pump.

2.7 Valves and actuators

2.7.1 Every ballast tank is to be provided with remote isolating valves for filling and/or emptying purposes.

The valves are to be able to be operated from the central ballast control station.

An emergency system is to be provided to operate the remote ballast valves.

The isolating ballast tank valves should be closed in case of loss of power.

The flow may be controlled by isolating valve when this valve is designed to reduce the wear associated with sealing surface contact and to maintain the sealing integrity. Other means may be provided to ensure tightness of the valve.

The arrangement for hydraulic and pneumatic controlled valves is to be submitted to the Society.

A speed control system is to be installed for remote valves in order to adjust the operating time. The operating time is to be long enough to avoid any water hammering in the valve and pipe, whist being in accordance with the manufacturer's recommendation.

The valves and actuators are to be certified as sea side valves.

2.8 Pressurized ballast tanks

2.8.1 Compressed air systems used to fill or empty the ballast tanks are to be specially considered.

Adequate means to control and to mitigate the risks of overpressure are to be provided.

A description of the air pressure system is to be submitted.

2.9 Control and monitoring

2.9.1 Central ballast control station

The central ballast control station defined in Ch 9, Sec 2, [2.2] is to include the following:

- a ballast pump control system
- a ballast pump status-indicating system
- a ballast valves control system
- a ballast valves position-indicating system
- a ballast tank level indicating and monitoring system as defined in Ch 9, Sec 6
- a ballast valve status monitoring system as defined in Ch 9, Sec 6
- a draught indicating system, indicating the draught at each draft scale of the unit or at presentative positions as required by the Society
- a power availability indicating system (main and emergency)
- a ballast system hydraulic / pneumatic pressure-indicating system
- a permanently installed means of communication, independent of the unit's main source of electrical power, between the control station and those spaces containing the ballast pumps and valves or their manual controls, or other spaces that may contain equipment necessary for the operation of the ballast system.

3 Scuppers and sanitary discharges

3.1 Arrangement of scuppers and sanitary discharges

3.1.1 The requirements for scuppers and sanitary discharges are to consider the maximum submerged waterline in lieu of the summer waterline.

Section 6 Electrical Installations and Controls

1 Emergency source of power

1.1 Essential service

1.1.1 The emergency source of power is to be able to supply the emergency ballast functions defined in Ch 9, Sec 5, [2.3.3] in addition to the other essential services.

2 Controls

2.1 Draft mark automatic gauges

2.1.1 An automatic draft gauging system is to be fitted and the information is to be displayed on the central ballast control station.

In case of submersion to the maximum draft, an automatic visible and audible alarm is to be provided in the central ballast control station.

Note 1: The alarm should be triggered when the mean sea level is higher than the maximum submerged draft.

2.2 Ballast tanks gauging system

2.2.1 The ballast tanks are to be provided with effective means of measuring the filling level. The variations of water ballast level are to be able to be directly observed.

2.2.2 An automatic gauging system is to be provided with the information accessible from the central ballast control station.

2.2.3 The ballast tank filling level is to be continuously monitored during ballasting operations and compared with the provisional values.

2.3 Ballast valves monitoring

2.3.1 The open/close status of valves is to be continuously monitored.

2.4 Communication means

2.4.1 The communication system should be arranged for direct 2-way communication between the central ballast control station and:

- the bridge or command centre of the ship
- the dynamic positioning control stand, when relevant.

Section 7 Safety Features

1 Fire safety

1.1 General

1.1.1 The cargo deck is to be protected by a fire-fighting system readily accessible in case of fire during a transit.

1.2 Fire hydrants

1.2.1 Fire hydrant located forward and aft of the cargo deck on both sides and with sufficient hose length to reach all the cargo deck area may be considered acceptable as an alternative to requirements of Pt C, Ch 4, Sec 6, [1.2.5].

2 Means of escape

2.1 Transit conditions

2.1.1 Means of safe transfer between aft and fore parts of the ship are to be provided and to be practical in transit conditions.

2.2 Temporary submerged conditions

2.2.1 Internal spaces of buoyancy towers are normally unmanned during temporary submerged conditions.

3 Life-saving appliances

3.1 Temporary submerged conditions

3.1.1 If buoyancy casings are manned during temporary submerged conditions, they should be provided with life-saving appliances suitable for the intended number of persons present on the casing in case of ship abandonment.

Section 8 Initial Inspection and Testing

1 General

1.1 Application

1.1.1 The present Section provides requirements for initial inspection and testing specific to the submersion function of the ship at new build stage or after substantial modifications or repair.

The submersion testing is to be conducted according to the submersion procedure submitted to the Society by the Interested Party.

The Society is to be duly informed of the time and place of the commissioning tests of the ballasting equipment and of the submersion trials.

Any additional testing not mentioned in the present Section may be required, to the satisfaction of the attending Surveyor.

2 Commissioning

2.1 At quay

2.1.1 Before putting the equipment into service, the inspection and testing should include, as a minimum, the:

a) verification of the presence on board of the submersion procedure as defined in Ch 9, Sec 1

b) examination of the connection of the buoyancy casings with the hull

c) functional testing of the ballasting system including its control and monitoring system for the different modes of operation defined in Ch 9, Sec 5, [2.2]

d) functional testing of the interface between the ballast system and the loading instrument

e) examination of ballast tank gauging system.

2.2 Sea trials

2.2.1 Submersion trials are to be performed under survey of the Society.

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 10
STANDBY RESCUE VESSELS

Section 1 General

Section 2 Rescue Arrangement, Accommodation and Equipment

Section 3 Hull and Stability

Section 4 Machinery

Section 5 Electrical Installations

Section 6 Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **standby rescue** as defined in Pt A, Ch 1, Sec 2, [4.12.9].

This service notation is to be completed by the number of survivors that the vessel is intended to carry.

Depending on the vessel operation area, the Society may adapt the requirements regarding the survivors accommodation and / or the safety equipment. In such a case, the service notation is to be completed by the vessel operation area.

For example:

standby rescue (150 survivors)

standby rescue (150 survivors, Guinea Gulf)

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 90 m	• Part B • Ch 10, Sec 2 **(1)**	• NR566 • Ch 10, Sec 2 **(1)**
	L < 90 m	• NR600 • Ch 10, Sec 2 **(1)**	• NR566 • Ch 10, Sec 2 **(1)**
Hull	L ≥ 90 m	• Part B • Ch 10, Sec 3	• Part B • Ch 10, Sec 3
	L < 90 m	• NR600 • Ch 10, Sec 3	• NR600 • Ch 10, Sec 3
Stability		• Part B • Ch 10, Sec 3	• NR566 • Ch 10, Sec 3
Machinery and cargo systems		• Part C • Ch 10, Sec 4	• NR566 • Ch 10, Sec 4
Electrical installations		• Part C • Ch 10, Sec 5	• NR566 • Ch 10, Sec 5
Automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C • Ch 10, Sec 6	• NR566 • Ch 10, Sec 6

(1) In addition to rescue and accommodation arrangement, Ch 10, Sec 2 includes requirements for safety and medical equipment.

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

1.1.3 Other standards

In order to ensure consistency with other applicable standards (e.g. national authorities, industry bodies), the requirements of this chapter may be completed or replaced, as necessary, by the following recognized standards upon agreement of the Society:

- Canada Atlantic Standby Vessel Guidelines (June 2015 or later)
- DMA Guidance on standby vessels (July 1997 or later)
- NMA Regulation N°853 on standby vessels (December 2014 or later)
- NMA Instructions to Class regarding Standby Vessels (February 2014 or later)

- NOGEPA Industry Guideline n°6 (V1 - June 2004 or later)
- Oil & Gas UK - Emergency Response & Rescue Vessel - Management Guidelines (Issue 5 - April 2013 or later)
- Oil & Gas UK - Emergency Response & Rescue Vessel - Survey Guidelines (Issue 6 - April 2013 or later)

Standards not listed above may be considered by the Society on a case-by-case basis.

Deviations from the requirements of this chapter and/or application of additional requirements based on recognized standards are to be specified in a memorandum.

1.2 Documents to be submitted

1.2.1 In addition to the provisions of Pt B, Ch 1, Sec 4, the following documents are to be submitted to the Society for approval:

- Arrangement of rescue areas
- Rescue and safety equipment plan showing position and quantity of all life safety rescue equipment on board
- Towing arrangement, if applicable
- Structural arrangement of the winch and its remote control of the quick-release device for opening under load, if applicable
- Structural arrangement of the hook and its remote control of the quick-release device for opening under load, if applicable
- Connection of the towing system (winch and hook) with the hull structures, if applicable
- Arrangement of windows with information on type of glass, frames, including references of standards and deadlights where applicable.

Section 2 Rescue Arrangement, Accommodation and Equipment

1 General

1.1 Wheelhouse

1.1.1 Manoeuvrability

The vessel is to be easily manoeuvrable from the wheelhouse by one person only.

1.1.2 Visibility

The wheelhouse is to be designed to offer an unobstructed view at all times on:

- the rescue zone, including ship's sides
- the helicopter winching area
- the areas where the fast rescue crafts (FRCs) are launched and recovered

2 Rescue equipment and facilities

2.1 Rescue zone

2.1.1 The vessel is to be arranged on both sides with a rescue zone extending minimum 8 m in length.

2.1.2 The rescue zone is to be located sufficiently far away from the propellers or thrusters and clear of any ship side discharges up to 2 m below the summer waterline.

2.1.3 It should be arranged so that the necessity of vertical transfer is be kept to a minimum.

2.1.4 The area is to be clearly marked on the ship's side in contrasting colours.

2.1.5 The ship's side in way of the rescue zone shall be free of any obstruction like fenders or anything which may harm climbing survivors.

2.1.6 Dedicated lighting is to be provided along the rescue zone.

2.1.7 Deck area in way of the rescue zone should preferably be free from air pipes, valves, smaller hatches, etc., and covered with anti-slip coating. However, when this becomes impractical, proper arrangement is to be provided as protection against personnel injury.

2.1.8 Bulwarks and railing in way of the rescue zone shall be of the type that are easy to open or remove, to enable direct boarding on the deck.

2.1.9 Unobstructed stretcher access from the rescue zone to the accommodation is to be provided and covered with anti-slip coating.

2.2 Scrambling net

2.2.1 Each rescue zone is to be provided with a scrambling net made for climbing the ship's side from the sea or from the Fast Rescue Craft.

It is to be made of corrosion resistant and non-slip material, hang clear of the ship's side and extend below the waterline level at lightest draught.

2.3 Retrieval device

2.3.1 The vessel is to be equipped with a power-assisted device operated from the vessel and capable of recovering at least 5 able or disabled persons from sea directly onto the vessel.

This could be achieved by means of a crane with a rescue basket. In such case, attention is drawn to Flag State requirements that may have to be complied with for the crane.

2.4 Rescue hooks

2.4.1 At least two poles with rounded-off hooks at ends are to be provided to assist survivors alongside the vessel.

2.5 Fast Rescue Craft (FRC)

2.5.1 The vessel is to be equipped with at least one SOLAS approved fast rescue boat for standby duties, arranged and maintained to be permanently ready for use under severe weather conditions, and which may be accepted as forming part of the ship's life saving appliances. The launching arrangement shall also be SOLAS approved.

2.6 Safety equipment

2.6.1 Vessels having a gross tonnage lower than 500 are to be provided with the following minimum safety equipment:

- 1 line-throwing appliance with not less than 4 projectiles and 4 lines
- 1 daylight signalling lamp
- 6 lifebuoys, 4 being with self-igniting electric light and buoyant line (SOLAS type approved)
- 1 SOLAS type approved immersion suit for each crew member
- 1 SOLAS type approved lifejacket for each crew member plus 25% of the number of survivors for which the vessel is intended to carry
- 1 whistle and 1 bell
- Equipment for at least 2 surface swimmers.

2.7 Helicopter winching area

2.7.1 The vessel is to be arranged with a designated helicopter winching area on deck for transferring personnel or stretchers.

2.7.2 The area is to be at least 5 m in diameter and free of any obstructions. It is to be arranged away from superstructures.

2.7.3 The area is to be painted in yellow colour and illuminated so that it remain visible by the helicopter at all times.

2.7.4 Unobstructed stretcher access from the accommodation to the helicopter winching area is to be provided.

2.7.5 The winching area and the passage leading thereto are to be provided with anti-slip coating.

3 Survivors spaces

3.1 General

3.1.1 A dedicated space is to be available for treatment, reception and accommodation of survivors. The space is to be sheltered from bad weather and direct sun radiation and provided with lighting, ventilation, or heating according to the intended zone of operation.

3.2 Decontamination area

3.2.1 An area equipped with a shower system for cleaning survivors and crew before proceeding to the reception area is to be arranged.

3.3 Reception area

3.3.1 An enclosed area with access to accommodations is to be arranged for medical assessment and registration of survivors, as well as for the distribution of supplies.

3.4 Treatment room

3.4.1 A dedicated room of at least 15 m^2 is to be equipped to provide first-aid to injured persons.

3.5 Accommodations

3.5.1 10% of the number of survivors the vessel is rated for are to be able to lie down. Permanent seating is to be provided for the rest of them.

3.5.2 In an emergency, survivors may be accommodated in crew accommodation except for sanitary accommodation, galley, berths for the master and 2 crew members, the radio room, the wheelhouse and main access passageways which should be kept clear.

3.5.3 Sanitary facilities are to be available exclusively for the survivors. At least one installation comprising a toilet, a wash basin and a shower is to be provided per group of 50 survivors.

3.6 Non-survivors

3.6.1 Facilities to store corpses out of sight of survivors in a cool and ventilated space, with arrangements for shelving and securing, is to be provided. This storage space should permit maximum discretion for other survivors.

4 Medical equipment and supplies

4.1 Water

4.1.1 Per group of 50 survivors, there is to be a minimum of 0,85 tonnes of fresh water for washing, showering, etc., and a minimum of 0,7 tonnes of potable water.

4.1.2 Water heating facilities are to be able to feed all the showers dedicated to the survivors with 40°C water for at least 2 hours.

4.2 Meals

4.2.1 It should be possible to serve soup or stew to the rated number of survivors for at least 2 days.

4.3 Sundries

4.3.1 The vessel is to be provided with blankets, towels, socks and disposable coveralls in sufficient quantity for the number of survivors the vessel is intended to carry.

4.4 Medical equipment

4.4.1 The treatment room is to be adequately equipped and furnished to perform the largest possible scope of medical operations on board. Typical required medical equipment are listed below for guidance:

- surgical instruments and suture materials
- resuscitation equipment
- various examination, surveillance and treatment equipment
- dressings and bandages
- stretchers
- medicaments.

Section 3 Hull and Stability

1 Stability

1.1 General

1.1.1 The stability of the ship is to be in compliance with the requirements in Ch 3, Sec 3.

1.1.2 The requirement in Pt D, Ch 11, Sec 3, [2.2.4] adresssing the crowding of passengers is to be complied with, considering the number of survivors that the vessel is intended to carry as passengers.

1.2 Additional requirements for towing operations

1.2.1 The stability of vessels intended to perform towing operations is to be in compliance with Ch 1, Sec 2, [2].

1.3 Additional requirements for water spraying

1.3.1 Vessels fitted with a water-spraying system are to meet the stability requirements of Ch 4, Sec 2.

2 Hull

2.1 Vessels intended for towing operations

2.1.1 Vessels intended to perform towing operations are to comply with the requirements of Ch 1, Sec 3, [2.2] to Ch 1, Sec 5, [2.1].

2.2 Lifeboat towing

2.2.1 In addition to the optional towing capabilities mentioned in [2.1.1], the vessel is to be fitted with simple and suitable arrangements for connecting and towing lifeboats and liferafts, such as towing points and towlines.

Section 4 Machinery

1 General

1.1 Application

1.1.1 In addition to the present Section, the relevant requirements of Ch 3, Sec 5 are to be applied.

1.2 Ship propulsion and manoeuvrability

1.2.1 Propulsion redundancy

The vessel shall be equipped with at least two independent propulsion systems, which may be either:

- single screw propulsion with variable pitch or reversible gearbox and a 360° azimuth thruster unit
- twin screw propulsion and a side thruster
- two azimuth thrusters
- any equivalent system approved by the Society on a case-by-case basis.

1.2.2 Minimum speed

During sea trials, it is to be verified that in calm water conditions, the vessel is to be capable of attaining an ahead speed of at least 10 knots, and 4 knots with the most powerful propulsion system out of action.

1.2.3 Stationary position and manoeuvring capabilities

The vessel is to be capable of manoeuvring at low speed and maintaining position in currents, waves and winds expected in the operations areas.

1.3 Exhaust pipes

1.3.1 The exhaust outlets from engines are to be fitted as high as practicable above the upper deck and are to be provided with spark arresters.

Section 5 Electrical Installations

1 General

1.1 Electrical installations

1.1.1 The electrical installations are to allow the simultaneous use of all the electric equipment needed for rescue operations.

1.1.2 The vessel is to be provided with sufficient emergency power sources to allow the rescue operations to continue for at least 1 hour after failure of the main power supply.

1.2 Searchlight

1.2.1 A searchlight is to be available on each side of the vessel and operated from the navigation bridge. The searchlights are to be able to provide an illumination of 50 lux at a distance of 250 m.

Section 6 Fire Protection

1 General

1.1 Additional requirements for water spraying

1.1.1 Vessels fitted with a water-spraying system are to meet the applicable requirements of Ch 4, Sec 4.

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 11
ACCOMMODATION UNITS

Section 1	General
Section 2	Electrical Installations and Automation
Section 3	Fire Protection, Detection and Extinction
Section 4	Specific Requirements for Ships assigned the Additional Service Feature SPxxx-capable
Section 5	Specific Requirements for Ships assigned the Additional Service Feature IPxxx-Capable

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the present Chapter are eligible for the assignment of the service notation **accommodation**, as defined in Pt A, Ch 1, Sec 2, [4.12.5].

The service notation **accommodation** is completed by at least one of the following additional service features:

- the additional service feature **IPxxx**, as detailed in Pt A, Ch 1, Sec 2, [4.16.9], is assigned when the ship is intended for the accommodation of industrial personnel in compliance with the requirements of the IMO International Code of Safety for Ships Carrying Industrial Personnel (IP Code) and provided with all facilities for this purpose
- the additional service feature **IPxxx-capable** is assigned when accommodation facilities may be added as separate modules during the service life of the ship, with a view to complying with the IP Code
- the additional service feature **SPxxx**, as detailed in Pt A, Ch 1, Sec 2, [4.16.8], is assigned when the ship is intended for the accommodation of special personnel in compliance with the requirements of the IMO Code of Safety for Special Purpose Ships (SPS Code) and provided with all facilities for this purpose
- the additional service feature **SPxxx-capable** is assigned when accommodation facilities may be added as separate modules during the service life of the ship, with a view to complying with the SPS Code

For notations **SPxxx** and **IPxxx**, xxx denotes the total number of persons on board (including crew and, as applicable, industrial personnel and/or special personnel as defined in [1.3]).

For notations **SPxxx-capable** and **IPxxx-capable**, xxx denotes the total number of persons on board once the modules have been added (including crew and, as applicable, industrial personnel and/or special personnel as defined in [1.3]).

These additional service features are completed by the additional service feature **MOU**, when the ship complies with the requirements of Ch.2 to 9 and Ch.13 of IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU Code).

Examples of notations are given below:

accommodation IP65

accommodation SP70 MOU

accommodation IP120-capable

accommodation SP80 SP240-capable

1.2 Applicable rules

1.2.1 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- Applicable requirements according to Tab 1.

1.2.2 Ships less than 500 GT will be specially considered by the Society.

1.3 Definitions

1.3.1 Crew

Crew means all persons carried on board the ship to provide navigation and maintenance of the ship, its machinery, systems and arrangements essential for propulsion and safe navigation or to provide services for other persons on board.

1.3.2 Industrial personnel

Industrial personnel means all persons who are transported or accommodated on board for the purpose of offshore industrial activities performed on board other vessels and/or other offshore facilities. Industrial personnel:

- Are not less than 16 years of age, and
- Are physically and medically fit, and
- Have demonstrated adequate knowledge of the working language on board in order to be able to communicate effectively and understand any instructions given by the ship's crew, and
- Have received training or instruction prior to boarding the ship with respect to personal survival, fire safety and personal safety.

1.3.3 Special personnel

Special personnel means all persons who are not passengers or members of the crew or children of under one year of age and who are carried on board in connection with the special purpose of that ship or because of special work being carried out aboard that ship.

Special personnel are expected to be able bodied with a fair knowledge of the layout of the ship and to have received some training in safety procedures and the handling of the ship's safety equipment before leaving port.

Table 1 : Applicable requirements

Item		Rule reference
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B **(2) (3)** • Ch 11, Sec 4 **(4)** • Ch 11, Sec 5 **(5)**
	L < 65 or 90 m **(1)**	• NR600 **(2) (3)** • Ch 11, Sec 4 **(4)** • Ch 11, Sec 5 **(5)**
Stability		• Part B **(2) (3)** • Ch 11, Sec 4 **(4)** • Ch 11, Sec 5 **(5)**
Structural assessment	L ≥ 65 or 90 m **(1)**	• Part B **(2) (3)**
	L < 65 or 90 m **(1)**	• NR600 **(2) (3)**
Machinery and systems		• Part C **(2) (3)** • Ch 11, Sec 4 **(4)** • Ch 11, Sec 5 **(5)**
Electrical installations and automation		• Part C **(2) (3)** • Ch 11, Sec 2 • Ch 11, Sec 4 **(4)** • Ch 11, Sec 5 **(5)**
Fire protection, detection and extinction		• Part C **(2) (3)** • Ch 11, Sec 3 • Ch 11, Sec 4 **(4)** • Ch 11, Sec 5 **(5)**

(1) Refer to the scope of application of NR600

(2) When the notation **SPxxx** is assigned, reference is made to the applicable requirements listed in Pt A, Ch 1, Sec 2, [4.16.8].

(3) When the notation **IPxxx** is assigned, reference is made to the applicable requirements listed in Pt A, Ch 1, Sec 2, [4.16.9].

(4) When the notation **SPxxx-capable** is assigned

(5) When the notation **IPxxx-capable** is assigned.

Note 1:NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m

2 Documents to be submitted

2.1 General

2.1.1 The documents listed in Tab 2 are to be provided, as a minimum.

Table 2 : Documents to be submitted

No.	I / A **(1)**	Documents to be submitted
1	I	General arrangement showing the location of the accommodation spaces
2	A	Structural fire protection plan and insulation details
3	I	General arrangement of electrical installation

(1) A : To be submitted for approval ; I : To be submitted for information

Section 2 Electrical Installations and Automation

1 Interaction with operational ships or units

1.1 Application

1.1.1 The requirements of this article apply to ships that may be located close to drilling or oil or gas production units.

1.2 Emergency Shutdown

1.2.1 Arrangements are to be provided to ensure the selective disconnection of the following equipment, in the event of an emergency situation where explosion hazard may extend up to the ship:

- Ventilation systems
- Non-essential electrical apparatuses
- Essential electrical apparatuses
- Main generator prime movers
- Emergency apparatuses, including the emergency generators, except those certified for installation in Zone 1

Note 1: In the case of ships with dynamic positioning systems as a sole means of position keeping, special consideration may be given to the selective disconnection of shutdown of machinery and equipment associated with maintaining the operability of the dynamic positioning system.

1.2.2 Disconnection or shutdown is to be possible from at least two widely separated locations.

1.2.3 Shutdown systems that are provided to comply with [1.2.1] are to be so designed that the risk of unintentional stoppages caused by malfunction in a shutdown system and the risk of inadvertent operation of a shutdown are minimized.

1.2.4 Services to be operable after emergency shutdown

Equipment which is located in spaces other than enclosed spaces and which is capable of operation after shutdown as given in [1.2.1] are to be suitable for installation in zone 2 locations. Such equipment which is located in enclosed spaces is to be suitable for its intended application to the satisfaction of the Society. At least the following facilities are to be operable for half an hour after an emergency shutdown:

a) emergency lighting:
   - at every muster and embarkation station on deck and over sides
   - in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks
   - in the machinery spaces and main generating stations including their control positions
   - in all control stations, machinery control rooms, and at each main and emergency switchboard

b) navigation aids

c) general alarm system

d) public address system

e) battery-supplied radiocommunication installations.

Section 3 Fire Protection, Detection and Extinction

1 Interaction with operational ships or units

1.1 Application

1.1.1 The requirements of this article apply to ships that may be located close to drilling or oil or gas production units.

1.2 Structural integrity

1.2.1 The superstructures and deckhouses containing accommodation spaces are to have external boundaries made of steel.

1.2.2 In addition, if the ship may be located within 100m of a drilling or oil or gas production unit, the external boundaries of superstructures or deckhouses containing accommodation spaces are to have fire integrity as follows:

- If the boundary is located within 30m of the centre of the rotary table of a drilling unit or of the process or storage area of a production unit, it is to have A-60 fire integrity
- If the boundary is located within 100m of the centre of the rotary table of a drilling unit or of the process or storage area of a production unit, it is to have A-0 fire integrity.

1.3 Installation layout

1.3.1 Accommodation spaces and control stations are to be located outside hazardous areas, taking into account hazardous areas on drilling or oil or gas production units in close proximity.

1.3.2 Ventilation intakes are to be located so as to minimize the risk of ingress of gas or smoke in the event of a gas release or of a fire on drilling or production units in close proximity.

Section 4 Specific Requirements for Ships assigned the Additional Service Feature SPxxx-capable

1 General

1.1 Application

1.1.1 The present Section provides requirements for ships on which accommodation modules are intended to be added at a later stage.

1.1.2 The additional service feature **SPxxx-capable** applies when the accommodation modules are not installed on board.

1.1.3 When the accommodation modules are installed on board, the additional service feature **SPxxx** is to be activated in replacement of **SPxxx-capable**. For this purpose, the Society will check that the additional modules and the ship including the additional modules are in compliance with the applicable requirements.

1.1.4 In case xxx is above 240, the feasibility of assigning the additional service feature **SPxxx-capable** will be assessed on a case-by-case basis by the Society. In this respect, specific attention is to be paid to the requirements of [2.3].

1.1.5 Provisions applicable to the ship in general are to be considered during the ship design and construction, although the additional accommodation modules are not installed on board yet.

1.2 Documents to be submitted

1.2.1 A description of a likely arrangement of the ship with the additional accommodation modules is to be provided for information, including the following information as a minimum:

- List of equipment to be added on board together with the accommodation modules, if any
- General description of the modules, number and arrangement on board
- Assumed electrical power balance

1.2.2 For the purpose of the stability assessment, the following documents are to be provided by the ship designer, taking into account a likely arrangement for the accommodation modules:

- General Arrangement
- Intact and damage stability calculations

2 Design review

2.1 Specific requirements

2.1.1 The requirements of Part B and Part C of the present Rules are to be complied with, as applicable.

2.1.2 The ship without the additional accommodation modules is to comply with the specific requirements listed in Tab 1.

2.2 Stability assessment

2.2.1 When the accommodation modules are installed on board and in order to activate the additional service feature **SPxxx**, it is to be demonstrated that the actual module arrangement, if different from the initially assumed arrangement, is properly covered by the initial stability assessment.

Table 1 : Applicable requirements for notation SPxxx-capable

<table>
<tr><th>Item</th><th>Reference requirement</th><th colspan="3">Provisions to be applied depending on
the total number of persons on board (POB) (1)</th></tr>
<tr><td colspan="2"></td><td colspan="2">POB < 240</td><td>240 ≤ POB</td></tr>
<tr><td>Arrangement</td><td>• Pt B, Ch 2, Sec 1, [1.1]
• Pt B, Ch 2, Sec 1, [6.1.2]
• Pt B, Ch 2, Sec 2, [1.1]</td><td colspan="2">• Pt B, Ch 2, Sec 1, [1] to Pt B, Ch 2, Sec 1, [5],
• Pt B, Ch 2, Sec 2,
considering the industrial personnel as crew</td><td>• Pt B, Ch 2, Sec 1, [1] to Pt B, Ch 2, Sec 1, [5]
• Pt D, Ch 11, Sec 2,
• Pt B, Ch 2, Sec 2
considering the industrial personnel as passengers</td></tr>
<tr><td rowspan="2">Stability</td><td>Pt B, Ch 3, Sec 1, [1.2]</td><td colspan="2">• Part B, Chapter 3
• Pt D, Ch 11, Sec 3, [2.3.14]
considering the industrial personnel as crew</td><td>• Part B, Chapter 3
• Pt D, Ch 11, Sec 3
considering the industrial personnel as passengers</td></tr>
<tr><td>• Pt B, Ch 3, Sec 3, [1.2.1]
• Pt B, Ch 3, Sec 3, [4.1.2]
• Pt B, Ch 3, App 2, [1.2.18]</td><td colspan="2">• Pt B, Ch 3, Sec 3
• Pt D, Ch 11, Sec 3, [2.3] (except Pt D, Ch 11, Sec 3, [2.3.12]), considering the industrial personnel as passengers, and where R is taken as defined in Pt B, Ch 3, Sec 3, [1.2.1]</td><td>• Pt B, Ch 3, Sec 3
• Pt D, Ch 11, Sec 3, [2.3] considering the industrial personnel as passengers, and where R is taken as defined in Pt B, Ch 3, Sec 3, [1.2.1]</td></tr>
<tr><td colspan="2"></td><td>POB ≤ 60</td><td>60 < POB ≤ 240</td><td>240 < POB</td></tr>
<tr><td rowspan="2">Machinery and systems</td><td>Pt C, Ch 1, Sec 10, [6.1.2]</td><td colspan="3">Pt D, Ch 11, Sec 4, [1], considering industrial personnel as passengers</td></tr>
<tr><td>Pt C, Ch 1, Sec 14, [1.1.2]</td><td colspan="2">Pt C, Ch 1, Sec 14, considering the ship as a cargo ship</td><td>Pt C, Ch 1, Sec 14, considering the ship as a passenger ship</td></tr>
<tr><td rowspan="3">Electrical installations and automation</td><td>Pt C, Ch 2, Sec 3, [3.6.3], item g)</td><td colspan="3">For ships having a length greater than 50m</td></tr>
<tr><td>Pt C, Ch 2, Sec 3, [2.3.21]</td><td>–</td><td colspan="2">Pt D, Ch 11, Sec 5, [2]</td></tr>
<tr><td>Pt C, Ch 2, Sec 3, [3.4]</td><td>–</td><td colspan="2">Pt D, Ch 11, Sec 5, [1.2.1]</td></tr>
<tr><td>Fire protection, detection and extinction</td><td>Pt C, Ch 4, Sec 1, [1.3.2]</td><td>Part C, Chapter 4, considering the ship as a cargo ship</td><td>Part C, Chapter 4, considering the ship as a passenger ship carrying not more than 36 passengers</td><td>Part C, Chapter 4, considering the ship as a passenger ship carrying more than 36 passengers</td></tr>
<tr><td colspan="5">(1) POB in the total number of persons on board, indicated as xxx in the SPxxx-capable additional service feature</td></tr>
</table>

2.3 Safe Return to Port

2.3.1 The provisions of [2.3] apply to ships assigned the additional service feature **SPxxx-capable** and for which:

- xxx is greater than 240 and
- L_{LL} as defined in Pt B, Ch 1, Sec 3, [2.1.2] is greater than or equal to 120m or the ship includes three or more main vertical zones as defined in Pt C, Ch 4, Sec 1, [2.31]

2.3.2 Special attention is to be given to redundancies on at least the following systems, with a view to complying with the requirements for **SRTP** additional service feature:

- propulsion
- steering systems and steering-control systems
- navigational systems
- systems for fill, transfer and service of fuel-oil
- internal communication
- external communication
- fire main system
- fixed fire-extinguishing systems
- fire and smoke detection system
- bilge and ballast system
- power-operated watertight and semi-watertight doors
- systems intended to support safe areas
- flooding detection systems

2.3.3 When the accommodation modules are installed on board and together with the activation of the additional service feature **SPxxx**, compliance with the requirements for the additional service feature **SRTP** is to be demonstrated.

Section 5 Specific Requirements for Ships assigned the Additional Service Feature IPxxx-Capable

1 General

1.1 Application

1.1.1 The present Section provides requirements for ships on which accommodation modules are intended to be added at a later stage.

1.1.2 The additional service feature **IPxxx-capable** applies when the accommodation modules are not installed on board.

1.1.3 When the accommodation modules are installed on board, the additional service feature **IPxxx** is to be activated in replacement of **IPxxx-capable**. For this purpose, the Society will check that the additional modules and the ship including the additional modules are in compliance with the applicable requirements.

1.1.4 In case xxx is above 240, the feasibility of assigning the additional service feature **IPxxx-capable** will be assessed on a case-by-case basis by the Society. In this respect, specific attention is to be paid to the requirements of [2.3].

1.1.5 Provisions applicable to the ship in general are to be considered during the ship design and construction, although the additional accommodation modules are not installed on board yet.

1.2 Documents to be submitted

1.2.1 A description of a likely arrangement of the ship with the additional accommodation modules is to be provided for information, including the following information as a minimum:

- List of equipment to be added on board together with the accommodation modules, if any
- General description of the modules, number and arrangement onboard
- Assumed electrical power balance.

1.2.2 For the purpose of the stability assessment, the following documents are to be provided by the ship designer, taking into account a likely arrangement for the accommodation modules:

- General Arrangement
- Intact and damage stability calculations

2 Design review

2.1 Specific requirements

2.1.1 The requirements of Part B and Part C of the present Rules are to be complied with, as applicable.

2.1.2 The ship without the additional accommodation modules is to comply with the specific requirements listed in Tab 1.

2.2 Stability assessment

2.2.1 When the accommodation modules are installed on board and in order to activate the additional service feature **IPxxx**, it is to be demonstrated that the actual module arrangement, if different from the initially assumed arrangement, is properly covered by the initial stability assessment.

Table 1 : Applicable requirements for notation IPxxx-capable

<table>
<tr><th>Item</th><th>Reference requirement</th><th colspan="3">Provisions to be applied depending on the total number of persons on board (POB) (1)</th></tr>
<tr><td colspan="2"></td><td colspan="2">POB < 240</td><td>240 ≤ POB</td></tr>
<tr><td>Arrangement</td><td>• Pt B, Ch 2, Sec 1, [1.2]
• Pt B, Ch 2, Sec 1, [6.1.3]
• Pt B, Ch 2, Sec 2, [1.2]</td><td colspan="2">• Pt B, Ch 2, Sec 1, [1] to Pt B, Ch 2, Sec 1, [5],
• Pt B, Ch 2, Sec 2,
considering the industrial personnel as crew</td><td>• Pt B, Ch 2, Sec 1, [1] to Pt B, Ch 2, Sec 1, [5]
• Pt D, Ch 11, Sec 2,
• Pt B, Ch 2, Sec 2
considering the industrial personnel as passengers</td></tr>
<tr><td rowspan="2">Stability</td><td>Pt B, Ch 3, Sec 1, [1.3]</td><td colspan="2">• Part B, Chapter 3
• Pt D, Ch 11, Sec 3, [2.3.14]
considering the industrial personnel as crew</td><td>• Part B, Chapter 3
• Pt D, Ch 11, Sec 3
considering the industrial personnel as passengers</td></tr>
<tr><td>• Pt B, Ch 3, Sec 3, [1.2.1]
• Pt B, Ch 3, Sec 3, [4.1.2]
• Pt B, Ch 3, App 2, [1.2.19]</td><td colspan="2">• Pt B, Ch 3, Sec 3
• Pt D, Ch 11, Sec 3, [2.3] (except Pt D, Ch 11, Sec 3, [2.3.12]), considering the industrial personnel as passengers, and where R is taken as defined in Pt B, Ch 3, Sec 3, [1.2.1]</td><td>• Pt B, Ch 3, Sec 3
• Pt D, Ch 11, Sec 3, [2.3] considering the industrial personnel as passengers, and where R is taken as defined in Pt B, Ch 3, Sec 3, [1.2.1]</td></tr>
<tr><td colspan="2"></td><td>POB ≤ 60</td><td>60 < POB ≤ 240</td><td>240 < POB</td></tr>
<tr><td rowspan="2">Machinery and systems</td><td>Pt C, Ch 1, Sec 10, [6.1.3]</td><td colspan="3">Pt D, Ch 11, Sec 4, [1], considering industrial personnel as passengers</td></tr>
<tr><td>Pt C, Ch 1, Sec 14, [1.1.3]</td><td colspan="2">Pt C, Ch 1, Sec 14, considering the ship as a cargo ship</td><td>Pt C, Ch 1, Sec 14, considering the ship as a passenger ship</td></tr>
<tr><td rowspan="3">Electrical installations and automation</td><td>Pt C, Ch 2, Sec 3, [3.6.3], item g)</td><td colspan="3">For ships having a length greater than 50m</td></tr>
<tr><td>Pt C, Ch 2, Sec 3, [2.3.21]</td><td>–</td><td colspan="2">Pt D, Ch 11, Sec 5, [2]</td></tr>
<tr><td>Pt C, Ch 2, Sec 3, [3.4]</td><td>–</td><td colspan="2">Pt D, Ch 11, Sec 5, [1.2.1]</td></tr>
<tr><td>Fire protection, detection and extinction</td><td>Pt C, Ch 4, Sec 1, [1.3.2]</td><td>Part C, Chapter 4, considering the ship as a cargo ship</td><td>Part C, Chapter 4, considering the ship as a passenger ship carrying not more than 36 passengers</td><td>Part C, Chapter 4, considering the ship as a passenger ship carrying more than 36 passengers</td></tr>
<tr><td colspan="5">(1) POB in the total number of persons on board, indicated as xxx in the IPxxx-capable additional service feature
Note 1: For ships assigned the following service notations, additional requirements are to be applied:
• oil tanker or FLS tanker, see Pt D, Ch 7, Sec 1, [1.3.1]
• chemical tanker, see Pt D, Ch 8, Sec 1, [2.2]
• liquefied gas carrier, see Pt D, Ch 9, Sec 1, [3.3].
Note 2: For supply vessels as defined in Pt E, Ch 3, Sec 1, additional requirements are to be applied, see Pt E, Ch 3, Sec 1, [1.5.1].</td></tr>
</table>

2.3 Safe Return to Port

2.3.1 The provisions of this sub-article apply to ships assigned the additional service feature **IPxxx-capable** and for which:

- xxx is greater than 240 and
- L_{LL} as defined in Pt B, Ch 1, Sec 3, [2.1.2] is greater than or equal to 120m or the ship includes three or more main vertical zones as defined in Pt C, Ch 4, Sec 1, [2.31].

2.3.2 Special attention is to be given to redundancies on at least the following systems, with a view to complying with the requirements for **SRTP** additional service feature:

- propulsion
- steering systems and steering-control systems
- navigational systems
- systems for fill, transfer and service of fuel-oil
- internal communication
- external communication
- fire main system
- fixed fire-extinguishing systems

- fire and smoke detection system
- bilge and ballast system
- power-operated watertight and semi-watertight doors
- systems intended to support safe areas
- flooding detection systems

2.3.3 When the accommodation modules are installed on board and together with the activation of the additional service feature **IPxxx**, compliance with the requirements for the additional service feature **SRTP** is to be demonstrated.

Part E
Service Notations for Offshore/Wind Farm Service Vessels and Tugs

CHAPTER 12
PIPE LAYING UNITS

Section 1 General

Section 2 Stability and Subdivision

Section 3 Structural assessment

Section 4 Initial Inspection and Testing

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the present Chapter are eligible for the assignment of the service notation **pipe laying** as defined in Pt A, Ch 1, Sec 2, [4.12.7].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A of the Rules
- NR216 Materials and Welding
- applicable requirements according to Tab 1 and specific requirements for initial inspection and testing as detailed in Ch 12, Sec 4.

Table 1 : Applicable requirements

Item		Greater than or equal to 500 GT	Less than 500 GT
Ship arrangement	L ≥ 65 or 90 m **(1)**	• Part B	• NR566
	L < 65 or 90 m **(1)**	• NR600	• NR566
Stability		• Part B • Ch 12, Sec 2	• NR566 • Ch 12, Sec 2
Structural assessment	L ≥ 65 or 90 m **(1)**	• Part B • Ch 12, Sec 3	• Part B • Ch 12, Sec 3
	L < 65 or 90 m **(1)**	• NR600 • Ch 12, Sec 3	• NR600 • Ch 12, Sec 3
Machinery and systems		• Part C	• NR566
Electrical installations and automation		• Part C	• NR566
Fire protection, detection and extinction		• Part C	• NR566

(1) Refer to the scope of application of NR600

Note 1:

NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT

NR600: Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m

1.2 Scope

1.2.1 The present Chapter addresses the requirements regarding the structural assessment of the foundations of the pipe laying equipment and the stability of the ship during pipe laying operations.

1.2.2 The certification of the pipe laying system is not covered by the present Chapter. Certification of pipe laying system pieces of equipment may be considered independently as detailed in [2.2].

2 Pipe laying system

2.1 General

2.1.1 The term pipe laying system is used herein to designate the system used for assembling and installing rigid or flexible pipelines to the seabed.

Pipe laying systems include:

- S lay systems
- J lay systems
- Flex lay systems
- Reel lay system

with the following typical pieces of equipment:

- stingers, towers, ramps and tensioners
- wheels, reels, davits and chutes
- carousels, baskets and pipe racks

- winches, ropes and sheaves
- pipe handling systems and clamps.

2.2 Certification of the pipe laying equipment

2.2.1 At the request of the Party applying for classification, the pipe laying system pieces of equipment may be certified and covered under the scope of classification, provided that the additional class notation **OHS** is assigned to the ship.

3 Documents to be submitted

3.1 General

3.1.1 The documents listed in Tab 2 are to be provided.

Table 2 : Documents to be submitted

No.	Documents to be submitted	I / A **(1)**
1	Pipe laying operational restrictions (pay load, limiting environmental conditions, …)	I
2	Pipe laying equipment documentation: • operating manual (see [3.2.1]) • calculation notes (see [3.2.2])	I
3	General arrangement of the ship showing the pipe laying equipment position during transit and operations	I
4	General arrangement of the pipe laying equipment showing the control stations	I
Stability		
5	Loading conditions during transit and pipe laying operations	A
6	Trim and stability booklet including operational loading conditions, when relevant	A
Structural assessment		
7	Structural arrangement showing the foundations of the equipment and the hull structure reinforcements (stinger, lay tower, winches, etc.)	A
8	Scantlings and steel grades of the connecting bolts between the equipment and its foundations	I
9	Material specification of the foundations of the equipment	A
10	Welding procedure and welding book of the foundation	A
(1) A : To be submitted for approval; I : To be submitted for information		

3.2 Pipe laying equipment documentation

3.2.1 Operating manual

The operating manual is to contain full information concerning:

- the pipe laying operational limitations, for each relevant wind and sea state
- all limitations during normal and emergency operations taking into account the ship stability and structure:
  - maximum wind and sea state
  - maximum heel and trim
  - design temperature
  - maximum pay load on the pipe lay equipment
- the description of the equipment
- the design technical standard, if any
- the description of the safety devices
- the user instructions to operate, erect, dismantle and transport the system
- the inspection and testing programme of the equipment.

3.2.2 Calculation notes

Calculation notes including the items listed below are to be provided for information:

- loading conditions and design loads applied on the supporting structure of the pipe laying equipment including:
  - maximum safe working loads with respect to environmental conditions
  - dynamic amplification factors
  - maximum holding loads
- the mass and location of centre of gravity of the main components of the pipe laying equipment
- loads lowering in the foundations
- structural assessment of the connecting bolts between the lifting equipment and its foundations.

Section 2 Stability and Subdivision

1 General

1.1 Application

1.1.1 The stability requirements described in this Section may be applied to ships when the pipe laying operation induces significant heeling moment.

1.1.2 In that case, the stability criteria required for lifting operation and described in Ch 8, Sec 3 are to be applied in order to check the residual stability during pipe laying operations.

For that purpose, the term “lifting” is to be replaced by “pipe laying”.

1.2 Loading conditions

1.2.1 When relevant, the stability criteria are to be satisfied for all pipe laying operational conditions and with the pipe laying load at the most unfavourable positions.

Section 3 Structural assessment

1 General

1.1 Application

1.1.1 This Section provides requirements for the structural assessment of the foundations of pipe laying equipment supported by the hull structure, such as stingers, lay tower, ramps, reels, davits, chutes, carousels, pipe racks, winches and sheaves.

2 Hull girder strength

2.1 Principles

2.1.1 When the pipe laying operations induce significant hull girder stresses, the hull girder loads due to the pipe laying operations are to be considered in the hull scantling verification, as defined in Ch 8, Sec 4, [3].

Note 1: For that purpose, the term “lifting” is to be replaced by “pipe laying”.

3 Materials and welding

3.1 Structural category and steel grades for the foundations of the pipe laying equipment

3.1.1 The steel grade of the structural elements of the foundation is to comply with Pt B, Ch 4, Sec 1, taking into account the structural categories given in Tab 1.

Table 1 : Guidance for structural categories

Category / Class	Structural elements
Primary / Class II	Hull supporting structure
Special / Class III	Insert plate of deck plating or hull shell in way of stingers, davits or lay tower

4 Pipe laying equipment foundations

4.1 General

4.1.1 The foundations of the pipe laying equipment and the connecting bolts between the equipment and the foundations are to comply with the relevant requirements applicable to lifting units defined in Part E, Chapter 8, i.e.:

- for design loads: Ch 8, Sec 4, [3]
- for loading conditions: Ch 8, Sec 4, [3.3]
- for allowable stress: Ch 8, Sec 4, [5]
- for buckling: Ch 8, Sec 4, [6]
- for fatigue: Ch 8, Sec 4, [7].

Note 1: For that purpose, the term “lifting” is to be replaced by the term “pipe laying”.

4.2 Connecting bolts

4.2.1 The arrangement and scantling of the connecting bolts between the pipe laying equipment and the foundations are to comply with a recognized standard.

4.2.2 The manufacture, steel grades and installation of bolts and nuts used for the connection of the lifting equipment on the foundation are to comply with a recognized standard.

Section 4 Initial Inspection and Testing

1 General

1.1 Application

1.1.1 The present Section provides requirements for inspection and testing of the pipe laying installations when first installed onboard or after re-installation.

1.1.2 These tests are to be conducted according to an inspection and testing specification to be submitted to the Society by the interested party.

The Society is to be duly informed of the time and place of the commissioning tests of the pipe laying equipment.

1.1.3 Any additional testing may be required to the satisfaction of the attending Surveyor.

2 Onboard testing

2.1 Pipe laying installations

2.1.1 Before putting into service, the inspection and testing of the pipe laying installations should include, as a minimum:

a) Verification of the presence onboard of the operating manual as defined in Ch 12, Sec 1

b) Inspection of the structural arrangement and scantlings of the foundations of the pipe laying equipment

c) Load tests in accordance with the pipe laying equipment testing program.

2.1.2 As a rule, all the connections between the supporting ship and the pipe laying equipment are to be presented for examination by the Surveyor.

NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part F
Additional Class Notations

Chapter 1	VeriSTAR System (STAR)
Chapter 2	Availability of Machinery (AVM)
Chapter 3	Automation Systems (AUT)
Chapter 4	Integrated and Digital Systems
Chapter 5	Monitoring Equipment
Chapter 6	Comfort on Board and Habitability
Chapter 7	Refrigerating Installations (REF)
Chapter 8	Navigation in Cold Environment
Chapter 9	Environmental Protection
Chapter 10	CBRN and BIORISK
Chapter 11	Manoeuvring, Mooring, Anchoring and Position Keeping
Chapter 12	Cargo Operation, Securing and Safety
Chapter 13	Additional Notation for Fire Protection
Chapter 14	Electric Propulsion or Power Supply
Chapter 15	Other Additional Class Notations

July 2025

Table of Content

Chapter 1 VeriSTAR System (STAR)

Section 1 VeriSTAR-HULL and VeriSTAR-HULL CM

1 General 37

1.1 Application
1.2 Scope

2 Assignment of the notation 37

2.1 VeriSTAR-Hull
2.2 VeriSTAR-HULL CM

Section 2 Star-Mach, Star-Mach SIS

1 General 39

1.1 Application
1.2 Definitions
1.3 Scope
1.4 Objectives

2 Assignment of the notation 40

2.1 Documentation to be submitted
2.2 STAR-MACH
2.3 STAR-MACH SIS

Section 3 Star-Regas

1 General 43

1.1 Application
1.2 Scope
1.3 Objectives

2 Assignment of the notation 43

2.1 Documentation to be submitted
2.2 STAR-REGAS

Section 4 Star-Cargo

1 General 44

1.1 Application
1.2 Scope
1.3 Objectives

2 Assignment of the notation 44

2.1 Documentation to be submitted
2.2 STAR-CARGO

Appendix 1 Owner's Hull Inspection Reports

1 General 45

1.1

2 Report for inspection of spaces 45

2.1 General
2.2 Identification data
2.3 Summary of findings and repairs
2.4 Details of findings and repairs
2.5 Attached documentation

3 Report for inspection of equipment 47
3.1 General
3.2 Identification data
3.3 Detailed report
3.4 Attached documentation

Chapter 2 Availability of Machinery (AVM)

Section 1 Alternative Propulsion System (AVM-APS)

1 General 50
1.1 Application
1.2 Definitions
1.3 Documentation to be submitted

2 General design requirements 51
2.1 Principle
2.2 Alternative propulsion machinery

3 Special arrangements 52
3.1 Propulsion system
3.2 Systems for cooling, lubrication, fuel supply, air starting, monitoring and control
3.3 Electrical installations

4 Tests on board 53
4.1 Operational tests
4.2 Sea trials

Section 2 Duplicated Propulsion System (AVM-DPS)

1 General 54
1.1 Application
1.2 Definitions
1.3 Documents to be submitted

2 General design requirements 56
2.1 Principle
2.2 Propulsion machinery
2.3 Steering machinery

3 Specific design requirements 57
3.1 Steering systems
3.2 Electrical installations
3.3 Automation

4 Additional requirements for ships having the notation AVM-DPS/P or AVM-DPS/NS or AVM-DPS/P/NS 57
4.1 Propulsion machinery
4.2 Electrical installations

5 Tests on board 57
5.1 Operating tests
5.2 Sea trials

Section 3 Independent Propulsion Systems (AVM-IPS)

1 General 59
1.1 Application
1.2 Definitions
1.3 Documents to be submitted

Table of Content

2 General design requirements 61

2.1 Principle
2.2 Compartment arrangement
2.3 Propulsion machinery
2.4 Steering machinery
2.5 Electrical power plant

3 Specific design requirements 62

3.1 Propulsion machinery
3.2 Steering systems
3.3 Electrical installations
3.4 Automation

4 Additional requirements for ships having the notation AVM-IPS/NS 63

4.1 Propulsion machinery
4.2 Electrical installations

5 Tests on board 63

5.1 Operating tests
5.2 Sea trials

Section 4 Fire Mitigation for Main Diesel-Generator Rooms (AVM-FIRE)

1 General 64

1.1 Application
1.2 Definitions
1.3 Documents to be submitted

2 General design requirements 65

2.1 Principle
2.2 Electrical power plant
2.3 Propulsion and steering
2.4 Fire protection and detection

3 Tests on board 66

3.1 Operating tests
3.2 Sea trials

Appendix 1 Procedures for Failure Modes and Effect Analysis

1 General 67

1.1 Introduction
1.2 Objectives
1.3 Sister ships
1.4 FMEA basics
1.5 FMEA analysis

2 FMEA performance 69

2.1 Procedures
2.2 System definition
2.3 Development of system block diagram
2.4 Identification of failure modes, causes and effects
2.5 Failure effects
2.6 Failure detection
2.7 Corrective measures
2.8 Use of probability concept
2.9 Documentation

3 Tests and reporting 72

3.1 Test program
3.2 Reporting

4 Probabilistic concept 73

4.1 General
4.2 Occurrences
4.3 Probability of occurrences
4.4 Effects
4.5 Safety level
4.6 Numerical values

Chapter 3 Automation Systems (AUT)

Section 1 Unattended Machinery Spaces (AUT-UMS)

1 General 77

1.1 Application
1.2 Exemptions
1.3 Communication system

2 Documentation 78

2.1 Documents to be submitted

3 Fire and flooding precautions 78

3.1 Fire prevention
3.2 Fire detection
3.3 Fire fighting
3.4 Protection against flooding

4 Control of machinery 80

4.1 General
4.2 Diesel propulsion plants
4.3 Steam propulsion plants
4.4 Gas turbine propulsion plants
4.5 Gas-only and dual fuel engines
4.6 Electrical propulsion plant
4.7 Shafting, clutches, CPP, gears
4.8 Auxiliary system
4.9 Control of electrical installation

5 Alarm system 97

5.1 General
5.2 Alarm system design
5.3 Machinery alarm system
5.4 Alarm system on navigation bridge

6 Safety systems 97

6.1 General

7 Testing 98

7.1 General
7.2 Specific requirement for ships fitted with engine using both low-flashpoint gaseous fuels and fuel oil as fuel

Section 2 Centralised Control Station (AUT-CCS)

1 General 99

1.1 Application
1.2 Exemptions
1.3 Communication system

2 Documentation 99

2.1 Documents to be submitted

3 Fire and flooding precautions 99
3.1 General
4 Control of machinery 99
4.1 Propulsion plant operation
4.2 Control position location
5 Alarm system 100
5.1 General
6 Safety system 100
6.1 General
7 Testing 100
7.1 Tests after completion
7.2 Sea trials

Section 3 Automated Operation in Port (AUT-PORT)
1 General 101
1.1 Application
1.2 Exemptions
1.3 Communication system
2 Documentation 101
2.1 Documents to be submitted
3 Fire and flooding precautions 101
3.1 general
4 Control of machinery 102
4.1 Plant operation
5 Alarm system 102
5.1 General
6 Testing 102
6.1 Tests after completion

Section 4 Integrated Machinery Spaces (AUT-IMS)
1 General 103
1.1 Application
2 Documentation 103
2.1 Documents to be submitted
3 Fire and flooding precautions 103
3.1 Fire prevention
3.2 Fire detection
3.3 Fire fighting
3.4 Protection against flooding
4 Integrated computer based systems 104
4.1 General
4.2 Design requirements
5 Construction requirements 105
5.1 Electrical and electronic construction requirements
5.2 Pneumatic construction requirements
5.3 Hydraulic construction requirements

6 Control of machinery 105
6.1 General
6.2 Diesel propulsion plants
6.3 Steam propulsion plants
6.4 Gas turbine propulsion plant
6.5 Electric propulsion plant
6.6 Shafting, clutches, CPP, gears
6.7 Auxiliary systems
6.8 Control of electrical installation
7 Testing 113
7.1 Additional testing
7.2 Maintenance equipment

Chapter 4 Integrated and Digital Systems

Section 1 Centralised Navigation Equipment (SYS-NEQ)

1 General 115
1.1 Application
1.2 Operational assumptions
1.3 Regulations, guidelines, standards
1.4 Definitions
2 Documentation 117
2.1 Documents to be submitted
3 Bridge layout 117
3.1 General
4 Bridge instrumentation and controls 118
4.1 General
4.2 Safety of navigation: collision-grounding
4.3 Position fixing
4.4 Controls - Communication
5 Design and reliability 119
5.1 General
5.2 Power supply
5.3 Environmental conditions
6 Prevention of accidents caused by operator’s unfitness 120
6.1 Field of vision
6.2 Alarm/warning transfer system - Communications
6.3 Bridge layout
7 Ergonomical recommendations 121
7.1 Lighting
7.2 Noise level
7.3 Vibration level
7.4 Wheelhouse space heating/cooling
7.5 Navigator’s safety
8 Testing 122
8.1 Tests

Table of Content

Section 2 Integrated Bridge Systems (SYS-IBS)

1 General 123

1.1 Application
1.2 Reference Regulations
1.3 Definitions
1.4 Abbreviations

2 Documentation 126

2.1 Documents to be submitted

3 General requirements 126

3.1 General
3.2 Integration
3.3 Data exchange
3.4 Failure analysis
3.5 Quality assurance

4 Operational requirements 128

4.1 Human factors
4.2 Functionality
4.3 Training

5 Technical requirements 129

5.1 Sensors
5.2 Alarm management
5.3 Human factors
5.4 Power interruptions and shutdown
5.5 Power supply

6 Testing 131

6.1 Introduction
6.2 General requirements
6.3 Operational requirements
6.4 Technical requirements

Section 3 Ship-Shore Communication

1 General 135

1.1 Application
1.2 Scope
1.3 Definitions
1.4 Documentation to be submitted

2 General requirements 139

2.1 General
2.2 Software
2.3 Components
2.4 Onboard testing

3 Additional requirements for notation ASYNC-COM 140

3.1 General
3.2 Onboard testing

4 Additional requirements for notation SYNC-COM 141

4.1 General
4.2 Software
4.3 Protection against message errors
4.4 Cyber Security
4.5 External communication provider
4.6 Risk assessment
4.7 Onboard testing

Table of Content

5 Additional requirements for notations ASYNC-COM-R and SYNC-COM-R 145

5.1 General
5.2 Onboard testing

Section 4 Data Infrastructure (DATA-INFRA)

1 General 148

1.1 Scope and application
1.2 Type approval

2 Definitions 149

2.1 General
2.2 Data Infrastructures
2.3 Acquisition LAN
2.4 Data logger

3 Documentation to be submitted 151

3.1 General

4 Infrastructure description 151

4.1 General
4.2 Data Producer Inventory
4.3 Data Consumer Inventory
4.4 Architecture

5 Requirements for acquisition LAN 156

5.1 General
5.2 Data producer
5.3 Data logger

6 Data logger functions 158

6.1 Administration management functions
6.2 Input / output communication functions
6.3 Data processing functions
6.4 Data logging
6.5 Error log management functions

7 Ship network configuration 159

7.1 General
7.2 On board data server

8 Ship-shore communication configuration 160

8.1 General

9 Server 160

9.1 General

10 Data management 160

10.1 Data model
10.2 Data format
10.3 Data quality framework
10.4 Monitoring

11 Installation and testing 161

11.1 Data logger type approval
11.2 On board testing

Chapter 5 Monitoring Equipment

Section 1 Hull Stress and Motion Monitoring (MON-HULL)

1 General 164

1.1 Application
1.2 Documentation

2 Sensors design 165

2.1 General
2.2 Measurements ranges and tolerances
2.3 On-site calibration of sensors
2.4 Environmental and EMC requirements

3 System design 165

3.1 General
3.2 Data processing
3.3 Data displaying
3.4 Alarms
3.5 Data storage
3.6 Exploitation of stored data
3.7 Checking facility
3.8 Power supply

4 Installation and testing 167

4.1 General
4.2 Installation of sensors
4.3 Testing of Hull Monitoring System

Section 2 Shaft Monitoring (MON-SHAFT)

1 General 168

1.1 Applicability of MON-SHAFT notation
1.2 Documentation to be submitted

2 Requirements for oil lubricated shafts 169

2.1 Arrangement
2.2 Lubricating oil analysis

3 Requirements for water lubricated shafts 169

3.1 General requirements
3.2 Additional requirements for forced water lubrication systems
3.3 Data to be recorded

4 Requirements for pod 170

4.1 Arrangement
4.2 Lubricating oil analysis
4.3 Additional data to be recorded

Section 3 Real-time Emissions Reporting (REALTIME)

1 General 171

1.1 Scope
1.2 Application
1.3 Definitions

2 Reporting schemes 172

2.1 General
2.2 Reference documents for CII reporting scheme
2.3 Reference documents for EU MRV regulations
2.4 Reference documents for EU ETS reporting scheme
2.5 References documents for FuelEU reporting scheme

3 Classification notations 173
3.1 Notation REALTIME( )
3.2 Documentation to be submitted
4 Type approval of ODS and SDS software 174
4.1 Type approval of ODS and SDS software
4.2 Datasets for CII reporting scheme
4.3 Datasets for EU ETS and FuelEU reporting schemes
5 Onboard Digital Solution (ODS) 177
5.1 Requirements for inputs
5.2 Requirements for functions
6 Shore Digital Solution (SDS) 178
6.1 Requirements for functions
7 Initial Survey 179
7.1 Onboard Digital Solution (ODS)
7.2 Shore Digital Solution (SDS)

Chapter 6 Comfort on Board and Habitability

Section 1 COMF Notations - General Requirements
1 General 181
1.1 Application
1.2 Basic principles
1.3 Regulations, Standards
1.4 Definitions
1.5 Document to be submitted
2 Conditions of attribution 183
2.1 Measurements
2.2 Determination of comfort rating number
2.3 Measuring locations
3 Testing conditions 185
3.1 General
3.2 Harbour test conditions
3.3 Sea trial conditions

Section 2 COMF Notations - Additional Requirements for Ships of less than 1600 GT
1 General 187
1.1 Application
2 COMF-NOISE 187
2.1 Measurement procedure
2.2 Noise levels
2.3 Sound insulation measurements
3 COMF-VIB 188
3.1 Measurement procedure
3.2 Vibration levels

Section 3 COMF Notations - Additional Requirements for Crew Areas - Ships Greater than or Equal to 1600 GT
1 General 190
1.1 Application

Table of Content

2 COMF-NOISE 190

2.1 Measurement procedure
2.2 Noise levels
2.3 Sound insulation measurements

3 COMF-VIB 192

3.1 Measurement procedure
3.2 Vibration levels

Section 4 COMF Notations - Additional Requirements for Passenger Areas - Ships Greater than or Equal to 1600 GT

1 General 194

1.1 Application

2 COMF-NOISE 194

2.1 Measurement procedure
2.2 Noise levels
2.3 Sound insulation measurements
2.4 Impact measurements

3 COMF-VIB 196

3.1 Measurement procedure
3.2 Vibration levels

Section 5 COMF Notations - Additional Requirements for Yachts

1 General 198

1.1 Application

2 COMF-NOISE 198

2.1 Measurement procedure
2.2 Noise levels
2.3 Sound insulation measurements
2.4 Impact measurements

3 COMF-VIB 200

3.1 Measurement procedure
3.2 Vibration levels

4 COMF + 201

4.1 Application
4.2 Data processing and analysis
4.3 Measurement procedure
4.4 COMF + Sound insulation index
4.5 COMF + Impact index
4.6 COMF + Emergence
4.7 COMF + intermittent noise
4.8 COMF + intelligibility

Section 6 Habitability

1 General 204

1.1 Scope
1.2 Equivalences and alternatives

2 Accommodation 204

2.1 General
2.2 General design requirements
2.3 Sleeping rooms
2.4 Sleeping rooms - Special arrangements for passenger ships and special purpose ships
2.5 Mess rooms
2.6 Sanitary facilities and accommodation
2.7 Hospital accommodation
2.8 Miscellaneous

3 Vibration prevention 208
3.1 General
3.2 Design requirements
3.3 Testing
4 Noise prevention 210
4.1 General
4.2 Design requirements
4.3 Testing
5 Ventilation, heating and air conditioning 213
5.1 General
5.2 Design requirements
5.3 Testing
6 Lighting 216
6.1 General
6.2 Design requirements
6.3 Testing

Chapter 7 Refrigerating Installations (REF)

Section 1 General Requirements

1 General 219
1.1 Application
1.2 Temperature conditions
1.3 Definitions
2 Design criteria 220
2.1 Reference conditions
3 Documentation 220
3.1 Refrigerating installations
3.2 Controlled atmosphere installations
3.3 Ships assigned with the notation QUICKFREEZE
4 General technical requirements 222
4.1 Refrigeration of chambers
4.2 Defrosting
4.3 Prime movers and sources of power
4.4 Pumps
4.5 Sea connections
4.6 Refrigerating machinery spaces
4.7 Exemptions for small plants
4.8 Personnel safety
5 Refrigerated chambers 224
5.1 Construction of refrigerated chambers
5.2 Penetrations
5.3 Access to refrigerated spaces
5.4 Insulation of refrigerated chambers
5.5 Protection of insulation
5.6 Miscellaneous requirements
5.7 Installation of the insulation
5.8 Drainage of refrigerated spaces
6 Refrigerants 226
6.1 General
6.2 Rated working pressures

7 Refrigerating machinery and equipment 226
7.1 General requirements for prime movers
7.2 Common requirements for compressors
7.3 Reciprocating compressors
7.4 Screw compressor bearings
7.5 Pressure vessels
7.6 General requirements for piping
7.7 Accessories
7.8 Refrigerating plant overpressure protection
8 Specific requirements for direct and indirect refrigerating systems 229
8.1 Specific requirements for refrigerating systems
8.2 Specific requirements for air cooling systems and distribution and renewal of air in cargo spaces
9 Instrumentation, alarm, monitoring 230
9.1 General
9.2 Instrumentation, alarm and monitoring arrangement
10 Material tests, inspection and testing, certification 231
10.1 Material testing
10.2 Shop tests
10.3 Pressure tests at the workshop
10.4 Thermometers and manometers
10.5 Shipboard tests
10.6 Defrosting system

Section 2 Additional Requirements for Notation REF-CARGO

1 General 234
1.1 Application
1.2 Refrigeration of cargo spaces
1.3 Heating
2 Refrigerated cargo spaces 234
2.1 Insulation
3 Instrumentation 234
3.1 Thermometers in cargo spaces
4 Additional requirements for AIR-CONT notation 235
4.1 General
4.2 Controlled atmosphere cargo spaces and adjacent spaces
4.3 Gas systems
4.4 Miscellaneous equipment
4.5 Gas detection and monitoring equipment
4.6 Instrumentation, alarm and monitoring arrangement
4.7 Safety
4.8 Tests and trials
5 Additional requirements for notations PRECOOLING and QUICKFREEZE 241
5.1 General
5.2 Shipboard tests

Section 3 Additional Requirements for Notation REF-CONT

1 General 242
1.1 Application
2 Ships supplying electrical power to self-refrigerated containers 242
2.1 Electrical equipment
2.2 Installation of containers

Section 4 Additional Requirements for Notation REF-STORE

1 General 243

1.1 Application

Chapter 8 Navigation in Cold Environment

Section 1 ICE Class Notations - General Requirements

1 General 245

1.1 Application
1.2 Owner's responsibility
1.3 Documents to be submitted

2 Ice class draughts and ice thickness 245

2.1 Definitions
2.2 Draught limitations in ice
2.3 Ice thickness

3 Output of propulsion machinery 247

3.1 Required engine output for ICE CLASS IA SUPER, ICE CLASS IA, ICE CLASS IB and ICE CLASS IC

Section 2 ICE Class Notations - Hull and Stability

1 General 250

1.1 Application
1.2 Hull regions
1.3 Ice strengthened area

2 Structure design principles 252

2.1 General framing arrangement
2.2 Transverse framing arrangement
2.3 Bilge keels

3 Design loads 253

3.1 General
3.2 Ice loads

4 Hull scantlings 255

4.1 Gross scantlings
4.2 Plating
4.3 Stiffeners
4.4 Primary supporting members

5 Other structures 258

5.1 Application
5.2 Fore part
5.3 Aft part
5.4 Deck strips and hatch covers
5.5 Sidescuttles and freeing ports

6 Hull outfitting 259

6.1 Rudders and steering arrangements
6.2 Bulwarks

7 Additional class notations YOUNG ICE 1 and YOUNG ICE 2 260

7.1 Area to be strengthened
7.2 Design loads
7.3 Plating
7.4 Stiffeners and primary supporting members
7.5 Sidescuttles and freeing ports

Table of Content

Section 3 ICE Class Notations - Machinery

1 Requirements for propulsion machinery of the class notation ICE CLASS IA SUPER, ICE CLASS IA, ICE CLASS IB and ICE CLASS IC 263

1.1 Scope
1.2 Design ice conditions
1.3 Materials
1.4 Design loads
1.5 Propeller blade design
1.6 Controllable pitch propeller and built-up propeller
1.7 Propulsion line design
1.8 Coupling
1.9 Gear
1.10 Chockfast calculation
1.11 Azimuthing main propulsors

2 Requirements for propulsion machinery of ICE CLASS ID 287

2.1 Ice torque
2.2 Propellers
2.3 Shafting

3 Miscellaneous requirements 288

3.1 Starting arrangements
3.2 Sea inlets, ballast systems and cooling water systems of machinery
3.3 Steering gear
3.4 Fire pumps
3.5 Transverse thrusters
3.6 Test and certification for propellers

Section 4 COLD Notations - Cold Weather Conditions

1 General 290

1.1 Application
1.2 Documentation to be submitted
1.3 Testing

2 General requirements for machinery installations for COLD DI, COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE) 292

2.1 General
2.2 Principles
2.3 Design requirements

3 General requirements for electrical installations for COLD DI, COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE) 293

3.1 General
3.2 System design

4 Other general requirements for COLD DI, COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE)) 293

4.1 Application
4.2 De-icing of deck areas
4.3 De-icing tools
4.4 Protection of deck machinery
4.5 Closing appliances and doors
4.6 HVAC plant
4.7 Other protections

5 Additional requirements for hull and stability for COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE) 294

5.1 Hull
5.2 Stability

6 Additional requirements for machinery installations for notations COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE) 295

6.1 Application
6.2 Materials
6.3 General principles
6.4 Design requirements

7 Other additional requirements for COLD BASIC (H tDH, E tDE) and COLD (H tDH, E tDE) 296

7.1 Application
7.2 Electrical equipment fitted in open decks
7.3 Cableways supports
7.4 Navigation and communication equipment
7.5 Fire safety systems
7.6 Personal protection and evacuation equipment

8 Additional requirements for COLD (H tDH, E tDE) 297

8.1 Application
8.2 Machinery installations
8.3 Electrical system design
8.4 Protection of electrical systems
8.5 De-icing of deck areas

9 Requirements for notation COLD CARGO 298

9.1 Application
9.2 Arrangement principles
9.3 Design and arrangement of the cargo heating means
9.4 Risk analysis
9.5 Materials

Chapter 9 Environmental Protection

Section 1 General Requirements

1 Scope and application 301

1.1 General

2 Definitions and abbreviations 302

2.1 Definitions related to sea pollution
2.2 Definitions related to air pollution
2.3 Abbreviations

Section 2 Notations CLEANSHIP and CLEANSHIP SUPER

1 General 305

1.1 Application
1.2 Documents to be submitted

2 Design requirements for the additional class notation CLEANSHIP 308

2.1 Waste management and monitoring
2.2 Oily wastes
2.3 Wastewaters
2.4 Garbage and hazardous wastes
2.5 Hull anti-fouling systems
2.6 Prevention of pollution by oil spillage and leakage
2.7 Refrigeration systems
2.8 Fire-fighting systems
2.9 Emission of nitrogen oxides (NOx)
2.10 Emission of sulphur oxides (SOx)

Table of Content

3 Additional design requirements for the additional class notation CLEANSHIP SUPER 316

3.1 Waste minimization and recycling program
3.2 Oily wastes
3.3 Wastewaters
3.4 Food wastes
3.5 Prevention of pollution by oil spillage and leakage
3.6 Protection against oil pollution in the event of collision or grounding
3.7 Prevention of air pollution

4 Onboard tests and measurements 318

4.1 Application
4.2 Periodical tests and measurements done by the Shipowner

Section 3 Notations AWT-A, AWT-B and AWT-A/B

1 General 320

1.1 Application
1.2 Documents to be submitted

2 Additional class notations AWT-A, AWT-B and AWT-A/B 320

2.1 Scope
2.2 Definitions and abbreviations
2.3 Design of the AWT plant

3 Onboard tests and measurements 321

3.1 Periodical tests and measurements done by the Shipowner

Section 4 Notations BWE and BWT

1 General 323

1.1 Application
1.2 Documents to be submitted

2 Additional class notation BWE 323

2.1 Scope
2.2 Design requirements

3 Additional class notation BWT 324

3.1 Scope
3.2 Design and installation requirements

Section 5 Notations GWT, NDO-x days and OWS-x ppm

1 General 325

1.1 Application
1.2 Documents to be submitted

2 Additional class notation GWT and GWT-B 325

2.1 Scope
2.2 Design of the grey water treatment plant

3 Additional class notation NDO-x days 326

3.1 Scope
3.2 Design requirements

4 Additional class notation OWS-x ppm 326

4.1 Scope
4.2 Design requirements

Section 6 Notations NOX-x% and SOX-x%

1 General 328

1.1 Application
1.2 Documents to be submitted

Table of Content

2 Additional class notation NOX-x% 328

2.1 Scope
2.2 Design requirements

3 Additional class notation SOX-x% 329

3.1 Scope
3.2 Design requirements

Section 7 EGCS-SCRUBBER and SCRUBBER READY

1 General 330

1.1 Application

2 Additional class notation EGCS-SCRUBBER 330

2.1 Scope
2.2 Documents to be submitted
2.3 Design and installation requirements

3 Requirements for the additional class notation SCRUBBER-READY 331

3.1 Scope of this notation
3.2 Documentation to be submitted
3.3 General arrangement
3.4 Hull items
3.5 Machinery items
3.6 Electricity items
3.7 Safety items
3.8 Stability items

Section 8 Ultra-Low Emission Vessel (ULEV)

1 General 335

1.1 Scope
1.2 Application
1.3 Documents to be submitted

2 Definitions 336

2.1

3 Requirements for ULEV additional class notation 336

3.1 Requirements for the engines
3.2 Emission levels
3.3 Emission control monitoring
3.4 ULEV Mode

4 Emission measurements 338

4.1 Pollutants to be measured
4.2 Measurements
4.3 Fuel specification
4.4 Deterioration factors
4.5 Control areas

5 Onboard surveys 341

5.1 Initial survey

Section 9 Exhaust Gas Measurements (EXGEM)

1 General 342

1.1 Application
1.2 Additional class notation
1.3 Definitions
1.4 Documents to be submitted

2 Requirements for the EXGEM notation 343

2.1 Engines

3 Emission measurements 344

3.1 Values to be measured
3.2 Measurement methodology
3.3 Test fuel
3.4 Data evaluation for gases emissions
3.5 Calculation of the gases emissions

4 Initial survey 345

4.1 Onboard survey

Section 10 Vapour Control System (VCS)

1 General 346

1.1 Application
1.2 Definitions
1.3 Documentation to be submitted

2 Vapour system 347

2.1 General
2.2 Vapour manifold
2.3 Vapour hoses
2.4 Vapour overpressure and vacuum protection

3 Instrumentation 349

3.1 Cargo tank gauging equipment
3.2 Cargo tank high level alarms
3.3 Cargo tank overfill alarms
3.4 High and low vapour pressure alarms

4 Instruction manual 350

4.1 General
4.2 Content

5 Testing and trials 351

5.1
5.2 Shipboard trials

6 Additional requirements for notation “TRANSFER” 351

6.1 Application
6.2 Equipment

Section 11 Protected FO Tanks (PROTECTED FO TANKS)

1 General 352

1.1 Application
1.2 Definitions

2 Design requirements 352

2.1 Distance from the bottom shell plating
2.2 Distance from the side shell plating
2.3 Oil fuel piping lines
2.4 Suction wells

Section 12 Fast Oil Recovery System (FORS)

1 General 354

1.1
1.2 Documents to be submitted
1.3 Definitions

2 Requirements for the design and installation of the connectors 355

2.1 General
2.2 Number of connectors
2.3 Design of the connectors
2.4 Installation and access

3 Additional requirements for -NS notation 356
3.1 General
3.2 Requirements

Section 13 BIOFUEL READY
1 General 357
1.1 Scope
1.2 Application
1.3 Documents to be submitted
1.4 Definitions and abbreviations
2 Requirements for the BIOFUEL READY notation 358
2.1 Technical analysis
2.2 Onboard arrangement
2.3 Biofuel specification
2.4 Engine testing

Section 14 OCC-Prepared
1 General 360
1.1 Application
1.2 Definitions and abbreviations
1.3 Documentations to be submitted
2 Requirements for OCC-PREPARED 361
2.1 General
2.2 General ship design
2.3 Detailed design

Chapter 10 CBRN and BIORISK

Section 1 CBRN Notations - General Requirements
1 General 365
1.1 Scope
1.2 Application
1.3 Documents to be submitted
1.4 Definitions and abbreviations
2 Construction testing and inspection 367
2.1 General
2.2 Closure test
2.3 Collective protection ventilation test
2.4 CBRN detection test
2.5 Pre-wetting and washdown test

Section 2 CBRN Notations - Ship Arrangement
1 Citadel 369
1.1 Spaces to be included in the citadel
1.2 Spaces where explosive atmosphere may occur
1.3 Boundaries of the citadel
1.4 Means of access to the citadel
2 CBRN Control station 370
2.1 Function
2.2 Location
3 Space for rescued people 371
3.1 Accommodation for rescued people
3.2 Means of escape

4 Shelter 371
4.1 Sheltered spaces
4.2 Openings in shelter boundary
5 Airlock 371
5.1 Arrangement
5.2 Doors
5.3 Purging
6 Cleansing station 371
6.1 Arrangement
6.2 Doors and boundaries
7 Machinery space arrangement 372
7.1 Allowable arrangements for engine room and internal combustion machinery spaces
7.2 Machinery space included in the citadel
7.3 Sheltered machinery space
7.4 Unprotected machinery space
7.5 Fire protection
7.6 Engine room cooling
8 Superstructure design 373
8.1 Precautions for decontamination
9 Marking 374
9.1 Openings
9.2 Equipment

Section 3 CBRN Notations - CBRN Protection
1 Detection system 375
1.1 Detection
1.2 Alarm and monitoring
2 Collective Protection system 375
2.1 Citadel ventilation
2.2 Ventilation of machinery spaces or hazardous spaces included in the citadel
2.3 CBRN Protection plant
2.4 Airlocks and cleansing stations
3 Airblast Resistance 377
3.1 Application
3.2 Protection of ventilation openings
3.3 Protection of collective protection system air inlet
4 Personal protective equipment (PPE) 377
4.1 General
4.2 Self-contained breathing apparatus

Section 4 CBRN Notations - Piping and Electrical Equipment
1 Piping systems 378
1.1 General
1.2 Scupper and bilge systems
1.3 Air, sounding and overflow pipes
2 Electrical equipment 378
2.1 Environmental protection
2.2 Emergency source of power

Section 5 CBRN Notations - Pre-Wetting and Washdown System
1 General 380
1.1 Application
1.2 Ventilation openings

2 Pre-wetting and washdown system 380
2.1 System arrangement
2.2 System equipment

Section 6 Biological Risk Management (BIORISK)
1 General 381
1.1 Application
1.2 Documents to be submitted
2 BIORISK MANAGED 381
2.1 Biological risk assessment
2.2 Outbreak Management Plan
2.3 Personal Protective Equipment (PPE)
2.4 Signs and marking
3 Additional requirements for BIORISK SECURED 383
3.1 General
3.2 Quarantine area
3.3 Ventilation of accommodation spaces and normally manned control stations
3.4 Other equipment
4 Onboard testing 384
4.1 Initial survey

Chapter 11 Manoeuvring, Mooring, Anchoring and Position Keeping

Section 1 Ship Manoeuvrability (MANOVR)
1 General 387
1.1 Application
1.2 Manoeuvre evaluation
2 Definitions 387
2.1 Geometry of the ship
2.2 Standard manoeuvres and associated terminology
3 Requirements 388
3.1 Foreword
3.2 Conditions in which the requirements apply
3.3 Criteria for manoeuvrability evaluation
4 Additional considerations 389
4.1 Trials in different conditions
4.2 Dynamic instability

Section 2 Heading Control in Adverse Conditions
1 General 390
1.1 Application
1.2 Definitions
1.3 Documents to be submitted
2 Heading control analysis 392
2.1 General
2.2 Environmental adverse conditions
2.3 Loading conditions
2.4 Performance criteria

3 Requirements for duplicated propulsion and steering systems 393
3.1 Principles
3.2 Failure and casualty scenarios
3.3 Propulsion and steering systems
3.4 Propulsion auxiliary systems
3.5 Steering systems
3.6 Electrical installations
3.7 Automation
4 Requirements for independent propulsion and steering systems 394
4.1 General design requirements
4.2 Propulsion and steering systems
4.3 Electrical installations
4.4 Automation
4.5 Compartment arrangement
4.6 Propulsion auxiliary systems
4.7 Ventilation system
5 Tests on board 396
5.1 Operating tests
5.2 Sea trials

Section 3 Single Point Mooring (SPM)
1 General 397
1.1 Application
2 Documentation 397
2.1 Documentation for approval
2.2 Documentation for information
3 General arrangement 397
3.1 General provision
3.2 Typical layout
3.3 Equipment
4 Number and safe working load of chain stoppers 399
4.1 General
5 Mooring components 399
5.1 Bow chain stopper
5.2 Bow fairleads
5.3 Pedestal roller fairleads
5.4 Winches or capstans
6 Supporting hull structures 401
6.1 General
7 Strength criteria 401
7.1 General

Section 4 Unsheltered Anchoring
1 General 402
1.1 Application
2 Anchoring equipment 402
2.1 Equipment number for deep and unsheltered water
2.2 Anchors
2.3 Chain cables for bower anchors
2.4 Anchor windlass and chain stopper

Section 5 Dynamic Positioning (DYNAPOS)

1 General 404

1.1 Application
1.2 Definitions
1.3 Dynamic positioning sub-systems
1.4 Additional and optional class notation
1.5 Installation survey during construction
1.6 List of documents to be submitted

2 Performance analysis 408

2.1 General
2.2 Condition of analysis
2.3 Modelling and simulations
2.4 Failure mode and effects analysis

3 Equipment class 410

3.1 General
3.2 Equipment class according to single failure

4 Functional requirements 411

4.1 General
4.2 Power system
4.3 Monitoring and management of the electricity production and propulsion
4.4 Thruster system
4.5 Thruster control
4.6 Thruster monitoring and protection
4.7 DP operator station
4.8 DP control system
4.9 Computers
4.10 Networks
4.11 Independent joystick system

5 Position reference systems and environmental sensors 418

5.1 General
5.2 Arrangement and performance of reference systems
5.3 Type of position reference system
5.4 Other reference systems
5.5 Environmental sensors

6 Installation requirements 420

6.1 Cables and piping systems
6.2 Thruster location

7 Operational requirements 420

7.1 General

8 Tests and trials 421

8.1 Inspection at works
8.2 Trials

9 Environmental station keeping index ESKI 421

9.1 Definition
9.2 Environmental conditions
9.3 Condition of ESKI estimation
9.4 Documentation to be submitted and example

10 Enhanced DP system 423

10.1 General
10.2 DP Control system
10.3 Position reference system
10.4 Other vessel sensors

11 Digital DP survey 424

11.1 General
11.2 Definitions
11.3 Documentation and test attendance
11.4 Recorded parameters
11.5 Data Communication and Management
11.6 Hardware requirements
11.7 Cyber security
11.8 Validation
11.9 Verification
11.10 Qualification

Chapter 12 Cargo Operation, Securing and Safety

Section 1 SINGLEPASSLOADING

1 General 433

1.1 Application
1.2 Definitions

2 Documentation to be submitted 433

2.1 Design loading rate
2.2 Loading sequences
2.3 Hold mass curves

3 Loading instrument and alternative loading 434

3.1 Loading instrument
3.2 Alternative loading

4 Hull requirements 434

4.1 General
4.2 Hull structure
4.3 Control and monitoring

5 System requirements 435

5.1 General
5.2 Ballast piping
5.3 Control and monitoring

Section 2 Bow and Stern Loading / Unloading Systems

1 General 436

1.1 Application
1.2 Class notations
1.3 Scope of classification
1.4 Definitions
1.5 Documents to be submitted
1.6 Operating Manual

2 Materials 437

2.1 General

3 General design 437

3.1 Mooring system
3.2 Cargo piping system
3.3 Ventilation
3.4 Hazardous areas and electrical installations
3.5 Positioning
3.6 Emergency Disconnection System (EDS)
3.7 Control station
3.8 Communications
3.9 Safety features

Table of Content

Section 3 Supply at Sea (SAS)

1 General 440

1.1 Application
1.2 Documents to be submitted
1.3 Definitions

2 Design and construction 441

2.1 SAS equipment
2.2 Steering capability

3 Arrangement and installation 442

3.1 General
3.2 Arrangement of SAS stations
3.3 SAS control station arrangement
3.4 Communication
3.5 Fluid transfer
3.6 Solid transfer
3.7 Electrical installation

4 Certification, inspection and testing 445

4.1 Type approval procedure
4.2 Inspection at works of the SAS equipment
4.3 Prototype tests
4.4 Tests on board

Section 4 Centralised Cargo and Ballast Water Handling Installations (CARGOCONTROL)

1 General 447

1.1 Application
1.2 Documents to be submitted

2 Design and construction requirements 447

2.1 Control station
2.2 Remote control, indication and alarm systems

3 Inspection and testing 448

3.1 Equipment and systems
3.2 Testing on board

Section 5 Container Lashing Equipment

1 General 449

1.1 Additional class notations
1.2 Definitions
1.3 Documentation to be submitted
1.4 Materials
1.5 Cargo Safe Access Plan (CSAP)

2 Arrangement of containers 452

2.1 General
2.2 Stowage in holds within cell guides
2.3 Stowage in holds without cell guides
2.4 Stowage on exposed deck
2.5 Uniform line load stowage on deck or hatch covers

3 Approval of the fixed and portable containers securing fittings 455

3.1 General
3.2 Type tests
3.3 Additional functional test for fully automatic twistlocks
3.4 Production testing of the fixed and portable container securing fitting
3.5 Reception on board of the container securing fitting

4 Forces applied to containers 459
4.1 General
4.2 Definitions
4.3 Still water and inertial forces
4.4 Passive free-surface anti-roll tank
4.5 Wind forces
4.6 Forces imposed by securing fittings
5 Resulting loads in container securing fittings and container frames 464
5.1 Calculation hypothesis
5.2 Distribution of forces
5.3 Containers only secured by locking devices
5.4 Containers secured by means of securing fittings or buttresses
5.5 Stiffness values
6 Strength criteria 468
6.1 Maximum stack weight
6.2 Permissible loads on containers
6.3 Permissible loads induced by securing fitting on container corners
6.4 Permissible loads on securing fittings
7 Lashing software 471
7.1 General
7.2 Operation manual
7.3 Requirements for lashing software
7.4 Approval of a lashing software
Section 6 OPEN-HATCH
1 General 474
1.1 Application
1.2 Definitions
2 Loading conditions 474
2.1 Intact flooded condition
3 Freeboard 475
3.1 General
4 Stability 475
4.1 Intact stability without water ingress
4.2 Intact stability considering water ingress
4.3 Damage Stability
5 Hull 476
5.1 Hull girder ultimate strength
5.2 Hull scantlings
6 Procedure of model tests 476
6.1 General
7 Ship arrangement 477
7.1 Hold bilge dewatering system and freeing ports
8 Fire protection 478
8.1 Fire insulation
8.2 Water-spray system
8.3 Dangerous goods
9 Testing 479
9.1 Onboard tests

Table of Content

Section 7 Efficient Washing of Cargo Tanks (EWCT)

1 General 480

1.1 Application
1.2 Documents to be submitted

2 Design requirements 480

2.1 Cargo tanks
2.2 Cargo piping system
2.3 Cargo tank cleaning system

Section 8 Increased Admissible Cargo Tank Pressure (IATP)

1 Application 481

1.1 Ships covered by this section
1.2 Scope

2 Documentation to be submitted 481

2.1 Drawings and documents to be submitted to the Society

3 Definitions 481

3.1

4 General design requirements 482

4.1 Ship design
4.2 Cargo tanks pressure relieving system
4.3 Boil-off gas management system

5 Control, monitoring and safety systems 483

5.1 Cargo tanks pressure alarms
5.2 Indication of the cargo tanks pressure setting

6 Other 483

6.1 Shop and gas trials
6.2 Ship to ship transfer

Section 9 Electric Vehicle Onboard Charging (EVOC)

1 General 484

1.1 Application
1.2 Definitions and abbreviations
1.3 Documents to be submitted

2 Arrangement and safety assessment 485

2.1 Recharging area arrangement
2.2 Risk assessment

3 Electrical installation 485

3.1 General
3.2 Sockets and outlets
3.3 Electrical cables and connections
3.4 Charging station

4 Fire safety 487

4.1 Fire detection
4.2 Fixed fire-extinguishing systems
4.3 Portable equipment

5 Prevention of explosion and limitation of the consequences of toxicity 488

5.1 Sources of ignition
5.2 Ventilation

6 Testing 489

6.1 Type testing
6.2 Workshop tests
6.3 Shipboard test

Appendix 1 Definition of Specific Routes for the Notation LASHING-RSSA

1 General 490

1.1 Definition of the reference specific routes and crossed areas
1.2 Allowance criterion for deviations from the reference specific routes

Chapter 13 Additional Notation for Fire Protection

Section 1 Enhanced Fire Protection (EFP-AMC)

1 General 500

1.1 Application

2 Protection of accommodation spaces (EFP-A) 500

2.1 Application
2.2 Prevention of fire
2.3 Detection and alarm
2.4 Containment of fire
2.5 Escape

3 Protection of machinery spaces (EFP-M) 501

3.1 Application
3.2 Machinery spaces general arrangement
3.3 Detection and alarm
3.4 Ventilation system
3.5 Fixed water-based local application fire-fighting system
3.6 Escape
3.7 Central control station

4 Protection of cargo decks and cargo spaces (EFP-C) 502

4.1 Cargo ships
4.2 Ro-ro cargo ships, PCTC and PCC
4.3 Oil tankers, FLS tankers and chemical tankers
4.4 Liquefied gas carriers

5 Onboard testing 504

5.1 Hot spot verification

Section 2 Enhanced Cargo Fire Protection for Container Ships (ECFP)

1 General 505

1.1 Application
1.2 Innovative technologies
1.3 Documents to be submitted

2 Requirements for the notation ECFP-1 506

2.1 General
2.2 Portable equipment
2.3 Compressed air system for breathing apparatuses

3 Additional requirements for the notation ECFP-2 507

3.1 General
3.2 Central control station
3.3 Fire detection
3.4 Water supply systems
3.5 Mobile water monitors
3.6 Fixed water monitors covering the on-deck cargo stowage area
3.7 Water-spray system below hatch cover
3.8 Flooding system for the cargo holds
3.9 Water-spray system for the protection of the superstructure block
3.10 Design of the ventilation system

4 Additional requirements for the notation ECFP-3 513
4.1 General
4.2 Central control station
4.3 Portable equipment
4.4 Fire detection
4.5 Water-spray system below hatch cover
4.6 Design of the ventilation system
5 Certification and testing 515
5.1 Type approval of portable fire-fighting devices for stacked containers
5.2 Type testing of fixed water monitors
5.3 Onboard tests
Section 3 Cofferdam Ventilation (COVENT)
1 General 517
1.1 Application
1.2 Documents to be submitted
2 Design and construction 517
2.1 Arrangement
2.2 Other technical requirements
3 Inspection and testing 518
3.1 Equipment and systems
3.2 Testing on board
Section 4 Enhanced Fire Protection for Ships carrying Electrical Vehicles (EVFP)
1 General 519
1.1 Application
1.2 Electrical vehicles (EV)
1.3 Classification notations
1.4 Documentation to be submitted
2 General requirements 520
2.1 Operational manual
2.2 Area for the storage of electric vehicles (EV storage area)
2.3 Detection and alarm
2.4 Fire-fighting systems
3 Additional requirements for notation EVFP-2 520
3.1 General
3.2 Decontamination area
3.3 Detection and alarm
3.4 Fire-fighting systems
4 Additional requirements for notation EVFP-3 521
4.1 General
4.2 Arrangement, prevention of fire and structural integrity
4.3 Smoke extraction systems
4.4 Fire-fighting systems
5 Testing 522
5.1 Onboard Tests
6 Certification of portable devices and gas detection systems 522
6.1 General
6.2 Specific tests for type approval of portable fire-fighting devices
6.3 Type approval of gas detection systems

Chapter 14 Electric Propulsion or Power Supply

Section 1 Electric Hybrid

1 General 525

1.1 Application
1.2 Documents to be submitted
1.3 Definitions

2 System design 527

2.1 Quality of power supply
2.2 Power distribution

3 Electric Energy Storage System (ESS) 528

3.1 General
3.2 ESS semiconductor converter
3.3 ESS transformer
3.4 Energy Control System (ECS)
3.5 ESS capacity
3.6 ESS charging
3.7 ESS control and instrumentation

4 Testing 530

4.1 Factory acceptance tests
4.2 Onboard tests
4.3 Tests of battery room and fire-extinguishing system

Section 2 Electric Hybrid Prepared

1 General 531

1.1 Application
1.2 Definitions and abbreviations
1.3 Documents to be submitted
1.4 Documents to be submitted when requesting additional class notation ELECTRIC HYBRID

2 System design 533

2.1 Ship design
2.2 Cables

3 Electric energy storage system (ESS) 533

3.1 ESS Batteries
3.2 ESS semiconductor converter and transformer
3.3 ESS Control and instrumentation

4 Installation on board 534

4.1 Spaces

5 Testing 534

5.1 Factory acceptance tests
5.2 On-board tests

Section 3 Hybrid Mechanical Propulsion Systems (HMPS)

1 General 535

1.1 Application
1.2 Definitions
1.3 Documents to be submitted

Table of Content

2 System design 536

2.1 Propulsion systems
2.2 Electric Production systems
2.3 Diesel propulsion systems
2.4 Electrical propulsion systems
2.5 Combined diesel and electric propulsion systems

3 Control of propulsion machinery 537

3.1 Remote control from navigation bridge of the propulsion machinery
3.2 Local control of the propulsion machinery
3.3 Switch over from one propulsion type mode to another one
3.4 Displays and alarms

4 Testing 538

4.1 Onboard tests

Section 4 HMPS-PREPARED

1 General 539

1.1 Application
1.2 Definitions and abbreviations
1.3 Documentations to be submitted

2 System design 540

2.1 Ship design
2.2 Cables
2.3 Safety

3 Installation on board 541

3.1 Spaces

4 Testing 541

4.1 Type tests

Section 5 Onshore Power Supply (OPS)

1 General 542

1.1 Application
1.2 Definitions
1.3 Documentation to be submitted

2 Electrical Installations 544

2.1 General requirements
2.2 Ship to Shore installation
2.3 Monitoring
2.4 Protection

3 Testing and trials 548

3.1 Equipment Testing
3.2 Initial tests

Section 6 OPS-PREPARED

1 General 550

1.1 Application
1.2 Definitions and abbreviations
1.3 Documentation to be submitted

2 Requirements for OPS( )-PREPARED 551

2.1 General
2.2 General ship design - arrangement
2.3 General ship design - electrical system design
2.4 Detailed design

3 Additional requirements for notation -C 553
3.1 Cable routing

Chapter 15 Other Additional Class Notations

Section 1 Strengthened Bottom (STRENGTHBOTTOM)
1 General 555
1.1 Application
2 Primary supporting members arrangement 555
2.1 General
2.2 Ships with a longitudinally framed bottom
2.3 Ships with a transversely framed bottom
3 Bottom scantlings 555
3.1 Plating
3.2 Stiffeners
3.3 Primary supporting memers

Section 2 Grab Loading (GRABLOADING)
1 General 557
1.1 Application
2 Scantlings 557
2.1 Inner bottom plating

Section 3 In-Water Survey Arrangements (INWATERSURVEY)
1 General 558
1.1 Application
1.2 Documentation to be submitted
2 Structure design principles 558
2.1 Marking
2.2 Rudder arrangements
2.3 Tailshaft arrangements
3 Sea inlets and cooling water systems of machinery 559
3.1

Section 4 Permanent Means of Access (ACCESS)
1 General 560
1.1 Application
1.2 Definitions

Section 5 Helideck (HEL)
1 General 561
1.1 Application
1.2 Reference standard

Section 6 Man Overboard Detection (MOB)
1 Application 562
1.1 General
1.2 Reference to other regulations and standard
1.3 Definitions
1.4 Documents to be submitted

Table of Content

2 General design requirements 563

2.1 System description
2.2 MOB detection zone
2.3 MOB alert and alarm
2.4 Data storage
2.5 Control system
2.6 Events markers
2.7 Voyage Data Recorder

3 Survey onboard 564

3.1 General
3.2 MOB testing manikin
3.3 Environmental conditions
3.4 Probability of detection
3.5 Testing
3.6 False alerts

Section 7 FSRU-READY

1 General 566

1.1 Application
1.2 Definition
1.3 Plans and documents to be submitted
1.4 Conversion to FSRU

2 Requirements for the additional class notation FSRU-READY 567

2.1 Assumption for site condition
2.2 General arrangement
2.3 Hull and stability
2.4 Design loads
2.5 Structural strength
2.6 Sloshing on-site

3 Additional requirements for notations P, R and I 568

3.1 Notation P
3.2 Notation R
3.3 Notation I

Section 8 Sustainable Ships

1 General 570

1.1 Scope
1.2 Documents to be submitted
1.3 Notation SUSTAINABLESHIP-1
1.4 Notation SUSTAINABLESHIP-2
1.5 Initial survey

Part F
Additional Class Notations

CHAPTER 1
VERISTAR SYSTEM (STAR)

Section 1 VeriSTAR-HULL and VeriSTAR-HULL CM

Section 2 Star-Mach, Star-Mach SIS

Section 3 Star-Regas

Section 4 Star-Cargo

Appendix 1 Owner’s Hull Inspection Reports

Section 1 VeriSTAR-HULL and VeriSTAR-HULL CM

1 General

1.1 Application

1.1.1 The additional class notation **VeriSTAR-HULL**, **VeriSTAR-HULL CM** and **VeriSTAR-HULL SIS** are assigned at the design stage or after construction. The notation **Veri-STAR-HULL SIS** is to be maintained during the service life. These notations are granted to ships complying with the requirements of this Section, in accordance with Pt A, Ch 1, Sec 2, [6.2].

1.2 Scope

1.2.1 The additional class notation **VeriSTAR-HULL** is assigned to a ship in order to reflect the fact that a structural tridimensional analysis has been performed for the hull structures, as defined in:

- Part B, Chapter 8 or Pt B, Ch 7, App 1, or
- the Common Structural Rules (NR606), as applicable.

The additional class notation **VeriSTAR-HULL** may be completed by the notation **FLM** when a complementary structural tridimensional analysis has been performed for the hull structures based on a full length finite elements model, as defined in:

- NI640 for ships assigned the service notation **passenger ship**, **ro-ro passenger ship**, **ro-ro cargo ship**, **PCTC** or **PCC**
- Pt B, Ch 8, App 3 for ships assigned other service notations.

Note 1: For ships assigned the service notation **passenger ship**, **ro-ro passenger ship**, **ro-ro cargo ship**, **PCTC** or **PCC**, the additional class notation **VeriSTAR-HULL FLM** is to be considered in lieu of the additional class notation **VeriSTAR-HULL** and requirements defined in Part B, Chapter 8 and Pt B, Ch 7, App 1 may be disregarded.

1.2.2 The additional class notation **VeriSTAR-HULL CM** is assigned to a ship in order to reflect the following:

- the ship fulfils requirements of additional class notation **VeriSTAR-HULL** as given in [1.2.1]
- a hot spot map has been made available for construction surveys and is kept on board the ship after delivery.

The additional class notation **VeriSTAR-HULL CM** may be completed by the notation **FLM** when the complementary requirements for the assignment of the notation **VeriSTAR-HULL FLM** are complied with.

2 Assignment of the notation

2.1 VeriSTAR-Hull

2.1.1 The procedure for the assignment of a **VeriSTAR-HULL** notation to a ship is as follows:

a) The Interested Party submits to the Society the following documents:
   - Plans and documents necessary to carry out the structural analysis, listed in Pt B, Ch 1, Sec 4 or in the Common Structural Rules (NR606)
   - Results of the analysis of the longitudinal strength and local scantlings of the plating and secondary stiffeners located in the central part, as defined in Pt B, Ch 1, Sec 1, [2.1.3], in compliance with the requirements of:
     - Part B, Chapter 6 and Pt B, Ch 7, Sec 4 and Pt B, Ch 7, Sec 5, respectively, or
     - the Common Structural Rules (NR606).
   - Results of the tridimensional analysis of the hull structure described in Pt B, Ch 7, Sec 6 or in the Common Structural Rules (NR606)
   - Results of the fatigue analysis of the hull structure described in Part B, Chapter 10 or in the Common Structural Rules (NR606), as applicable.

b) the Interested Party reports to the Society the changes in structural scantlings or design made during the design and building phase. In particular, an as-built version of the drawings is to be submitted to the Society for further reference

c) the Society reviews the structural analyses and contents of the ship structural database and, if satisfied with the results, assigns the **VeriSTAR-HULL** notation.

2.2 VeriSTAR-HULL CM

2.2.1 General

The procedure for the assignment of the **VeriSTAR-HULL CM** notation to a ship is as follows:

a) The procedure described in [2.1.1] is to be followed

b) The Interested Party submits to the Society a hot spot map as described in [2.2.2]

c) The Society reviews the hot spot map and, if satisfied with the results, grants the **VeriSTAR-HULL CM** notation.

2.2.2 Hot spot map

The items to be included in the hot spot map are, in general, the following:

- items (such as plating panels or primary supporting members) for which the FEM analysis carried out at design stage show that the ratio between applied loads and allowable limits exceed 0,975
- items identified as “hot spot item” during structural reassessment, taking into account actual conditions revealed by updated thickness gaugings
- structural details subjected to fatigue, based on the list defined in Pt B, Ch 13, Sec 5 or NR606, Chapter 9. As a rule, only fatigue details with a calculated damage ratio above 0,8 are to be included in the hot spot map
- other items, depending on the results of the structural analyses and/or on experience.

At early design stage, a preliminary hot spot map with a list of hot spots based only on experience may be provided to the Society to achieve the first construction surveys. This preliminary document is to be updated according to the calculation results obtained from FEM analysis and fatigue analysis as soon as they are available.

The layout of the hot spot map is to be as convenient as possible for inspection/survey purpose.

Section 2 Star-Mach, Star-Mach SIS

1 General

1.1 Application

1.1.1 The additional class notations **STAR-MACH** and **STAR-MACH SIS** are assigned after construction, to ships complying with the requirements of this Section in accordance with Pt A, Ch 1, Sec 2. The notation **STAR-MACH SIS** is to be maintained during the ship service life.

1.2 Definitions

1.2.1 Risk Analysis

Risk analysis is a process of identifying assets and threats, prioritizing the related vulnerabilities, and identifying appropriate measures and protections in order to decrease these vulnerabilities to an acceptable level. On a ship, the risk analysis shall identify critical equipment in compliance with ISM Code, Section 10.

The most suitable risk analysis technique to be applied in this Section is the Reliability Centred Maintenance (RCM) methodology defined by or on behalf of the Operator, as described in [1.2.4]. Other risk analysis techniques providing an equivalent maintenance strategy may be recognized by the Society on a case by case basis. Condition monitoring techniques may be implemented.

1.2.2 Operator

In this Section, Operator means the Owner of the vessel or any other organization or person, such as the Manager or the Bareboat Charterer, who declares to be in charge of the maintenance of the ship.

1.2.3 Maintenance Management System

In this Section, the Operator's Maintenance Management System means the computerized support, as well as the content, that is the maintenance plan and the historical data.

1.2.4 Reliability Centred Maintenance (RCM)

RCM is defined by the international recognized standards, such as SAE JA1011 "Evaluation Criteria for RCM Processes" and SAE JA 1012 "Guide to the Reliability Centred Maintenance (RCM) Standard" or IEC 60300-3-11 "Dependability management - Part 3-11: Application guide - Reliability centred maintenance".

It is a process used to select suitable failure management policies in order to ensure that any physical asset continues to function according to its performance standards and in its present operating context. It is generally used to achieve improvements in fields such as the establishment of safe minimum levels of maintenance, changes to operating procedures and strategies and the establishment of capital maintenance regimes and plans in order to increase the probability that an asset will function in the required manner over its design life-cycle with a minimum amount of maintenance and downtime.

The RCM process generally consists of answering the seven basic questions for each asset or system under review:

- Function: What are the functions and associated performance standards of the asset in its present operating context?
- Functional Failure: In what ways does it fail to fulfil its functions?
- Failure Mode: What causes each functional failure?
- Failure Effect: What happens when each failure occurs?
- Consequence: In what way does each failure matter?
- Pro-active task: What can be done to predict or prevent each failure?
- Default task: What should be done if a suitable proactive task cannot be found?

1.3 Scope

1.3.1 The scope of **STAR-MACH** and **STAR-MACH SIS** is limited to the ship propulsion and steering systems, auxiliaries (machinery, electrical). It includes class machinery items and excludes any statutory equipment. A typical list of systems covered by these additional class notations is presented below:

- propulsion plant, including thrusters if any
- actuating systems of controllable pitch propellers
- electricity production and distribution
- cooling water systems
- lubricating oil transfer, treatment, supply systems
- fuel oil transfer, treatment, supply systems

- compressed air systems for starting and control
- hydraulic oil systems
- automation
- bilge system
- ballast / trimming / heeling systems
- fire detection and alarm system
- fire-fighting systems
- fuel / lubricating oil drainage / recovery
- exhaust gas systems
- steam production and distribution systems
- feed water and condensate systems
- thermal oil heating system
- steering gear system
- forced ventilation for machinery spaces, but excluding air conditioning
- waste pumping, but excluding treatment
- sewage pumping, but excluding treatment system.

1.4 Objectives

1.4.1 The additional class notation **STAR-MACH** is assigned to a ship in order to reflect that a RCM study has been performed for the ship systems mentioned in [1.3], in order to support and validate the maintenance plan/program in the operational context.

1.4.2 The additional class notation **STAR-MACH SIS** is assigned to a ship in order to reflect the following:

- a RCM study has been performed for the ship systems mentioned in [1.3], in order to support and validate the maintenance plan/program in the operational context
- the Operator, by taking into account the results of the RCM study, is able to demonstrate the effective implementation and follow-up of the approved maintenance plan/program
- the RCM study is periodically up-dated, usually at the class renewal survey, according to ship operation, maintenance and equipment behaviour (failures …).

2 Assignment of the notation

2.1 Documentation to be submitted

2.1.1 The following documentation is to be submitted to the Society for review (written either in English or in French):

- the Maintenance Plan, including information detailed in [2.1.3]
- the RCM study documentation in paper or electronic form, which should include the following:
  - Equipment or System selection methodology identifying critical equipment in compliance with ISM Code, Section 10 (if separate from the RCM process)
  - Operator RCM methodology or process (including operator maintenance philosophy and strategy) and reference to an applicable standard, such as the ones mentioned in [1.2.4]
  - Methodology for continuous improvement / tuning of the RCM study (in case the RCM study has already been updated before)
  - Qualifications of team involved in the RCM study (training and experience in RCM and equipment / system operation and maintenance)
  - Overview report of the RCM study – i.e. Number of systems, Number of equipment, number of completed, equipment types, level of details, etc (if available)
  - RCM study (Equipment Criticality Analysis, Functional Analysis, FME(C)A, Maintenance Selection Analysis, etc.) of each system including the sources used to collect the reliability data (see [2.1.5]).

  The frequency of maintenance and its scope should be justified by Manufacturer's recommendations or from documented experience.

On a case by case basis, if the RCM study is not documented, the Society can carry out a RCM study, based on the submitted documentation as listed in [2.1.2].

2.1.2 The following documentation is to be submitted to the Society for information regarding systems mentioned in [1.3]:

- Master Equipment List
- System drawings
- Specifications and operational description of systems/ components.
- Equipment operation and maintenance manuals, on a case by case basis
- Attestation from the Operator stating that there are no design changes foreseen in the next 5 years at the date of the application for the **STAR-MACH** notation
- Historical data of equipment maintenance and failures (if any), see [2.1.4].

2.1.3 Maintenance Plan

The Operator is to provide a Maintenance Plan representing the collection of maintenance tasks together with the schedule of execution.

For each maintenance task, the following information must be made available:

- maintenance type (on-condition monitoring, inspection, reconditioning/overhauling, discarding/replacing, testing, routine, service and lubricating, testing/failure finding)
- maintenance frequency (periodicity value unit is to be clearly specified, i.e. hour, day, week, month, year)
- maintenance description/scope.

2.1.4 Historical data

The Operator is to provide the Society with the ship history reports for any piece of equipment on:

- carried-out preventive, preventive and failure finding maintenance (periodic or condition-based)
- damage or breakdown entailing unplanned maintenance (corrective)
- unsatisfactory condition found during maintenance.

Any recorded failure or breakdown should at least contain a detailed description of failure, date of occurrence, equipment counter hours at occurrence, possible cause.

2.1.5 Reliability Data Sources

The Operator is to provide the Society with the reliability data sources used during the RCM process. Reliability data sources could be, but are not limited to:

- Historical data (see [2.1.4])
- Experience of the RCM team members
- Data collected from previous RCM studies in similar systems
- Reliability databases (OREDA, …)
- Manufacturer data, manuals or specifications.

2.2 STAR-MACH

2.2.1 The procedure for the assignment of a **STAR-MACH** notation to a ship, on receipt of the documents listed in [2.1] regarding systems mentioned in [1.3], is as follows:

a) The Society performs a documentation technical review of the RCM study, as described in [2.2.2], in order to approve the Maintenance Plan.

On a case by case basis, if the RCM study is not documented, the Society can carry out a RCM study based on the submitted documentation, in order to approve the Maintenance Plan.

b) On approval of the maintenance plan, the **STAR-MACH** notation is assigned.

2.2.2 The process of the RCM study technical review is:

a) Verification that the Operator RCM methodology or process is based on an acceptable and applicable standard (including Equipment Criticality Analysis (ECA), Failure Modes and Effects Analysis (FMEA), and Maintenance Selection Analysis (MSA)).

b) Verification that the RCM study team members have adequate skills and experience in undertaking RCM studies and are knowledgeable in the studied systems/ equipment.

c) Verification that the RCM study covers all the systems included in the scope.

d) Verification that the most critical systems / equipment defined for the RCM study include some typical critical systems / equipment that would be expected for the ship and include equipment for which serious or frequent failures have been reported.

e) Verification that all class machinery items are included in the scope of the RCM study.

f) Carry out a review of the RCM study applied for selected main equipment of some systems, in order to check all possible scenarios in terms of criticality and maintenance strategies. If the review is acceptable and in accordance with the Operator RCM methodology, the RCM study of other equipment will not be fully reviewed. If considered unacceptable, a review of other equipment will be carried out for confirmation. If this review is also unacceptable, the Society will require a complete review of all other equipment.

g) For the RCM study of each selected system / equipment, verification of the complete RCM process regarding:
   - consistency with the Operator RCM methodology
   - completeness of equipment considered in the system (including controls, instrumentation and protective devices)
   - completeness of considered failure modes
   - completeness and consistency of assigned maintenance strategy, assigned maintenance tasks and intervals with Failure Mode characteristics, criticality and related reliability data
   - cross-references with the Maintenance Plan.

h) Carry out a review of the Maintenance Plan: for most critical systems / equipment and class machinery items, verification that the submitted maintenance plan lists some typical maintenance tasks that would be expected for the relevant item from manufacturers' instructions, under any maintenance regime. These would include, but may not be limited to:
   - equipment performance checks
   - standard condition monitoring checks (vibrations, lubricant analysis, electrical characteristics, thermography, etc.)
   - inspections of components liable to wear or other age related degradation, i.e., fouling
   - periodic tests of instrumentation and protective devices.

i) For most critical systems / equipment and/or class machinery items, where typical tasks have not been found in the submitted maintenance plan, review the RCM study for justification.

j) Review any inconsistencies in maintenance task intervals included in the submitted maintenance plan.

2.3 STAR-MACH SIS

2.3.1 The procedure for the assignment of a **STAR-MACH SIS** notation to a ship, on receipt of the documents listed in [2.1] regarding systems mentioned in [1.3], is as follows:

a) The Society performs a documentation technical review of the RCM study, as described in [2.2.2], in order to approve the Maintenance Plan.

   On a case by case basis, if the RCM study is not documented, the Society can carry out a RCM study, based on the submitted documentation, in order to approve the Maintenance Plan.

b) An Implementation survey is carried out, on board the ship, as per the implementation survey performed in the scope of the Planned Maintenance Survey System described in Pt A, Ch 2, App 1, [5.1].

c) On approval of the maintenance plan and completion of the Implementation survey, the **STAR-MACH SIS** notation is assigned.

Section 3 Star-Regas

1 General

1.1 Application

1.1.1 The additional class notation **STAR-REGAS** is assigned, after construction, to liquefied gas carriers assigned with the additional service feature **REGAS** (with or without **STL-SPM**) and complying with the requirements of this Section in accordance with Pt A, Ch 1, Sec 2. No requirements are provided for the maintenance of this notation during the ship's service life.

1.2 Scope

1.2.1 The scope of the **STAR-REGAS** notation is limited to the regasification installation, its associated systems and the send out systems. A typical list of systems covered by this additional class notation is presented below:

- regasification system
- send out system (HP gas manifold and/or Submerged Turret Loading system)
- heating system
- inert gas system
- vent and relief system
- automation
- fire and gas detection system for regasification and send out areas
- fire-fighting systems for regasification and send out areas
- electricity production and distribution for regasification and send out
- compressed air system for regasification and send out.

1.3 Objectives

1.3.1 The additional class notation **STAR-REGAS** is assigned to a liquefied gas carrier in order to reflect that a RCM study (see Ch 1, Sec 2, [1.2.1] and Ch 1, Sec 2, [1.2.4]) has been performed for the regasification installation and its associated systems, in order to support and validate the maintenance plan in the operating context.

2 Assignment of the notation

2.1 Documentation to be submitted

2.1.1 The following documentation is to be submitted to the Society for review (written either in English or in French):

- The RCM study documentations (see Ch 1, Sec 2, [2.1.1])
- The systems documentation (see Ch 1, Sec 2, [2.1.2]
- The Maintenance Plan, including information detailed in Ch 1, Sec 2, [2.1.3]
- The historical data of equipment maintenance and failures, if any, see Ch 1, Sec 2, [2.1.4].

2.2 STAR-REGAS

2.2.1 The procedure for the assignment of a **STAR-REGAS** notation to a liquefied gas carrier, on receipt of the documents listed in [2.1.1] regarding systems mentioned in [1.2] is as follows:

a) the Society performs a documentation technical review of the RCM study, as described in Ch 1, Sec 2, [2.2.2], in order to approve the Maintenance Plan.

   On a case by case basis, if the RCM study is not documented, the Society can carry out the RCM study, based on the submitted documentation, in order to approve the Maintenance Plan.

b) On approval of the maintenance plan, the **STAR-REGAS** notation is assigned.

Section 4 Star-Cargo

1 General

1.1 Application

1.1.1 The additional class notation **STAR-CARGO** is assigned, after construction, to ships liable to carry cargoes (i.e cargo ships, bulk carriers, combination carriers, gas carriers, tankers, chemical tankers, oil tankers or other ships as relevant) complying with the requirements of this Section in accordance with Pt A, Ch 1, Sec 2, [4].

No requirements are provided for the maintenance of this notation during the ship's service life.

1.2 Scope

1.2.1 The scope of the **STAR-CARGO** notation is limited to the cargo handling installation and its associated systems, excluding structural elements part of cargo tanks and containment system.

1.3 Objectives

1.3.1 The additional class notation **STAR-CARGO** is assigned to a ship in order to reflect that a RCM study (see Ch 1, Sec 2, [1.2.1] and Ch 1, Sec 2, [1.2.4]), has been performed for the cargo handling installation and its associated systems in order to support and validate the maintenance plan in the operating context.

2 Assignment of the notation

2.1 Documentation to be submitted

2.1.1 The following documentation is to be submitted to the Society for review (written either in English or in French):

- The RCM study documentation (see Ch 1, Sec 2, [2.1.1])
- The systems documentation (see Ch 1, Sec 2, [2.1.2])
- The Maintenance Plan, including information detailed in Ch 1, Sec 2, [2.1.3]
- The historical data of equipment maintenance and failures, if any (see Ch 1, Sec 2, [2.1.4]).

2.2 STAR-CARGO

2.2.1 The procedure for the assignment of a **STAR-CARGO** notation to a ship, on receipt of the documents listed in [2.1.1] regarding systems mentioned in [1.2], is as follows:

a) The Society performs a documentation technical review of the RCM study, as described in Ch 1, Sec 2, [2.2.2], in order to approve the Maintenance Plan.

On a case by case basis, if the RCM study is not documented, the Society can carry out the RCM study, based on the submitted documentation, in order to approve the Maintenance Plan.

b) On approval of the maintenance plan, the **STAR-CARGO** notation is assigned.

Appendix 1 Owner's Hull Inspection Reports

1 General

1.1

1.1.1 Application

As stated in Ch 1, Sec 1, inspection reports are to be prepared by the Owner's person responsible each time an inspection is carried out within the scope of the Inspection and Maintenance Plan. Two models of inspection report are provided for this purpose:

- one model for inspection of spaces (applicable to inspection of deck area structure, ballast tanks, dry cargo holds and spaces, superstructures and other accessible compartments)
- one model for inspection of hull equipment (applicable to hatch covers and small hatches, deck equipment, sea connections and overboard discharges).

One separate inspection report is to be issued for each different space or equipment inspected.

1.1.2 Use of models

The Owner is to adapt these models, so far as practicable and appropriate, to the ship concerned, the spaces to be inspected and the existing equipment. However, the general content of the report and its layout are to comply with the models.

2 Report for inspection of spaces

2.1 General

2.1.1 The model of Owner's report for space inspection is given in Tab 1.

2.1.2 The report is divided into four parts:

- general identification data
- summary of findings and repairs for the different areas of the space and for the fittings in this space
- details of findings and repairs, as applicable
- additional documentation attached to the report.

2.2 Identification data

2.2.1 The identification data are to give the information about the space inspected, date and place of inspection and name of the person under whose responsibility the inspection has been carried out.

2.2.2 The identification of the space is to be such that:

- it is easy to trace the space concerned, in particular in cases where several identical spaces exist on the ship
- the same identification is used for the subsequent inspection reports pertaining to the same space.

2.3 Summary of findings and repairs

2.3.1 Each space inspected is divided into items corresponding to:

- the different boundaries of the space
- the internal structure of the space
- the fittings of the space.

For better understanding, the second column of the table may be used to clarify which elements belong to each item or which fittings are concerned.

2.3.2 For each item, as applicable, the summary table is to give a general answer to the findings and to the possible repairs made.

- When coating condition is concerned, the answer is to be either “no coating”, or “good”, or “fair”, or “poor”, as per the definition of such conditions given in Pt A, Ch 2, Sec 2.
- Anode condition is to be answered by giving an estimated average loss of weight as a percentage, bearing in mind the acceptance criteria given in Ch 1, Sec 1.
- The other columns (fractures, general corrosion, pitting/grooving, deformations, repairs) are to be answered “yes” or “no”, depending on whether or not such defect/repair has been found/performed.
- The column “other” is to be used to indicate whether another type of inspection has been carried out, such as thickness measurement, pressure test or working test.

Table 1 : Owner’s report for space inspection

Person responsible:	
Date of inspection:	Place of inspection:
Name of ship:	Register number:
Name and type of space:	Location (port/stbd, from frame ... to frame ...):

Structure area, fittings	Items in the area	Coating / anode condition	Fractures	General corrosion	Pitting or grooving	Deformations	Repairs	Other
Top								
Bottom								
Port side								
Stbd side								
Forward bulkhead								
Aft bulkhead								
Internal structure								
Fittings								

Findings during inspection: (location, type, details)	Action taken: required repair, temporary repair, permanent repair (location, type and extent)
Other documentation attached to the report : sketches [ ] , photos [ ] , thickness measurement report [ ] , other [ ]	

2.4 Details of findings and repairs

2.4.1 Each time the answer in the summary table is “poor” for coating, or “yes” for other topics, this part of the report is to be used to give details on the findings, defects or repairs concerned.

2.4.2 As guidance, the following details are to be given:

- for coating found in poor condition:
  structural elements concerned, type of coating defect (breakdown, hard scale)
- for fractures:
  location of fractures, dimension, number of identical fractures
- for general corrosion:
  structural elements concerned, extent of wastage on these elements, estimation of wastage (if thickness measurements have been taken)
- for pitting/grooving:
  structural elements concerned and location, depth of pitting/grooving, percentage of affected surface using diagrams in Appendix 5, length of grooving
- for deformations:
  type of deformation (buckling, external cause), location of the deformation and structural elements concerned, estimation of size
- for repairs (if performed without the attendance of a Surveyor, when this is possible or acceptable):
  type of repairs, elements or areas concerned.

2.5 Attached documentation

2.5.1 It is recommended that the report is supported by attaching sketches, photos, the thickness measurement report or other documentation, when this is deemed necessary to clarify the findings and/or repairs given in the detailed part.

For example:

- photos may be used to show the condition of the coating and anodes, the extent of general corrosion, pitting and grooving, or the appearance and extent of fractures
- sketches may be used to indicate fractures, deformations and repairs, especially when a photo cannot encompass the whole image and give a complete representation.

3 Report for inspection of equipment

3.1 General

3.1.1 The model of Owner’s report for equipment inspection is given in Tab 2.

3.1.2 The report is divided into three parts:

- general identification data
- detailed report of findings and repairs
- additional documentation attached to the report.

3.2 Identification data

3.2.1 The identification data are to give the information about the equipment inspected, date and place of inspection and name of the person under whose responsibility the inspection has been carried out.

3.2.2 The identification of the equipment is to be such that:

- it is easy to trace the item of equipment concerned, in particular in cases where several identical items of equipment exist on the ship
- the same identification is used for the subsequent inspection reports pertaining to the same item of equipment.

3.3 Detailed report

3.3.1 The detailed report of inspection is divided into three parts:

- inspection done:
  - the type of inspection carried out:
    visual external examination, internal examination after dismantling, overhaul
  - readings performed, when applicable:
    clearances, thickness measurements, working pressure, or other working parameters of the equipment

- findings during the inspection:
  corrosion, fractures, pieces of equipment worn out, broken or missing.
- maintenance done, repairs carried out and pieces renewed
- results of tests performed after the inspection, such as working test, pressure test, hose test or equivalent for hatch covers or other weathertight fittings, sea trials.

3.4 Attached documentation

3.4.1 It is recommended that the report is supported by attaching sketches, photos, the thickness measurement report or other documentation, when this is deemed necessary to clarify the findings and/or repairs given in the detailed part.

For example:

- photos may be used to show the condition of the pieces of equipment before their overhaul or renewal, the coating condition of piping, or the extent of corrosion
- sketches may be used to indicate fractures and deformations, clearances taken, or other measurements performed.

Table 2 : Owner's report for equipment inspection

Person responsible:	
Date of inspection:	Place of inspection:
Name of ship:	Register number:
Name and type of equipment:	Location (port/stbd, at frame ..., ...):

Type of inspection, findings and readings:
Repairs, maintenance, pieces renewed:
Working tests, pressure test, trials, ... :
Other documentation attached to the report : sketches [ ] , photos [ ] , thickness measurement report [ ] , other [ ]

CHAPTER 2
AVAILABILITY OF MACHINERY (AVM)

Section 1 Alternative Propulsion System (AVM-APS)

Section 2 Duplicated Propulsion System (AVM-DPS)

Section 3 Independent Propulsion Systems (AVM-IPS)

Section 4 Fire Mitigation for Main Diesel-Generator Rooms (AVM-FIRE)

Appendix 1 Procedures for Failure Modes and Effect Analysis

Section 1 Alternative Propulsion System (AVM-APS)

1 General

1.1 Application

1.1.1 The additional class notation **AVM-APS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.3.2] to self propelled ships arranged with means for alternative propulsion system complying with the requirements of this Section.

1.1.2 Installation of machinery and electrical systems is to comply with relevant provisions of Part C.

1.1.3 The alternative propulsion system is an arrangement of machinery suitable to maintain the ship in operating condition in case of loss of the main propulsion system.

The alternative propulsion system may be used either to allow the ship to reach the first suitable port or place of refuge, or to escape from severe environment, allowing minimum services for navigation, safety, preservation of cargo and habitability.

1.1.4 Alternative propulsion system is to be designed for permanent operation with unrestricted working duration.

1.2 Definitions

1.2.1 Main propulsion system

The main propulsion system is a system that provides thrust to the ship in normal condition of operation. It includes:

- the prime mover, including the integral equipment, driven pumps, etc.
- the equipment intended to transmit the torque
- the propulsion electric motor, where applicable
- the equipment intended to convert the torque into thrust
- the auxiliary systems necessary for operation
- the control, monitoring and safety systems.

1.2.2 Alternative propulsion system

The alternative propulsion system is a system that provides thrust of the ship in emergency conditions, when the main propulsion system becomes unavailable after a failure. It may be supplied either by a stand-by emergency engine or electric motor, or by a shaft generator, provided it has been designed for readily reversible operation as propulsion motor, in the case of loss of the main engine.

The alternative propulsion system also includes the following associated systems:

- the equipment intended to convert the torque into thrust
- the auxiliary systems necessary for operation
- the control, monitoring and safety systems.

1.2.3 Propulsion auxiliary systems

Propulsion auxiliary systems include all the systems that are necessary for the normal operation of a propulsion system. It includes or may include:

- the fuel oil supply system from and including the service tanks (see Note 1)
- the lubricating oil systems serving the engines, the gearbox, the shaftline bearings, the stern tube, etc. (see Note 2)
- the hydraulic oil systems for operating clutches, controllable pitch propellers, waterjet reverse deflectors, starting systems, etc.
- the fresh water cooling systems serving any component of the propulsion system or used for cooling the fuel oil circuits, the lubricating oil circuits, the hydraulic oil circuits, etc.
- the sea water cooling systems used for cooling any component of the propulsion system or any of the afore-mentioned systems
- the heating systems (using electricity, steam or thermal fluids)
- the starting systems (air, electrical, hydraulic)
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems
- the ventilation installation where necessary (e.g. to supply combustion air or cooling air to the primer movers).

Note 1: The fuel oil filling, transfer and purifying systems are not included.

Note 2: The lubricating oil filling, transfer and purifying systems are not inc2luded.

1.2.4 Safety systems

Safety systems include all the systems that are necessary for the safety of the ship operation. They include:

- fire fighting systems
- bilge system
- communication systems
- navigation lights
- life-saving appliances
- machinery safety systems which prevent of any situation leading to fire or catastrophic damage.

1.2.5 Active components

Active component means the prime mover of the main propulsion and any component of propulsion auxiliary systems that transmits or transfers energy by mechanical, thermal or chemical means such as fans, pumps, heat exchangers or compressors, including their monitoring and control systems.

Gears, shafts, propeller, pipes, manually controlled valves and tanks are not to be considered as active components.

Electric cables are to be considered as active components.

1.2.6 System failure

A system failure means any failure of an active component which is necessary for the operation of a propulsion system or power generation plant, including their auxiliary systems.

Only a single failure of the active components of the systems defined in [1.2.1] to [1.2.4] needs to be considered.

1.2.7 Essential components

Essential components include pumps, heat exchangers, valve actuators, and electrical type approved components, as required in Pt C, Ch 2, Sec 1, [4.1.1].

1.3 Documentation to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Electrical load balance, including alternative propulsion system conditions
2	I	Machinery spaces general arrangement of the alternative propulsion system
3	A	Diagrams of fuel oil system, cooling system, lubricating system, starting air system
4	A	Description of the alternative propulsion system and interface with main propulsion system
5	A	Torsional vibration calculation in alternative propulsion mode
6	A	A risk analysis demonstrating the availability of the operating conditions as per [2.2.1] in case of a single failure as per [1.2.6] **(2)**
7	I	An operating manual with the description of the operations necessary to recover the propulsion and essential services in case of a single failure as described in [1.2.6]

(1) A : to be submitted for approval;
I : to be submitted for information

(2) This analysis may be in the form of a Failure Mode and Effect Analysis (FMEA), unless the actual arrangement of the machinery and equipment is quite simple and sufficient operating experience can be demonstrated such as to make unlike the possibility of consequence failure in the case of a single failure. In such a case the Society may consider to accept a functional description of system in lieu of the requested analysis.

2 General design requirements

2.1 Principle

2.1.1 Ships assigned the additional class notation **AVM-APS** are to be fitted with:

- at least one main propulsion systems as defined in [1.2.1]
- at least one alternative propulsion system, as defined in [1.2.2], so designed and arranged that, in case of any failure as defined in [1.2.6] affecting the main propulsion system or its auxiliary services, there remain sufficient propulsion to operate the ship in safe conditions, as defined in [2.2.1]
- an electrical power plant so designed that in case of any failure, as defined in [1.2.6] in the plant, there remains enough electrical power to maintain simultaneously:
  - sufficient propulsion and steering capability to operate the ship in safe conditions, as defined in [2.2.1]
  - the availability of safety systems.

2.1.2 Compliance with requirements [2.1.1]above is to be demonstrated by a risk analysis.

2.2 Alternative propulsion machinery

2.2.1 The alternative propulsion machinery is to be so arranged that, in case the main propulsion system becomes inoperative, the propulsion power of the ship remains available or can be recovered, allowing the ship to proceed at a speed of not less than 7 knots assuming that:

- the ship is fully laden
- normal weather conditions: BF 5.

2.2.2 The auxiliary systems serving the main propulsion and the alternative propulsion systems may have common components, be arranged for possible interconnection or serve other systems on board the ship provided that in case of any single failure affecting those systems, not more than one of the main or auxiliary propulsion systems is disabled. This is to be substantiated by the risk analysis.

3 Special arrangements

3.1 Propulsion system

3.1.1 Change-over from main propulsion to auxiliary propulsion

The alternative propulsion system is to be capable of being brought into operation within 30 mn after the loss of the main propulsion system.

Means are to be provided to protect the crew from any risk of injury during the change-over procedure from main propulsion to auxiliary propulsion.

Where necessary, arrangements are to be made to:

- prevent any inadvertent starting of the engine
- maintain the shafting in locked position.

3.1.2 Automation

a) The alternative propulsion system is to be integrated with any automation system installed on board.

b) In case the alternative propulsion system is electrical, the automation system of electrical motor is to be suitable for the electrical propulsion plant.

3.2 Systems for cooling, lubrication, fuel supply, air starting, monitoring and control

3.2.1 Cooling system

The circuit for the main engine may be used provided that it can be operated with the part relative to the main engine itself being cut off.

3.2.2 Lubrication system

The lubrication oil system of the alternative propulsion system is to be independent of the main engine one.

Where the a gear box is used for both main and auxiliary propulsions, its lubricating oil system is to be independent of the main engine one.

3.2.3 Fuel oil system

The circuit for the main engine may be used provided that:

a) Proper operation is ensured with the part relative to the main engine itself being cut off

b) The alternative propulsion system is to be supplied from a least two service tanks and two storage tanks. Means and procedures are to be provided to periodically equalize the content on each storage tank and on each service tank during the consumption of the fuel.

3.2.4 Air starting system

If applicable, the circuit for the main engine may be used provided that proper operation is ensured with the part relative to the main engine itself being cut off.

3.2.5 Monitoring and control system

Monitoring and control systems of alternative propulsion system are to be independent of that for the main engine (see also [3.1.2]).

3.3 Electrical installations

3.3.1 Single failure leading to the loss of more than one generating set at one time may be accepted, provided the FMEA demonstrates that, after the failure, enough power still remains available to operate the ship under the conditions stated in [2.2.1] without any stand-by generating set still available.

3.3.2 The electrical power available is to be sufficient to withstand starting of the heaviest consumer without impairing the electrical distribution balance. Arrangement are to be made to avoid any untimely overload.

The recourse to the capacity of emergency source is not to be considered.

3.3.3 Electrical stand-by pumps may not be considered in the electrical load balance during alternative propulsion mode operation.

3.3.4 Main switchboard is to be automatically separable in two sections.

Where a failure occurs on one section of the main switchboard, the remaining section is to be able to supply the services indicated in [1.2.1].

4 Tests on board

4.1 Operational tests

4.1.1 The alternative propulsion system is to be subjected to the operational tests required by the Rules for similar systems.

4.2 Sea trials

4.2.1 The alternative propulsion system is to undergo the following tests during the sea trials:

- Test required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures.
- The values of the power and speed developed by the alternative propulsion system are to be recorded, as well as the electrical consumption.
- An activation test to demonstrate the propulsion mode changeover and corresponding time to operate as indicated in [3.1.1].

Section 2 Duplicated Propulsion System (AVM-DPS)

1 General

1.1 Application

1.1.1 The additional class notation **AVM-DPS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.3.3] to ships arranged with redundant propulsion and steering installations complying with the requirements of this Section.

1.1.2 Machinery, electrical installation and automation are to comply with the relevant provisions of Part C.

1.1.3 The additional suffix **P** may be added to the additional class notation **AVM-DPS** when all components as defined in [1.2.6], item b) are included in the definition of system failure.

1.1.4 The additional suffix **NS** may be added to the additional class notation **AVM-DPS** when the ship is intended for normal operation with one propulsion system out of service and designed in accordance with the provisions of [4]. The availability of electric production is not covered by this additional suffix.

1.2 Definitions

1.2.1 Propulsion system

A propulsion system is a system that provides thrust to the ship. It includes:

- the prime mover, including the integral equipment, driven pumps, etc.
- the equipment intended to transmit the torque
- the propulsion electric motor, where applicable
- the equipment intended to convert the torque into thrust
- the auxiliary systems necessary for operation
- the control, monitoring and safety systems.

1.2.2 Steering system

A steering system is a system that controls the heading of the ship. It includes

- the power actuating system
- the equipment intended to transmit the torque to the steering device
- the steering device (e.g. rudder, rotatable thruster, waterjet steering deflector, etc.).

1.2.3 Propulsion auxiliary systems

Propulsion auxiliary systems include all the systems that are necessary for the normal operation of a propulsion system. It includes or may include:

- the fuel oil supply system from and including the service tanks

Note 1: The fuel oil filling, transfer and purifying systems are not included.

- the lubricating oil systems serving the engines, the gearbox, the shaftline bearings, the stern tube, etc.

Note 2: The lubricating oil filling, transfer and purifying systems are not included.

- the hydraulic oil systems for operating clutches, controllable pitch propellers, waterjet reverse deflectors, starting systems, etc.
- the fresh water cooling systems serving any component of the propulsion system or used for cooling the fuel oil circuits, the lubricating oil circuits, the hydraulic oil circuits, etc.
- the sea water cooling systems used for cooling any component of the propulsion system or any of the afore-mentioned systems,
- the heating systems (using electricity, steam or thermal fluids)
- the starting systems (air, electrical, hydraulic)
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems
- the ventilation installation where necessary (e.g. to supply combustion air or cooling air to the primer movers).

1.2.4 Steering auxiliary systems

Steering auxiliary systems include all the systems that are necessary for the normal operation of a steering system. It includes or may include:

- the fresh water cooling systems
- the sea water cooling systems
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems.

1.2.5 Safety systems

Safety systems include all the systems that are necessary for the safety of the ship operation. They include:

- fire fighting systems
- bilge system
- communication systems
- navigation lights
- life-saving appliances
- machinery safety systems which prevent of any situation leading to fire or catastrophic damage

1.2.6 System failure

a) A system failure means any failure of any component of a propulsion system, steering system or power generation plant, including their auxiliary and control systems.

Components such as pipes, manually controlled valves and tanks are not to be considered. Electric cables are to be considered.

b) In addition to the requirements of item a), when the additional suffix **/P** is to be assigned, components such as pipes, manually controlled valves, tanks are to be considered.

Only single failure needs to be considered.

1.2.7 Essential components

Essential components include pumps, heat exchangers, valve actuators, and electrical type approved components, as required in Pt C, Ch 2, Sec 1, [4.1.1].

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Electrical load balance, including one of the propulsion system out of service
2	I	Machinery spaces general arrangement of duplicated propulsion system steering systems and main electrical components
3	A	Diagram of fuel oil system, lubricating system, hydraulic oil systems, sea water and fresh cooling systems, heating systems, starting air system, control air system, steering system
4	A	Single line diagrams of main electrical distribution system
5	A	Description of the duplicated propulsion system
6	A	A risk analysis demonstrating the availability of the operating conditions as per [2.2.1] in case of a single failure as per Ch 2, Sec 1, [1.2.6] **(2)**
7	I	An operating manual with the description of the operations necessary to recover the propulsion, steering and safety systems in case of a single failure (see [2.1.1])

(1) A : to be submitted for approval ; I : to be submitted for information

(2) The risk analysis may be in the form of a Failure Mode and Effect Analysis (FMEA). Ch 2, App 1 describes an acceptable procedure for carrying out the FMEA.

2 General design requirements

2.1 Principle

2.1.1 Ships assigned the additional class notation **AVM-DPS** are to be fitted with:

- at least two propulsion systems and two steering systems so designed and arranged that, in case of any failure as defined in [1.2.6] affecting such systems or their auxiliary services, there remains sufficient propulsion and steering capabilities to operate the ship in safe conditions, as defined in [2.2.1]
- an electrical power plant so designed that in case of any failure as defined in [1.2.6] in the plant, there remains enough electrical power to maintain simultaneously:
  - sufficient propulsion and steering capability to operate the ship in safe conditions, as defined in [2.2.1]
  - the availability of safety systems.

2.1.2 The loss of one compartment due to fire or flooding is not to be considered as a failure. Accordingly, the propulsion systems and/or their auxiliary systems or components thereof may be installed in the same compartment. This also applies to the steering systems and the electrical power plant.

2.1.3 Compliance with requirements [2.1.1] above is to be demonstrated by a risk analysis.

2.2 Propulsion machinery

2.2.1 The propulsion machinery is to consist of at least two mechanically independent propulsion systems so arranged that, in case one propulsion system becomes inoperative, at least 50% of the propulsion power of the ship remains available and allows the ship to proceed at a speed of not less than 7 knots assuming that:

- the ship is fully laden
- normal weather conditions: BF 5

Note 1: Propulsion power means the total maximum continuous rated output power in kilowatts of all the ship's main propulsion machinery which appears on the ship's certificate of registry or other official document.

2.2.2 The auxiliary systems serving the propulsion systems may have common components, be arranged for possible interconnection or serve other systems on board the ship provided that in case of any single failure affecting those systems, not more than one propulsion system is disabled. This is to be substantiated by the risk analysis.

2.2.3 Where a propulsion system becomes inoperative due to a failure as indicated in [2.2.2] above, the following conditions are to be satisfied:

- other propulsion systems that were in operation before the failure are not to be affected by the failure. In particular there should be no significant modification of the power or rotational speed of the concerned prime mover
- other propulsion systems that were not in operation before the failure are to be maintained available (heating and prelubrication) so as to allow restarting of a propulsion system within 45 seconds after the failure.

Note 1: The blackout recovery time is excluded, however restarting time for propulsion system in case of blackout is not to exceed 120 seconds.

- safety precautions for the failed propulsion system are to be taken, such as shaft blocking.

This is to be demonstrated during the sea trials.

2.3 Steering machinery

2.3.1 The steering machinery is to consist of at least two independent steering systems, each one complying with the following provisions:

- Pt C, Ch 1, Sec 14, [2]in the case of a standard arrangement with rudder and steering gear, and in particular the requirement of Pt C, Ch 1, Sec 14, [2.2.1] relating to the performance of the steering gear
- Pt C, Ch 1, Sec 14, [4] in the case of rotatable thrusters.

Note 1: Other types of combined propulsion and steering systems (such as waterjets or cycloidal propellers) will be given special consideration.

2.3.2 The steering systems are to be so designed and arranged that in case of any failure, as defined in Ch 2, Sec 2, in the systems or in the associated auxiliary systems (cooling systems, electrical power supply, control system, etc.) not more than one steering system is disabled, thus allowing the steering capability to be continuously maintained. This is to be substantiated by the risk analysis.

3 Specific design requirements

3.1 Steering systems

3.1.1 Synchronising system

The steering capability of the ship is to be maintained in case of failure of the synchronising system required by the Rules, Pt C, Ch 1, Sec 14, [3.2], without stopping.

3.2 Electrical installations

3.2.1 Single failure leading to the loss of more than one generating set at one time may be accepted, provided the FMEA demonstrates that, after the failure, enough power still remains available to operate the ship under the conditions stated in [2.2.1] without any stand-by generating set still available.

The recourse to the capacity of emergency source is not to be considered.

3.2.2 The main switchboard is to be automatically separable in two sections.The switchboard is to be arranged with all circuits properly distributed between these sections.

Where a failure occurs on one section of the main switchboard, the remaining section is to be able to supply the services defined in [1.2.1] to [1.2.5].

3.3 Automation

3.3.1 The automation system is to be arranged in such a way that a single failure of the control system may lead to the loss of one propulsion system only.

4 Additional requirements for ships having the notation AVM-DPS/P or AVM-DPS/NS or AVM-DPS/P/NS

4.1 Propulsion machinery

4.1.1 Each propulsion system fitted to ships having the notation **AVM-DPS/NS** or **AVM-DPS/P/NS** is to be so designed that in case of failure of an essential component affecting the following systems:

- fuel oil supply system
- lubricating oil system
- sea water and fresh water cooling systems
- starting air system
- control air system
- control, monitoring and safety systems
- ventilation of machinery spaces
- fuel oil transfer system
- fuel oil storage tanks.

The operation of the propulsion system can be sustained or speedily restored without any power limitation.

4.1.2 Oil fuel storage and transfer systems

In addition to the requirements of Article [2], when the additional suffix /**P** is to be assigned, at least two storage tanks for each type of fuel used by the propulsion engines and the generating sets are to be provided. Means and procedures are to be provided to periodically equalize the content on each storage tank and on each service tank during the consumption of the fuel.

4.1.3 Oil fuel supply lines

In addition to the requirements of [4.1.2], when the additional suffix **/P** is to be assigned, oil fuel supply from the service tank to the propulsion machinery and to the electrical power plant is to be ensured by two separate lines.

4.2 Electrical installations

4.2.1 Electrical stand-by pumps are to be considered in the electrical load balance when **NS** notation suffix is granted.

5 Tests on board

5.1 Operating tests

5.1.1 The propulsion systems, steering system as well as the power generation plant are to be subjected to the tests required by the Rules.

5.2 Sea trials

5.2.1 The propulsion machinery, steering machinery and the power generation plant are to undergo the following tests during the sea trials:

- tests required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures
- the values of the power and speed developed by the propulsion prime movers under test are to be recorded, as well as the electrical consumption.
- Tests with one propulsion system out of service, in order to verify the requirement [2.2.3].

Manoeuverability tests, as required by the risk analysis, may be performed only for the leader ship of a series of sister ships.

Note 1: The speed is to be recorded with one propulsion system out of service, in order to verify the speed criteria required in [2.2.1].

Section 3 Independent Propulsion Systems (AVM-IPS)

1 General

1.1 Application

1.1.1 The additional class notation **AVM-IPS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.3.4] to ships arranged with independent propulsion and steering installations complying with the requirements of this Section.

1.1.2 Machinery, electrical installation and automation are to comply with the relevant provisions of Part C.

1.1.3 The additional suffix **NS** may be added to the additional class notation **AVM-IPS** when the ship is intended for normal operation with one propulsion system out of service and designed in accordance with the provisions of Ch 2, Sec 2, [4]. The availability of electric production is not covered by this additional suffix.

1.2 Definitions

1.2.1 Propulsion system

A propulsion system is a system that provides thrust to the ship. It includes:

- the prime mover, including the integral equipment, driven pumps, etc.
- the equipment intended to transmit the torque
- the propulsion electric motor, where applicable
- the equipment intended to convert the torque into thrust
- the auxiliary systems necessary for operation
- the control, monitoring and safety systems.

1.2.2 Steering system

A steering system is a system that controls the heading of the ship. It includes

- the power actuating system
- the equipment intended to transmit the torque to the steering device
- the steering device (e.g. rudder, rotatable thruster, waterjet steering deflector, etc.).

1.2.3 Propulsion auxiliary systems

Propulsion auxiliary systems include all the systems that are necessary for the normal operation of a propulsion system. It includes or may include:

- the fuel oil supply system from and including the service tanks, and the parts of the filling, transfer and purifying systems located in machinery spaces
- the lubricating oil systems serving the engines, the gearbox, the shaftline bearings, the stern tube, etc., and the parts of the lubricating oil filling, transfer and purifying systems located in machinery spaces
- the hydraulic oil systems for operating clutches, controllable pitch propellers, waterjet reverse deflectors, starting systems, etc.
- the fresh water cooling systems serving any component of the propulsion system or used for cooling the fuel oil circuits, the lubricating oil circuits, the hydraulic oil circuits, etc
- the sea water cooling systems used for cooling any component of the propulsion system or any of the afore-mentioned systems
- the heating systems (using electricity, steam or thermal fluids)
- the starting systems (air, electrical, hydraulic)
- the control air systems
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems
- the ventilation installation where necessary (e.g. to supply combustion air or cooling air to the primer movers).

1.2.4 Steering auxiliary systems

Steering auxiliary systems include all the systems that are necessary for the normal operation of a steering system. It includes or may include:

- the fresh water cooling systems
- the sea water cooling systems
- the control air systems
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems.

1.2.5 Safety systems

Safety systems include all the systems that are necessary for the safety of the ship operation. They include:

- fire fighting systems
- bilge system
- communication systems
- navigation lights
- life-saving appliances
- machinery safety systems which prevent of any situation leading to fire or catastrophic damage.

1.2.6 System failure

A system failure means any failure of any component of a propulsion system, steering system or power generation plant, including their auxiliary and control systems.

Components such as pipes or electric cables are also to be considered.

Only single failure needs to be considered.

1.2.7 Fire and flooding casualty

Fire and flooding casualties are to be considered only in machinery spaces and limited to a single space.

1.2.8 Essential components

Essential components include pumps, heat exchangers, valve actuators, and electrical type approved components, as required in Pt C, Ch 2, Sec 1, [4.1.1].

1.2.9 Separate compartments

Separate compartments mean compartments which are separated by a fire and watertight bulkhead.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Electrical load balance, including one of the propulsion system out of service
2	I	Machinery spaces general arrangement of independent propulsion system, steering systems and main electrical components
3	A	Diagram of fuel oil system, lubricating system, hydraulic oil systems, sea water and fresh cooling systems, heating systems, starting air system, control air system, steering system
4	A	Single line diagrams of main electrical distribution system
5	A	Description of the independent propulsion system
6	A	A risk analysis demonstrating the availability of the concerned systems in case of a single failure (see [2.1.4] [2.3.3] and [2.4.2]) **(2)**
7	I	An operating manual with the description of the operations necessary to recover the propulsion, steering and safety systems in case of a single failure (see [2.1])
8	A	Bulkhead arrangement of separate machinery spaces

(1) A : to be submitted for approval,
I : to be submitted for information,

(2) The risk analysis may be in the form of a Failure Mode and Effect Analysis (FMEA). Ch 2, App 1 describes an acceptable procedure for carrying out the FMEA.

2 General design requirements

2.1 Principle

2.1.1 Ships assigned the additional class notation **AVM-IPS** are to comply with the provisions relevant to notation **AVM-DPS/P**, as mentioned in Ch 2, Sec 2, [2.1.1].

2.1.2 In addition, in the event of fire or flooding casualty in the machinery spaces, the propulsion, steering and power generation capabilities are to remain sufficient to operate the ship in safe conditions defined in [2.3.2].

2.1.3 Where a propulsion system becomes inoperative due to a fire or flooding casualty, other propulsion systems are not to be affected by the casualty.

2.1.4 Compliance with requirements [2.1] and [2.1.2] above is to be demonstrated by a risk analysis.

2.2 Compartment arrangement

2.2.1 Separation bulkhead between machinery compartments is to be A60.

2.2.2 The separation bulkhead between two compartments are to be designed so as to withstand the maximum water level expected after flooding.

2.2.3 The machinery control room is to be separated from all machinery spaces by A60 bulkhead.

2.2.4 The main switchboard is not to be located in the control room

2.3 Propulsion machinery

2.3.1 The propulsion machinery is to consist of at least two mechanically independent propulsion systems located in separate compartments and so arranged that, in case one propulsion system becomes inoperative due to a system failure, at least 50% of the propulsion power of the ship remains available and allows the ship to proceed at a speed of not less than 7 knots assuming that:

- the ship is fully laden,
- normal weather conditions: BF 5

Note 1: Propulsion power means the total maximum continuous rated output power in kilowatts of all the ship's main propulsion machinery which appears on the ship's certificate of registry or other official document

2.3.2 In case of a fire or a flooding casualty, sufficient propulsion power is to remain available to allow the ship to proceed at speed of not less than 7 knots assuming that:

- the ship is fully laden,
- normal weather conditions: BF 5

2.3.3 The auxiliary systems serving the propulsion systems may have common components, be arranged for possible interconnection or serve other systems on board the ship provided that in case of any single failure or fire or flooding casualty affecting those systems, not more than one propulsion system is disabled. This is to be substantiated by the risk analysis.

Note 1: The risk analysis is to consider that any space containing a component of a propulsion system or auxiliary system thereof, as defined in requirements [1.2.1] and [1.2.3] may be affected by a fire or flooding casualty.

2.3.4 Where a propulsion system becomes inoperative due to a system failure, the following conditions are to be satisfied:

- other propulsion systems that were in operation before the failure are not to be affected by the failure. In particular there should be no significant modification of the power or rotational speed of the concerned prime mover
- other propulsion systems that were not in operation before the failure are to be maintained available (heating and prelubrication) so as to allow restarting of propulsion system within 45 seconds after the failure
- safety precaution for the failed propulsion system are to be taken, such as shaft blocking.

This is to be demonstrated during the sea trials.

2.4 Steering machinery

2.4.1 The steering machinery is to consist of at least two independent steering systems located in separate compartments, each one complying with the following provisions of Pt C, Ch 1, Sec 14:

- Pt C, Ch 1, Sec 14, [3] in the case of a standard arrangement with rudder and steering gear, and in particular Pt C, Ch 1, Sec 14, [2.2.1] thereof relating to the performance of the steering gear
- Pt C, Ch 1, Sec 14, [4] in the case of rotatable thrusters.

Note 1: Other types of combined propulsion and steering systems (such as waterjets or cycloidal propellers) will be given special consideration.

2.4.2 The steering systems are to be so designed and arranged that in case of:

- any single failure in a steering system or in the associated auxiliary systems as defined in [1.2.2] and [1.2.4]
- or fire or flooding casualty affecting one of concerned space

not more than one steering system is disabled, thus allowing the steering capability to be maintained. This is to be substantiated by the risk analysis.

2.5 Electrical power plant

2.5.1 Electrical power plant, including main distribution system is to be arranged in separate compartments, so that in case of fire or flooding casualty, the electrical power necessary to supply the systems defined in [1.2.1] to [1.2.5] remain available.

3 Specific design requirements

3.1 Propulsion machinery

3.1.1 Oil fuel storage and transfer systems

At least two storage tanks for each type of fuel used by the propulsion machinery and the electrical power plant are to be provided. Means and procedures are to be provided to periodically equalize the content on each storage tank during the consumption of the fuel.

3.1.2 Oil fuel service tanks and supply lines

Oil fuel service tanks are to be located in separate spaces and means and procedures are to be provided to periodically equalize their content during the consumption of the fuel.

Oil fuel supply from each service tank to the propulsion machinery and to the electrical power plant is to be ensured by two separate lines.

3.1.3 Oil fuel units

Oil fuel units serving the propulsion machinery and the electric power plant are to be distributed in two separate spaces so that in case of fire in one of those spaces, the availability criteria set out in [2.1.2] are satisfied.

3.1.4 Oil fuel purifying system

Where provided, oil fuel purifiers are to be distributed in two separate spaces.

3.1.5 Ventilation system

The ventilation system is to be so designed and arranged that in case of fire in one machinery space accompanied with ventilation stopping, the ventilation is to remain operative in other spaces, so that the availability criteria set out in [2.1.2] are satisfied.

3.2 Steering systems

3.2.1 Synchronising system

The steering capability of the ship is to be maintained in case of failure of the synchronising system required by the Rules, Pt C, Ch 1, Sec 14, [3.2], without stopping.

3.3 Electrical installations

3.3.1 Single failure and fire and flooding casualties leading to the loss of more than one generating set at one time may be accepted, provided the FMEA demonstrates that, after the failure, enough power still remains available to operate the ship under the conditions stated in [2.3.1] and [2.3.2] without any stand-by generating set still available.

The recourse to the capacity of emergency source is not to be considered.

3.3.2 The main switchboard is to be automatically separable in two sections distributed in independent spaces separated by watertight and A60 fire resistant bulkheads.The switchboard is to be arranged with all circuits properly distributed between these sections.

Where a failure occurs on one section of the main switchboard, the remaining section is to be able to supply the services indicated in [1.2.1] to [1.2.5].

3.4 Automation

3.4.1 The automation system is to be arranged in such a way that a single failure of the control system, including fire and flooding casualty, may lead to the loss of one propulsion system only.

3.4.2 Control stations of propulsion and steering system are to be arranged so as in case of fire or flooding casualty, the control is still available.

4 Additional requirements for ships having the notation AVM-IPS/NS

4.1 Propulsion machinery

4.1.1 Each propulsion system fitted to ships having the notation **AVM-IPS/NS** is to be so designed that in case of failure of an essential component affecting the following systems:

- fuel oil supply system
- lubricating oil system
- sea water and fresh water cooling systems
- starting air system
- control air system
- control, monitoring and safety systems

the operation of the propulsion system can be sustained or speedily restored without any power limitation.

4.2 Electrical installations

4.2.1 Electrical stand-by pumps are to be considered in the electrical load balance when **NS** notation suffix is granted.

5 Tests on board

5.1 Operating tests

5.1.1 Each propulsion systems, steering system as well as the power generation plant are to be subjected to the tests required by the Rules.

5.2 Sea trials

5.2.1 The propulsion machinery, steering machinery and the power generation plant are to undergo the following tests during the sea trials:

- tests required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures
- the values of the power and speed developed by the propulsion prime movers under test are to be recorded, as well as the electrical consumption
- Tests with one propulsion system out of service, in order to verify the requirement [2.3.1].

Note 1: The speed is to be recorder with one propulsion system out of service, in order to verify the speed criteria required in [2.3.1].

Section 4 Fire Mitigation for Main Diesel-Generator Rooms (AVM-FIRE)

1 General

1.1 Application

1.1.1 The additional class notation **AVM-FIRE** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.3.5] to self-propelled ships arranged with means complying with the requirements of this Section for maintaining a minimum of propulsion, steering, and habitability in case of fire.

1.1.2 Installation of machinery, electrical systems and automation is to comply with relevant provisions of Part C.

1.1.3 The additional class notation **AVM-FIRE** is assigned alone or in addition to the additional class notation **AVM-APS** or **AVM-DPS**.

1.2 Definitions

1.2.1 Propulsion system

A propulsion system is a system that provides thrust to the ship. It includes:

- prime mover, including the integral equipment, driven pumps, etc
- equipment intended to transmit the torque
- propulsion electric motor, where applicable
- equipment intended to convert the torque into thrust
- auxiliary systems necessary for operation
- control, monitoring and safety systems.

1.2.2 Steering system

A steering system is a system that controls the heading of the ship. It includes:

- power actuating system
- equipment intended to transmit the torque to the steering device
- steering device (e.g. rudder, rotatable thruster, waterjet steering deflector, etc.).

1.2.3 Propulsion auxiliary systems

Propulsion auxiliary systems include all the systems that are necessary for the normal operation of a propulsion system. Propulsion auxiliary systems include or may include:

- fuel oil supply system from, and including, the service tanks, and the parts of the filling, transfer and purifying systems located in machinery spaces
- lubricating oil systems serving the engines, the gearbox, the shaftline bearings, the stern tube, etc., and the parts of the lubricating oil filling, transfer and purifying systems located in machinery spaces
- hydraulic oil systems for operating clutches, controllable pitch propellers, waterjet reverse deflectors, starting systems, etc
- fresh water cooling systems serving any component of the propulsion system or used for cooling the fuel oil circuits, the lubricating oil circuits, the hydraulic oil circuits, etc
- sea water cooling systems used for cooling any component of the propulsion system or any of the aforementioned systems
- heating systems (using electricity, steam or thermal fluids)
- starting systems (air, electrical, hydraulic)
- control air systems
- power supply (air, electrical, hydraulic)
- control, monitoring and safety systems
- ventilation installation where necessary (e.g. to supply combustion air or cooling air to the primer movers).

1.2.4 Steering auxiliary systems

Steering auxiliary systems include all the systems that are necessary for the normal operation of a steering system. Steering auxiliary systems include or may include:

- fresh water cooling systems
- sea water cooling systems
- control air systems
- power supply (air, electrical, hydraulic)
- control, monitoring and safety systems.

1.2.5 Safety systems

Safety systems include all the systems that are necessary for the safety of the ship operation:

- fire fighting systems
- bilge system
- communication systems
- navigation lights
- life-saving appliances
- machinery safety systems which prevent any situation leading to fire or catastrophic damage.

1.2.6 Habitability services

Services considered necessary for crew and passenger areas habitability include:

- sanitary water
- toilets
- ventilation
- HVAC
- galley facility
- provision rooms systems
- lighting.

1.2.7 Fire casualty

Fire casualty is to be considered only in one main diesel-generator room and limited to this single space.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Electrical load balance, including main diesel-generator room out of service
2	I	Machinery spaces general arrangement of main diesel-generator room, with main electrical components and cable routing
3	A	Single line diagrams of main electrical distribution system
4	A	A risk analysis demonstrating the availability of the concerned systems in case of fire in a main diesel-generator room (see [2.1]) **(2)**
5	I	An operating manual with the description of the operations necessary to recover the propulsion, steering and safety systems in case of fire in main diesel-generator room (see[2.1])
6	A	Structural fire protection arrangement of main diesel-generator rooms

(1) A : To be submitted for approval
I : To be submitted for information.

(2) The risk analysis may be in the form of a failure Mode and Effect analysis (FMEA). Ch 2, App 1 describes an acceptable procedure for carrying out the FMEA.

2 General design requirements

2.1 Principle

2.1.1 Machinery is to be so designed and arranged that, in case of any fire casualty occurring in one main diesel-generator room as defined in [1.2.7], sufficient operating functionality for propulsion, steering is still available as required in [2.3] and a minimum of 50% of the habitability services as defined in [1.2.6] remain operative.

2.1.2 Control stations of propulsion and steering system are to be arranged so as, in case of fire casualty occurring in one main diesel-generator rooms, the control of remaining propulsion and steering systems is still available.

2.1.3 Manual intervention may be accepted in order to make the systems available as required in [2.1.1] in the minimum possible time. In general, feasibility of manual actions should be demonstrated by tests or drills.

2.1.4 Compliance with requirements [2.1.1] and [2.1.2] is to be demonstrated by a risk analysis.

2.2 Electrical power plant

2.2.1 Main diesel-generators are to be distributed between at least two engine rooms.

2.2.2 Main diesel-generators and the main distribution system are to be arranged so that, in case of fire in one main diesel-generator room, the electrical power necessary to supply the systems defined in [1.2.1] to [1.2.6] remains available, in accordance with the principles detailed in [2.1].

2.2.3 Single failure and fire casualties in one main diesel-generator room leading to the loss of more than one generating set at one time may be accepted, provided that, after the failure, enough power still remains available to operate the ship under the conditions stated in [2.3.1] and [2.3.2] without any stand-by generating set still available. The recourse to the capacity of emergency source is not to be considered.

2.3 Propulsion and steering

2.3.1 In case of a fire casualty as defined in [1.2.7], sufficient propulsion power is to remain available to allow the ship to proceed at speed of not less than 7 knots, assuming:

- the ship is fully loaded
- normal weather conditions: BF 5.

2.3.2 The steering systems are to be so designed and arranged that, in case of fire casualty as defined in [1.2.7], not more than one steering system is disabled, thus allowing the steering capability to be continuously maintained.

2.4 Fire protection and detection

2.4.1 Each main diesel-generator room shall be surrounded by A60 bulkheads and overhead deck.

2.4.2 The fire detection might be lost only in the main diesel-generator room affected by the fire casualty and shall remain operational in all other spaces.

3 Tests on board

3.1 Operating tests

3.1.1 Each propulsion system, steering system as well as the power generation plant are to be subjected to the tests required by the Rules.

3.2 Sea trials

3.2.1 The propulsion machinery, steering machinery and the power generation plant are to undergo the following tests during the sea trials:

- tests required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures as well as certain manual actions as defined in [2.1.3]
- the values of the power and speed developed by the propulsion prime movers under test are to be recorded, as well as the electrical consumption.

Note 1: The speed is to be recorded with one propulsion system out of service, in order to verify the speed criteria required in [2.3.1].

Appendix 1 Procedures for Failure Modes and Effect Analysis

1 General

1.1 Introduction

1.1.1 FMEA requirement

As specified in Ch 2, Sec 1, Ch 2, Sec 2 and Ch 2, Sec 3 in order to grant the **AVM** notations, an FMEA is to be carried out, with the exception indicated in Note (2) of Ch 2, Sec 1, Tab 1 in case of single failure to the propulsion, steering and power generating system, the ship is still capable to achieve the performances indicated in the applicable Sections as a condition for granting the notation.

1.1.2 Scope of the Appendix

This Appendix describes a failure mode and effects analysis (FMEA) and gives guidance as to how it may be applied by:

a) explaining basic principles

b) providing the procedural steps necessary to perform an analysis

c) identifying appropriate terms, assumptions, measures and failure modes, and

d) providing examples of the necessary worksheets.

1.1.3 Definition of FMEA

A practical, realistic and documented assessment of the failure characteristics of the ship and its component systems should be undertaken with the aim of defining and studying the important failure conditions that may exist.

1.1.4 FMEA principles

The FMEA is based on a single failure concept under which each considered system at various levels of a system's functional hierarchy is assumed to fail by one probable cause at a time. The effects of the postulated failure are analysed and classified according to their severity. Such effects may include secondary failures (or multiple failures) at other level(s). Any failure mode which may cause a catastrophic effect should be guarded against by system or equipment redundancy unless the probability of such failure is extremely improbable. For failure modes causing hazardous effects corrective measures may be accepted in lieu. A test programme should be drawn up to confirm the conclusions of FMEA.

1.1.5 Alternatives

While FMEA is suggested as one of the most flexible analysis techniques, it is accepted that there are other methods which may be used and which in certain circumstances may offer an equally comprehensive insight into particular failure characteristics.

1.2 Objectives

1.2.1 Primary objective

The primary objective of FMEA is to provide a comprehensive, systematic and documented investigation which establishes the important failure conditions of the ship propulsion, steering and power generation systems, as well as any other system requested by the Owner, and assesses their significance with regard to the safety of the ship and its occupants.

1.2.2 Aim of the analysis

The main aims of undertaking the analysis are to:

a) provide ship and system designers with data to audit their proposed designs

b) provide the Owner with the results of a study into ship's selected systems failure characteristics so as to assist in an assessment of the arrangements and measures to be taken to limit the damages consequent of the failure within acceptable limits

c) provide the Master and crew of the ship with data to generate comprehensive training, operational and maintenance programmes and documentation.

1.3 Sister ships

1.3.1 For ships of the same design and having the same equipment, one FMEA on any one of such ships may be sufficient, but each of the other ships are to be subject to the same FMEA conclusion trials.

However, manoeuverability tests if required by the FMEA conclusion may be performed only for the leader ship of a series of sister ships.

1.4 FMEA basics

1.4.1 Before proceeding with a detailed FMEA into the effects of the failure of the system elements on the system functional output it is necessary to perform a functional failure analysis of the considered systems. In this way only systems which fail the functional failure analysis need to be investigated by a more detailed FMEA.

1.4.2 Operational modes

When conducting a system FMEA the following typical operational modes within the normal design environmental conditions of the ships are to be considered:

a) normal seagoing conditions at full speed

b) maximum permitted operating speed in congested waters

c) manoeuvring alongside

d) seagoing conditions in emergency, as defined in Ch 2, Sec 1, Ch 2, Sec 2 and Ch 2, Sec 3.

1.4.3 Functional interdependence

This functional interdependence of these systems is also to be described in either block diagrams or fault tree diagrams or in a narrative format to enable the failure effects to be understood. As far as applicable, each of the systems to be analysed is assumed to fail in the following failure modes:

a) complete loss of function

b) rapid change to maximum or minimum output

c) uncontrolled or varying output

d) premature operation

e) failure to operate at a prescribed time

f) failure to cease operation at a prescribed time.

Depending on the system under consideration other failure modes may have to be taken into account.

1.4.4 Systems which can fail without catastrophic effects

If a system can fail without any hazardous or catastrophic effect, there is no need to conduct a detailed FMEA into the system architecture. For systems whose individual failure can cause hazardous or catastrophic effects and where a redundant system is not provided, a detailed FMEA as described in the following paragraphs should be followed.

Results of the system functional failure analysis should be documented and confirmed by a practical test programme drawn up from the analysis.

1.4.5 Redundant systems

Where a system, the failure of which may cause a hazardous or catastrophic effect, is provided with a redundant system, a detailed FMEA may not be required provided that:

a) the redundant system can be put into operation or can take over the failed system within the time-limit dictated by the most onerous operational mode without hazarding the ship

b) the redundant system is completely independent from the system and does not share any common system element the failure of which would cause failure of both the system and the redundant system. Common system element may be acceptable if the probability of failure complies with [4].

c) the redundant system may share the same power source as the system. In such case an alternative power source should be readily available with regard to the requirement of a) above.

The probability and effects of operator error to bring in the redundant system are also to be considered.

1.5 FMEA analysis

1.5.1 The systems to be subject to a more detailed FMEA investigation at this stage are to include all those that have failed the system FMEA and may include those that have a very important influence on the safety of the ship and its occupants and which require an investigation at a deeper level than that undertaken in the system functional failure analysis. These systems are often those which have been specifically designed or adapted for the ship, such as the craft's electrical and hydraulic systems.

2 FMEA performance

2.1 Procedures

2.1.1 The following steps are necessary to perform an FMEA:

a) to define the system to be analysed

b) to illustrate the interrelationships of functional elements of the system, by means of block diagrams

c) to identify all potential failure modes and their causes

d) to evaluate the effects on the system of each failure mode

e) to identify failure detection methods

f) to identify corrective measures for failure modes

g) to assess the probability of failures causing hazardous or catastrophic effects, where applicable

h) to document the analysis

i) to develop a test programme

j) to prepare FMEA report.

2.2 System definition

2.2.1 The first step in an FMEA study is a detailed study of the system to be analysed, through the use of drawings and equipment manuals. A narrative description of the system and its functional requirements is to be drawn up including the following information:

a) general description of system operation and structure

b) functional relationship among the system elements

c) acceptable functional performance limits of the system and its constituent elements in each of the typical operational modes

d) system constraints.

2.3 Development of system block diagram

2.3.1 Block diagram

The next step is to develop block diagram(s) showing the functional flow sequence of the system, both for technical understanding of the functions and operation of the system, and for the subsequent analysis. As a minimum the block diagram is to contain:

a) breakdown of the system into major sub-systems or equipment

b) all appropriate labelled inputs and outputs and identification numbers by which each sub-system is consistently referenced

c) all redundancies, alternative signal paths and other engineering features which provide “fail-safe” measures.

2.3.2 Block diagrams and operational modes

It may be necessary to have a different set of block diagrams prepared for each different operational modes.

2.4 Identification of failure modes, causes and effects

2.4.1 Failure mode

Failure mode is the manner by which a failure is observed. It generally describes the way the failure occurs and its impact on the equipment or system. As an example, a list of failure modes is given in Tab 1. The failure modes listed in Tab 1 can describe the failure of any system element in sufficiently specific terms. When used in conjunction with performance specifications governing the inputs and outputs on the system block diagram, all potential failure modes can be thus identified and described. Thus, for example, a power supply may have a failure mode described as “loss of output” (29), and a failure cause “open (electrical)” (31).

2.4.2 System failure

A failure mode in a system element could also be the failure cause of a system failure. For example, the hydraulic line of a steering gear system might have a failure mode of “external leakage” (10). This failure mode of the hydraulic line could become a failure cause of the steering gear system’s failure mode “loss of output” (29).

2.4.3 Top-down approach

Each system should be considered in a top-down approach, starting from the system’s functional output, and failure is to be assumed by one possible cause at a time. Since a failure mode may have more than one cause, all potential independent causes for each failure mode are to be identified.

2.4.4 Delay effect when operating back-up systems

If major systems can fail without any adverse effect there is no need to consider them further unless the failure can go undetected by an operator. To decide that there is no adverse effect does not mean just the identification of system redundancy. The redundancy is to be shown to be immediately effective or brought on line with negligible time lag. In addition, if the sequence is: “failure - alarm - operator action - start of back up - back up in service”, the effects of delay should be considered.

2.5 Failure effects

2.5.1 Concept

The consequence of a failure mode on the operation, function, or status of an equipment or a system is called a “failure effect”. Failure effects on a specific sub-system or equipment under consideration are called “local failure effects”. The evaluation of local failure effects will help to determine the effectiveness of any redundant equipment or corrective action at that system level. In certain instances, there may not be a local effect beyond the failure mode itself.

Table 1 : Example of failure mode list

1	Structural failure (rupture)	18	False actuation
2	Physical binding or jamming	19	Fails to stop
3	Vibration	20	Fails to start
4	Fails to remain in position	21	Fails to switch
5	Fails to open	22	Premature operation
6	Fails to close	23	Delayed operation
7	Fails open	24	Erroneous input (increased)
8	Fails closed	25	Erroneous input (decreased)
9	Internal leakage	26	Erroneous output (increased)
10	External leakage	27	Erroneous output (decrease)
11	Fails out of tolerance (high)	28	Loss of input
12	Fails out of tolerance (low)	29	Loss of output
13	Inadvertent operation	30	Shorted (electrical)
14	Intermittent operation	31	Open (electrical)
15	Erratic operation	32	Leakage (electrical)
16	Erroneous indication	33	Other unique failure conditions as applicable to the system characteristics, requirements and operational constraints
17	Restricted flow		

2.5.2 End effect

The impact of an equipment or sub-system failure on the system output (system function) is called an “end effect”. End effects should be evaluated and their severity classified in accordance with the following categories:

a) catastrophic

b) hazardous

c) major

d) minor.

The definition of these four categories of failure effects is in [4].

2.5.3 Catastrophic and hazardous effects

If the end effect of a failure is classified as hazardous or catastrophic, back-up equipment is usually required to prevent or minimize such effect. For hazardous failure effects corrective operational procedures may be generally accepted.

2.6 Failure detection

2.6.1 Detectable failures

The FMEA study in general only analyses failure effects based on a single failure in the system and therefore a failure detection means, such as visual or audible warning devices, automatic sensing devices, sensing instrumentation or other unique indications, is to be identified.

2.6.2 Non detectable failures

Where the system element failure is non-detectable (i.e. a hidden fault or any failure which does not give any visual or audible indication to the operator) and the system can continue with its specific operation, the analysis is to be extended to determine the effects of a second failure, which in combination with the first undetectable failure may result in a more severe failure effect e.g. hazardous or catastrophic effect.

2.7 Corrective measures

2.7.1 Back-up equipment response

The response of any back-up equipment, or any corrective action initiated at a given system level to prevent or reduce the effect of the failure mode of system element or equipment, is also to be identified and evaluated.

2.7.2 Corrective design provisions

Provisions which are features of the design at any system level to nullify the effects of a malfunction or failure, such as controlling or deactivating system elements to halt generation or propagation of failure effects, activating back-up or standby items or systems, are to be described. Corrective design provisions include:

a) redundancies that allow continued and safe operation

b) safety devices, monitoring or alarm provisions, which permit restricted operation or limit damage

c) alternative modes of operation.

2.7.3 Manual corrective actions

Provisions which require operator action to circumvent or mitigate the effects of the postulated failure are to be described. The possibility and effect of operator error is to be considered, if the corrective action or the initiation of the redundancy requires operator input, when evaluating the means to eliminate the local failure effects.

2.7.4 Acceptability of corrective action

It is to be noted that corrective responses acceptable in one operational mode may not be acceptable at another, e.g. a redundant system element with considerable time lag to be brought into line, while meeting the operational mode “normal seagoing conditions at full speed” may result in a catastrophic effect in another operational mode, e.g. “maximum permitted operating speed in congested water“.

2.8 Use of probability concept

2.8.1 Acceptance criteria

If corrective measures or redundancy as described in preceding paragraphs are not provided for any failure, as an alternative the probability of occurrence of such failure is to meet the following criteria of acceptance:

a) a failure mode which results in a catastrophic effect is to be assessed to be extremely improbable

b) a failure mode assessed as extremely remote is to not result in worse than hazardous effects

c) a failure mode assessed as either frequent or reasonably probable is not to result in worse than minor effects.

2.8.2 Data

Numerical values for various levels of probabilities are laid down in [4]. In areas where there is no data from ships to determine the level of probabilities of failure other sources can be used such as:

a) workshop test

b) history of reliability used in other areas under similar operating conditions

c) mathematical model if applicable.

2.9 Documentation

2.9.1 Worksheet

It is helpful to perform FMEA on worksheets. Tab 2 shows an example of worksheet.

2.9.2 Worksheet organization

The worksheets are be organized to first display the highest system level and then proceed down through decreasing system levels.

Table 2 : FMEA worksheet

Name of system: Mode of operation: Sheet No: Date: Name of analyst:							References: System block diagram: Drawings:				
Equipment name or number	Function	Ident. No.	Failure mode	Failure cause	Failure effect		Failure detection	Corrective action	Severity of failure effect	Probability of failure (if applicable)	Remarks
					Local effect	End effect					

3 Tests and reporting

3.1 Test program

3.1.1 FMEA validation test

An FMEA test programme is to be drawn up to prove the conclusions of FMEA. It is recommended that the test programme is to include all systems or system elements whose failure would lead to:

a) major or more severe effects

b) restricted operations

c) any other corrective action.

For equipment where failure cannot be easily simulated on the ship, the results of other tests can be used to determine the effects and influences on the systems and ship

3.1.2 Further investigations

The trials are also to include investigations into:

a) the layout of control stations with particular regard to the relative positioning of switches and other control devices to ensure a low potential for inadvertent and incorrect crew action, particularly during emergencies and the provision of interlocks to prevent inadvertent operation for important system operation

b) the existence and quality of the craft's operational documentation with particular regard to the pre-voyage checklists. It is essential that these checks account for any unrevealed failure modes identified in the failure analysis

c) the effects of the main failure modes as prescribed in the theoretical analysis.

3.2 Reporting

3.2.1 The FMEA report is to be a self-contained document with a full description of the craft, its systems and their functions and the proposed operation and environmental conditions for the failure modes, causes and effects to be understood without any need to refer to other plans and documents not in the report. The analysis assumptions and system block diagrams are to be included, where appropriate.

The report is to contain a summary of conclusions and recommendations for each of the systems analysed in the system failure analysis and the equipment failure analysis. It is also to list all probable failures and their probability of failure where applicable, the corrective actions or operational restrictions for each system in each of the operational modes under analysis. The report is to contain the test programme, reference any other test reports and the FMEA trials.

4 Probabilistic concept

4.1 General

4.1.1 Different undesirable events may have different orders of acceptable probability. In connection with this, it is convenient to agree on standardized expressions to be used to convey the relatively acceptable probabilities of various occurrences, i.e. to perform a qualitative ranking process.

4.2 Occurrences

4.2.1 Occurrence

Occurrence is a condition involving a potential lowering of the level of safety.

4.2.2 Failure

Failure is an occurrence in which a part, or parts, of the ship fail. A failure includes:

a) a single failure

b) independent failures in combinations within a system, and

c) independent failures in combinations involving more than one system, taking into account:

   1) any undetected failure that is already present

   2) such further failures as would be reasonably expected to follow the failure under consideration, and

d) common cause failure (failure of more than one component or system due to the same cause).

Note 1: In assessing the further failures which follow, account should be taken of any resulting more severe operating conditions for items that have not up to that time failed.

4.2.3 Event

Event is an occurrence which has its origin outside the craft (e.g., waves).

4.2.4 Error

Error is an occurrence arising as a result of incorrect action by the operating crew or maintenance personnel.

4.3 Probability of occurrences

4.3.1 Frequent

Frequent is one which is likely to occur often during the operational life of a particular ship.

4.3.2 Reasonably probable

Reasonably probable is one which is unlikely to occur often but which may occur several times during the total operational life of a particular ship.

4.3.3 Recurrent

Recurrent is a term embracing the total range of frequent and reasonably probable.

4.3.4 Remote

Remote is one which is unlikely to occur to every ship but may occur to a few ships of a type over the total operational life of a number of ship of the same type.

4.3.5 Extremely remote

Extremely remote is one which is unlikely to occur when considering the total operational life of a number of ships of the type, but nevertheless should be considered as being possible.

4.3.6 Extremely improbable

Extremely improbable is one which is so extremely remote that it should not be considered as possible to occur.

4.4 Effects

4.4.1 Effect

Effect is a situation arising as a result of an occurrence.

4.4.2 Minor effect

Minor effect is an effect which may arise from a failure, an event, or an error which can be readily compensated for by the operating crew; it may involve:

a) a small increase in the operational duties of the crew or in their difficulty in performing their duties, or

b) a moderate degradation in handling characteristics, or

c) slight modification of the permissible operating conditions.

4.4.3 Major effect

Major effect is an effect which produces:

a) a significant increase in the operational duties of the crew or in their difficulty in performing their duties which by itself should not be outside the capability of a competent crew provided that another major effect does not occur at the same time, or

b) significant degradation in handling characteristics, or

c) significant modification of the permissible operating conditions, but will not remove the capability to complete a safe journey without demanding more than normal skill on the part of the operating crew.

4.4.4 Hazardous effect

Hazardous effect is an effect which produces:

a) a dangerous increase in the operational duties of the crew or in their difficulty in performing their duties of such magnitude that they cannot reasonably be expected to cope with them and will probably require outside assistance, or

b) dangerous degradation of handling characteristics, or

c) dangerous degradation of the strength of the ship, or

d) marginal conditions for, or injury to, occupants, or

e) an essential need for outside rescue operations.

4.4.5 Catastrophic effect

Catastrophic effect is an effect which results in the loss of the craft and/or in fatalities.

4.5 Safety level

4.5.1 Safety level is a numerical value characterizing the relationship between ship performance represented as horizontal single amplitude acceleration (g) and rate of acceleration (g/s) and the severity of acceleration-load effects on standing and sitting humans. The safety levels and the corresponding severity of effects on passengers and safety criteria for ship performance are defined in Tab 3.

4.6 Numerical values

4.6.1 Where numerical probabilities are used in assessing compliance with requirements using the terms similar to those given above, the approximate values given in Tab 4 may be used as guidelines to assist in providing a common point of reference. The probabilities quoted should be on an hourly or per journey basis, depending on which is more appropriate to the assessment in question.

Note 1: Different occurrences may have different acceptable probabilities, according to the severity of their consequences (see Tab 5).

Table 3 : Severity levels on passengers

Effect	Criteria not to be exceeded Type of load	Value **(2)**	Comment
Level 1 Minor Effect Moderate degradation of safety	Maximum acceleration measured horizontally **(1)**	0,20 g	0,08 g and 0,20 g/s **(3)**: Elderly person will keep balance when holding 0,15 g and 0,20 g/s: Mean person will keep balance when holding 0,15 g and 0,80 g/s : Sitting person will start holding
Level 2 Major Effect Significant degradation of safety	Maximum acceleration measured horizontally **(1)**	0,35 g	0,25 g and 2 g/s : Maximum load for mean person keeping balance when holding 0,45 g and 10 g/s : Mean person fails out of seat when nor wearing seat belts
Level 3 Hazardous Effect Major degradation of safety	Collision design condition calculated Maximum structural design load, based on vertical acceleration at centre of gravity	1 g	Risk of injury to persons, safe emergency operation after collision 1 g : Degradation of person safety
Level4 Catastrophic Effect		1 g	Loss of ship and/or fatalities

(1) The recording instruments used are to be such that the acceleration accuracy is better than 5% of the real value and frequency response is to be minimum 20 Hz. Antialiasing filters with maximum passband attenuation 100 + 5% are to be used

(2) g = gravity acceleration (9,81 m/s^2)

(3) g-rate of jerk may be evaluated from acceleration/time curves.

Table 4 : Guidance for probability levels

Frequent	More than 10^{-3}
Reasonably probable	10^{-3} to 10^{-5}
Remote	10^{-5} to 10^{-7}
Extremely remote	10^{-7} to 10^{-9}
Extremely improbable	Whilst no approximate numerical probability is given for this, the figures used should be substantially less than 10^{-9}

Table 5 : Examples of acceptable levels

SAFETY LEVEL	1	1	1	2	3	4
EFFECT ON SHIP AND OCCUPANTS	Normal	Nuisance	Operating limitations	Emergency procedures; significant reduction in safety margins; difficult for crew to cope with adverse conditions; person injuries	Large reduction in safety margin; crew overburden because of workload or environmental conditions; serious injuries to small number of persons	Casualties and deaths, usually with loss of ship
F.A.R. PROBABILITY **(1)**	Probable			Improbable		Extremely improbable
JAR-25 PROBABILITY **(2)**	Probable			Improbable		Extremely improbable
	Frequent		Reasonably probable	Remote	Extremely remote	
	10^{-0}	10^{-2}	10^{-3}	10^{-5}	10^{-7}	10^{-9}
CATEGORY OF EFFECT	Minor			Major	Hazardous	Catastrophic

(1) The United States Federal Aviation Regulation
(2) European Joint Airworthiness Regulations

CHAPTER 3
AUTOMATION SYSTEMS (AUT)

Section 1 Unattended Machinery Spaces (AUT-UMS)

Section 2 Centralised Control Station (AUT-CCS)

Section 3 Automated Operation in Port (AUT-PORT)

Section 4 Integrated Machinery Spaces (AUT-IMS)

Section 1 Unattended Machinery Spaces (AUT-UMS)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-UMS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.2] to ships fitted with automated installations enabling periodically unattended operation of machinery spaces, and complying with the requirements of this Section.

Note 1: Machinery spaces are defined in Pt C, Ch 4, Sec 1, [2.29.1].

1.1.2 *The arrangements provided shall be such as to ensure that the safety of the ship in all sailing conditions, including manoeuvring, is equivalent to that of a ship having the machinery spaces manned.*

1.1.3 The requirements of this Section are additional to the general rule requirements applicable to the ships.

1.1.4 For ships not covered by SOLAS, the following requirements are applicable:

- control of electrical installations: Pt C, Ch 2, Sec 3, [2.2.7], Pt C, Ch 2, Sec 3, [2.2.8] and Pt C, Ch 2, Sec 3, [2.2.9]
- arrangements of remote stop: Pt C, Ch 4, Sec 2, [2.1]
- arrangements of machinery spaces: Pt C, Ch 4, Sec 6, [4.1.2].

1.2 Exemptions

1.2.1 For ships of less than 500 gross tonnage and with a propulsive power of less than 1 MW, the requirements laid down in [5.4.3] do not apply.

1.2.2 For ships of less than 500 gross tonnage and with a propulsive power of less than 1 MW, the requirements laid down in [4], except [4.1.2] [4.1.3], do not apply.

Diesel engines installed on ships are to be equipped with:

a) Indicators, as detailed below:
   - for auxiliary engine of 1000 kW and above:
     The requirements laid down in Pt C, Ch 1, Sec 2, Tab 4; Pt C, Ch 1, Sec 2, Tab 5 and Pt C, Ch 1, Sec 2, Tab 6 apply
   - for propulsion engine or auxiliary engine with a power less than 1000 kW:
     - lubrication oil pressure indication
     - fresh water temperature indication.

   The indicators are to be fitted at the centralised control position.

b) Alarms, as detailed below:
   - for auxiliary engine of 1000 kW and above:
     The requirements laid down in Pt C, Ch 1, Sec 2, Tab 4; Pt C, Ch 1, Sec 2, Tab 5 and Pt C, Ch 1, Sec 2, Tab 6 apply
   - for propulsion engine or auxiliary engine with a power less than 1000 kW:
     - lubrication oil low pressure alarm
     - very low lubricating oil pressure alarm
     - overspeed alarm.

   The alarms are to be visual and audible at the centralised control position.

c) Automatic control, as detailed below:
   - for auxiliary engine of 1000 kW and above:
     The requirements laid down in Pt C, Ch 1, Sec 2, Tab 4; Pt C, Ch 1, Sec 2, Tab 5 and Pt C, Ch 1, Sec 2, Tab 6 apply
   - for propulsion engine or auxiliary engine with a power less than 1000 kW:
     - shut-down on very low lubricating oil pressure
     - shut-down on overspeed.

1.2.3 For ships of less than 500 gross tonnage and with a propulsive power of less than 1 MW, automatic stop is to be provided for lubricating oil failure of engines, reduction gears, clutches and reversing gears. A possible override of this automatic stop is to be available at the control stations, and an indication is to be provided at each control station, when override is activated.

1.2.4 The requirements laid down in [3.3.1] do not apply to cargo ships of less than 1 600 gross tonnage, insofar as the arrangements of the machinery space access make it unnecessary.

1.2.5 Fishing vessels of less than 45 m in length are exempted from the application of:

- alarm system requirements given in [5.2.3] and [5.4.2]
- fire detection system requirements given in [3.2] insofar as the location of the spaces considered allows people on board to detect fire outbreaks easily, and
- requirements given in [3.4.3].

1.2.6 Fishing vessels of less than 75 m in length are exempted from the application of the requirements laid down in [1.3.2], [3.1.2] and [3.3.1].

1.3 Communication system

1.3.1 *A reliable means of vocal communication shall be provided between the main machinery control room or the propulsion machinery control position as appropriate, the navigation bridge and the engineer officers' accommodation.*

This means of communication is to be foreseen in collective or individual accommodation of engineer officers.

1.3.2 Means of communication are to be capable of being operated at least half an hour even in the event of failure of supply from the main source of electrical power (black-out).

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to those mentioned in Pt C, Ch 3, Sec 1, Tab 1, the documents in Tab 1 are required.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	A	Means of communication diagram
2	A	Technical description of automatic engineer's alarm and connection of alarms to accommodation and bridge, when applicable
3	A	System of protection against flooding
4	A	Fire detection system: diagram, location and cabling
(1) A : to be submitted for approval I : to be submitted for information.		

3 Fire and flooding precautions

3.1 Fire prevention

3.1.1 *Where daily service oil fuel tanks are filled automatically, or by remote control, means shall be provided to prevent overflow spillages.*

3.1.2 Where heating is necessary, it is to be arranged with automatic control. A high temperature alarm is to be fitted and the possibility of adjusting its threshold according to the fuel quality is to be provided. Such alarm may be omitted if it is demonstrated that the temperature in the tank cannot exceed the flashpoint under the following conditions: volume of liquid corresponding to the low level alarm and maximum continuous heating power during 24 hours.

3.2 Fire detection

3.2.1 For fire detection, the requirements given in Pt C, Ch 4, Sec 3 are applicable.

3.2.2 *Means are to be provided to detect and give alarms at an early stage in case of fires:*

- *in boiler air supply casing and exhausts (uptakes), and*
- *in scavenging air belts of propulsion machinery*

unless the Society considers this to be unnecessary in a particular case.

Especially, it is deemed unnecessary to provide means to detect fires at an early stage and give alarms in the following cases:

- for boilers with no inherent fire risk in the air supply casing, i.e. boilers with no heat exchangers (e.g. rotary heat exchangers) having surfaces exposed alternately to air and flue gas.
- for boilers with no inherent fire risk in the flue gas uptake, i.e. boilers with no heat exchangers using flue gases as the heating medium e.g. air/water preheaters or economisers.

Note 1: "flue gas" means exhaust gas from boiler furnace.

3.2.3 Location of fire detectors for boilers

The means to detect and give alarms at an early stage in cases of fires in boiler air supply casing and exhausts are to be located at a representative location:

- either in the air supply casing or in the fuel gas uptake for boilers with heat exchangers having surfaces exposed alternatively to air and flue gas.
- in the flue gas uptake for boilers with heat exchangers using flue gases as the heating medium e.g. air/water preheaters or economisers.

3.2.4 An automatic fire detection system is to be fitted in machinery spaces of category A, as defined in Pt C, Ch 4, Sec 1, [2.30.1], intended to be unattended.

3.2.5 The fire detection system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm.

3.2.6 The fire detection indicating panel is to be located on the navigation bridge, fire control station, or other accessible place where a fire in the machinery space will not render it inoperative.

3.2.7 The fire detection indicating panel is to indicate the place of the detected fire in accordance with the arranged fire zones by means of a visual signal. Audible signals clearly distinguishable in character from any other signals are to be audible throughout the navigation bridge and the accommodation area of the personnel responsible for the operation of the machinery space.

3.2.8 Fire detectors are to be of such type and so located that they will rapidly detect the onset of fire in conditions normally present in the machinery space. Consideration is to be given to avoiding false alarms. The type and location of detectors are to be approved by the Society and a combination of detector types is recommended in order to enable the system to react to more than one type of fire symptom.

3.2.9 Except in spaces of restricted height and where their use is specially appropriate, detection systems using thermal detectors only are not permitted. Flame detectors may be installed, although they are to be considered as complementary and are not to replace the main installation.

3.2.10 Fire detector zones are to be arranged in a manner that will enable the operating staff to locate the seat of the fire. The arrangement and the number of loops and the location of detector heads are to be approved in each case. Air currents created by the machinery are not to render the detection system ineffective.

3.2.11 When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements are to be allowed to fix and identify the set point.

3.2.12 When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a preset time.

3.2.13 The fire detection indicating panel is to be provided with facilities for functional testing.

3.2.14 The fire detecting system is to be fed automatically from the emergency source of power by a separate feeder if the main source of power fails.

3.2.15 Facilities are to be provided in the fire detecting system to manually release the fire alarm from the following places:

- passageways having entrances to engine and boiler rooms
- the navigation bridge
- the control station in the engine room.

3.2.16 The detection equipment is to be so designed as to signal in less than 3 minutes a conventional seat of fire resulting from the combustion of 500 g textile waste impregnated with 25 cl of diesel oil in a square gutterway 30 cm wide x 15 cm high. Alternative means of testing may be accepted at the discretion of the Society.

3.3 Fire fighting

3.3.1 Unless otherwise stated, pressurisation of the fire main at a suitable pressure by starting a main fire pump and carrying out the other necessary operations is to be possible from the navigation bridge and fire control station. Alternatively, the fire main system may be permanently under pressure.

3.3.2 The arrangements for the ready availability of water supply are to be:

- in passenger ships of 1 000 gross tonnage and upwards, such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to allow the continuation of the output of water by the automatic starting of a required fire pump
- in passenger ships of less than 1 000 gross tonnage and in cargo ships, to the satisfaction of the Society.

3.3.3 In addition to the fire-extinguishing arrangements mentioned in Part C, Chapter 4, periodically unattended spaces containing steam turbines (whose power is at least 375 kW) are to be provided with one of the fixed fire-extinguishing systems required in the same chapter for machinery spaces of category A containing oil fired boilers or fuel oil units.

3.3.4 Local application fire-extinguishing system provided in machinery spaces of category A in accordance with Pt C, Ch 4, Sec 6, [4.7.2] are to have an automatic release capability in addition to the manual release.

3.4 Protection against flooding

3.4.1 Bilge wells or machinery spaces bilge levels are to be monitored in such a way that the accumulation of liquid is detected in normal angles of trim and heel, and are to be large enough to accommodate easily the normal drainage during the unattended period.

3.4.2 *Where the bilge pumps are capable of being started automatically, means shall be provided to indicate when the influx of liquid is greater than the pump capacity or when the pump is operating more frequently than would normally be expected.*

3.4.3 In addition to the requirements provided in this Section, the location of controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system is to comply with Pt C, Ch 1, Sec 10, [5.5.4].

3.4.4 Bilge level alarms are to be given at the main control station and the navigation bridge.

3.4.5 According to Pt D, Ch 11, Sec 5, [1.3.1], for passenger ships carrying 36 or more persons an alarm is to be given to the navigation bridge in case of flooding into the machinery space situated below the load line.

4 Control of machinery

4.1 General

4.1.1 *Under all sailing conditions, including manoeuvring, the speed, direction of thrust and, if applicable, the pitch of the propeller shall be fully controllable from the navigation bridge.*

4.1.2 All manual operations or services expected to be carried out with a periodicity of less than 24 h are to be eliminated or automated, particularly for: lubrication, topping up of make up tanks and filling tanks, filter cleaning, cleaning of centrifugal purifiers, drainage, load sharing on main engines and various adjustments. Nevertheless, the transfer of operation mode may be effected manually.

4.1.3 *A centralised control position shall be arranged with the necessary alarm panels and instrumentation indicating any alarm.*

4.1.4 Parameters for essential services which need to be adjusted to a preset value are to be automatically controlled.

4.1.5 *The control system shall be such that the services needed for the operation of the main propulsion machinery and its auxiliaries are ensured through the necessary automatic arrangements.*

4.1.6 *It shall be possible for all machinery essential for the safe operation of the ship to be controlled from a local position, even in the case of failure in any part of the automatic or remote control systems.*

4.1.7 *The design of the remote automatic control system shall be such that in the case of its failure an alarm will be given. Unless impracticable, the preset speed and direction of thrust of the propeller shall be maintained until local control is in operation.*

4.1.8 Critical speed ranges, if any, are to be rapidly passed over by means of an appropriate automatic device.

4.1.9 Propulsion machinery is to stop automatically only in exceptional circumstances which could cause quick critical damage, due to internal faults in the machinery. The design of automation systems whose failure could result in an unexpected propulsion stop is to be specially examined. An overriding device for cancelling the automatic shutdown is to be considered.

Automatic slow down of propulsion machinery may be omitted during crash astern sequence.

4.1.10 Where the propulsive plant includes several main engines, a device is to be provided to prevent any abnormal overload on each of them.

4.1.11 *Where standby machines are required for other auxiliary machinery essential to propulsion, automatic changeover devices shall be provided.*

4.1.12 The additional remote indications to be displayed at the centralised control position, shown with the symbol "R" in the following tables Tab 2 to Tab 29, are required for **AUT-CCS** notation only, as mentioned in Ch 3, Sec 2, [4.1.2].

4.2 Diesel propulsion plants

4.2.1 When a diesel engine is used for the propulsion plant, monitoring and control of equipment is to be performed according to Tab 2 for cross-head (slow speed) engines or Tab 3 for trunk-piston (medium or high speed) engines.

Table 2 : Main propulsion cross-head (slow speed) diesel engine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm **(1)**	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Fuel oil system							
• Fuel oil pressure after filter (engine inlet)	L	R					
						X	
• Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)	H + L						
					X		
• Leakage from high pressure pipes where required	X						
• Common rail fuel oil pressure	L						
Lubricating oil system							
• Lubricating oil to main bearing and thrust bearing pressure	L	R	X				
						X	
	LL			X			
• Lubricating oil to crosshead bearing pressure when separate	L	R	X				
						X	
	LL			X			
• Lubricating oil to camshaft pressure when separate	L						
						X	
	LL			X			
• Lubricating oil to camshaft temperature when separate	H						
					X		
• Lubricating oil inlet temperature	H						
					X		
• Thrust bearing pad temperature or bearing oil outlet temperature	H	local	X				
	HH			X			
• Activation of oil mist detection arrangements **(2) (10)**	X		X				
• Crankcase oil mist detector failure	X						
• Flow rate cylinder lubricator (each apparatus)	L		X				
• Level in lubricating oil tanks or oil sump, as appropriate **(3)**	L						
• Common rail servo oil pressure	L						
• Lubricating oil to turbocharger inlet pressure **(4)**	L						
• Turbocharger lubricating oil outlet temperature on each bearing **(5)**	H						
Piston cooling system							
• Piston coolant inlet pressure	L		X **(6)**				
						X	
• Piston coolant outlet temperature on each cylinder	H	local	X				
• Piston coolant outlet flow on each cylinder **(7)**	L	local	X				
• Level of piston coolant in expansion tank	L						
Sea water cooling system							
• Sea water cooling pressure	L						
						X	

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm **(1)**	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Cylinder fresh cooling water system							
• Cylinder fresh cooling water system inlet pressure	L	local **(9)**	X				
						X	
• Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature	H	local	X				
• Oily contamination of engine cooling water system (when main engine cooling water is used in fuel and lubricating oil heat exchangers)	X						
• Level of cylinder cooling water in expansion tank	L						
Fuel valve coolant system							
• Pressure of fuel valve coolant	L						
						X	
• Temperature of fuel valve coolant	H						
• Level of fuel valve coolant in expansion tank	L						
Scavenge air system							
• Scavenging air receiver pressure		R					
• Scavenging air box temperature (detection of fire in receiver, see [3.2.2])	H	local	X				
• Scavenging air receiver water level	H						
Exhaust gas system							
• Exhaust gas temperature after each cylinder	H	R	X				
• Exhaust gas temperature after each cylinder, deviation from average	H						
• Exhaust gas temperature before each turbocharger	H	R					
• Exhaust gas temperature after each turbocharger	H	R					
Miscellaneous							
• Speed of turbocharger **(8)**	H	R					
• Engine speed (and direction of speed when reversible)		R					
					X		
• Engine overspeed **(9)**	H			X			
• Wrong way	X						
• Control, safety, alarm system power supply failure	X						

(1) Where alarm is associated to slowdown or shutdown, this alarm is to anticipate the action of shutdown and slowdown (pre-alarm).

(2) For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

(3) If separate lubricating oil tanks are installed, then an individual level alarm for each tank is required.

(4) Unless provided with a self-contained lubricating oil system integrated with the turbocharger.

(5) Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design alternative arrangement may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.

(6) Not required, if the coolant is oil taken from the main cooling system of the engine.

(7) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted.

(8) Only required for turbochargers of Categories B and C as defined in Pt C, Ch 1, Sec 17, [1.1.3].

(9) For engines of 220 kW and above.

(10) Activation of oil mist detection arrangements is equivalent to activation of the temperature monitoring systems, or equivalent devices, of:

- the engine main, crank and crosshead bearing oil outlet; or
- the engine main, crank and crosshead bearing

Table 3 : Main propulsion trunk-piston (medium or high speed) diesel engine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm **(1)**	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Fuel oil system							
• Fuel oil pressure after filter (engine inlet)	L	R					
						X	
• Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)	H + L						
					X		
• Leakage from high pressure pipes where required	H						
• Common rail fuel oil pressure	L						
Lubricating oil system							
• Lubricating oil to main bearing and thrust bearing pressure	L	R					
	X					X	
	LL			X			
• Lubricating oil filter differential pressure	H	R					
• Lubricating oil inlet temperature	H	R					
					X		
• Activation of oil mist detection arrangements **(2) (7)**	X			X			
• Crankcase oil mist detector failure	X						
• Flow rate cylinder lubricator (each apparatus)	L		X				
• Common rail servo oil pressure	L						
• Lubricating oil to turbocharger inlet pressure **(3)**	L	R					
• Turbocharger lub oil temperature each bearing **(4)**	H						
Sea water cooling system							
• Sea water cooling pressure	L	R					
						X	
Cylinder fresh cooling water system							
• Cylinder water inlet pressure or flow	L	R	X				
						X	
• Cylinder water outlet temperature	H	R	X				
• Level of cylinder cooling water in expansion tank	L						
Scavenge air system							
• Scavenging air receiver temperature	H						
Exhaust gas system							
• Exhaust gas temperature after each cylinder **(5)**	H	R	X				
• Exhaust gas temperature after each cylinder **(5)**, deviation from average	H						
Miscellaneous							
• Engine speed		R					
					X		
• Engine overspeed	H			X			
• Speed of turbocharger **(6)**	H	R					
• Control, safety, alarm system power supply failure	X						

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm **(1)**	Indication	Slow-down	Shut-down	Control	Standby Start	Stop

(1) Where alarm is associated to slowdown or shutdown, this alarm is to anticipate the action of shutdown and slowdown (pre-alarm).

(2) For engine of 2250 kW and above or having cylinders of more than 300 mm bore: for each engine, one oil mist detector (or engine bearing temperature monitoring system or equivalent device) having two independent outputs for initiating the alarm and shut-down would satisfy the requirement for independence between alarm and shut-down systems.

(3) Unless provided with a self contained lubricating oil system integrated with the turbocharger.

(4) Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.

(5) For engine power > 500 kW/cyl.

(6) Only required for turbochargers of Categories B and C as defined in Pt C, Ch 1, Sec 17, [1.1.3].

(7) Activation of oil mist detection arrangements is equivalent to activation of the temperature monitoring systems, or equivalent devices, of:

- the engine main and crank bearing oil outlet; or
- the engine main and crank bearing

4.3 Steam propulsion plants

4.3.1 For steam propulsion plants, control and monitoring functions of steam turbines are required according to Tab 4.

Table 4 : Steam turbines used for main propulsion

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Lubricating oil system							
• Supply pressure						X	
	L						
	LL			X			
• Cooler inlet temperature	H						
• Temperature of reduction gear bearings	H **(1)**						
• Temperature of turbine bearings and thrust bearings	H **(1)**						
• Level of return tank	L **(2)**						
• Level of gravity tank	L **(2)**						
Miscellaneous							
• Main turbine speed		R			X		
	H			X			
• Main turbine vibration	H						
	HH			X			
• Main turbine axial displacement	H						
	HH			X			
• Automatic spinning fault	X						
• Gland seals fault at exhaust fans	X						
• Gland seals pressure of steam supply	L + H						
• Superheated steam temperature	L			X			

(1) Alternatively: group alarm associated with means to find out the fault.

(2) Sensor to be located near the normal level.

4.3.2 Turbine spinning is to take place automatically at regular intervals when the shaft line is stopped during manoeuvring.

4.3.3 Spinning is not allowed until the equipment is in a safe position.

4.3.4 Lubrication of gear and turbines is to be automatically ensured until the plant is stopped (driven oil pump or gravity tank).

4.3.5 If a special crash astern sequence is provided, it is to be carried out through a separate device or by placing the control gear in a special position; precautions are to be taken to avoid its unintended use.

According to the type of plant, this control may be achieved by:

- cancelling the low vacuum shutdown device
- shutting off the steam to the ahead turbine
- opening the turbine cylinder drain valves, the astern stop valve and the astern manoeuvring valve.

4.3.6 For steam propulsion plants, control and monitoring functions of main boilers are required according to Tab 5.

4.3.7 Additional arrangements may be required according to the type of boilers considered, in particular in the case of forced circulation boilers, concerning unexpected circulation shutdown.

Reheat cycle type boilers are also to be subjected to a special examination.

4.3.8 Where the propulsive plant includes several main boilers, automatic shutdown of one is to involve automatic slowdown of the turbines with a view to saving the maximum available steam for electricity production.

4.3.9 Unless special arrangements are provided, fire in boiler air ducts is to be detected.

4.3.10 For evaporators associated to steam propulsion plants, control, alarm and monitoring functions are required according to Tab 6.

Table 5 : Main boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Fuel oil system							
• Fuel oil delivery pressure or flow	L						
• Fuel oil temperature after heater or viscosity fault	L + H						
					X		
Combustion							
• Flame failure of each burner	X						
				X			
• Failure of atomising fluid	X						
• Boiler casing and economiser outlet smoke temperature (in order to detect possible fire outbreak)	H						
	HH			X			
• Burning air flow or equivalent	L						
General steam system							
• Superheated steam pressure	L + H	R					
					X		
• Superheated steam temperature	H						
• Desuperheated steam pressure (except if pressure is that of superheated steam)	L						
• Desuperheated steam temperature	H						
• Lifting of safety valve (or equivalent: for instance high pressure alarm)	X						
• Water level inside the drum of each boiler					X		
	L	R					
	H						X **(1)**
	HH			X			
	LL			X			
(1) Stop of the feed water pump							

Table 6 : Evaporators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Evaporator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Electric fault at pump	X						
Heating fluid pressure or flow	L						
Excessive salinity of distilled water before drain valve or re-circulation valve					X **(1)**		
Excessive salinity of distilled water after drain valve or re-circulation valve (at tank inlet)	H						
(1) Automatic draining to bilge or re-circulation							

4.4 Gas turbine propulsion plants

4.4.1 For gas turbines, monitoring and control elements are required according to Tab 7.

Table 7 : Propulsion gas turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Lubricating oil system							
• Turbine supply pressure	L		X			X	
	LL			X			
• Differential pressure across lubricating oil filter	H						
• Bearing or lubricating oil (discharge) temperature	H						
Mechanical monitoring of gas turbine							
• Speed		R			X		
	H			X			
• Vibration	H						
	HH			X			
• Rotor axial displacement (not applicable to roller bearing)	H						
	HH			X			
• Number of cycles performed by rotating parts	H						
Gas generator monitoring system							
• Flame and ignition failure				X			
• Fuel oil supply pressure	L						
• Fuel oil supply temperature	H + L						
					X		
• Cooling medium temperature	H						
• Exhaust gas temperature or gas temperature in specific locations of flow gas path (alarm before shutdown)	H						
	HH			X			
• Pressure at compressor inlet (alarm before shutdown)	L						
Miscellaneous							
• Control system failure	X						
• Automatic starting failure	X						

4.5 Gas-only and dual fuel engines

4.5.1 For ships assigned with additional service feature **LNGfuel**, **CNGfuel** or **LPGfuel** or, as relevant, other service features defined in Pt A, Ch 1, Sec 2, [4.13], control and monitoring functions of gas-only and dual fuel engines are to be in compliance with NR529.

4.6 Electrical propulsion plant

4.6.1 Documents to be submitted

The following additional documents are to be submitted to the Society:

- a list of the alarms and shutdowns of the electrical propulsion system
- when the control and monitoring system of the propulsion plant is computer based, a functional diagram of the interface between the programmable logic controller and computer network.

4.6.2 Alarm system

The following requirements are applicable to the alarm system of electrical propulsion:

- alarms circuits of electrical propulsion are to be connected to the main alarm system on board. As an alternative, the relevant circuit may be connected to a local alarm unit. In any case, a connection between the local alarm unit and the main alarm system is to be provided
- the alarms can be arranged in groups, and shown in the control station. This is acceptable when a discrimination is possible locally
- when the control system uses a computer based system, the requirements of Pt C, Ch 3, Sec 3 are applicable, in particular, for the data transmission link between the alarm system and the control system
- individual alarms are considered as critical and are to be individually activated at the control stations, and acknowledged individually
- shutdown activation is to be considered as an individual alarm.

4.6.3 Safety functions

The following requirements are applicable to the safety system of electrical propulsion:

- as a general rule, safety stop using external sensors such as temperature, pressure overspeed, main cooling failure, stop of converter running by blocking impulse is to be confirmed by the automatic opening of the main circuit using a separate circuit
- in order to avoid accidental stop of the propulsion line and limit the risk of blackout due to wire break, the tripping of the main circuit-breaker is to be activated by an emission coil with a monitoring of the line wire break
- in the case of a single line propulsion system, the power limitation order is to be duplicated
- as a general rule, when the safety stop is activated, it is to be maintained until local acknowledgement.

4.6.4 Transformers

For transformers, parameters according to Tab 8 are to be controlled or monitored.

4.6.5 Converters

For converters, parameters according to Tab 9, Tab 10 and Tab 11 are to be monitored or controlled.

4.6.6 Smoothing coil

For the converter reactor, parameters according to Tab 12 are to be monitored or controlled.

4.6.7 Propulsion electric motor

For propulsion electric motors, parameters according to Tab 13 are to be monitored or controlled.

4.6.8 All parameters listed in the tables of this item are considered as a minimum requirement for unattended machinery spaces.

Some group alarms may be locally detailed on the corresponding unit (for instance loss of electronic supply, failure of electronic control unit, etc.).

4.7 Shafting, clutches, CPP, gears

4.7.1 For shafting and clutches, parameters according to Tab 14 are to be monitored or controlled.

4.7.2 For controllable pitch propellers, parameters according to Tab 15 are to be monitored or controlled.

4.7.3 For reduction gears and reversing gears, parameters according to Tab 16 are to be monitored or controlled.

Table 8 : Transformers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Earth failure on main propulsion circuits	I						
Circuit-breaker, short-circuit	I **(2)**			X			
Circuit-breaker, overload	I **(2)**			X			
Circuit-breaker, undervoltage	I **(2)**			X			
Temperature of winding on phase 1, 2, 3 **(1) (4)**	G,I, H		X **(3)**				
	G,I, HH			X			
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						
Cooling pump pressure or flow	G, L		X				
						X	
Cooling medium temperature	G, H		X				
Leak of cooling medium	G		X				

(1) A minimum of 6 temperature sensors are to be provided:
- 3 temperature sensors to be connected to the alarm system (can also be used for the redundant tripping of the main circuit-breaker)
- 3 temperature sensors connected to the control unit.

(2) To be kept in the memory until local acknowledgement.

(3) Possible override of slowdown by the operator.

(4) Not applicable to oil immersed type transformers. Those transformers are to be fitted with alarms and protections specified in Pt C, Ch 2, Sec 13, [4.1.1].

Table 9 : Network converter

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Short-circuit current I max	I			X			
Overvoltage	G			X			
Undervoltage	G						
Phase unbalanced	I			(X) **(1)**			
Power limitation activated	I						
Protection of filter circuit trip	I						
Circuit-breaker opening operation failure	I						
Communication circuit, control circuits, power supplies, watchdog of control system according to supplier's design	G			X			

(1) This parameter, when indicated in brackets, is only advisable according to the supplier's requirements.

Table 10 : Motor converter

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Short-circuit current I max	I			X			
Overvoltage	G			X			
Undervoltage	G			X			
Phase unbalanced	I						
Protection of filter circuit trip	I						
Communication circuit, control circuits, power supplies, watchdog of control system according to supplier's design	G			X			
Speed sensor system failure	G					X **(1)**	
Overspeed	I			X			
Braking resistor temperature (where applicable)	I, H						
(1) Automatic switch-over to the redundant speed sensor system.							

Table 11 : Converter cooling circuit

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Air cooling temperature high	I	R					
Ventilation, fan failure	G						
			X				
Cooling pump pressure or flow low	G	R					
						X	
Cooling fluid temperature high	G						
Leak of cooling medium	G		X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						

Table 12 : Smoothing coil

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Temperature of coil	I, H	R					
	I, HH						
Air cooling temperature	I, H						
Ventilation fan failure	G						
			X				
Cooling pump pressure or flow low	G	R					
						X	
Cooling fluid temperature high	G						
Leak of cooling medium	G						
			X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						

Table 13 : Propulsion electric motor

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm **(1)**	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Automatic tripping of overload and short-circuit protection on excitation circuit	G, H			X			
Loss of excitation	G			X			
Winding current unbalanced	G						
Harmonic filter supply failure	I						
Interface failure with power management system	I		X				
Earthing failure on stator winding and stator supply	I	R					
Temperature of winding on phase 1, 2, 3	I, H		X				
	I, HH			X			
Motor cooling air temperature	I, H	R					
Cooling pump pressure or flow	G, L	R	X				
						X	
Cooling fluid temperature	G, H						
Leak of cooling medium	G		X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						
Motor bearing temperature	G, H	R					
Bearing lubrication oil pressure (for self-lubricated motor, when the speed is under the minimum RPM specified by the manufacturer, shutdown is to be activated)	I, L	R	X				
						X	
Turning gear engaged	I						
Brake and key engaged	I						

(1) Where alarm is associated to slowdown or shutdown, this alarm is to anticipate the action of shutdown and slowdown (pre-alarm).

Table 14 : Shafting and clutches of propulsion machinery

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Temperature of each shaft thrust bearing (not applicable for ball or roller bearings)	H		X				
Sterntube bush oil gravity tank level	L						
Clutch oil temperature (if applicable)	H		X				
Clutch oil tank level (if applicable)	L						

Table 15 : Controllable pitch propeller

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Control oil temperature before cooler	H						
Oil tank level	L						

Table 16 : Reduction gears/reversing gears

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Lubricating oil temperature at the oil cooler outlet	H	R **(1)**	X				
Lubricating oil pressure	L **(1)**	R				X	
	LL			X			
Oil tank level **(2)**	L	R					

(1) May be omitted in the case of restricted navigation notation.

(2) May be omitted when the small size of the gearbox makes it unpracticable (low pressure alarm to be representative of a low level in the gearbox casing).

4.8 Auxiliary system

4.8.1 *Where standby machines are required for other auxiliary machinery essential to propulsion, automatic change- over devices shall be provided.*

Change-over restart is to be provided for the following systems:

- cylinder, piston and fuel valve cooling
- cylinder cooling of diesel generating sets (where the circuit is common to several sets)
- main engine fuel supply
- diesel generating sets fuel supply (where the circuit is common to several sets)
- sea water cooling for propulsion plant
- sea water to main condenser (main turbines)
- hydraulic control of clutch, CPP or main thrust unit
- thermal fluid systems (thermal fluid heaters).

4.8.2 When a standby machine is automatically started, an alarm is to be activated.

4.8.3 When the propulsion plant is divided into two or more separate units, the automatic standby auxiliary may be omitted, when the sub-units concerned are fully separated with regard to power supply, cooling system, lubricating system etc.

Some of the propulsive plants may be partially used for reasons of economy (use of one shaft line or one propulsion engine for instance). If so, automatic change-over, necessary for this exploitation mode, is to be provided.

4.8.4 Means shall be provided to keep the starting air pressure at the required level where internal combustion engines are used for main propulsion.

4.8.5 *Where daily service fuel oil tanks are filled automatically, or by remote control, means shall be provided to prevent overflow spillages.*

4.8.6 Arrangements are to be provided to prevent overflow spillages coming from equipment treating flammable liquids.

4.8.7 *Where daily service fuel oil tanks or settling tanks are fitted with heating arrangements, a high temperature alarm shall be provided if the flashpoint of the fuel oil can be exceeded.*

4.8.8 For auxiliary systems, the parameters according to Tab 17 to Tab 27 are to be monitored or controlled.

4.8.9 For exhaust gas treatment systems, alarms and indications required in Pt C, Ch 1, Sec 11, [2.4.6] are to be available at the centralised control position.

4.8.10 For ballast water management systems, alarms and indications required in Pt C, Ch 1, Sec 13, [2.5] are to be available at the centralised control position.

4.8.11 For carbon capture systems (CCS), alarms and indications required in Pt C, Ch 1, Sec 12, [2.7] are to be available at the centralised control position.

4.9 Control of electrical installation

4.9.1 Following a blackout, automatic connection of a standby generating set is to be followed by an automatic restart of the primary essential services. If necessary, time delay sequential steps are to be provided to allow satisfactory operation.

In case of failure of the emergency generator, manual restart of a main generating set is admitted. Refer to Pt C, Ch 2, Sec 3, [2.3.9].

4.9.2 Monitored parameters for which alarms are required to identify machinery faults and associated safeguards are listed in Tab 28 and Tab 29. These alarms are to be indicated at the control location for machinery as individual alarms; where the alarm panel with all individual alarms is installed on the engine or in the vicinity, a common alarm in the control location for machinery is required. For communication of alarms from the machinery space to the bridge area and accommodation for engineering personnel, detailed requirements are contained in [5].

Table 17 : Incinerators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Combustion air pressure	L			X			
Flame failure	X			X			
Furnace temperature	H			X			
Exhaust gas temperature	H						
Fuel oil pressure **(2)**	L						
Fuel oil temperature or viscosity **(1)**	H + L						
(1) Where heavy fuel is used. **(2)** Where pressure is important for the combustion or a pump is not an integral part of the burner.							

Table 18 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Water level					X		
	L + H			X			
Fuel oil temperature or viscosity **(3)**	H + L						
Flame failure	X						
				X			
Combustion air supply fan low pressure				X			
Temperature in boiler casing (fire)	H						
Steam pressure					X		
	H **(1)**			X			
Steam temperature				X **(2)**			
(1) When the automatic control does not cover the entire load range from zero load. **(2)** For superheated steam over 330°C. **(3)** Where heavy fuel is used.							

Table 19 : Fuel oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Fuel oil in daily service tank level	L						
Fuel oil daily service tank temperature **(3)**	H				X		
Fuel oil in daily service tank level	H **(1)**						
Fuel oil overflow tank level	H						
Air pipe water trap level on fuel oil tanks	H **(2)**						
Heater outlet fuel oil temperature					X		
	H **(4)**			X **(5)**			
Sludge tank level	H						
Fuel oil settling tank level	H **(1)**						
Fuel oil settling tank temperature **(3)**	H				X		
Fuel oil centrifugal purifier overflow	H			X **(6)**			

(1) To be provided if no suitable overflow arrangement
(2) Or alternative arrangement as per Pt C, Ch 1, Sec 10, [9.1.7]
(3) Applicable where heating arrangements are provided.
(4) Or low flow alarm in addition to temperature control when heated by steam or other media.
(5) Cut off of electrical power supply when electrically heated.
(6) Shutdown of the fuel oil supply.

Table 20 : Lubricating oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Air pipe water trap level of lubricating oil tank See Pt C, Ch 1, Sec 10, [9.1.7]	H						
Sludge tank level	H						
Lubricating oil centrifugal purifier overflow	H			X **(1)**			

(1) Shutdown of the lubricating oil supply.

Table 21 : Thermal oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Thermal fluid temperature heater outlet	H						
	HH			X **(1)**			
Thermal fluid pressure pump discharge **(4)**	H			X			
Thermal fluid flow through heating element	L					X	
	LL			X **(1)**			

(1) Shut-off of heat input only.
(2) Shut-off of heat input and delayed stop of fluid flow.
(3) Where heavy fuel is used.
(4) Not applicable to centrifugal pumps.

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Expansion tank level	L						
	LL			X **(2)**			
Expansion tank temperature	H						
Combustion air pressure	L			X			
Fuel oil pressure	L						
Fuel oil temperature or viscosity **(3)**	H + L						
Burner flame failure	X			X			
Flue gas temperature heater outlet	H						
	HH			X **(2)**			

(1) Shut-off of heat input only.
(2) Shut-off of heat input and delayed stop of fluid flow.
(3) Where heavy fuel is used.
(4) Not applicable to centrifugal pumps.

Table 22 : Hydraulic oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Pump pressure	H						
Service tank level	L						X **(1)**

(1) The automatic stop of the hydraulic pumps is to be operated in the same circumstances, except where this stop can lead to propulsion stop.

Table 23 : Boiler feed and condensate system for main and auxiliary boiler

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Sea water flow in condenser or equivalent	L					X	
Vacuum in condenser **(2)**	L						
	LL			X			
Water level in main condenser (unless justified)	H + L						
					X		
	HH			X			
Salinity of condensate	H						
Feed water pump delivery pressure	L					X	
Feed water tank level	L						
Deaerator inside temperature or pressure **(2)**	L + H **(1)**						
Water level in deaerator **(2)**	L + H						
Extraction pump pressure **(2)**	L						
Drain tank level	L + H						

(1) In the case of forced circulation boiler.
(2) When installed.

Table 24 : Compressed air system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Air temperature at compressor outlet	H						
Compressor lubricating oil pressure (except where splash lubrication)	LL			X			
Control air pressure **(3)**	L	R					
					X		
Starting air pressure before main shut-off valve	L **(2)**	local + R **(1)**					
					X		
	X					X	
Safety air pressure **(3)**	L						
					X		

(1) Remote indication is required if starting of air compressor is remote controlled, from wheelhouse for example.

(2) For starting air, the alarm minimum pressure set point is to be so adjusted as to enable at least four starts for reversible propulsion engines and two starts for non-reversible propulsion engines.

(3) When supplied through reducing valve, see Pt C, Ch 1, Sec 10, [2.5.4].

Table 25 : Cooling system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Sea water pump pressure or flow	X					X	
	L						
Fresh water pump pressure or flow	X					X	
	L						
Level in cooling water expansion tank	L						

Table 26 : Thrusters

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Thruster			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Control oil temperature (preferably before cooler)	H						
Oil tank level	L						

Table 27 : Control and monitoring of auxiliary electrical systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)		Monitoring		Automatic control				
				Main Engine			Auxiliary	
Identification of system parameter		Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Electric circuit, blackout		X						
Power supply failure of control, alarm and safety system		X						
Harmonic filter (when provided) **(1)**	Electrical protection (each phase)	X						
	Unbalance current	X						

(1) Not required for harmonic filters installed for single application frequency drives such as pump motors.

Table 28 : Auxiliary trunk-piston reciprocating I.C. engines driving generators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Fuel oil viscosity or temperature before injection (for engine running on heavy fuel)	L + H	local					
					X		
Fuel oil pressure		local					
Common rail fuel oil pressure	L						
Fuel oil leakage from high pressure pipes	H						
Lubricating oil temperature	H						
Lubricating oil pressure	L	local				X **(4)**	
	LL			X			
Activation of oil mist detection arrangements **(1) (5) (7)**	X			X			
Crankcase oil mist detector failure	X						
Exhaust gas temperature after each cylinder **(2)**	H	R	X				
Turbocharger lubricating oil inlet pressure **(2) (3)**	L	local					
Common rail servo oil pressure	L						
Pressure or flow of cooling system, if not connected to main system	L	local					
Temperature of cooling medium	H	local					
Level in cooling water expansion tank, if not connected to main system	L						
Engine speed		local					
					X		
	H			X			
Speed of turbocharger **(6)**	H						
Fault in the electronic governor system	X						

(1) For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

(2) For engine power > 500 kW/cyl.

(3) If without integrated self contained oil lubricating system.

(4) When a stand by pump is required.

(5) For each engine one oil mist detector (or engine bearing temperature monitoring system or equivalent device) having two independent outputs for initiating the alarm and shut-down would satisfy the requirement for independence between alarm and shut-down systems.

(6) Only required for turbochargers of Categories B and C as defined in Pt C, Ch 1, Sec 17, [1.1.3].

(7) Activation of oil mist detection arrangements is equivalent to activation of the temperature monitoring systems, or equivalent devices, of:

- the engine main and crank bearing oil outlet; or
- the engine main and crank bearing

Note 1: When the emergency generator is used in port, this Table applies.

Note 2: For engine driving emergency generator, see Pt C, Ch 1, Sec 2, Tab 7.

Table 29 : Auxiliary steam turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote (**AUT-CCS** only)	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Turbine speed		local					
					X		
	HH			X			
Lubricating oil supply pressure	L					X	
	LL			X			

5 Alarm system

5.1 General

5.1.1 A system of alarm displays is to be provided which readily allows identification of faults in the machinery and satisfactory supervision of related equipment. This may be arranged at a main control station or, alternatively, at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

5.1.2 Unless otherwise justified, separation of monitoring and control systems is to be provided.

5.1.3 The alarm system is to be designed to function independently of control and safety systems, so that a failure or malfunction of these systems will not prevent the alarm system from operating. Common sensors for alarms and automatic slowdown functions are acceptable as specified in each specific table.

5.1.4 *The alarm system shall be continuously powered and shall have an automatic change-over to a standby power supply in the case of loss of normal power supply.*

5.2 Alarm system design

5.2.1 The alarm system and associated sensors are to be capable of being tested during normal machinery operation.

5.2.2 Insulation faults on any circuit of the alarm system are to generate an alarm, when an insulated earth distribution system is used.

5.2.3 An engineers' alarm is to be activated when the machinery alarm has not been accepted in the machinery spaces or control room within 5 minutes.

5.2.4 The alarm system is to have a connection to the engineers' public rooms and to each of the engineers' cabins through a selector switch, to ensure connection to at least one of those cabins.

5.3 Machinery alarm system

5.3.1 The local silencing of the alarms on the bridge or in accommodation spaces is not to stop the audible machinery space alarm.

5.3.2 Machinery faults are to be indicated at the control locations for machinery.

5.4 Alarm system on navigation bridge

5.4.1 Alarms associated with faults requiring speed reduction or automatic shutdown are to be separately identified on the bridge.

5.4.2 The alarm system is to activate an audible and visual alarm on the navigation bridge for any situation which requires action by or the attention of the officer on watch.

5.4.3 Individual alarms are to be provided at the navigation bridge indicating any power supply failures of the remote control of propulsion machinery.

6 Safety systems

6.1 General

6.1.1 Safety systems of different units of the machinery plant are to be independent. Failure in the safety system of one part of the plant is not to interfere with the operation of the safety system in another part of the plant.

6.1.2 In order to avoid undesirable interruption in the operation of machinery, the system is to intervene sequentially after the operation of the alarm system by:

- starting of standby units
- load reduction or shutdown, such that the least drastic action is taken first.

6.1.3 The arrangement for overriding the shutdown of the main propelling machinery is to be such as to preclude inadvertent operation.

6.1.4 After stoppage of the propulsion engine by a safety shutdown device, the restart is only to be carried out, unless otherwise justified, after setting the propulsion bridge control level on "stop".

7 Testing

7.1 General

7.1.1 Tests of automated installations are to be carried out according to Pt C, Ch 3, Sec 6 to determine their operating conditions. The details of these tests are defined, in each case, after having studied the concept of the automated installations and their construction. A complete test program is to be submitted for approval.

7.1.2 The tests of equipment carried out alongside the quay under normal conditions of use include, for instance:

- the electrical power generating set
- the auxiliary steam generator
- the automatic bilge draining system
- automatic centrifugal separators or similar purifying apparatus
- automatic change-over of service auxiliaries
- detection of high pressure fuel leaks from diesel generating sets or from flexible boiler burner pipes
- in case of flooding alarm provided a test of protection against flooding.
- test of fire detection system:
  - test of normal operation of the fire detection system (detection, system faults)
  - test of detection in the scavenging air belt and boiler air duct
  - test of the fire detection system as per [3.2.16].

7.1.3 Sea trials are used to demonstrate the proper operation of the automated machinery and systems. For this purpose, for instance, the following tests are to be carried out:

- Test of the remote control of propulsion:
  - checking of the operation of the automatic control system: programmed or unprogrammed starting speed increase, reversal, adjusting of the propeller pitch, failure of supply sources, etc.
  - checking of the crash astern sequence, to ensure that the reversal sequence is properly performed from full away, the ship sailing at its normal operation speed. The purpose of this check is not to control the nautical performances of the ship (such as stopping distance, etc.)
  - finally, checking of the operation of the whole installation in normal working conditions, i.e. as a general rule without watch-keeping personnel for the monitoring and/or running of the machinery during 6 h at least
  - The following procedure may, for instance, be chosen: “underway” at the ship’s rated power during 3 h, then decreasing to “full ahead”. Staying in that position during 5 min. Then stopping for 15 min. Then, putting the control lever in the following positions, staying 2 minutes in each one: astern slow, astern half, astern full, full ahead, half ahead, stop, full astern, stop, ahead dead slow, half ahead, then increasing the power until “underway” position.
- Test of the operating conditions of the electrical production:
  - automatic starting of the generating set in the event of a blackout
  - automatic restarting of auxiliaries in the event of a blackout
  - load-shedding in the event of generating set overload
  - automatic starting of a generating set in the event of generating set overload.
- Test of operating conditions, including manoeuvring, of the whole machinery in an unattended situation for 6 h.

7.2 Specific requirement for ships fitted with engine using both low-flashpoint gaseous fuels and fuel oil as fuel

7.2.1 For ships assigned with **LNGfuel dualfuel**, **CNGfuel dualfuel**, **LPGfuel dualfuel** or, as relevant, other additional service features defined in Pt A, Ch 1, Sec 2 [4.13], the sea trials are to include additional tests to demonstrate the following capabilities in gas fuel mode:

a) Engine starting in gas fuel mode, if applicable

b) Switchover from oil fuel mode to gas fuel mode and vice versa at different loads

c) Blackout test (when the dual fuel engine drives a generator), in order to check:
   - the automatic starting and connecting of stand-by generator(s)
   - the satisfactory operation of the tank pressure and temperature control system
   - the satisfactory operation of gas fuel handling and supply systems

d) Checking of the crash astern sequence (when the dual fuel engine is used as a propulsion engine).

7.2.2 The proper operation of the automated machinery and systems is to be demonstrated in both oil fuel mode and gas fuel mode. The tests defined in [7.1.3] are to be carried out during a period of at least 6 h in oil fuel mode and during an additional period of at least 1 h in gas mode in addition to shipboard trials required in Pt C, Ch 1, App 2, [4.3.1].

Section 2 Centralised Control Station (AUT-CCS)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-CCS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.3] to ships fitted with a machinery installation operated and monitored from a centralised control station, and complying with the requirements of this Section.

It applies to ships which are intended to be operated with machinery spaces unattended, but with continuous supervision from a position where control and monitoring devices of machinery are centralised.

Note 1: Machinery spaces are defined in Pt C, Ch 4, Sec 1, [2.30.1].

1.1.2 Remote indications for continuous supervision of the machinery are to be located in a centralised control position, to allow a watch service of the machinery space.

1.1.3 The provisions of Ch 3, Sec 1, [1.1.3] and Ch 3, Sec 1, [1.1.4] are also applicable for the additional class notation **AUT-CCS**.

1.2 Exemptions

1.2.1 Exemptions mentioned in Ch 3, Sec 1, [1.2] may also be considered for the additional class notation **AUT-CCS**.

1.3 Communication system

1.3.1 A means of communication is to be provided between the centralised control station, the navigation bridge, the engineers' accommodation and, where necessary, the machinery spaces.

1.3.2 The requirements mentioned in Ch 3, Sec 1, [1.3] are applicable.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to those mentioned in Pt C, Ch 3, Sec 1, Tab 1, documents according to Tab 1 are required.

Table 1 : Documentation to be submitted

No	I/A **(1)**	Document
1	A	Means of communication diagram
2	A	Central control position layout and location
3	A	System of protection against flooding
(1) A: to be submitted for approval ; I: to be submitted for information.		

3 Fire and flooding precautions

3.1 General

3.1.1 The requirements mentioned in Ch 3, Sec 1, [3] are applicable, except for Ch 3, Sec 1, [3.4.4].

The calculation of the time it takes to reach the sea valves required under Ch 3, Sec 1, [3.4.3] should be determined based on the distance between the centralised control station and the platform from where the valves are manually operated.

3.1.2 The fire detection and flooding alarms are to be transmitted to the centralised control position.

4 Control of machinery

4.1 Propulsion plant operation

4.1.1 The centralised control position is to be designed, equipped and installed so that the machinery operation is as safe and effective as if it were under direct supervision.

4.1.2 Monitoring and control of main systems are to be designed according to the requirements mentioned in Ch 3, Sec 1, [4]. Additional indications, as alarms and measured values, in the centralised control position are required, and shown in the table with the symbol R.

4.1.3 In the centralised control position, it is to be possible to restore the normal electrical power supply in the case of power failure (e.g. with remote control of the generating sets), unless an automatic restart is provided.

4.1.4 Automatic restart of essential auxiliaries for propulsion and steering may be replaced by remote control from the centralised control position.

4.1.5 The status of machinery (in operation or on standby) and all parameters crucial to the safe operation of essential machinery are to be shown at the centralised control position.

4.1.6 Under all sailing conditions including manoeuvring, the speed, direction of thrust and, if applicable, the pitch of the propeller are also to be fully controllable from the centralised control position.

4.1.7 In addition to the requirements in Ch 3, Sec 1, [4.1.10], the device to prevent overload, when automatic or remote controlled from the centralised control position, is to be fitted with an alarm indicating the necessity of slowing down.

4.2 Control position location

4.2.1 The centralised control position is to be located in the machinery space or adjacent to it. Other arrangements are to be submitted to the satisfaction of the Society.

4.2.2 If the centralised control position is an enclosed space located in the machinery spaces, it is to be provided with two safe fire escapes.

5 Alarm system

5.1 General

5.1.1 Every alarm is to be indicated visually and audibly at the centralised control position.

5.1.2 Requirements mentioned in Ch 3, Sec 1, [5] are applicable except Ch 3, Sec 1, [5.2.4].

6 Safety system

6.1 General

6.1.1 Safeguard disactivation, if provided at the centralised control position, is to be so arranged so that it cannot be operated accidentally; the indication «safety devices off» is to be clearly visible. This device is not to disactivate the overspeed protection.

6.1.2 Safety systems provided with automatic operation may be replaced by remote manual operation from the centralised control position.

7 Testing

7.1 Tests after completion

7.1.1 Tests are to be carried out of all systems which are required to be in operation at the quay, such as the fuel oil purifier system, electrical power generation, auxiliary steam generator, etc.

7.2 Sea trials

7.2.1 The sea trials are to demonstrate the proper operation of automation systems. A detailed test program is to be submitted for approval. As a minimum, the following are to be tested:

- the remote control system of propulsion machinery
- electrical production and distribution
- efficiency of the fire detection and fire alarm system
- protection against flooding
- continuous operation in all sailing conditions, including manoeuvring, for 6 hours with unattended machinery spaces and at least one person in CCS.

Section 3 Automated Operation in Port (AUT-PORT)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-PORT** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.4] to ships fitted with automated installations enabling the ship's operation in port or at anchor without personnel specially assigned for the watch-keeping of the machinery in service, and complying with the requirements of this Section.

1.1.2 The arrangements provided are to be such as to ensure that the safety of the ship in port is equivalent to that of a ship having the machinery spaces manned.

1.1.3 The provisions of Ch 3, Sec 1, [1.1.3] and Ch 3, Sec 1, [1.1.4] are also applicable for the additional class notation **AUT-PORT**.

1.2 Exemptions

1.2.1 Exemptions mentioned in Ch 3, Sec 1, [1.2] may also be considered for the notation **AUT-PORT**.

1.2.2 Ship of less than 1600 gross tonnage and fishing ships of less than 75 metres in length are exempted from the requirements in [3.1.2].

1.2.3 Fishing vessels of less than 45 metres in length are exempted from the requirements in [3.1.2] insofar as the location of the spaces considered allows people on board to easily detect fire outbreaks.

1.3 Communication system

1.3.1 The requirements of Ch 3, Sec 1, [1.3] are applicable.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the those mentioned in Pt C, Ch 3, Sec 1, Tab 1, documents according to Tab 1 are required.

Table 1 : Documentation to be submitted

No	I/A **(1)**	Document
1	A	Means of communication diagram
2	A	Technical description of automatic engineers' alarm and connection of alarms to accommodation and bridge, when applicable
3	A	System of protection against flooding
4	I	List of machinery to be in operation in port
(1) A: to be submitted for approval ; I: to be submitted for information.		

3 Fire and flooding precautions

3.1 general

3.1.1 The requirements given in Ch 3, Sec 1, [3] are applicable unless otherwise indicated below.

3.1.2 The remote control of the main fire pump for the pressurisation of the fire main may be located at the bridge running station if the wheelhouse and officers' cabins are close together. Failing this, such remote control is to be fitted at a place close to the officers' cabins or to the engine room exit. Alternatively, the fire main may be permanently under pressure.

3.1.3 Transmission to the navigation bridge of fire alarm and flooding is not required, but these alarms are to be directed at the intervention personnel.

3.1.4 Automatic fire detection is to be fitted at the navigation bridge if unmanned during ship's operation in port.

4 Control of machinery

4.1 Plant operation

4.1.1 The machinery and systems which are to be in operation in port are to be designed according to Ch 3, Sec 1, [4], unless otherwise stated.

4.1.2 The requirements regarding electrical production for propulsion Ch 3, Sec 1 are not applicable.

4.1.3 The operation of auxiliaries, other than those associated with propulsion, is to be designed according to Ch 3, Sec 1.

5 Alarm system

5.1 General

5.1.1 The alarm system is to be designed according to Ch 3, Sec 1, [5], unless otherwise stated in this Section.

5.1.2 The alarm system is to be designed so as to inform of any situation which requires attention of the personnel on watch. For this purpose, an audible and visual alarm is to be activated in the centralised control station, in the engineers' public rooms and at each engineer's cabin through a selector switch. Any other arrangement is to be to the satisfaction of the Society.

6 Testing

6.1 Tests after completion

6.1.1 Tests are to be carried out of all systems which are required to be in operation in port, such as: the fuel oil purifier system, electrical power generation, auxiliary steam generator, etc.

Section 4 Integrated Machinery Spaces (AUT-IMS)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-IMS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.5] to ships fitted with automated installations enabling periodically unattended operation of machinery spaces and additionally provided with an integrated computer based system for the control and monitoring of machinery.

This notation is assigned when the requirements of this Section are complied with in addition to those of Ch 3, Sec 1 for the assignment of the notation **AUT-UMS**.

1.1.2 The design of automation systems including computer based systems is to be such that functionality of all services remains available when a single failure occurs.

1.1.3 The notation **-HWIL** is added to the additional class notation **AUT-IMS** when the control system has been verified according to the requirements of NR632 Hardware-in-the-loop Testing.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the those mentioned in Pt C, Ch 3, Sec 1, Tab 1 and Ch 3, Sec 1, Tab 1, documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No	I/A **(1)**	Document
1	I	Block diagram of the integrated computer based systems
2	I	Description of the data transmission protocol
3	I	Description of the auto-diagnosis function
4	I	Failure Mode and Effect Analysis describing the effects of failures on the integrated computer based system used for the control and monitoring of machinery.
(1) A: to be submitted for approval ; I: to be submitted for information.		

3 Fire and flooding precautions

3.1 Fire prevention

3.1.1 The height of oil-tight coamings of boiler gutterways is to be designed in accordance with Pt C, Ch 1, Sec 10, [5.10.4]. Other gutterways are to have a coaming height not less than 150 mm. Their drain inlet is to be fitted with suitable protection such as a grid or small welded rods. Drain pipes are to be sufficiently large and free from sharp bends or horizontal or rising portions.

The height of gutterway coamings around the fuel oil components of diesel engines (injection pumps, filters, etc.) may, due to their small dimensions, be reduced to 75 mm.

On small diesel engines, when construction of such gutterways around the aforesaid devices is difficult, a gutterway of 150 mm height around the considered engine is acceptable.

3.1.2 The fastening of connections (nuts, screw, etc.) of lubricating oil or fuel oil pipes with a maximum working pressure above 1,8 bar is to be locked.

3.1.3 In addition to the requirements of Ch 3, Sec 1, [3.1], lubricating oil and fuel oil tanks are to be provided with a high level alarm.

3.2 Fire detection

3.2.1 In addition to that required in Ch 3, Sec 1, [3.2], fire detection is also to be provided in rooms containing oil hydraulic equipment, operated without watch-keeping personnel, and adjacent to such rooms or to those listed in Ch 3, Sec 1, [3.2].

3.2.2 Fire detection is to be able to detect either smoke or combustion gas.

3.2.3 Each detector is to be provided with a clear indicator showing that it is activated by a fire. A repeater of this indicator is required for detectors situated in spaces which are not easily accessible or can be locked, such as fuel or oil purifier rooms, workshops, stores, etc.

Repeaters may be omitted for fixed fire detection and fire alarm system with remotely and individually identifiable fire detectors (i.e. addressable fire detectors).

3.3 Fire fighting

3.3.1 Some of the portable and mobile extinguishers required are to be located in the following places:

- close to the engine room entrances
- close to the engine control room.

3.3.2 The emergency stop of machinery space ventilation is to be possible from the navigation bridge or in proximity.

3.3.3 Where some remote safety action is possible from the wheelhouse on thermal fluid heaters or incinerators, the alarm grouping is to enable the operator to avoid any confusion when initiating such action.

3.4 Protection against flooding

3.4.1 An alarm is to be given on the navigation bridge in the event of flooding in machinery spaces situated below the load line. This alarm is to be separated from the others, individual for each machinery space and triggered early, at flooding outset.

4 Integrated computer based systems

4.1 General

4.1.1 The following requirements apply in addition to those in Pt C, Ch 3, Sec 3 and Ch 3, Sec 1.

4.1.2 Integrated computer based system used for the control and monitoring of services essential for the propulsion and safety of the ship (e.g. propulsion, electricity production) is to be fault tolerant.

4.1.3 A Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC Publication 60812:2018 or any other recognised standard in order to demonstrate that control and monitoring functions remain available in the event of a single failure of the integrated computer based system.

Note 1: Requirements given in Ch 2, App 1 may be used for guidance.

Note 2: Normally, no consideration is given to defects occurring simultaneously; however in the case of defects which would remain undetected, it might be necessary to take into consideration the adding of several independent defects.

4.2 Design requirements

4.2.1 Necessary arrangements are to be made to avoid interaction between the various automatic control circuits in the event of a fault in one of them (e.g. galvanic separation of automatic control electric circuits or earth leak monitoring device with possibility of disconnecting the faulty circuit, keeping the others in service); this applies in particular to the propulsion plant of steam vessels.

4.2.2 The machinery computer network is to allow communication between subsystems to an extent acceptable for this network. The subsystems interconnected on the network are as follows:

- automation systems for control of machinery according to the requirements of Ch 3, Sec 1, [4], and
- automation systems for dynamic positioning when applicable.

4.2.3 The machinery computer network is not to be used for non-essential functions. A separate network is to be provided for these non-essential functions, where necessary.

4.2.4 In addition to the requirements of Pt C, Ch 3, Sec 3, [6], the machinery computer network is to be redundant and, in the case of failure of one network, automatic switching to the other network is to be provided.

4.2.5 The integrated automation system is to be designed such that the subsystem is still operating in the case of loss of transmission of the network.

4.2.6 In the case of failure of one workstation, the corresponding functions are to be possible from any other station, without a stop of the system in operation. Particular attention is to be paid to the configuration of the workstations.

5 Construction requirements

5.1 Electrical and electronic construction requirements

5.1.1 In order to resist vibrations, connections are to be made carefully, for instance by using terminals crimped on the insulated conductor, or by means of heat shrinkable sleeves, etc.

5.1.2 Direct soldered connections on printed cards are to be avoided. Fastening of the printed cards is to make their connectors free of mechanical stresses. Response to vibration of the printed cards and of their components is to be specially considered.

5.2 Pneumatic construction requirements

5.2.1 Compressed air is to be supplied from two sources having sufficient flow rate to allow normal operation while one is out of service. The pressure is to be automatically maintained at a value allowing satisfactory operation of the installation.

5.2.2 One or more air vessels fitted with non-return valves are to be provided and reserved for monitoring and control installations.

5.2.3 If compressed air used for monitoring and control circuits is supplied by reducing valves, the latter are to be duplicated, together with their filters, unless an emergency air supply is provided.

5.2.4 Necessary provision is to be made to ensure continuous and automatic cooling, filtering, dehydration and oil separation of the compressed air prior to its introduction into the monitoring and control circuits.

5.2.5 When oiling of the air is necessary for the lubrication of some pneumatic components, it is to be done directly to the supply side of these components.

5.3 Hydraulic construction requirements

5.3.1 At least two feed pumps are to be provided so that the pressure in circuits can be maintained while one of the pumps is out of service. Piping and accessories are to be so arranged that it is possible to carry out maintenance and repairs on one pump while the second remains in operation.

5.3.2 The capacity of the tanks is to be sufficient to ensure:

- the maintenance of a suitable level in normal service and during stop periods
- the settling of impurities and the air-freeing of the liquid.

5.3.3 The filling and return piping for these tanks is to be so arranged as to avoid any abnormal turbulence and excessive aeration of the liquid. The location of tanks and suction pipes is to ensure correct supply of the pumps.

5.3.4 The hydraulic fluids are to have appropriate and constant characteristics for their use and particularly a satisfactory viscosity at all the temperatures at which they are to operate in normal service; their flashpoint and their temperature of self-ignition or of destruction by heat are to be the highest possible. The materials used for the various parts of the circuits are to be adapted to the nature and characteristics of the liquids employed.

5.3.5 Transducers connecting pipes are to be so designed as to avoid any delay in the transmission of information, especially when viscous fluids are used.

5.3.6 Air venting facilities are to be foreseen for the various circuits.

6 Control of machinery

6.1 General

6.1.1 The necessary operations to pass from «manoeuvring» to «underway», and vice versa, are to be automated. This applies, for example, to the starting of auxiliary boilers or of diesel generating sets as well as to main engine fuel oil change-over when this change-over is necessary.

6.1.2 When passing from «stand by» to «underway» and vice versa, the gradual process of power increase and decrease, if considered necessary by the builder, is to be automatic; nevertheless, when provided, this device is to be able to be quickly cancelled from the bridge, to perform emergency manoeuvring.

6.1.3 The operations to be effected from the monitoring and control stations are to be defined with due consideration to the type of installations and to their automation level. Operating conditions are also to be considered during periods when machinery watch-keeping is ensured and during trouble periods, when intervention, or even watch-keeping, is foreseen.

6.1.4 Where sufficiently centralised controls are situated near the various components of the plant to allow quick intervention by a reduced personnel, the above-mentioned monitoring and control station may be replaced by a simple monitoring station, providing information necessary for rapid and easy intervention.

6.1.5 Where some indications are transmitted to a control station by means of fluids, necessary arrangements are to be made to avoid a leak from the piping having a detrimental effect on the operation of the surrounding equipment (circuits, terminals). In particular, the piping of liquid fluids is to be separated from electrical apparatuses and gutters are to be provided for draining leakage.

6.1.6 Measuring instruments located on the navigation bridge are to be lighted or luminescent; it is to be possible to adjust their light intensity to protect the operator from dazzling. The number of dimmers is to be reduced as far as possible. Partial covers on lamps are to be avoided; an adjusting system by trimmer is to be preferred. It is not to be possible to hide or totally extinguish the luminous signals of alarms.

6.1.7 Arrangements are to be made to allow the propulsion plant to be restarted from the navigation bridge after a blackout. Special attention is to be paid to certain operations such as:

- reset of the safety shutdown devices
- restart of disengageable main engines, or
- automatic firing of an auxiliary boiler.

An indication is to be shown on the navigation bridge as soon as propulsion can be restarted.

6.1.8 Where control and monitoring are under the supervision of one watchkeeper only, his unavailability is to release an alarm at the bridge station.

6.2 Diesel propulsion plants

6.2.1 The lubricating system for cylinder liners, when fitted, is to be equipped with an alarm device which operates in the event of failure of one of the distribution boxes. The monitoring is to be performed on at least two feed lines for each box and on at least one line per cylinder.

6.2.2 Drainage of the under piston spaces of cross-head engines is to be carried out either continuously or automatically at regular intervals. The frequency of the operation is to be manually adjustable to take account of the operating conditions and of the engine condition (adjusting of cylinder lubrication, condition of piston rings, etc.); in this case, an alarm is to operate if drainage has not been effected in the allotted time.

6.2.3 An alarm is to indicate any abnormal presence of water in the super-charging manifolds; in this case, unless otherwise justified, an automatic blocking of the engine start is also to be provided.

6.2.4 In a manoeuvring condition, correct engine operation is to remain ensured automatically:

- where main engines are fed with heavy heated fuel oil in the “manoeuvring” condition, suitable arrangements are to be provided to enable long duration stops
- if particular arrangements are necessary, such as a change in injector cooling, they are to be automated.

6.2.5 Unless justified by the Manufacturer, for remotely started engines, means are to be provided on the bridge for turning the main engine with compressed air after any intentional stop longer than 10 min. For this purpose a warning light, suitably labelled and automatically switched on, or any other equivalent arrangement, may be used.

This operation is to be possible only when the following conditions are fulfilled:

- shaft line brake released
- turning gear disengaged
- fuel pump rack at zero position
- bridge control system “on”.

In addition, means are to be provided at the control station in operation to check that the turning is correctly carried out.

The remote control of turning with air from the bridge is to be suppressible from the control station or the engine room.

6.2.6 For each main engine, the bridge running station is to be provided with the following additional devices:

- one tachometer for disengageable engines
- a load indicator (fuel oil pump rack) or an overload alarm
- a signal “automatic starting valve manually closed”.

6.2.7 The following additional alarms are to be provided:

- thermal engine overload (exhaust gas temperature)
- low temperature of cylinder and/or piston coolant (except where justified such as for sea water recirculation). Furthermore, the inlet and outlet valves of each cylinder are to be locked in the open position
- differential pressure through fuel oil filters
- high temperature of each reduction gear, reverse gear or clutch bearing.

6.3 Steam propulsion plants

6.3.1 In addition to the requirements stated in [6.1.7], special attention is to be paid to certain operations such as:

- reset of the safety shutdown devices
- restart of disengageable main engines, or
- automatic firing of a main or auxiliary boiler.

On board steam ships, automatic re-firing of at least one main boiler is to be provided.

6.3.2 In addition to that required in Ch 3, Sec 1, [4.3], the power reduction is to be carried out also in case of fire in exhaust gas boilers provided with finned tubes.

6.3.3 In the event of a lack of energy supply, the dead position of the control components (valves, actuators, etc.) is to lead to as safe a situation as possible. This relates in particular to the following components:

- control valve of level in the steam drum
- control valve of desuperheating by water injection
- control valve of fuel supply (position reducing the combustion rate to a safe value, whatever the steam demand may be. Such a fault is as a general rule not to give rise to the complete fuel shut-off, especially in the case of ships having a single main boiler)
- intake vanes of forced draught fan (as a general rule open; in such case and consequently, adjustment of the air flow is to follow the fuel rate fluctuations and not vice versa).

6.3.4 Special arrangements are to be made to avoid accidental tripping of the water level safety monitoring devices, due for instance to ship motions. If the action of such devices has been time delayed, justification of the time value is to be given to the Society.

6.3.5 An automatic monitoring device is to shut off immediately the fuel feeding in the case of non-detection of the corresponding flame: arrangements are to be made to prevent this device from being influenced by the radiation emitted by the other burners.

Automatic flame monitoring devices are to be so designed and constructed as to ensure satisfactory safety: any defect of such devices is to have an active character and lead to an alarm, as well as the extinguishing of the burner concerned.

Flame control sensors are to be suitably protected against thermal effects which would be harmful as well as against soot deposits.

Fuel shut-off to a burner through a safety monitoring device may be followed by an automatic firing attempt, provided that all precautions are taken to ensure the safety of the operation. No second attempt is allowed without manual local action.

An automatic flame monitoring system is to be in operation while burners are automatically operated. However, the flame monitoring may be overridden to allow burner light up, soot blowing and manual combustion control. During the automatic firing period, monitoring disactivation is to be automatic: duration of disactivation is to be set to the minimum compatible with sure light up and in all cases is to be inferior to a period of time t, in seconds, given by the formula:

$t = 151 \times 10^6 / Pci \times Q$

Pci : Lower calorific value, in J

Q : Flow provided for light up of first burner in automatic mode, in kg/h.

If necessary, permanent auxiliary burners may be used; such burners are to be provided with their own flame monitoring devices.

6.3.6 Following a blackout, the automatic re-firing of at least one main boiler is to be provided. The sequential re-firing is to be possible only if there is a non-dangerous situation. Firing of the first burner is to be automatically prepared by an air pre-purge sequence of the furnace and uptakes. A pre-purge sequence is only allowed to take place when fluid pressure before the last valve is cancelled or greately reduced. The duration of this sequence is to enable the delivery of a volume of air of more than 3 times the combustion chamber and uptake volume. During this sequence, burner air registers and dampers which may be located in the gas path are to be wide open and forced draught fans are to be settled at a speed sufficient to ensure good scavenging. The number of burners fired automatically is to allow normal speeds and notably «full astern». Firing of burners by proximity may be accepted subject to justification and satisfactory tests. In the event of unsatisfactory tests (flame in bad position, limited explosion, etc.), one igniter for each burner may be required.

6.3.7 Arrangements are to be made so that in the event of «crash astern» the boiler is able to automatically supply all the necessary output; the burner control system is to be particularly considered for this purpose.

6.3.8 It is to be possible to individually control each burner from a monitoring station situated in the engine room. Adjusting of the combustion rate is to be carried out automatically. Light up or extinguishing of burners, when necessary, is to be done without intervention of the personnel. According to their type, automatic draining of burners during shut-off may be required. Closing of a burner register is as a rule, except during its firing period, to give rise to the shut-off of its own fuel supply. When a boiler is shut down (safety shutdown action, remote action, during pre-purge before firing, after a blackout, etc.), fuel pressure before the terminal shut-off device of burner(s) is to be automatically disactivated or greatly reduced by appropriate means.

6.3.9 Steps are to be taken to avoid and detect any pollution of condensed water returns from heating steam circuits by hydrocarbons. For instance, hydrocarbons can be automatically monitored before entering the drain tank.

6.3.10 Where carried out by an automatic device, soot blowing is to be preceded by a warning and draining of the piping. If necessary, steps are to be taken to prevent detrimental conditions being induced in the boiler operation by cleaning actions. All blowers are to be locally operable.

6.3.11 Permanent recording of the following parameters is to be provided:

- drum water level (for each boiler)
- burner supply pressure
- burner air flow or pressure
- superheated steam pressure and temperature.

Furthermore, the additional arrangements listed in Tab 2 are to be provided.

Table 2 : Main boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Feed water turbo pump automatic shutdown	X						
Presence of water in fuel oil, except where arrangement is such (volume contained below suction pipe) that draining once a day gives sufficient safety	X						
Pressure drop through filters	L						
Combustible gas pressure	H			X **(1)**			
Combustible gas temperature	H + L			X **(1)**			
Combustible gas uptake fan stop	X			X **(1)**			
Gas detection in the uptakes	X			X **(1)**			
Smoke opacity of combustion gas	H						
Superheated steam pressure	L		X **(2)**				
Soot blowing automatic sequence fault	X						
Steam heating drain oil pollution	X						
Pressure drop through de-oiler	X						
Fire in air heater (where heat exchanger is provided from smoke to air)	X	local					
Rotative air heater fire	X						
Rotative air heater rotation stop	X						
Rotative air heater bearing and thrust bearing temperatures	H						
Rotative air heater motor drive	X						
Forced draught fan lubricating oil pressure	L		X				
Forced draught fan overspeed (turbo only)	X						
Forced draught fan plain bearings temperature	H						

(1) Automatic shut-off of the burner line.
(2) Shutdown of the large consumers which are not essential to propulsion, such as cargo or ballast turbo pump, etc.

6.3.12 Maintaining of a sufficient vacuum is to be ensured even in the event of crash astern or during long full astern manoeuvre.

6.3.13 To prevent shutdown in the case of vacuum loss when in full astern during an excessive period, the setting point of the vacuum fault alarm is to be adjusted to give sufficient time for the possible necessary precautions to be taken (slowdown). This alarm is to involve automatic slowdown or is to indicate clearly in the wheelhouse the necessity to slow down.

6.3.14 The functions and equipment listed below are the subject of a particular examination, in order to determine the arrangements, alarms and safeguards to be provided:

- automated steam bypass to the condenser
- H.P. bled steam circuits (in order to avoid possible water return into the H.P. turbine in the event of malfunctions)
- water drains from which there is a risk of pollution by sea water.

6.3.15 During automatic spinning, when the steam pressure of the turbines reaches a preset value stated by the builder, without having caused the line shafting to turn, a safety device is to shut down the manoeuvring gear. At every control position a separate audible and visible signal is to precede spinning in sufficient time to allow the cycle to be stopped if necessary.

6.3.16 The propeller r.p.m control device is to moderate the variation rate of steam input pressure, in correct and safe relation to the turbine and boiler capability.

6.3.17 When manoeuvring, correct plant operation is to be ensured automatically. For this purpose, some operations are to be automated. This applies, in particular, to the following:

- manoeuvring of the astern stop valve
- opening and closing of the main turbine and manifold drain valves
- operation of the automatic spinning sequence.

6.3.18 The operations necessary to pass from “manoeuvre” to “underway” and vice versa are to be automated. This applies in particular to the following:

- bleed steam circuits
- steam bypass valves to the turbines
- additional valves
- circulation of sea water by scoop or by pump
- steam bypass to main condenser.

6.3.19 Additional requirements for steam turbine propulsion plants are given in Tab 3.

Table 3 : Main turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Pressure drop through lubricating oil filter	H						
Water in lubricating oil of reduction gear return tank, or level in lubricating oil of reduction gear return tank (when dehydrator is provided)	H						
	H						
Main condenser flooding				X **(1)**			
Auxiliary condenser sea water flow or equivalent	L						
Auxiliary condenser delivery pressure, or flow, of condensate pump	L						
Exhaust steam manifold to atmosphere or equivalent (high pressure)	X						
(1) When axial condenser.							

6.4 Gas turbine propulsion plant

6.4.1 Additional requirements for gas turbine propulsion plants are given in Tab 4.

6.4.2 Normal operation of the turbine is to include regular rinsing of the combustion air circuit.

Table 4 : Gas turbine propulsion plants

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Metal particle detection in lubricating oil	X						
Lubricating oil temperature inlet to turbine	H						
Lubricating oil tank level	L						
Metal particle detection in fuel oil	X						
Fuel oil deaerator efficiency	X						

6.5 Electric propulsion plant

6.5.1 Additional requirements for the electric propulsion plant are listed in Ch 3, Sec 1, [4.6].

6.6 Shafting, clutches, CPP, gears

6.6.1 The temperature of each shaft bearing fitted between the main engine (or the reduction gear) and the sterntube is to be monitored (alternatively, a group alarm associated with means to detect the fault is acceptable). This monitoring is not required for ball or roller bearings.

6.7 Auxiliary systems

6.7.1 Low pressure in air vessels is to trigger an alarm.

6.7.2 If the production of auxiliary steam is necessary for the proper operation of the installations covered by the notation, and if it is dependent on the propulsion plant power, its continuity is to be ensured in case of change in propulsion power.

6.7.3 Oil fired automated auxiliary boilers necessary for propulsion (for instance necessary to fuel heating supplying the main engine) are to be fitted with continuous or on/off automatic combustion control. Furthermore, automatic firing of at least one of these boilers is to be provided after blackout.

6.7.4 Package burner units, which could cause serious fires where they break their fastening or in the event of accidental or inadvertent removal from the boiler, with the possibility of automatic firing in that position, are to be provided with appropriate safety devices, such as:

- additional mechanical support of heavy units
- micro switch included in the firing sequence, or equivalent.

6.7.5 Where a burner is switched off, fuel pressure before the last valve is to be automatically suppressed or notably reduced by an arrangement provided for this purpose.

6.7.6 The additional arrangements listed in Tab 5 are to be provided. However, they are not compulsory for auxiliary boilers used for cargo or accommodation heating only.

Table 5 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Water level	H			X **(1)**			
Oil pollution in the steam heating drains	X						
Circulating pump delivery pressure or flow	L			X **(1)**			
Steam pressure	L						
Fuel oil pressure	L						
Misfire	X						
(1) Automatic fuel shut-off.							

6.7.7 Fire in an exhaust gas finned tube boiler (exhaust gas manifold high temperature) is to trigger an alarm.

6.7.8 Any risk of introducing a heated product into a stopped oil circuit is to be prevented by appropriate means (pressurisation with nitrogen, compressed air, etc.). The additional arrangements listed in Tab 6 are to be provided.

Table 6 : Thermal fluid heaters

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Thermal fluid leak into furnace	X						
				X **(1)**			
Fault in pressurisation system	X						
Critical fire in boiler	X			X			
(1) Automatic fuel shut-off and shutdown of the circulation.							

6.7.9 The detection system for possible oil leakage into the boiler furnace is not to introduce any risk of fire extension (in particular in connecting to the atmosphere). In addition, the oil coming from a safety valve discharge is to be suitably collected.

6.7.10 Thermal fluid heaters heated by main engine exhaust gas are to be specially examined by the Society. Taking into account the risk inherent in this type of equipment, particular arrangements or protection may be required.

6.7.11 Incinerators for chemical products are specially examined.

6.7.12 Installation of fuel oil blending units is to be submitted to the examination of the Society.

6.7.13 An alarm is to be triggered when the blending unit outflow is too low.

6.7.14 Unexpected modifications of the blend ratio are to be detected through an appropriate device. This monitoring, fitted at the blending unit heater outlet, is as a general rule to be effected:

- by supervision of the high and low temperature when heating adjustment is carried out through a viscosimeter
- by viscosity supervising, when heating adjustment is carried out by a thermostatic device.

6.7.15 Precautions are to be taken in order to prevent malfunction of the propulsion plant and electric power plant in case of blending unit failure (automatic change-over to light fuel oil for instance).

6.7.16 Where necessary, steps are to be taken to reduce or suppress blend heating when the heavy fuel rate is too low.

6.7.17 As a general rule, the homogeneity of the blend is to be ensured; this may involve a special arrangement, more particularly when tanks are provided between the blending unit and booster pumps.

6.7.18 Other evaporators than those associated to propulsion are to be provided with the arrangements listed in Tab 7.

Table 7 : Evaporators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Evaporator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Electric fault at pump	X						
Heating fluid pressure or flow	L						
Excessive salinity of distilled water	H				X **(1)**		
(1) Automatic draining to bilge or re-circulation							

6.8 Control of electrical installation

6.8.1 Where the electrical power is exclusively produced by diesel generator sets, the oil quantity in the crankcase (volume contained between the maximum and minimum levels indicated by the engine builder) is to allow continuous service of 24 h at full load with 2,5 g/kW/h oil consumption. Alternatively, automatic lubricating oil make up to the crankcase may be accepted.

6.8.2 Where generators can be paralleled, installation is to include automatic start, synchronising, connecting and load sharing.

6.8.3 Where the number of generators in service is to vary according to operating condition, starting and connecting of supplementary generators, entailed by the use of equipment during manoeuvring, is not to require intervention in machinery spaces.

6.8.4 Where starting of the standby generating set mentioned in Pt C, Ch 2, Sec 3, [2.2] depends on emergency generating set running, precautions are to be taken to ensure automatic connecting of the latter. In particular, the following alarms are to be provided:

- preheating and pre-lubricating failure (except where the engine Manufacturer stipulates that these operations are not indispensable)
- starting air pressure low (or equivalent)
- fuel oil tank level low.

6.8.5 The additional arrangements for electricity production listed in Tab 8 are to be provided.

Table 8 : Electricity production

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Prime mover			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Standby Start	Stop
Main diesel generator							
Cylinder cooling general outlet temperature (where preheating is provided)	L						
Pre-lubrification failure, if applicable	X						
Crankcase or return tank level (when electrical production is only supplied by diesel generator sets)	L						
Fuel oil pressure	L						
Differential pressure through filters (when fuel oil pipeline is common to several diesel generators)	X						
Turning gear or bar engaged				X **(1)**			
Fault of primary cooling (when centralised)	X						
Turbogenerator							
Thrust and reduction gear bearing temperature	H						
Generator							
Sleeve bearing temperature	H						
Flow or pressure of coolant (when liquid cooled)	L						
Cooler inlet temperature (when liquid cooled)	H						
Electric circuits							
Insulation resistance of electrical supply to essential automatic control system and to essential propulsion auxiliaries	L						
Generator overload (110 % of rated current)	X		X **(2)**				
(1) Safety lock of automatic start. **(2)** Automatic load shedding.							

6.8.6 The requirements stated in Pt C, Ch 3, Sec 2, [8.4.1] and Ch 3, Sec 1, [4.8.1] apply also to the following:

- turbo feed pumps of main boilers
- fuel oil supply pump to main boilers
- rotative air heater motor drive
- turbo generator lubricating oil pump (if necessary)
- main condensate pump (main condenser)
- vacuum pump (where air ejectors are provided, the steam supply valves are to be physically locked)
- condensate pump (auxiliary condenser)
- cooling sea water pump to auxiliaries of turbines and gearing (where essential auxiliaries are cooled)
- hydraulic pump for remote control.

6.8.7 The automatic restart of essential electrical auxiliaries after blackout is to be as fast as practicable and, in any case, less than 5 minutes.

7 Testing

7.1 Additional testing

7.1.1 In addition to those required in Ch 3, Sec 1, the following additional tests are to be carried out at sea:

- checking of the proper operating condition of fire detection in economisers, exhaust gas boilers fitted with finned tubes, etc.
- checking of the proper operating condition of the integrated computer based systems used for monitoring, control and safety of machinery and in particular:
  - visual inspection
  - functional operation of workstation
  - transfer of control of workstation
  - inhibition function of alarms
  - alarm acknowledgement procedure
  - simulation of internal and external failure of the integrated system, including loss or variation of power supply
  - wrong data insertion test.

7.2 Maintenance equipment

7.2.1 For maintenance, at least the following equipment is to be supplied:

- equipment for testing pressure sensors
- equipment for testing temperature sensors
- testing equipment as described in Ch 3, Sec 1, [3.2.16] for fire detectors, comprising extension rods for quick and easy testing
- a portable tachometer, if necessary.

CHAPTER 4
INTEGRATED AND DIGITAL SYSTEMS

Section 1 Centralised Navigation Equipment (SYS-NEQ)

Section 2 Integrated Bridge Systems (SYS-IBS)

Section 3 Ship-Shore Communication

Section 4 Data Infrastructure (DATA-INFRA)

Section 1 Centralised Navigation Equipment (SYS-NEQ)

1 General

1.1 Application

1.1.1 The additional class notation **SYS-NEQ** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.5.2], to ships fitted with a centralised navigation control system so laid out and arranged that it enables normal navigation and manoeuvring operation of the ship by two persons in cooperation.

This notation is assigned when the requirements of Articles [1] to [5], [7] and [8] of this Section are complied with.

1.1.2 The additional class notation **SYS-NEQ-1** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.5.2], when, in addition to [1.1.1], the installation is so arranged that the navigation and manoeuvring of the ship can be operated under normal conditions by one person for periodical one man watches. This notation includes specific requirements for prevention of accidents caused by the operator's unfitness.

This notation is assigned when the requirements of this Section are complied with.

1.1.3 The composition and the qualification of the personnel on watch remain the responsibility of the Owner and the Administration. The authorisation to operate the ship in such condition remains the responsibility of the Administration.

1.2 Operational assumptions

1.2.1 The requirements are framed on the following assumptions:

- Plans for emergencies are specified and the conditions under which a one man watch is permitted are clearly defined in an operations manual which is acceptable to the Administration with which the ship is registered.
- The manning of the bridge watch is in accordance with the national regulations in the country of registration and for the waters in which the ship is operating.
- The requirements of the International Convention on Standards of Training Certification and Watchkeeping for seafarers (STCW) and other applicable statutory regulations are complied with.

1.3 Regulations, guidelines, standards

1.3.1 The requirements are based on the understanding that the applicable regulations and guidelines issued by the International Maritime Organisation are complied with, in particular:

a) Regulations 15 to 28, Chapter V of the 1974 "International Convention for the Safety of Life at Sea" (SOLAS) and applicable amendments

b) The international Regulations for Preventing Collisions at Sea and all other relevant Regulations relating to Global Maritime Distress and Safety System (GMDSS) and Safety of Navigation required by Chapters IV and V of SOLAS 1974, as amended

c) the Provisional Guidelines for the Conduct of Trials in which the Officer of the Navigational Watch acts as the sole Lookout in Periods of Darkness (MSC Circular 566 of 2 July 1991)

d) IMO A.694: 1991, General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids

e) MSC Circular 982, Guidelines on ergonomic criteria for bridge equipment and layout

f) Convention on the International Regulations for Preventing Collision at Sea, 1972 (COLREG)

g) IMO Performance Standards for navigational equipment applicable to:
   - Magnetic compasses (Resolution A.382)
   - Gyrocompasses (Resolution A.424)
   - Performance standards for radar equipment (Resolution MSC.192(79))
   - Speed and distance measuring equipment (Resolution A.478, A.824, MSC.96 (72))
   - Echo sounding equipment (Resolution A.224, MSC.74 (69) Annex 4)
   - Electronic navigational aids – general requirements (Resolution A.574)
   - VHF Radio installation (Resolution MSC.68 (68) Annex 1, A.524 (13), A.803 (19), IMO Resolution MSC.511(105) and IMO Resolution MSC.515(105))
   - Heading control systems (HCS) (Resolution A.342, MSC.64 (67) Annex 3)
   - Rate-of-turn indicators (Resolution A.526)

- VHF watchkeeping receiver (Resolution A.803 (19), MSC.68 (68) Annex 1)
- Performance standards for track control systems (Resolution MSC.74 (69) Annex 2)
- Performance standards for marine transmitting heading devices (THDs) (Resolution MSC.116 (73))
- Performance standards for electronic chart display and information systems (Resolution MSC.191 (79) , MSC.232 (82))
- Maintenance of electronic chart display and information system (ECDIS) software (IMO circ.266)
- Performance standards for shipborne global positioning system receiver equipment (Resolution A.819 (19))
- Adoption of the revised performance standards for shipborne global positioning system (GPS) receiver equipment (Resolution MSC.112 (73))
- Adoption of the revised performance standards for shipborne GLONASS receiver equipment (Resolution MSC.113 (73))
- Adoption of the revised performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment (Resolution MSC.114 (73)).
- Performance standards for a universal automatic identification system (AIS) (Resolution MSC.74 (69) Annex 3)
- Performance standards for an integrated navigation system (INS) (Resolution MSC.86 (70) Annex 3)
- Adoption of the revised performance standards for integrated, navigation systems (INS) (Resolution MSC.252 (83))
- Performance standards for sound reception systems (Resolution MSC.86 (70) Annex 1)
- Performance standards for the presentation of navigation-related information on shipborne navigational displays (Resolution MSC.191(79))
- Performance standards for a bridge navigational watch alarm system (BNWAS) (Resolution MSC.128(75))
- Performance standards for shipborne voyage data recorders (VDRs) (Resolution A.861(20) as amended by IMO Res. MSC.214(81))
- System performance standard for the promulgation and coordination of maritime safety information using high-frequency narrow-band direct-printing (IMO Resolution MSC.507(105))
- Performance standards for the reception of maritime safety information and search and rescue related information by MF (NAVTEX) and HF (IMO Resolution MSC.508(105)),
- Performance standards for search and rescue radar transponders (IMO Resolution MSC.510(105)),
- Performance standards for shipborne MF and MF/HF radio installations capable of voice communication, digital selective calling and reception of maritime safety information and search and rescue related information (IMO Resolution MSC.512(105))
- Performance standards for INMARSAT-C ship earth stations capable of transmitting and receiving direct-printing communications (IMO Resolution MSC.513(105)).

1.3.2 The requirements and guidelines of ISO 8468 – ed. 3 “Ship’s bridge layout and associated equipment– Requirements and guidelines” are applicable.

1.3.3 Additional requirements may be imposed by the national authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction it is intended to operate.

1.4 Definitions

1.4.1 Terms used in the requirements are defined below:

- Acquisition: the selection of those target ships requiring a tracking procedure and the initiation of their tracking
- Alarm: a visual and audible signal indicating an abnormal situation
- ARPA: automatic radar plotting aid
- Backup navigator: any individual, generally an officer, who has been designated by the ship’s Master to be on call if assistance is needed on the navigation bridge
- Bridge: that area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings
- Bridge wings: those parts of the bridge on both sides of the ship's wheelhouse which, in general, extend to the ship side
- CPA: closest point of approach, i.e. the shortest target ship-own ship calculated distance that will occur in the case of no change in course and speed data
- Conning position: the place in the wheelhouse with a commanding view and which is used by navigators when monitoring and directing the ship mouvements
- Display: means by which a device presents visual information to the navigator, including conventional instrumentation
- Ergonomics: application of the human factor in the analysis and design of equipment, work and working environment
- Field of vision: angular size of a scene that can be observed from a position on the ship's bridge
- Lookout: activity carried out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision
- Navigation: all tasks relevant for deciding, executing and maintaining course and speed in relation to waters and traffic
- Navigator: person navigating, operating bridge equipment and manoeuvring the ship

- NAVTEX: an international maritime radio telex system sponsored by IMO and IHO, which automatically receives the broadcast telex information such as navigational, meteorological warnings and search and rescue (SAR) alerts on a 24-hour watch basis
- Normal conditions: when all systems and equipment related to navigation operate within design limits, and environmental conditions such as weather and traffic do not cause excessive workload to the officer of the watch
- Officer of watch: person responsible for safe navigating, operating of bridge equipment and manoeuvring of the ship
- Radar plotting: the whole process of target detection, tracking, calculation of parameters and display of information
- Seagoing ship: ship navigating on the high seas, i.e. areas along coasts and from coast to coast
- TCPA: time to closest point of approach
- Tracking: process of observing the sequential changes in the position of a target, to establish its motion
- Wheelhouse: enclosed area of the bridge
- Workstation: position at which one or several tasks constituting a particular activity are carried out.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the documents mentioned in Pt C, Ch 3, Sec 1, Tab 1, documents according to Tab 1 are to be submitted.

2.1.2 Additional plans and specifications are to be submitted for approval, if requested by the Society.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	A	General arrangement of bridge and wheelhouse showing the position of the control console and panels
2	A	Plans showing the field of vision from each workstation
3	A	List and specification of navigational equipment fitted on the bridge and references (Manufacturer, type, national authority approval...)
4	A	Functional block diagram indicating the relationship between the items of navigational equipment and between them and other equipment
5	A	List of alarms and instrumentation fitted on the bridge
6	A	Diagram of electrical supply to the navigational equipment
7	A	Diagram of the system linking the bridge alarms with the other operational locations **(2)**
8	A	Diagram of the communication systems
9	A	Diagram of the BNWAS
10	A	Test program including test method
11	I	List of the intended areas of operation of the ship

(1) A : to be submitted for approval
I : to be submitted for information.
(2) Documents to be submitted only when a **SYS-NEQ-1** notation is requested.

3 Bridge layout

3.1 General

3.1.1 The bridge configuration, the arrangement of consoles and equipment location are to enable the officer of the watch to perform navigational duties and other functions allocated to the bridge as well as maintain a proper lookout from a convenient position on the bridge, hereafter referred to as a 'workstation'.

3.1.2 A workstation for navigation and traffic surveillance/manoeuvring is to be arranged to enable efficient operation by one person under normal operating conditions. All relevant instrumentation and controls are to be easily visible, audible and accessible from the workstation.

3.1.3 The bridge layout design and workstations are to enable the ship to be navigated and manoeuvred safely by two navigators in cooperation.

3.1.4 The requirements and guidelines of the ISO 8468 Standard are to be regarded as a basic reference for the design of bridge layout.

4 Bridge instrumentation and controls

4.1 General

4.1.1 The instrumentation and controls at the workstation for navigation and traffic surveillance/manoeuvring are to be arranged to enable the officer of the watch to:

a) determine and plot the ship's position, course, track and speed

b) analyse the traffic situation

c) decide on collision avoidance manoeuvres

d) alter course

e) change speed

f) effect internal and external communications related to navigation and manoeuvring, radio communication on the VHF

g) give sound signals

h) hear sound signals

i) monitor course, speed, track, propeller revolutions (pitch), rudder angle and depth of water

j) record navigational data (may be manually recorded from data available at the workstation).

4.1.2 Irrespective of their size, gross tonnage and date of construction, all ships assigned the additional class notation **SYS-NEQ** are to be equipped with the instrumentation and controls described in [4.2] to [4.4] and as referred to in Tab 2.

Table 2 : List of mandatory equipment

Equipment	Additional class notations	
	SYS-NEQ	**SYS-NEQ 1**
Multifunction displays - according to MSC.191(79)	optional	optional
Radar **(1)**	CAT 1(H)/2(H)/3(H)	CAT 1(H)
Gyrocompass	one	one
Magnetic compass	yes	yes
Spare magnetic compass or second gyrocompass fed by main and emergency power supply and in addition by a transitional power supply (e.g. battery)	yes	yes
Transmitting Heading Device (THD)	yes	yes
Heading Control System (HCS), formerly autopilot	yes	yes
ECDIS with backup	yes	yes
Position receiver (GNSS …)	one	one
Bridge Navigation Watch Alarm System (BNWAS)	yes	yes
Alarm transfer system	–	yes, at least to master's cabin
Central alarm panel	–	yes
Echo sounder	yes	yes
Speed and Distance Measuring Equipment (SDME) **(2)**	yes	yes
Sound reception (if totally enclosed bridge)	yes	yes
VHF at conning position	one	one
A receiver capable of receiving MSI and search and rescue related information (e.g. NAVTEX)	yes	yes
Weather chart facsimile	yes	yes
Wind speed and direction	yes	yes
AIS	yes	yes
VDR	yes	yes

(1) According to [4.2.1], H: when approved for high speed application

(2) Speed of the ship through the water and over the ground

4.2 Safety of navigation: collision-grounding

4.2.1 The ship is to be equipped with an RADAR/ARPA system meeting the requirements of IMO Resolution MSC.192(79).

The categories of ship/craft with their radar performance requirements are specified in Tab 3.

4.2.2 An heading control system (HCS) is to be provided and monitored by a heading alarm addressed to the navigator, in case of malfunction. This alarm is to be derived from a system independent from the automatic steering system. An overriding control device is to be provided at the navigating and manoeuvring workstation.

Table 3 : Categories of ship/craft with their radar performance requirements

	Categoy of ship/craft		
	CAT 3	CAT 2	CAT 1
Size of ship/craft	<500 gt	500 gt to < 10000 gt and HSC < 10000 gt	all ships/craft ≥ 10000 gt
Minimum operational display area diameter	180 mm	250 mm	320 mm
Minimum display area	195 mm x 195 mm	270 mm x 270 mm	340 mm x 340 mm
Auto acquisition of targets	–	–	yes
Minimum acquired radar target capacity	20	30	40
Minimum activated AIS target capacity	20	30	40
Minimum sleeping AIS target capacity	100	150	200
Trial manoeuvre	–	–	yes

4.3 Position fixing

4.3.1 Ships are to be provided with the following position systems:

a) position fixing systems appropriate to the intended service areas

b) at least two independent radar, one of which is to operate within the X-band

c) a gyrocompass system

d) a speed log system

e) an echo sounding system.

f) an ECDIS with backup arrangement.

4.4 Controls - Communication

4.4.1 Ships are to be provided with the following control and communication:

a) a propulsion plant remote control system, located on the bridge

b) a whistle control device

c) a window wipe and wash control device

d) a main workstation console lighting control device

e) steering pump selector/control switches

f) an internal communication system

g) a VHF radiotelephone installation

h) a wheelhouse heating/cooling control device

i) a NAVTEX automatic receiver and recorder.

Note 1: The systems or controls under a) to g) are to be fitted within the reach of the officer of the watch when seated or standing at the main navigating and manoeuvring workstation.

5 Design and reliability

5.1 General

5.1.1 Where computerised equipment is interconnected through a computer network, failure of the network is not to prevent individual equipment from performing its individual functions.

5.2 Power supply

5.2.1 Power supply for AC equipment

a) Power to navigation equipment is to be supplied by two circuits, one fed directly from the main source of electrical power, and one fed directly from the emergency source of power. Power to radio equipment is also to be supplied by two circuits as described above and is additionally to be supplied by a reserve source of energy.

b) The power supplies to the distribution panels are to be arranged with automatic change-over facilities between the two sources.

c) The distribution of supplies to navigation equipment is to be independent of those for radio equipment. The circuits from the power sources is to be terminated either in one or two distribution panels. When one distribution panel is used, the two circuits supplying power to the panel are to be provided with split feeds into two separate bus bars, one for the radio equipment and one for the navigation equipment. The panel(s) is(are) to be sited on the navigation bridge or other suitable position on the bridge deck.

d) The circuits supplying the board(s) are, as far as practicable, to be separated from each other throughout their length. Facilities are to be provided in each distribution board for changing over between the main source of power and the emergency source of power. It is preferable that change over be initiated automatically. When a single distribution board is used for both radio and navigation equipment, separate change-over switches are to be provided for each service.

e) Where radio equipment requires an uninterrupted input of information from the ship's navigational equipment or other equipment, it is necessary for the equipment providing the data to be supplied from the same distribution board bus serving the radio equipment rather than the bus bar serving the navigation equipment.

f) Failure of any power supply to the panel is to initiate an audible and visual alarm at the navigation bridge.

g) Each consumer is to be individually connected to the distribution panel bus bar and individually provided with short-circuit protection.

h) An indicator is to be mounted in a suitable place to indicate when batteries of the reserve source of energy are being discharged.

5.2.2 Power supply for DC equipment

a) The requirements of [5.2.1] are applicable.

b) Where the equipment is fed via converters, separate converters are to be provided and these are to be located on the supply side of change-over facility.

c) The radio equipment and the navigation equipment are to be provided with separate converters.

5.2.3 Power supply for equipment operated either AC or DC

a) Each consumer is to be individually connected to the main source of electrical power and to a distribution bus bar of the panel which is fed from the emergency source of electrical power and also, in case of the radio equipment, from the reserve source of energy (radio batteries). These two circuits are to be separated throughout their length as fas as practicable.

b) The radio equipment and the navigation equipment are to be provided with separate converters.

c) An indicator is to be mounted in a suitable place visible for responsible member of the crew to indicate when batteries of the reserve source of energy are being discharged.

5.2.4 Following a loss of power which has lasted for 30 seconds or less, all primary functions are to be readily reinstated.

5.3 Environmental conditions

5.3.1 Shipborne navigational equipment specified in IMO Publication 978-88-04E "PERFORMANCE STANDARDS FOR NAVIGATIONAL EQUIPMENT" is to be capable of continuous operation under the conditions of various sea states, vibration, humidity, temperature and electromagnetic interference likely to be experienced in the ship in which it is installed.

5.3.2 Equipment which has been additionally specified in this notation is to comply with the environmental conditions specified in Pt C, Ch 2, Sec 2 for control and instrumentation equipment, computers and peripherals for shipboard use.

6 Prevention of accidents caused by operator's unfitness

6.1 Field of vision

6.1.1 For the purpose of performing duties related to navigation, traffic surveillance and manoeuvring, the field of vision from a workstation is to be such as to enable observation of all objects which may affect the safe conning of the ship. The field of vision from a workstation is to be in accordance with the guidelines on navigation bridge visibility, as specified in IMO Resolution A.708, MSC Circular 982 and ISO 8468 ed.3 as it applies to new ships.

6.2 Alarm/warning transfer system - Communications

6.2.1 Any alarm/warning that requires bridge operator response is to be automatically transferred to the Master and, if he deems it necessary, to the selected backup navigator and to the public rooms, if not acknowledged on the bridge within 30 seconds. Such transfer is to be carried out through the systems required by [6.2.3] and [6.2.7], where applicable.

6.2.2 Acknowledgement of alarms/warnings is only to be possible from the bridge.

6.2.3 The alarm/warning transfer is to be operated through a fixed installation.

6.2.4 Provision is to be made on the bridge for the operation of a navigation officer call-alarm to be clearly audible in the spaces of [6.2.1].

6.2.5 The alarm transfer system is to be continuously powered and have an automatic change-over to a standby power supply in the case of loss of normal power supply.

6.2.6 At all times, including during blackout, the officer of the watch is to have access to facilities enabling two-way speech communication with another qualified officer.

The bridge is to have priority over the communication system.

Note 1: The automatic telephone network is acceptable for this purpose, provided that it is automatically supplied during blackouts and that it is available in the locations specified in [6.2.1].

6.2.7 If, depending on the shipboard work organisation, the backup navigator may attend locations not connected to the fixed installation(s) described in [6.2.1], he is to be provided with a portable wireless device enabling both the alarm/warning transfer and the two-way speech communication with the officer of the watch.

6.2.8 External sound signals from ships and fog signals that are audible on open deck are also to be audible inside the wheelhouse; a transmitting device is to be provided to reproduce such signals inside the wheelhouse (recommended frequency range: 70 to 700 Hertz).

6.3 Bridge layout

6.3.1 The bridge configuration, the arrangement of consoles and equipment location are to enable the officer of the watch to maintain a proper lookout from a convenient workstation.

6.3.2 A workstation for navigation and traffic surveillance/manoeuvring is to be arranged to enable efficient operation by one person under normal operating conditions.

7 Ergonomical recommendations

7.1 Lighting

7.1.1 The lighting required on the bridge should be designed so as not to impair the night vision of the officer on watch. Lighting used in areas and at items of equipment requiring illumination whilst the ship is navigating is to be such that night vision adaptation is not impaired, e.g. red lighting. Such lighting is to be arranged so that it cannot be mistaken for a navigation light by another ship. It is to be noted that red lighting is not to be fitted over chart tables so that possible confusion in colour discrimination is avoided.

7.2 Noise level

7.2.1 The noise level on the bridge should not interfere with verbal communication and mask audible alarms.

7.3 Vibration level

7.3.1 The vibration level on the bridge should not be uncomfortable to the bridge personnel.

7.4 Wheelhouse space heating/cooling

7.4.1 Unless otherwise justified, wheelhouse spaces are to be provided with heating and air cooling systems. System controls are to be readily available for the officer of the watch.

7.5 Navigator's safety

7.5.1 There are to be no sharp edges or protuberances on the surfaces of the instruments and equipment installed on the bridge which could cause injury to the navigator.

7.5.2 Sufficient handrails or the equivalent are to be fitted inside the wheelhouse or around instruments and equipment therein for safety in bad weather.

7.5.3 Adequate means are to be made for anti-slip of the floor, whether it is dry or wet.

7.5.4 All wheelhouse doors are to be operable with one hand. Bridge wing doors are not to be self closing and means are to be provided to hold the doors in open position.

7.5.5 Where provision for seating is made in the wheelhouse, means for securing are to be provided, having regard to storm conditions.

8 Testing

8.1 Tests

8.1.1 Documentary evidence in the form of certification and/or test results is to be submitted to the satisfaction of the Society. Where acceptable evidence is not available, the requirements of Pt C, Ch 3, Sec 6 are applicable.

8.1.2 Shipboard tests and sea trials are to be carried out in accordance with the test procedures submitted for approval in advance to the Society. Tests and trials are to be performed under the supervision of the Surveyors.

8.1.3 After fitting on board, the installations are to be submitted to tests deemed necessary to demonstrate correct operation. Some tests may be carried out at quay side, while others are to be effected at sea trials.

Section 2 Integrated Bridge Systems (SYS-IBS)

1 General

1.1 Application

1.1.1 The additional class notation **SYS-IBS** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.5.3], to ships fitted with an integrated bridge system which allows simplified and centralised bridge operation of the main functions of navigation, manoeuvring and communication, as well as monitoring from the bridge of other functions, as specified in [1.1.3].

This notation is assigned when the requirements of this Section, and those specified in Ch 4, Sec 1, [1] to Ch 4, Sec 1, [5], Ch 4, Sec 1, [7] and Ch 4, Sec 1, [8] (**SYS-NEQ** notation) are complied with.

1.1.2 The additional class notation **SYS-IBS-1** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.5.3], to ships fitted with an integrated bridge system which allows simplified and centralised bridge operation of the main functions of navigation, manoeuvring and communication, as well as monitoring from the bridge of other functions, as specified in [1.1.3].

This notation is assigned when the requirements of this Section, and the one specified in Ch 4, Sec 1 (**SYS-NEQ-1** notation) are complied with.

1.1.3 The following functions are to be part of the additional class notation **SYS-IBS** and **SYS-IBS-1**:

- passage execution (according to Tab 1)
- route control and monitoring (according to Tab 1)
- control and monitoring of the machinery installation (according to Part C, Chapter 3 for **SYS-IBS** and according to Ch 3, Sec 1 for **SYS-IBS-1**).

Table 1 : List of mandatory equipment

Equipment	Additional class notation	
	SYS-IBS	**SYS-IBS-1**
Integrated Navigation System (INS)	optional	INS
Multifunction displays - according to MSC .191(79)	yes	yes
Radar **(1)**	CAT 1(H)/2(H)/3(H)	CAT 1(H)C
Gyrocompass	two	two
Magnetic compass	yes	yes
Spare Magnetic compass or second gyrocompass fed by main and emergency power supply and in addition by a transitional power supply (e.g. battery)	yes	yes
Transmitting Heading Device (THD)	yes	yes
Track Control System (TCS), class C	yes	yes
ECDIS with backup	yes	yes
Position receiver (GNSS…)	two	two
Conning display (it must include alarms from navigation and engine automation)	yes	yes
Bridge navigation watch alarm system (BNWAS)	yes	yes
Alarm transfer system	yes, at least to master's cabin	yes, at least to master's cabin
Central alarm panel	yes	yes
Echo sounder	yes	yes
Speed and Distance Measuring Equipment (SDME) **(2)**	yes	yes
Sound reception (if totally enclosed bridge)	yes	yes
VHF at conning position	one	one
NAVTEX	yes	yes
Weather chart facsimile	yes	yes
Wind speed and direction	yes	yes
AIS	yes	yes
VDR	yes	yes

(1) According to Ch 4, Sec 1, [4.2.1]: H: when approved for high speed applications; C: approved with a chart option

(2) Speed of the ship through the water and over the ground

In addition the following functions may be part of the additional class notation **SYS-IBS-1**:

- control communication system:
  - external communication linked with the safety of the ship (distress equipment)
  - internal communication system
- monitoring of specific cargo operations (loading and discharging of cargo, logging of cargo data, loading calculation)
- pollution monitoring
- monitoring of heating, ventilation and air conditioning for passenger ships.

1.1.4 This document specifies the minimum requirements for the design, manufacture, integration and testing of integrated bridge systems. The latter are to comply with IMO Resolution MSC 64.(67) Annex 1 of the International Maritime Organisation (IMO), and other relevant IMO performance standards, in order to meet the functional requirements contained in applicable IMO instruments, not precluding multiple usage of equipment and modules or the need for duplication.

1.1.5 The notation presumes efficient ship management by suitably qualified personnel providing for, inter alia, the uninterrupted functional availability of systems and for human factors.

1.1.6 The notation **-HWIL** is added to the additional class notation **SYS-IBS** or **SYS-IBS-1** when the control system has been verified according to the requirements of NR632 Hardware-in-the-loop Testing.

1.2 Reference Regulations

1.2.1 The following regulations are applicable:

- IEC 60945:2002, Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
- IEC 61162 (all parts), Maritime navigation and radiocommunication equipment and systems - Digital interfaces
- ISO 8468 ed.3, Ship's bridge layout and associated equipment - requirements and guidelines
- ISO 9001:2015, Quality management systems - Requirements
- IMO International Convention for the Safety of Life at Sea (SOLAS): 1974, as amended
- IMO A.1021(26) : 2009, Code on alerts and indicators
- IMO A.694: 1991, General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids
- IMO SN.1/Circ.288: 2010, Guidelines for bridge equipment and systems, their arrangement and integration (BES)
- IMO MSC.192(79) : performance standards for radar equipment
- IMO MSC/Circular 566: 1991, Provisional guidelines on the conduct of trials in which the officer of the navigational watch acts as the sole lookout in periods of darkness
- IMO MSC.191(79): performance standards for the presentation of navigation-related information on shipborne navigational displays
- IMO MSC.252 (83): performance standards for an integrated navigation system (INS)
- IMO MSC.74 (69) Annex 2: performance standards for track control systems
- IMO MSC.191 (79), MSC.232 (82): performance standards for electronic chart display and information systems
- IMO MSC/Circular 266: maintenance of electronic chart display and information system (ECDIS) software
- IMO MSC/Circular 265: guidelines on the application of SOLAS regulation V/15 to INS, IBS and bridge design.

1.3 Definitions

1.3.1 Configuration of complete system: all operational functions of the integrated bridge system as installed.

1.3.2 Configuration available: operation(s) allocated to and available at each workstation.

1.3.3 Configuration in use: operation(s) and task(s) currently in use at each workstation.

1.3.4 Connectivity: a complete data link and the presence of valid data.

1.3.5 Essential functions: functions related to determination, execution and maintenance of safe course, speed and position of the ship in relation to the waters, traffic and weather conditions.

Such functions include but are not limited to:

- route planning
- navigation
- collision avoidance
- manoeuvring
- docking
- monitoring of internal safety systems
- external and internal communication related to safety in bridge operation and distress situations.

1.3.6 Essential information: that information which is necessary for the monitoring of essential functions.

1.3.7 Functionality: ability to perform an intended function. The performance of a function normally involves a system of displays and instrumentation.

1.3.8 IMO requirements: IMO Conventions, Regulations, Resolutions, Codes, Recommendations, Guidelines, Circulars and related ISO and IEC standards.

1.3.9 Integrated bridge system (SYS-IBS): any combination of systems which are interconnected in order to allow centralised access to sensor information from workstations to perform two or more of the following operations:

- passage execution
- communications
- machinery monitoring
- loading, discharging and cargo monitoring, including HVAC for passenger ships.

1.3.10 Integrity: ability of a system to provide users with accurate, timely, complete and unambiguous information and warnings within a specified time when the system is not in use.

1.3.11 Latency: time interval between an event and the resulting information, including time for processing, transmission and reception.

1.3.12 Multi-function display: a single visual display unit which can present, either simultaneously or through a series of selectable pages, information from more than one operation of an integrated bridge system.

1.3.13 Novel systems or equipment: systems or equipment which embody new features not fully covered by provisions of SOLAS V, but which provide an equal or higher standard of safety.

1.3.14 Part: individual subsystem, equipment or module.

1.3.15 Performance check: a representative selection of short qualitative tests, to confirm correct operation or essential functions of the integrated bridge system.

1.3.16 Sensor: a device which provides information to or is controlled or monitored by the integrated bridge system.

1.3.17 Passage execution: the function of passage execution in an Integrated Bridge System (IBS) may be performed by an INS, as defined in IEC 61924.

1.3.18 Recognized mobile satellite service means any service which operates through a satellite system and is recognized by the IMO, for use in GMDSS.

1.3.19 Tack Control System (TCS) of category C: full track control on straight legs and turns.

1.4 Abbreviations

1.4.1 Abbreviations used in this standard and annexes:

AIS : Automatic identification system
DSC : Digital selective calling
EGC : Enhanced group call
EPIRB : Emergency position indicating radio beacon
GMT : Greenwich Mean Time
HF : High frequency
INMARSAT: International Mobile Satellite Organisation
ISO : International Standards Organisation
ITU-R : International Telecommunication Union - radio sector
ITU-T : International Telecommunication Union - telecommunication sector
MARPOL: IMO Convention for the prevention of pollution by ships
MEPC : IMO Marine Environmental Protection Committee
MF : Medium Frequency
MSC : IMO Maritime Safety Committee
NAV : IMO Subcommittee on Safety of Navigation
NAVTEX: System for broadcast and reception of maritime safety information
OOW : Officer of the watch
r.p.m. : Revolutions per minute
UTC : Universal coordinated time

VDU : Visual display unit

VHF : Visual high frequency.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the documents mentioned in Pt C, Ch 3, Sec 1, Tab 1, documents according to Tab 2 are to be submitted.

Table 2 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	A	General arrangement of the bridge showing the position of the control console and panels
2	A	Plans showing the field of vision from each workstation
3	A	List and specification of navigational equipment fitted on the bridge and references (Manufacturer, type...)
4	A	List of alarms and instrumentation fitted on the bridge
5	I	List and specification of automation equipment fitted on the bridge and references (Manufacturer, type...)
6	A	Functional block diagram indicating the relationship between the items of navigational equipment and between them and other equipment
7	A	Functional block diagram of automation equipment remote controlled from the bridge
8	A	Diagram of electrical supply to the navigational and automation equipment fitted on the bridge
9	A	Diagram of the system linking the bridge alarms with the other operational locations **(2)**
10	A	Diagram of the communication systems **(2)**
11	A	Diagram of the BNWAS **(2)**
12	A	Test program including test method
(1) A: to be submitted for approval ; I: to be submitted for information. **(2)** Documents to be submitted only when a **SYS-IBS-1** notation is requested.		

3 General requirements

3.1 General

3.1.1 The integrated bridge system is to comply with all applicable IMO requirements as contained in the reference regulations listed in [1.2] or other relevant IEC Standards. Parts executing multiple operations are to meet the requirements specified for each individual function they can control, monitor or perform. By complying with these requirements, all essential functions remain available in the event of a single failure. Therefore, means for operation independent of the integrated bridge system are not required.

3.1.2 Each part of an integrated bridge system is to meet the relevant requirements of IMO Resolution A.694(17) as

detailed in IEC 60945. As a consequence, the integrated bridge system is in compliance with these requirements without further environmental testing to IEC 60945.

Software is to be developed in accordance with Pt C, Ch 3, Sec 3

3.1.3 Where implemented, passage execution is not to be interfered with by other operations.

3.1.4 A failure of one part is not to affect the functionality of other parts except for those functions directly dependent upon the information from the defective part.

3.2 Integration

3.2.1 The functionality of the integrated bridge system is to ensure that operations are at least as effective as with stand-alone equipment.

3.2.2 Continuously displayed information is to be reduced to the minimum necessary for safe operation of the ship. Supplementary information is to be readily accessible.

3.2.3 Integrated display and control functions are to adopt a consistent man-machine interface philosophy and implementation. Particular consideration is to be given to:

- symbols
- colours
- controls
- information priorities
- layout.

3.2.4 Where multi-function displays and controls are used to perform functions necessary for safe operation of the ship, they are to be duplicated and interchangeable.

3.2.5 It is to be possible to display the complete system configuration, the available configuration and the configuration in use.

3.2.6 Any unintentional change of a configuration is to be brought to the immediate attention of the user. An unintentional change of the configuration in use is, in addition, to activate an audible and visual alarm.

3.2.7 Each part to be integrated is to provide details of its operational status and the latency and validity of essential information. Means is to be provided within the integrated bridge system to make use of this information.

3.2.8 An alternative means of operation is to be provided for essential functions.

3.2.9 For integrated machinery control, it is to be possible for all machinery essential for the safe operation of the ship to be controlled from a local position.

3.2.10 An alternative source of essential information is to be provided. The integrated bridge system is to identify loss of either source.

3.2.11 The source of information (sensor, result of calculation or manual input) is to be displayed continuously or on request.

3.3 Data exchange

3.3.1 Interfacing within the integrated bridge system and to an integrated bridge system is to comply with IEC 61162, as applicable.

3.3.2 Data exchange is to be consistent with safe operation of the ship. The Manufacturer is to specify in the System Specification Document (SSD) the maximum permissible latency for each function considering the use of fast control loop, normal control loop, essential information and other information.

3.3.3 Corrupted data are not to be accepted by the integrated bridge system. Corrupted or missing data are not affect functions which are not dependent on this data.

3.3.4 The integrity of data flowing on the network is to be ensured.

3.3.5 The network is to be such that in the event of a single fault between nodes there an indication, the sensors and displays on the network continue to operate and data transmission between them is maintained.

3.3.6 A failure in the connectivity is not to affect independent functionality.

3.4 Failure analysis

3.4.1 A failure analysis is to be performed and documented.

3.4.2 Parts, functions and connectivity are to be identified.

3.4.3 Possible failures of parts and connectivity associated with essential functions and information are to be identified.

3.4.4 Consequences of failures with respect to operation, function or status of the integrated bridge system are to be identified.

3.4.5 Each failure is to be classified with respect to its impact on the integrated bridge system taking into account relevant characteristics, such as detectability, diagnosability, testability, replaceability and compensating and operating provisions.

3.4.6 The results of the failure analysis are to confirm the possibility of continued safe operation of the ship.

3.5 Quality assurance

3.5.1 The integrated bridge system is to be designed, developed, produced, installed, and serviced by companies certified to ISO 9001:2015, as applicable.

4 Operational requirements

4.1 Human factors

4.1.1 The integrated bridge system is to be capable of being operated by personnel holding appropriate certificates.

4.1.2 The man-machine interface (MMI) is to be designed to be easily understood and in a consistent style for all integrated functions.

4.1.3 Operational information is to be presented in a readily understandable format without the need to transpose, compute or translate.

4.1.4 Indications, which may be accompanied by a short low intensity acoustic signal, are to occur when:

- an attempt is made to execute an invalid function
- an attempt is made to use invalid information.

4.1.5 If an input error is detected by the system it is to require the operator to correct the error immediately. Messages actuated by an input error are to guide the correct responses, e.g.: not simply “Invalid entry”, but “Invalid entry, re-enter set point between 0 and 10”.

4.1.6 Layered menus are to be presented in a way which minimises the added workload to find and return from the desired functions.

4.1.7 An overwiew is to be easily available to assist the operator in the use of a multiple page system. Each page is to have a unique identifier.

4.1.8 Where multi-function displays are used, they are to be in colour. Continuously displayed information and functional areas, e.g. menus, are to be presented in a consistent manner.

4.1.9 For actions which may cause unintended results, the integrated bridge system is to request confirmation from the operator.

Note 1: Examples of such actions are:

- attempting to change position of next waypoint while in track mode steering
- attempting to switch on bow thruster when insufficient electrical power is available.

4.1.10 Functions requested by the operator are to be acknowledged or clearly indicated by the integrated bridge system on completion.

4.1.11 Default values, where applicable, are to be indicated by the integrated bridge system when requesting operator input.

4.1.12 For bridge operation by one person, special consideration is to be given to the technical requirements in Ch 4, Sec 1, [1].

4.2 Functionality

4.2.1 It is always to be clear from where essential functions may be performed.

4.2.2 The system management is to ensure that one user only has the control of an input or function at the same time; all other users are to be informed of this by the integrated bridge system.

4.3 Training

4.3.1 Manufacturers of integrated bridge systems are to provide training possibilities for the ship’s crew. This training may take place ashore or on board and is to be carried out using suitable material and methods to cover the following topics:

- General understanding and operation of the system:
  - knowledge and understanding of the system’s configuration and application
  - reading and understanding of the operating manual
  - usage and understanding of brief description and instructions provided on the bridge
  - usage and understanding of electronic “HELP”-functions, if provided in the system
  - familiarisation with the system using safe trial modes
- Mastering of uncommon conditions in the system:
  - detecting and locating of failures
  - resetting the system to safe default values and modes
  - operating safely without certain sensor data or parts
  - possibilities for repair on board
  - identifying the potential for unintended results

- Methods and support for providing the above-mentioned training may be, for example:
  - printed material
  - training courses
  - video films
  - computer based learning programmes
  - simulation of different situations or data
  - recorded speech.

5 Technical requirements

5.1 Sensors

5.1.1 In order to ensure an adequate system functionality, the sensors employed are to be able to comply with the following, as applicable:

a) ensure communication compatibility in accordance with the relevant international marine interface Standard IEC 61162; and provide information about their operational status and about the latency and validity of essential information

b) respond to a command with minimal latency and indicate receipt of invalid commands, when remote control is employed

c) have the capability to silence and re-establish the audible portion of the local alarm

d) have information documented about deterministic and stochastic errors and how they are handled, insofar as signals are pre-processed locally, e.g. plausibility check.

5.2 Alarm management

5.2.1 The integrated bridge system alarm management as a minimum is to comply with the requirements of the Code on Alerts and Indicators, (IMO Resolution A.1021(26)) and the alarms required for each navigational equipment by IMO standards.

5.2.2 Appropriate alarm management on priority levels (see [5.2.5]) and grouping of alarms based on operations and tasks is to be provided within the integrated bridge system.

Note 1: The purpose of grouping of alarms is to achieve the following:

- to reduce the variety in type and number of audible and visual alarms and indicators so as to provide quick and unambiguous information to the personnel responsible for the safe operation of the ship
- to readily identify any abnormal situation requiring action to maintain the safe operation of the ship
- to avoid distraction by alarms which require attention but do not require immediate action to restore or maintain the safe operation of the ship.

5.2.3 The number of alarms is to be kept as low as possible by providing indications for information of lesser importance.

5.2.4 Alarms are to be displayed so that the reason for the alarm and the resulting functional restrictions can be easily understood. Indications are to be self-explanatory.

5.2.5 Alarms are to be prioritised as follows:

a) emergency alarms: alarms which indicate that immediate danger to human life or to the ship and its machinery exists and that immediate action is to be taken

b) distress, urgency and safety alarms: alarms which indicate that a mobile unit or a person is in distress, or the calling station has a very urgent message concerning the safety of a mobile unit or a person, or has an important warning to transmit

c) primary alarms: alarms which indicate a condition that requires prompt attention to prevent an emergency condition as specified in statutory and classification rules and regulations

d) secondary alarms: alarms which are not included above.

5.3 Human factors

5.3.1 A multi-function display, if used, is to be a colour display.

5.3.2 The size, colour and density of text and graphic information presented on a display are to be such that it may be easily read from the normal operator position under all operational lighting conditions.

5.3.3 Symbols used in mimic diagrams are to be standardised throughout the system's displays.

5.3.4 All information is to be presented on a background providing high contrast and emitting as little light as possible at night.

5.4 Power interruptions and shutdown

5.4.1 If subjected to an orderly shutdown, the integrated bridge system is, upon turn-on, to come to an initial default state.

5.4.2 After a power interruption full functionality of the integrated bridge system is to be available following recovery of all subsystems. The integrated bridge system is not to increase the recovery time of individual subsystem functions after power restoration.

5.4.3 If subjected to a power interruption, upon restoration of power the integrated bridge system is to maintain the configuration in use and continue automated operation as far as practicable. Safety related automatic functions, e.g. automated steering control, are only to be restored upon confirmation by the operator.

5.5 Power supply

5.5.1 General power supply requirements are summarised in Tab 3.

5.5.2 Power supply requirements applying to parts of the integrated bridge system as a result of other IMO requirements remain applicable.

5.5.3 The integrated bridge system is to be supplied:

- from the main and emergency sources of power with automated change-over through a local distribution board with provision to preclude inadvertent shutdown,
- from a transitional source of power for a duration of not less than 1 min, and
- where required in Tab 3, parts of the integrated bridge system are also to be supplied from a reserve source of power.

Table 3 : Power supply requirements in addition to the main source of energy

	Reserve source of energy **(2)**	Transitional source **(1)**	Emergency source **(1)**
Integrated bridge system		X **(3)**	X
VHF voice and DSC	X **(4)**		X **(5)**
MF voice and DSC	X **(6)**		X **(7)**
MF/HF voice, DSC and telex	X **(6)**		X **(7)**
INMARSAT ship earth station	X **(6)**		X **(7)**
EGC receiver	X **(6)**		X **(7)**
EPIRB	X **(8)**		X **(8)**
SAR transponders			X **(9)**
Aeronautical VHF SAR voice transceiver	X		X **(10)**
Lighting for radio installation **(11)**	X **(12)**		X
Equipment providing inputs to the radio installation	X **(13)**		X
Internal communication equipment and signals required in an emergency		X **(14)**	X
Magnetic compass and repeaters			X **(9)**
ECDIS or automatic graphical position display			X **(9)**
Automatic indentification system (AIS)		X	X **(9)**
Electronic position fixing system	X **(13)**		X **(9)**
Radar			X **(9)**
Gyrocompass and repeaters	X **(17)**		X **(9)**
Echo sounder			X **(9)**
Speed and distance log			X **(9)**
Rudder angle indicator			X **(9)**
Propeller rpm, thrust direction and pitch as applicable			X **(9)**
Heading control system			X **(9)**
Rate of turn indicator			X **(9)**
Voyage data recorder (VDR)			X **(9)**
Track control system (TCS)			X **(9)**
Integrated navigation system			X **(9)**
Bridge navigation watch alarm system (BNWAS)			X **(9)**
Weather chart facsimile			X **(9)**
Receiver capable of receiving MSI and search and rescue related information (e.g. NAVTEX)	X		X **(9)**
Transmitting heading device (THD)			X **(9)**
Fire detection and alarm system		X **(14)**	X

	Reserve source of energy **(2)**	Transitional source **(1)**	Emergency source **(1)**
Fire door holding and release		X **(15)**	X
Daylight signalling lamp, ship's whistle and manually operated call points		X **(14)**	X
Emergency lighting and navigation lights		X **(14)**	X
Fire pump			X
Automatic sprinkler pump			X **(15)**
Emergency bilge pump and remote controlled bilge valves			X **(15)**
Steering gear			X
Power-operated watertight doors and associated control, indication and alarm circuits		X **(15)**	X **(15)**
Lift cars			X **(15)**
Machinery alarm system **(16)**			X
Alarm transfer system for one person operated bridge **(16)**			X
Multifunction displays - according to MSC.191(79)			X **(9)**
Conning display			X **(9)**
Call system (back-up Officer)			X

(1) Emergency and transitional sources are defined in SOLAS II-1/42 and /43. Where the emergency source is an accumulator battery, a transitional source of emergency electrical power is not required, unless otherwise stated.

(2) Reserve source for radio installations is defined in SOLAS IV/13.

(3) A transitional source is required for essential functions of the integrated bridge system.

(4) Reserve source is required by SOLAS IV/13.2 for the installation to SOLAS IV/7.1.1.

(5) Emergency source is required by SOLAS II-1/42.2.2.2 and 43.2.3.2 responsible for installations to SOLAS IV/7.1.1, 7.1.2 and 7.1.5.

(6) Reserve source is required by SOLAS IV/13.2 for the installation to SOLAS IV/9.1.1, 10.1.2, 10.1.1 and 11.1.1 as appropriate for the sea area(s) for which the ship is equipped.

(7) Emergency source is required by SOLAS II/1/42.2.2.2.1, 42.2.2.2.2 and 42.2.2.2.3 and 43.2.3.2.1, 43.2.3.2.2 and 43.2.3.2.3 responsible for installations to SOLAS IV/9.1.1, 9.1.2, 10.1.1, 10.1.2, 10.1.3, 11.1.1 and 11.1.2 if applicable.

(8) If position input provided from external equipment.

(9) Local distribution panel(s) are to be arranged for all items of electrically operated navigational equipment. Each item is to be individually connected to its distribution panel. The power supplies to the distribution panel(s) are to be arranged with automatic change-over facilities between the main and the emergency.

(10) If not equipped with primary batteries.

(11) Required by SOLAS IV/6.2.4.

(12) Reserve source may be used (SOLAS IV/13.5) as supply independent from main and emergency sources.

(13) Reserve source may be used (SOLAS IV/13.8) for ship's navigational or other equipment which needs to supply uninterrupted input of information to the radio installation to ensure its proper performance as required by SOLAS IV.

(14) For cargo ships a transitional source is not required if the emergency source is a generator which can be automatically started and supply the required load within 45 s (see also **(1)**).

(15) Required for passenger ships only (see also **(1)**).

(16) A standby power supply with automatic change-over from normal power supply is required by Pt C, Ch 3, Sec 2, [2.1.1].

(17) If forming part of GDMDSS installation.

6 Testing

6.1 Introduction

6.1.1 The following tests to be carried out by the Shipyard and the Manufacturers are intended to supplement and not replace testing of parts that is required to meet the relevant IMO performance standards. They are intended to ensure that when parts are integrated there is no degradation of their individual functionality and the overall system meets the requirements contained in Articles [3], [4] and [5].

6.1.2 In all instances the performance standards for parts will form the minimum test requirement for an integrated system. Parts previously type approved will not require re-testing. Bridge-mounted parts for which no IMO performance standard exists are to be tested to the requirements of IEC 60945. Integration aspects of the integrated bridge system are to require testing to ensure compliance with requirements contained in Articles [3], [4] and [5].

6.1.3 The tests and confirmation set forth in [6.2] to [6.4] are to be reported in writing by the Shipyard and Manufacturers. This report is to be submitted to the Society for information.

6.2 General requirements

6.2.1 The Manufacturer is to state the operations intended to be performed by the integrated bridge system.

6.2.2 Since each integrated bridge system may integrate an individual set of operations and parts, it is not possible to define in advance which IMO requirements apply. Therefore, the following steps are to be taken with each individual integrated bridge system considered:

a) Produce a matrix of the applicable IMO requirements:
   - collect IMO requirements referring generally to **SYS-IBS** (e.g. SOLAS Chapter V and Code on Alerts and Indicators (IMO A.1021 (26))
   - collect IMO requirements applicable to the operations stated in [6.2.1] (e.g. if a radar/ARPA is integrated, collect IMO MSC.192 (79))
   - identify the individual parts of the integrated bridge system and their interfaces
   - identify parts executing multiple operations
   - identify functions necessary to perform the operations stated in [6.2.1]
   - identify power supply requirements for the individual parts of the integrated bridge system from Tab 3.

b) Verify the validity of the appropriate type approval certificates [3.1.1].

c) Verify that all functions identified in a) are performed [3.1.1].

6.2.3 In addition, the following is to be carried out:

- Confirm compliance with IEC 60945 by one of the following:
  - a valid type approval certificate
  - a test certificate issued by an appropriate body
  - successful completion of appropriate tests [3.1.2].
- Confirm by examination of the (SSD)(s) that operational functions in addition to passage execution are implemented on a non-interference basis [3.1.3].
- Independently disable each part identified in [6.2.2] a) and determine by a test that only those functions dependent on the disabled part are affected [3.1.4].
- Confirm by examination that only minimum information necessary for the safe operation of the ship and as applicable to the configuration in use is continuously displayed and that supplementary information is readily accessible [3.2.2].
- Where IMO requirements governing the symbols, colours, controls, information priorities and layout of the integrated display and control functions exist, confirm compliance by examination. Where no such requirements exist, confirm by examination that the use of symbols, colours, controls, information priorities and layout is consistent [3.2.3].
- Where used, confirm by examination that there are at least two identical and interchangeable multi-function displays and controls [3.2.4].
- Confirm by examination that it is possible to display the configuration of the complete system, the configuration available and the configuration in use [3.2.5].
- Disable a part of the configuration in use and confirm that an audible and visual alarm is activated [3.2.6].
- Confirm by examination of relevant certificates and documentation that each part integrated in the integrated bridge system provides details of its operational status and latency and validity of essential information. Confirm by a performance check that changes in status of the parts and of the latency and validity of information are used by the integrated bridge system in a safe and unambiguous manner [3.2.7].
- Confirm by examination of the SSD that there is an alternative means of performing each applicable essential function [3.2.8].
- Confirm by examination of the SSD that for integrated machinery control, it is possible for all machinery essential for the safe operation of the ship to be controlled from a local position.
- Confirm by examination that there is an alternative source of essential information. Confirm by a performance check that loss of essential information is recognised by the integrated bridge system.
- Confirm by examination that the source of information is displayed continuously or on request [3.2.11].
- Confirm by examination of relevant certificates and documentation that interfacing complies with IEC 61162, as applicable [3.3.1].
- Confirm by examination of the SSD that the stated latencies are appropriate to all intended operations. Confirm by examination of the Manufacturer's SSD that the stated latencies are achieved while the network is loaded to its maximum expected loading [3.3.2].
- Confirm by a performance check that corrupted data is not accepted by the integrated bridge system and that corrupted and missing data does not affect functions which are not dependent on this data [3.3.3].
- Confirm by examination of the Manufacturer's SSD that, as a minimum, data includes a check-sum in accordance with IEC 61162-1 and that, in addition, limit checking is applied to essential data [3.3.4].
- Create a representative number of single faults between network nodes and confirm that there is an indication of the fault, the displays and sensors continue to operate and data transmission is maintained [3.3.4].

- Identify the system connectivity by examination of the SSD. Independently interrupt each connection and determine by a performance check that only those functions dependent on the connection are affected and that all essential functions can still be performed [3.3.6].
- Confirm by examination of the SSD that a failure analysis has been performed and documented. The results of the failure analysis and the possibility of continued safe operation of the ship are to be verified by testing a representative selection of failures [3.4.1].
- Confirm by examination of the relevant certificate(s) that the Manufacturer complies with ISO 9000 Series Standards [3.5.1].

6.3 Operational requirements

6.3.1 The following tests are carried out:

- Confirm by examination that the integrated bridge system includes displays, controls and instrumentation necessary to perform the functions identified in [6.2.2] a).
- Confirm by a performance check, conducted by suitably qualified personnel, that information presented is understandable without the need to transpose, compute or translate and that operation of integrated functions of the integrated bridge system identified in [6.2.2] a) is as effective as for equivalent stand-alone equipment [3.2.1], [4.1.1] and [4.1.2].
- Confirm by examination of the Manufacturer's SSD that the specific requirements in MSC/Circular 566, paragraphs 10 to 32, are met, if applicable [4.1.2].
- Confirm by a performance check that normal execution of functions and use of information are not accompanied by acoustic signals. If provided, ensure that acoustic signals accompanying attempts to execute an invalid function or use invalid information are short, of low intensity and clearly distinguishable from alarms [4.1.4].
- Create an input error and ensure that immediate correction is required and that relevant guidance is given [4.1.5].
- Confirm by a performance check, conducted by suitably qualified personnel, that layered menus, if provided, are presented such as to minimise workload [4.1.6].
- If provided, ensure that multiple pages are uniquely identified and that an overview is available [4.1.7].
- Ensure that continuously displayed information and functional areas, e.g. menus, are presented in a consistent manner in multi-function displays [4.1.2], [4.1.8].
- Initiate a situation causing a potentially unintended result and ensure that the result is identified and that confirmation of the action is requested from the operator [4.1.9].
- Confirm by a performance check that completion of functions is acknowledged [4.1.10].
- Confirm that there is an indication of configuration available at each workstation [4.2.1].
- Confirm that essential functions cannot be performed simultaneously at more than one workstation and that there is an indication of the configuration in use at each workstation [4.2.2].

6.3.2 The Manufacturer is to produce a written statement that training possibilities are provided and confirm by examination of the training material that it covers general understanding and operation and mastering of uncommon conditions [4.3.1].

6.4 Technical requirements

6.4.1 The following tests are carried out:

- Confirm, as applicable, by examination of the SSD that sensors employed according to [5.1.1]:
  - communicate in accordance with IEC 61162
  - provide details of operational status, latency and validity of essential information
  - respond to a command with minimal latency and indicate receipt of invalid commands, when remote control is employed
  - have the capability to silence and re-establish the audible portion of the local alarm
  - have information documented about deterministic and stochastic errors and how they are handled.
- Initiate a situation identified in the SSD as requiring immediate reaction by an operator and confirm that the resultant alarm complies with IMO A.1021 (26) (see [5.2.1]).
- Create conditions necessary to generate all types of alarms and indications listed in the matrix prepared in [6.2.2] a).
- Confirm that appropriate alarm management on priority levels and functional groups is provided and that the number of the alarm types and their release is kept as low as possible by providing indications for information of lesser importance [5.2.2], [5.2.3].
- Confirm that alarms are displayed so that the reason for the alarm and the resulting functional restrictions can be easily understood and that indications are self-explanatory [5.2.4].
- Confirm that alarms are prioritised as emergency alarms, distress, urgency and safety alarms, primary alarms and secondary alarms [5.2.5].

- Confirm by examination, performed by suitably qualified personnel, that:
  - a multi-function display is a colour display [5.3.1]
  - the size, colour and density of text and graphic information displayed on a VDU are such that it can be easily read from the normal operator position under all operational lighting conditions [5.3.2]
  - symbols used in mimic diagrams are standardised throughout the system's displays [5.3.3]
  - all information is presented on a background providing high contrast and emitting as little light as possible at night [5.3.4].
- Perform an orderly shutdown of the integrated bridge system and confirm that when power is turned on again, the default state specified in the SSD is reached [5.4.1].
- Record the configuration in use and the recovery times of all subsystems. Disconnect all external sources of power and wait for expiration of the integrated bridge system transitional source of power. Restore power and wait for recovery of all subsystems. The recovery times of all subsystems are to be as recorded [5.4.2].
- The IBS is to come to the configuration in use and continue automated operation as far as practicable. Verify that safety related automatic functions are continued only after confirmation [5.4.3].
- Confirm by examination of the SSD that provision is made to comply with the power supply requirements listed in Tab 3 and in the matrix prepared in [6.2.2] a).

Section 3 Ship-Shore Communication

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships equipped with communication systems which can ensure asynchronous or synchronous transfer of data between the ship and the shore:

- An asynchronous communication is defined as a communication designed to transmit and receive time-insensitive data for applications where the timing of the data creation and consumption may be different, i.e. receiver sends a response, and the sender sends the next data without waiting for the response.

Note 1: Use cases include, for example, transmission of the IoT (Internet of Things) data, bathymetry mapping data, provision of access for crew and passenger welfare, operational exchanges by email, voice and video, etc.

- A synchronous communication is defined as a communication designed to transmit and receive time-sensitive data for applications where the time period between the data creation and consumption is limited by a latency threshold, i.e. the round trip time between the receiver and the sender is to be within the latency threshold.

Note 2: Use cases include, for example, teleoperation of inland vessels with a full remote control over individual thrusters via 4G/5G/LTE networks with latency below 150 ms, control of marine Unmanned Surface Vessels (USV) with a trajectory sent to the USV from Remote Operations Centre (ROC) via satellite communication with a 600 ms latency, etc.

1.1.2 In accordance with Pt A, Ch 1, Sec 2, [6.5], ships complying with the requirements of this Section may be assigned the following additional class notations:

- **ASYNC-COM** when the ship is equipped with asynchronous communication systems
- **SYNC-COM** when the ship is equipped with synchronous communication systems.

The additional class notations **ASYNC-COM** and **SYNC-COM** are complemented by the suffix **-R** when the ship is equipped with redundant communication systems.

1.1.3 The requirements for the assignment of the notation **ASYNC-COM** are given in Articles [2] and [3].

1.1.4 The requirements for the assignment of the notation **SYNC-COM** are given in Articles [2] and [4].

1.1.5 The additional requirements for the assignment of the notations **ASYNC-COM-R** and **SYNC-COM-R** are given in Article [5].

1.2 Scope

1.2.1 The scope of the notations **ASYNC-COM**, **ASYNC-COM-R**, **SYNC-COM** and **SYNC-COM-R** is limited to the functioning of the ship-shore communication systems in the geographic area covered by communication network(s) with which the onboard communication device(s) can exchange data. The geographic area is to be specified by the applicant as per [1.4]. For communication devices dependant on ad hoc networks, the maximum operating range of a node of the ad hoc network is to be specified.

1.2.2 The scope of the notations **ASYNC-COM** and **ASYNC-COM-R** includes operational data traffic, other than distress, urgency and safety messages, conducted by radio communication.

1.2.3 The scope of the notations **ASYNC-COM** and **ASYNC-COM-R** excludes:

- remote control over the computer based systems of categories II and III as defined in Pt C, Ch 3, Sec 3
- remote control over the autonomous ships and Unmanned Surface Vessels (USV) as defined in NI641 and NR681 respectively
- reception and transmission of distress, urgency and safety messages covered by the IMO SOLAS Chapter IV and by national regulations
- the shipborne communication equipment listed in IMO SOLAS Chapter IV
- communication using other ships for relay.

Note 1: NI641 refers to the Guidelines for autonomous shipping, NR681 refers to the Rule Note for Unmanned Surface Vessels (USV)

1.2.4 The requirements for notations **ASYNC-COM** and **ASYNC-COM-R** do not address the cyber security, for which reference is made to NR659 Rules on Cyber Security for the Classification of Marine Units.

1.2.5 The scope of the notations **SYNC-COM** and **SYNC-COM-R** includes:

- operational data traffic, other than distress, urgency and safety messages, conducted by radio communication
- the remote control over the computer based systems of categories II and III as defined in Pt C, Ch 3, Sec 3
- the remote control over the autonomous ships and unmanned surface vessels (USV) as defined in NI641 and NR681 respectively.

1.2.6 The scope of the notations **SYNC-COM** and **SYNC-COM-R** excludes:

- communication using other ships for relay
- reception and transmission of distress, urgency and safety messages covered by the IMO SOLAS Chapter IV and by national regulations
- the shipborne communication equipment listed in IMO SOLAS Chapter IV.

1.2.7 The requirements for notations **SYNC-COM** and **SYNC-COM-R** address the cyber security in [4.4].

1.2.8 Tab 1 summarises the scope of the notations **ASYNC-COM**, **ASYNC-COM-R**, **SYNC-COM** and **SYNC-COM-R**.

Table 1 : Scope of the notations

Items	**ASYNC-COM, ASYNC-COM-R**	**SYNC-COM, SYNC-COM-R**
Operational data traffic, other than distress, urgency and safety messages, conducted by radio communication	Includes	Includes
Remote control over the computer based systems of categories II and III as defined in Pt C, Ch 3, Sec 3	Excludes	Includes
Remote control over the autonomous ships and Unmanned Surface Vessels (USV) as defined in NI641 and NR681 respectively	Excludes	Includes
Shipborne communication equipment listed in IMO SOLAS Chapter IV	Excludes	Excludes
Reception and transmission of distress, urgency and safety messages covered by the IMO SOLAS Chapter IV and by national regulations	Excludes	Excludes
Use of other ships for relay	Excludes	Excludes
Cyber security	Excludes	Includes

1.3 Definitions

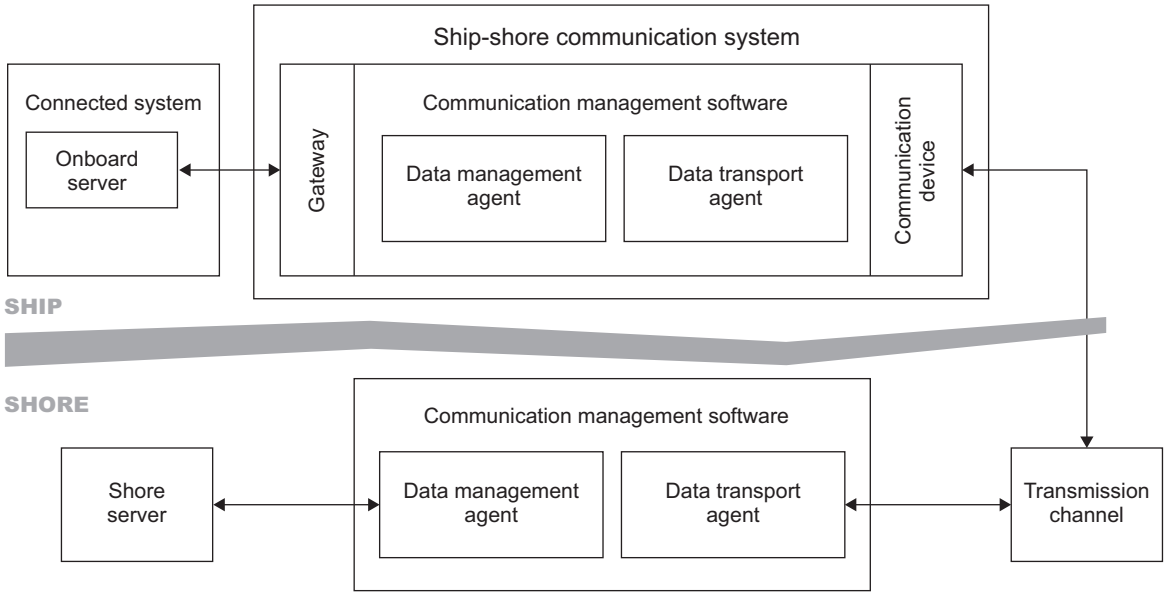
1.3.1 The following general definitions are used in the present Section:

- Ad hoc network: Terrestrial radio communication network which can be temporarily deployed in a limited geographic area for an exclusive use by a group of ships.
- Communication management software: Software, used for communication, that consists of a data management agent and a data transport agent, e.g. Software Defined Wide-Area Networking (SD-WAN) solution.
- Communication device: Radio receiving or transmitting device, e.g. 5G antenna with the associated modem.
- Connected system: Onboard system which depends on the ship-shore communication in order to perform its function.
- Connectivity coverage chart: Graphical representation of the geospatial data showing the boundaries of the electromagnetic signal coverage which enables the connectivity for the ship-shore communication system and which shows the Quality of Service parameters.
- Data management agent: Software for the control and transport of data between data transport agents.
- Data transport agent: Software installed on both ship and shore collecting and sending data to the data management agent, or receiving data from the data management agent.
- Essential ship functions: Functions essential for propulsion, steering and safety of the ship.
- External communication provider: Provider of information transmission services between communication devices and terrestrial networks.
- Fail-safe sequence: Sequence of automatic and/or manual actions which brings the ship-shore communication system, the connected system and the ship to a predefined managed risk state, which may be outside the operational envelope, following a failure or a degradation of performance of the ship-shore communication system.
- Forward Error Correction (FEC): Technique to reduce the errors in the packet transmission by adding redundant data for the purpose of error detection and correction.
- Function: Defined objective or characteristic action of a system or component (see ISO/IEC/IEEE 24765 Systems and software engineering - Vocabulary).
- Guaranteed Bit Rate subscription:Subscription for using an information transmission path for which the capacity, latency and bit error rate are guaranteed by the external communication provider.
- Hardware: Physical elements of a device, system or equipment which support the computation and/or data access for the software.
- Latency: Round trip time of a data frame between two nodes which may include the hosts of the data transport agents on board and on shore.

- Latency threshold:Threshold of latency beyond which a loss or degradation of the function of the connected system dependant on the ship-shore communication may occur.
- Redundant system: System capable to maintain its function following a single failure, this can be achieved by the installation of multiple redundant components or by the use of alternative means to perform the function.
- Redundant group: Group of equipment which can perform its function for the redundant system independently from other redundant groups.
- Remote Operations Centre (ROC): Location remote from the ship that can operate some or all aspects of the functions of the ship. The remote operation is performed via the ship-shore communication system. ROC is equivalent to Remote Control Centre (RCC) defined in NI641.
- Round Trip Time (RTT): Time measured from the transmission of a message at the sender until the sender receives a response from the receiver, excluding any time for processing in the receiver.
- Sequence numbering: Protection technique for safety critical message stream which includes adding a data field with a sequence number. The sequence number is to change in a predefined way from message to message permitting to check the correctness and completeness according to the message order. Sequence number is a protection against repetition, deletion, insertion and re-sequencing.
- Ship-shore communication system: Computer-based system designed to provide a data communication between the on-shore and shipboard servers (ship to shore and shore to ship). The system includes at least one communication device, a communication management software and a gateway to the ship's network. An example of the layout is given in Fig 1.
- Software: Computer code stored and executed in the computer hardware and the associated data.
- Time-out: Protection technique for safety critical message stream which includes checking if the delay between two consecutive messages received by a receiver exceeds a predefined maximum time.
- Traffic quota: Amount of data which can be transferred over a specified period of time.
- Quality of Service (QoS) parameters:

  Scalars used as a reference to a specific packet forwarding behaviour in a data flow of a cellular network's communication service subscription, e.g. packet loss rate, latency.

Figure 1 : Ship-shore communication system



1.4 Documentation to be submitted

1.4.1 The general documentation to be submitted for notations **ASYNC-COM**, **ASYNC-COM-R**, **SYNC-COM**, or **SYNC-COM-R** is listed in Tab 2.

1.4.2 In addition to the documents listed in Tab 2, the documentation listed in Tab 3 is to be submitted for the notation **SYNC-COM**.

1.4.3 In addition to the documents listed in Tab 2, and Tab 3 as applicable, the documentation listed in Tab 4 is to be submitted when notation **ASYNC-COM** or **SYNC-COM** is supplemented by the suffix **-R**.

Table 2 : General documentation to be submitted

No.	A/I (1)	Description
1	I	User manual, installation manual, functional description, and maintenance manual of ship-shore communication system on board, including the communication devices
2	I	List of onboard communication devices as a part of ship-shore communication system
3	I	Type Approval Certificates or Test Certificates for other recognized standards accepted by the Society as per [2.3.1]
4	A	Diagram presenting the integration between the ship-shore communication system and the ship's network. The diagram can be a network topology with communication devices, communication management software, gateways. The elements in the perimeter of the ship-shore communication system are to be clearly marked.
5	A/I	Documentation as required in Pt C, Ch 3, Sec 3 for the computer based systems used within the ship-shore communication system
6	I	List of data to be transmitted via the ship-shore connection with description and with a data priority level to be specified as per [2.1.2]
7	I	Management policy for bandwidth utilisation, data priority and traffic optimisation
8	A	Onboard functional test programme including the data sets for a test transmission
9	I	Templates of the transmission logs and the procedure for accessing the logs
10	I	Recovery procedure for the onboard components of the ship-shore communication system that can be executed without a remote intervention via a communication device
11	I	Network bandwidth calculation specifying the overall maximum capacity of the communication system and the capacity allocated to the connected system
12	I	Network traffic load analysis for the minimum throughput required for the connected system and other onboard traffic consumers, if any
13	I	Subscription details for the external communication service per communication device specifying the throughput and Quality-of-service parameters for the service availability
14	I	Antenna arrangement plan with the transmission frequencies
15	I	Diagrams for power supply and sensor inputs, if applicable, for the onboard ship-shore communication system
16	I	Description of the geographic coverage by each communication device and by each external communication provider. For ad hoc networks, the maximum operating range of a network node is to be specified
(1) A : To be submitted for approval; I : To be submitted for information		

Table 3 : Additional documentation to be submitted for the notation SYNC-COM

No.	A/I (1)	Description
1	I	Response procedures for the connected systems in the event of a loss of the ship-shore communication and in the event of failing to meet the minimum requirements of the connected system, e.g. exceeding the latency threshold defined in [4.1.2]
2	I	Minimum inbound and outbound data traffic and latency requirements of the connected system
3	I	List of antennas specifying their type: directional and non-directional, motion-compensated, electronically steered, stationary
4	I	Description of the traffic balancing prioritisation
5	I	Functional specification of ship-shore communication modes as per [4.1.3] with a correspondence to the degrees of remote control RC0-3 according to NI641, Sec 1, [1.9.4] and latency threshold selected by the Applicant as per [4.1]
6	A	For control over Cat. II and III systems as defined in Pt C, Ch 3, Sec 3: Risk and Technology Assessment as per [4.6] according to NI641, Sec 2
7	I	Sea trials programme for validating the modes as per [4.1.3] and [4.7.7]
8	I	Description of the onboard emergency stop for the ship-shore communication system including the topology diagram with the identification of the elements interfaced by the emergency stop panel as per [4.4.5] and [4.4.6], if applicable
(1) A : To be submitted for approval; I : To be submitted for information		

Table 4 : Additional documentation to be submitted for the notations ASYNC-COM-R and SYNC-COM-R

No.	A/I (1)	Description
1	A	Failure Mode and Effect Analysis (FMEA) of the ship-shore communication system
2	A	FMEA test programme for the ship-shore communication system
3	A	Topology diagram with a colour coding for redundant groups
4	A	Reliability block diagram with a colour coding for redundant groups
5	I	Description of the redundant geographic coverage and a small scale chart presentation of the area, which is the overlap of the coverages provided for each communication device, as applicable
(1) A : To be submitted for approval; I : To be submitted for information		

2 General requirements

2.1 General

2.1.1 A communication management software is to be implemented on board and is to be appropriately configured to handle the ship network's throughput on all dedicated communication devices. A communication management software is to be provided with means to:

- manage priority level for data transfer
- manage traffic quota based on amount of data transferred by an application, application category or user group
- provide information on communication system status, including the connectivity, communication device availability, estimated transfer rate.

2.1.2 Appropriate priority levels are to be set up for the data transferred, so that essential ship functions are not altered, and that sufficient bandwidth remains available for the critical ship usage.

2.1.3 Data transport agent is to apply a bandwidth management policy which corresponds to each communication device in use subject to its operational limits. The identifier and transmission status of the used communication device are to be fed into the data transport agent as inputs. The traffic prioritisation is to be provided either at the network layer in the communication stack of the data transport agent or at the application layer.

2.1.4 In no case, the operation or a single failure of the ship-shore communication system are to result in:

a) disruption of services providing the essential ship functions on board

b) compromised reception and transmission of distress, urgency and safety messages covered by the IMO SOLAS Chapter IV and by national regulations.

Note 1: A risk assessment report may be submitted to the Society upon request .

2.2 Software

2.2.1 The communication devices are to be provided on board with the means of a software recovery without the need for a remote intervention requiring such communication devices.

2.2.2 Communication management software is to log the transmissions with a timestamp and store the following meta data:

- communication device in use
- compression percentage
- priority tag for the data packets
- estimated bandwidth availability at the time of transmission
- transmission attempt count
- latency measured between the onboard data transport agent and the first shore node
- transmission protocol (e.g. Server Message Block (SMB), File Transfer Protocol (FTP), Message Queuing Telemetry Transport (MQTT) asynchronous message service)
- IP address of the node initiating transmission
- message queuing information, if applicable.

2.2.3 The ship-shore communication system is to include the means for viewing the log entries described in [2.2.2].

2.2.4 The communication management software is to provide a separate log of the outages per communication device with a duration.

2.3 Components

2.3.1 Components for the ship-shore communication system are to be of a type approved and tested according to Pt C, Ch 3, Sec 6. Test certificates for conformity to other recognized standards accepted by the Society including, but not limited to, IEC 60945 may be considered. Tab 5 lists the notations for which the components as indicated in Pt C, Ch 2, Sec 15, [2], are to be chosen from the list of type approved products:

2.3.2 Case by case approval may also be granted at the discretion of the Society, based on the submission of adequate documentation and subject to the satisfactory outcome of any required tests.

2.3.3 Components for ship-shore communication systems are to be tested and installed according to the environmental categories (EC code) as defined in Pt C, Ch 2, Sec 1, [3.10].

2.3.4 The design, construction, commissioning and maintenance of computer based systems where they depend on software for the proper achievement of the ship-shore connectivity are to be in accordance with Pt C, Ch 3, Sec 3 requirements and are to comply at least with the requirements for Category I systems for hardware and software.

Table 5 : Applicability of the requirement to provide the type approved components to each notation

Notation	Type approved components are required	
	Hardware	Software
ASYNC-COM	Yes	No
ASYNC-COM-R	Yes	No
SYNC-COM	Yes	No
SYNC-COM-R	Yes	No

2.4 Onboard testing

2.4.1 The initial installation survey is to include functional tests in accordance with the onboard functional test programme.

2.4.2 As far as practicable, functional tests are to be performed in the expected condition of ship's operation:

- functional test of a connected system involving the corresponding data transfers with the shore
- all intended data producers connected
- if the same communication device is used for other types of communication, such a parallel usage is to be maintained without intentional disruptions throughout the test.

2.4.3 A test dataset is to be provided to check the communication management software independently from the connected system. The dataset is to include the files with the size, compression and encryption representing the range of the permitted data types and the maximum throughput for which the communication management software is designed. The dataset can be provided by the manufacturer of the communication software or by the integrator of the overall ship-shore communication system including the communication devices.

2.4.4 A test dataset is to be provided to check the ship-shore communication system in transmissions for the connected system. The dataset is to include the files of the size, compression and encryption representing the range of the data types generated by the connected system and the maximum throughput required by the connected system. The communication test data is to be provided by manufacturer of the connected system.

2.4.5 During the onboard test witnessed by a Surveyor, the system is to be operated to demonstrate the transfer capability on each communication device including:

- two-way transmission of the test datasets described in [2.4.3] and [2.4.4] between the ship and the shore
- generation of a transmission log.

2.4.6 During the onboard test, the transmission log is to be shown to the Surveyor in order to confirm that the test data is transferred in an order established by the priority.

3 Additional requirements for notation ASYNC-COM

3.1 General

3.1.1 The ship is to be equipped with a ship-shore asynchronous communication system providing regular data transfers sufficient to support the operation of a specific connected system.

3.1.2 If a shore database is used by the communication management software to store the data produced by the vessel, a status of the storage is to be regularly transmitted to the vessel and at least monthly. The status message is to include the time span of the stored data, which meets the requirements to the data quality and integrity identified for the connected system.

3.1.3 In case of a shore database failure which prevents data exchange with the vessel for a period, duration of which can compromise the data quality and integrity identified for the connected system, or in the event of a loss of the previously replicated data, the communication management software is to provide a notification to an operator on board the vessel or to the ROC operator.

3.2 Onboard testing

3.2.1 The initial installation survey is to include a verification of the transmission schedule in the communication management software.

4 Additional requirements for notation SYNC-COM

4.1 General

4.1.1 The ship is to be equipped with a ship-shore synchronous communication system providing data transfers with a latency below the latency threshold to support the operation of a specific connected system.

4.1.2 Latency threshold is to be defined by the Applicant for the synchronous communication as follows:

- For RC3 (Full remote control) degree of remote control as per NI641, the threshold is not to exceed 150 ms
- For RC1 (Available remote control) and RC2 (Discontinuous remote control) degrees of remote control as per NI641, the threshold is not to exceed 650 ms
- For RC0 (if the ship-shore communication system is not used for remote control as per NI641), the threshold is not to exceed 1000 ms.

For the threshold value selection, the latency is to be understood as the RTT measured between the onboard transport agent and the shore transport agent (see Fig 2 and Fig 3) and provided for the percentage of the communication system's uptime defined by the Applicant. The requirements for the latency are summarised in Tab 6.

Figure 2 : Latency composed of two components during the ship-shore transmission,

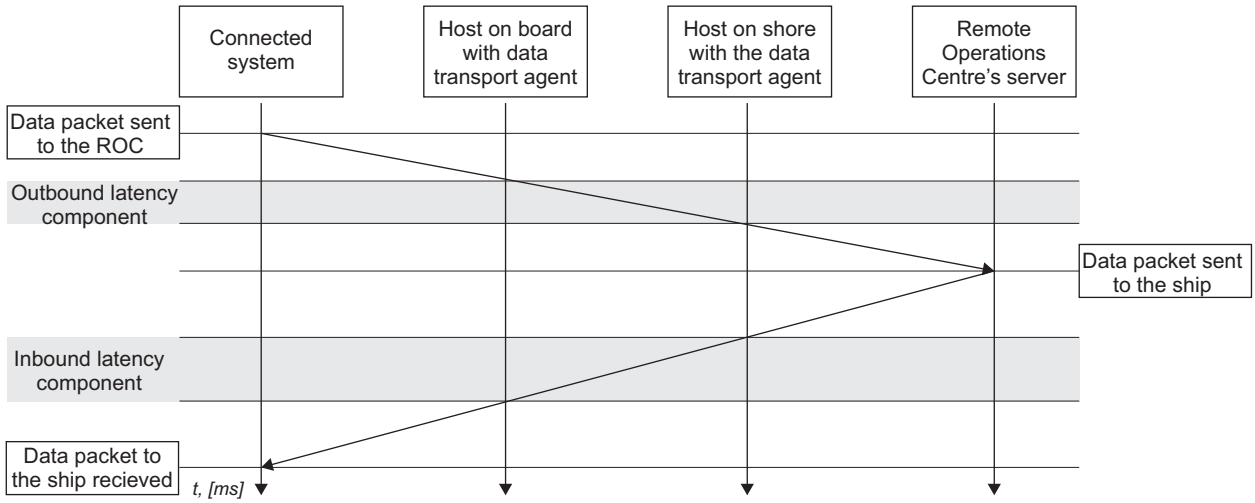


Figure 3 : Example of measuring the latency with the ping handshake

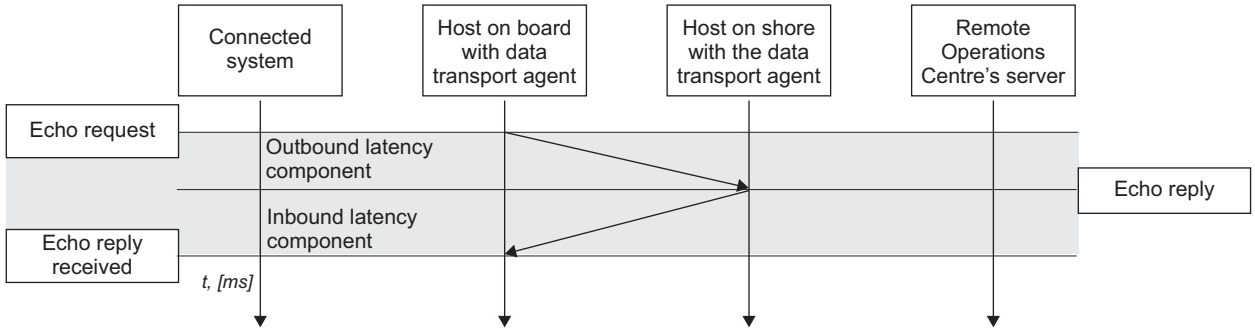


Table 6 : Latency threshold

Degree of remote control for the connected system	Maximum latency	Examples
RC3 (Full remote control)	150 ms	Manoeuvres in port and berthing with the ROC operator continuously providing input
RC1 (Available remote control) and RC2 (Discontinuous remote control)	650 ms	Automatic transit on a trajectory defined by the ROC operator, while the operator's continuous input is not required.
RC0 (No remote control)	1000 ms	Low latency monitoring solutions

4.1.3 Functional specification of ship-shore communication modes is to be defined including at least the normal, one intermediate degraded and one loss of communication states as per Tab 7. Fail-safe sequences are to be identified.

Note 1: It is recommended to deploy means of radio spectrum analysis for interference detection, e.g. sensitive omni-direction receiver antenna with a control and processing unit interfacing the ship-shore communication system. The antenna for spectrum analysis should have a frequency range adapted to the ship's radio communication frequency range, e.g. 9kHz to 18GHz, and mounted clear from the ship's transmitting antennas, if the ship's dimensions permit. Early detection of jamming may be used to alert the operators and to automatically redistribute the traffic to the intact communication channels. The timestamped jamming data may be further submitted to the local spectrum regulation authorities for mitigation.

Note 2: Application layer prioritisation is recommended for the degraded communication modes, e.g. prioritise the traffic related to navigation and collision avoidance over the video streaming from cameras.

Table 7 : Example of a table describing the operational modes of the ship-shore communication system

Mode	Mode's limiting parameters of the ship-shore communication system and of the measured traffic throughput	Effect on the connected system	Applicable operating instructions and emergency response procedures for personnel
Normal	Sets of parameters from [2.2.2] and [4.2.1] applicable for normal operation of the ship-shore communication system	Brief description of the global function of the connected system in nominal operation mode	Reference to the Operator Manual, ROC's standing orders, Onboard standing orders
Degraded	Sets of parameters from [2.2.2] and [4.2.1] applicable for degraded operation of the ship-shore communication system	Brief description of the effects caused by the degraded communication on the global function of the connected system. Automatic fail-safe sequences.	Reference to the Operator Manual, ROC's standing orders, Degraded communication checklist for the crew, Onboard standing orders. Manual fail-safe sequences in a form of checklists
Loss of communication	Sets of parameters from [2.2.2] and [4.2.1] representing the loss of the communication provided for the connected system	Effect due to a complete loss of the ship-shore communication. Automatic fail-safe sequences.	Reference to the Operator Manual, ROC's standing orders, Degraded communication checklist for the crew, Onboard standing orders. Manual fail-safe sequences in a form of checklists

4.1.4 The ship is to be provided with a digital user interface for automatically plotting the geographical position of the ship in relation to the connectivity coverage charts supplied as per [4.5.1].

4.1.5 Audio and visual alarms are to be provided at the control panel of the connected system on board in the event of the loss of communication.

4.1.6 The remote control user interface is to include:

- indication of the latency measured between the onboard data transport agent and the shore data transport agent
- alert in the event of exceeding the latency threshold
- alert in the event of loss of communication.

4.2 Software

4.2.1 Communication management software is to log the transmissions with a timestamp and store the following data:

- signal strength measured by each communication device in decibel-milliwatts (dBm)
- geographical coordinates and ship's heading
- latency measured between the onboard data transport agent and the shore data transport agent
- percentage of the uptime below the latency threshold on a modifiable sliding window which includes time spans of 15, 30 and 60 minutes
- inbound and outbound bandwidth distribution between the communication devices managed by the traffic balancing function
- active data traffic route for ship-shore exchange, e.g. static, SD-WAN, VPN
- azimuth and elevation for directed satellite antennas
- status of the ship-shore communication, the mode defined in [4.1.3]
- pitch and roll angles.

4.2.2 The ship-shore communication system is to include the means for viewing the log entries described in [4.2.1].

4.2.3 The ship-shore communication system is to use Forward Error Correction (FEC) for ship-shore transmissions.

4.2.4 The ship-shore communication system is to provide the following outputs to the connected system and to the shore data transport agent:

a) measured latency between the onboard data transport agent and the shore data transport agent

b) present mode defined in [4.1.3].

4.2.5 The communication management software is to provide visual and audible alarms on board and on shore in the event of a change of the mode defined in [4.1.3].

4.2.6 Where multiple communication devices are used, traffic balancing between the communication devices within the ship-shore communication system is to be provided. If an active connection fails, a changeover is to route the traffic through the remaining connections without interrupting the communication.

4.3 Protection against message errors

4.3.1 Where the ship-shore communication system is used for remote control over Cat. II or Cat. III systems, the data management agent is to provide detection of message errors for the data traffic involved in the control loop between the connected system and the ROC including:

a) sequence numbering

b) time-out monitoring.

4.3.2 The defences described in [4.3.1] may be implemented at the application layer of the data traffic between the connected system and the ROC.

4.3.3 Alternative means to [4.3.1] to ensure message timeliness and sequence may be accepted to the discretion of the Society as per recognised international standards, e.g. EN 50119:2020 Railway applications - Communication, signalling and processing systems - Safety related communication in transmission systems.

4.3.4 The software which provides sequence numbering or equivalent means of message sequence monitoring is to have testing facilities allowing to run functional tests of the protection against repetition, deletion, insertion and re-sequencing.

4.3.5 The detection of message errors described in [4.3.1] is to result in audible and visual alarms at the control panel of the connected system on board and in the remote control interface. The message errors are to be automatically logged.

4.4 Cyber Security

4.4.1 The ship is to comply with the requirements for assigning one of the notations **CYBER RESILIENT** or **CYBER SECURE** as defined in NR659.

Note 1: For the notation **CYBER RESILIENT**, the compliance to the standard IEC 61162-460 is accepted to the extent defined in NR659, Ch 3, Sec 2, [1.3] for the radio communication systems.

4.4.2 The communication management software is to be type approved according to the applicable requirements of NR659, Chapter 5.

4.4.3 The ship-shore communication system is to use secure connections (e.g. tunnels) with endpoint authentication, protection of integrity, and authentication and encryption at network or transport layer.

4.4.4 The gateway of the ship-shore communication system is to be provided with a locally posted instruction for manually disconnecting the gateway from the ship's network and for reinstating the gateway after the manual disconnection.

4.4.5 Where the ship-shore communication system is used for remote control over Cat. II or Cat. III systems, an emergency stop panel is to be installed on board in proximity to the control panel of the connected system. The manual operation of the emergency stop panel, e.g. pole switch, is to be able to either:

a) de-energise the gateway, or

b) activate a fail-safe sequence in the connected system which is to switch into a local control mode.

The emergency stop panel is to be protected from inadvertent operation.

4.4.6 Where separate gateways are used for control and for monitoring, the requirements of [4.4.5], item a) may be applicable only for the gateways used for the control data flow.

4.5 External communication provider

4.5.1 The coverage charts are to be provided on board and on shore in the ROC. A digital interface is to be provided to plot the quality-of-service data for each communication device on the connectivity coverage charts, including the signal strength, outages, and the name of the external provider, as measured during the transit in the areas.

Note 1: If cellular networks are used, the SLA should provide at least a single Guaranteed Bit Rate subscription which provides a latency below the latency threshold. It is recommended to choose the satellite communication provider's subscription with the equivalent of a Guaranteed Bit Rate, if available.

Note 2: It is recommended to choose SLA which includes provision and regular updates of the connectivity coverage charts indicating the signal strength in a format suitable for Electronic Navigation Chart overlay as per IHO S-57 or S-100 standards.

Note 3: The ad hoc networks are recommended for the areas with a high risk of the traffic congestion in the public wireless networks.

4.6 Risk assessment

4.6.1 Where the ship-shore communication system is used for remote control over Cat. II or Cat. III systems, the Risk and Technology Assessment (RTA) is to be provided as per NI641, Sec 2. The Risk and Technology Assessment may be limited to the items related to the ship-shore communication.

4.6.2 The Risk and Technology Assessment is to consistently refer to the mode specification and fail-safe sequences described in Tab 7 as mitigations.

4.7 Onboard testing

4.7.1 It is to be demonstrated to the Surveyor that during each functional test listed in [2.4] and [4.7] the latency threshold described in [4.1.2] has not been exceeded, unless the test includes intentional degradation of the latency or includes intentional interruption of the ship-shore communication.

4.7.2 For notations **SYNC-COM** and **SYNC-COM-R**, the two-way transmission of the test datasets described in [2.4.4] between the ship and the shore may be replaced by completion of the seatrials as per [4.7.7].

4.7.3 If directional antennas are used, the automatic azimuth seeking is to be tested by a performing a 360° turn.

4.7.4 Motion-compensated antennas are to be tested in the sea conditions. The test results may be presented to the Surveyor in a form of a sea trial report from the ship-shore communication system's integrator. The sea trial report is to include the trend and statistical data for the roll, pitch, latency and signal strength.

4.7.5 Where multiple communication devices are used, traffic balancing is to be validated in separate tests by

a) disabling the communication device with the highest outbound traffic allowance, and

b) disabling the communication devices operating on the same radio frequency band, if more than one radio frequency band is used.

4.7.6 Where the ship-shore communication system is used for remote control over Cat. II or Cat. III systems, the following tests are to be witnessed by the Surveyor for the data involved in the control loop between the connected system and the ROC:

a) tests for detecting repetition, deletion, insertion and re-sequencing

b) test for detecting a message time-out.

c) test of the local emergency shut down of the remote control as per [4.4.5] and [4.4.6].

4.7.7 The sea trials are to be performed to validate the functional specification of ship-shore communication modes defined in [4.1.3]:

a) In the normal operational mode the limiting parameters are not to be exceeded and the connected system's functions are to be demonstrated to the Surveyor.

Note 1: The RTT for RC1 and RC2 between the ROC server and connected system (Fig 2) should not exceed the values recommended in NI641, Sec 3, Table 1. The RTT for RC3 between the ROC server and connected system should not exceed 300 ms.

b) Remaining connected system's functions and fail-safe sequences are to be demonstrated when transitioning to the degraded mode

c) Fail-safe sequences are to be demonstrated when transitioning to the mode with a lost ship-shore communication.

4.7.8 The sea trials specified in [4.7.7] are to be either:

a) witnessed by a Surveyor on board, or

b) witnessed by a Surveyor remotely from the ROC.

5 Additional requirements for notations ASYNC-COM-R and SYNC-COM-R

5.1 General

5.1.1 The communication system is to be split into at least two redundant groups of equipment each consisting of minimum one communication device, one gateway to the connected system and one power source. The redundant groups are either

- to provide an equivalent total geographic coverage, or
- to overlap the restricted geographic region where the connected system is to use the ship-shore communication.

5.1.2 Notifications for a loss of redundancy due to a component failure and for a failure of the automatic changeover function are to be provided at the control panel of the connected system on board and in the remote control interface.

5.1.3 Each redundant group is to be supplied with an independent Uninterruptible Power Supply system (UPS) providing a sufficient capacity for 30 minutes of operation following a loss of the main power supply.

5.1.4 The antenna arrangement of the communication devices is to prevent any interference with the other transmitting and receiving equipment including the channel overlap and is to prevent a simultaneous masking of the signal path for all redundant communication devices at a time on any ship's heading.

Note 1: If the ship's dimensions permit, it is recommended to install at least one antenna at the fore in addition to the antennas mounted on the navigation bridge.

5.1.5 Each communication device and gateway is to be protected against an inadvertent shutdown by an operator.

5.1.6 For notation **SYNC-COM-R**, redundant transmission between the ROC and the ship is to be maintained via at least one communication device in each redundant group simultaneously.

5.1.7 In the event of a failure of the communication device in primary use, a notification is to be produced at the control panel of the connected system on board and in the remote control interface, the transition to the redundant communication device is to be automatic and without any intervention from the operator. As a minimum, two communication devices are to be running at a time, each from a separate redundant group.

5.1.8 A top-down Failure Mode and Effect Analysis (FMEA) is to be submitted and is to provide a conclusion about the effect on the ship-shore communication functions from a single point failure. The FMEA is to demonstrate the fault ride through capabilities and the overall redundancy of the ship-shore communication system. The FMEA is to take into account the independence of the corresponding external networks and inputs from the ship's sensors, e.g. heading indicators such as gyros. The perimeter of the analysis for the onboard installation is to extend from the transmission channels till the gateways which connect to the ship's network, including the gateways themselves.

Note 1: While it is understood that other hazard analysis methods exist, such as System Theoretic Process Analysis (STPA) and Functional Resonance Analysis Method (FRAM), the primary focus of the analysis is on the component failure where FMEA is deemed sufficient for the perimeter of the ship-shore communication system. The software error type hazards are to be managed as per the requirements for the computer based systems described in Pt C, Ch 3, Sec 3.

5.1.9 Single failures considered by the FMEA are to include, but not limited to:

- loss of any single component
- common cause failures in several components that may arise from a failure or malfunction in one component
- for each communication device, interferences limited to its operational radio frequency band(s)
- if applicable, simultaneous masking of multiple antennas by large objects common to the intended area of operation, e.g. bridges.

Loss of all components located in a given space that would be affected by fire or flooding need not be considered.

5.1.10 The FMEA tables may be prepared based on the requirements of IEC 60812:2018 and the example in the Tab 8 with the following columns adapted to the redundant ship-shore communication:

- the final effect of a single failure is given as the resultant status of the ship-shore communication (loss of function occurred or not)
- severity and probability columns are not required as the target configuration is redundant and as the probability of a single failure is not to be the subject of the study.

Table 8 : Example of a FMEA table for the notations ASYNC-COM-R and SYNC-COM-R

SYSTEM:	VSAT (Very Small Aperture Terminal)
SUB-SYSTEM:	ACU (Antenna Control Unit)
CONFIGURATION OF COMMUNICATION SYSTEM:	VSAT and FBB running simultaneously, FBB in hot standby, VSAT is the primary
DRAWING REFERENCE:	

FMEA ID	Component name Location and ID	Failure mode and Cause	Immediate local effect	Effect on other redundant groups and other systems	Global effect on Communication	Detection and Indication to Operator	Means of Protection and Mitigation	Reference to FMEA validation testing
ACU1	Model name, Antenna Control Unit (ACU) Instrument room ACU-abc1	Loss of heading input due to a loose cable or a failure of the gyro feeding the signal	No effect propagation to other systems, failure effects contained within the perimeter of the VSAT communication system	If there is no heading input due to the failure, alarms are indicated on the ACU display. Antenna switches to gyro-free mode automatically	Changeover to the secondary satellite communication system FBB (Fleet Broad Band) within 30 seconds. A traffic management policy applied according to the criticality, the transmission for the category X bandwidth consumers is maintained without disruptions	A visual and audible notification in the onboard portal of the communication system	Automatic changeover switch between VSAT and FBB	Test No 3 "Loss of Gyro Signal"

5.1.11 The FMEA is to be complemented by:

a) Topology diagram for power supply and network demonstrating the attribution to the redundant groups with a distinct colour coding. An example is provided in Fig 4.

b) Reliability block diagram demonstrating the changeovers with the same colour coding as per item a). An example is provided in Fig 5.

c) Test programme designed to confirm the fault detection, protection and redundant functions by simulating applicable single failures of the components.

5.1.12 The FMEA is to document any common elements and cross-connections between the redundant groups. If there are no cross-connections, it is to be stated explicitly. If the cross connections exist, each of them is to be isolated while the ship-shore communication system is in operation.

5.1.13 For notation **ASYNC-COM-R**, a network component of ship-shore communication system which is installed according to the environmental category EC11 (air conditioned command and control stations, accommodation spaces) may be exempted from the requirement [2.3.1], if the component is a part of a redundant group.

5.2 Onboard testing

5.2.1 During the onboard test witnessed by a Surveyor, the functions of the redundant design are to be checked according to the FMEA test programme, including:

- alarms in the event of failures
- automatic switching of the communication device in primary use
- alarm for Uninterruptible Power Supply (UPS) in a by-pass mode
- UPS endurance testing to confirm the available charge capacity.

Figure 4 : Dual redundant topology example with colour coding

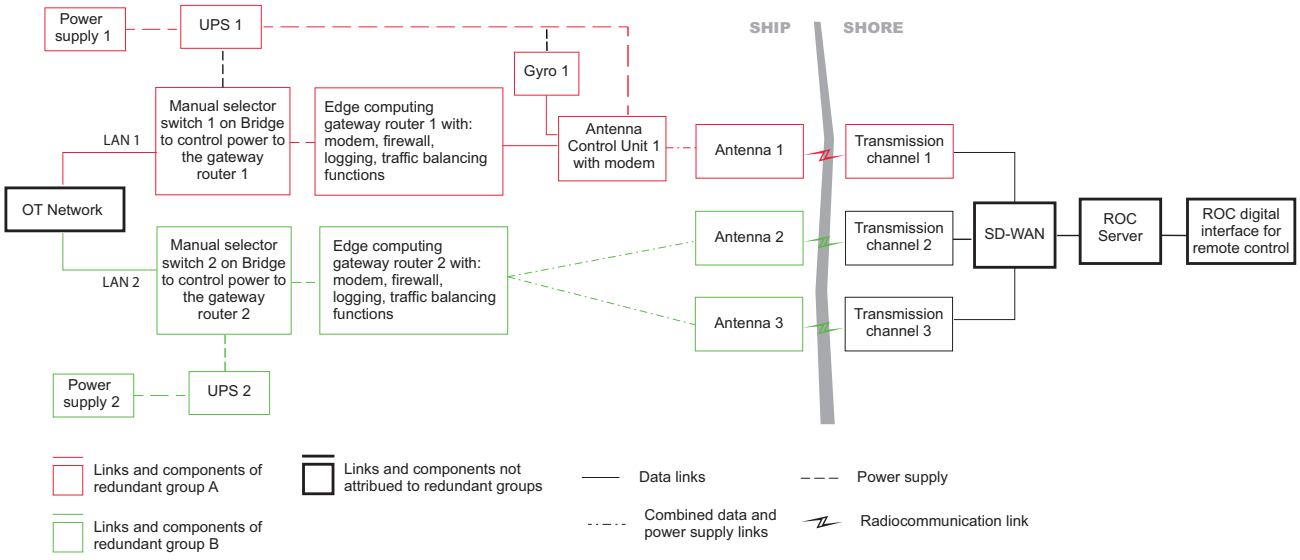
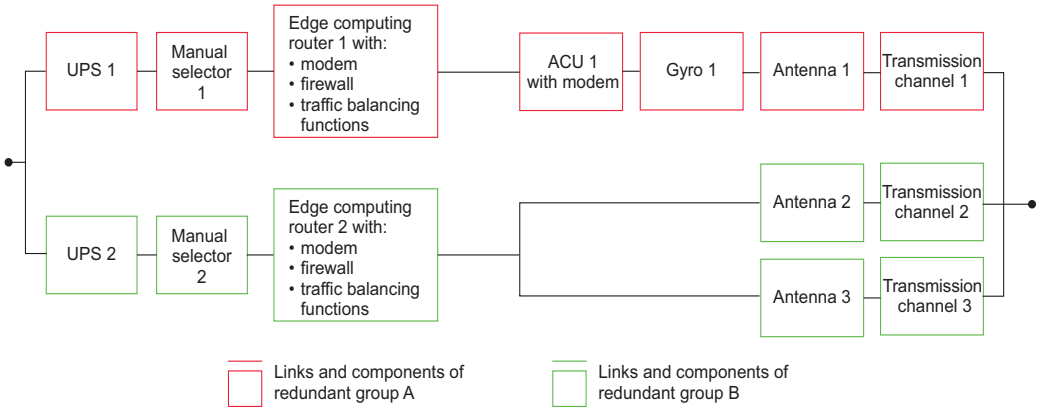


Figure 5 : Reliability block diagram for the example of topology. Components in at least one path through the diagram must be operational in order for the system to perform its designed function.



Section 4 Data Infrastructure (DATA-INFRA)

1 General

1.1 Scope and application

1.1.1 The additional class notation **DATA-INFRA** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.5], to ships fitted with data infrastructures complying with the requirements of this Section.

Data infrastructures consist of data assets, technologies, organisations and data management processes, which ensure reliable collection, transmission, storage, sharing and availability of data to multiple data consumers, as defined in [2].

Note 1: Smart functions are data consumers. For smart functions definition and requirements, refer to Rule Note NR675.

The additional class notation **DATA-INFRA** may be complemented by the suffix **-STAND**, when the data infrastructure implements international standards or norms, which ensure a higher level of interoperability with other systems, and complies with additional requirements given in Articles [6], [9] and [10].

Note 2: By providing access to a wide variety of ship data, data infrastructures are an enabler to ship digitalization, and a support for the implementation of visualization, analytic, augmented decision making or operations optimization.

Note 3: Reliability and interoperability of data infrastructures along with by cyber security and data quality framework, are essential for the implementation of new technologies onboard ships.

1.1.2 The scope of the data infrastructure is specified by the following documentation:

- Infrastructure description, defined in [4.1], which includes systems and boundaries definition, along with specification of implemented data standards.
- Data Producer Inventory, defined in [4.2], with the list of collected ship data.
- Data Consumer Inventory, defined in [4.3], with the list of expected data consumers and, when applicable, supported smart functions.

1.1.3 This Section does not apply to, or supersede requirements for:

- systems for which a direct control is to be ensured (e.g. automation systems)
- systems already covered by other requirements such as IEC 61162 network (navigation network)
- systems already covered by other additional class notations (e.g. **AUT-IMS**, **SYS-IBS**).

Note 1: However, these systems (e.g. automation) may be interfaced with the data infrastructure to ensure digitalization and access to these data by data consumers.

1.1.4 This Section does not cover:

- Cyber security for which reference is made to NR659 “Rules on cyber security for the classification of marine units”.
- Remote control (only telemetry is covered). Therefore data infrastructure for autonomous or remote-controlled ships, are not covered.
- Ship functions which require a (near) real time access to data.
- Data processing related to a dedicated usage, algorithm specifications, data consumers or any dedicated application or use of these data.
- Other onboard ship network and ship-shore communication devices and their interface with data infrastructure.

Note 1: See Article [2] for the definition of “other onboard systems”.

1.2 Type approval

1.2.1 For component, sub-systems or devices requested to be type approved product, the Type Approval scheme is described in Rule Note NR320 “Certification Scheme of Materials and Equipment for the Classification of Marine Units”, and consists of the following steps:

- documentation review
- type testing
- issuance of Type Approval Certificate.

1.2.2 Any significant modification to the data infrastructure is to be notified to the Society, and a new approval is to be carried out.

Note 1: A significant modification is a modification which influences the functionality and/or the safety of the system.

2 Definitions

2.1 General

2.1.1 The following general definitions are used in this Section:

- Buffer:
  Storage used temporarily while data is being moved from one place to another
- Data consumer:
  User interface, system or tool that uses data.
- Data pipeline:
  Succession of data processing elements, where the output of one element is the input of the next one.
- Data producer:
  Device, sensor, user interface, automation, service or system that collect data on board.
- Edge computing:
  Distributed computing paradigm that brings computation and data storage closer to the sources of data in order to improve response times and save network bandwidth.
- Ethernet:
  Family of networking technologies commonly used in LAN (specified in IEEE8 802.3)
- Fault tolerance:
  Refer to the ability of an IT system (hardware or software) to continue its operation without interruption when one or more components fails.
- High availability:
  Refer to the ability of a system to minimize downtime in case of critical failure.
- Indicator (Key Performance or Data Quality):
  Quantifiable measure of performance of a given objective over time.
- Interoperability:
  Ability of two or more systems, or components, to exchange information and to use the information that has been exchanged. The Levels of Conceptual Interoperability Model (LCIM) defines different levels of interoperability:
  - Level 0: no connection between devices
  - Level 1: technical level, a physical connectivity is established allowing bits and bytes to be exchanged
  - Level 2: syntactical level, data can be exchanged in standardized formats, (i.e. the same protocols and formats are supported)
  - Level 3: semantic level, not only data but also its contexts (i.e. information) can be exchanged. The unambiguous meaning of data is defined by common reference models.
- IP:
  Set of communication protocols used on the Internet or similar computer networks.
- Local Area Network (LAN):
  Physical or virtual computer network that interconnects devices within a limited area (e.g. machinery room, ship...).
- Metadata:
  Data defining and describing (e.g. providing context of) other data
- Modbus (Modicon bus):
  Data communication protocol. Modbus supports communication to and from multiple devices connected to the same cable, or Ethernet network.
- Message Queuing Telemetry Protocol (MQTT):
  (One among other) protocol for the Internet of Things (IoT) designed as a lightweight publish/subscribe messaging transport that enables remote devices connection with a small code footprint and minimal network bandwidth.
- OPC Open Platform Communication (OPC):
  Interoperability standard, developed by the OPC Foundation, for the secure and reliable exchange of data in the industrial automation space.
- Other onboard devices or systems:
  Refers to ship systems or devices which are not part of, but are connected or interfaced with, the data infrastructure covered by this Section.

Note 1: As stated in [1.1.4], the requirements of this Section do not apply to other onboard devices and systems.

- Programmable Logic Controller (PLC):
  Industrial controller adapted for the control of process.
- Purposely installed (devices):
  Refer to ship systems or devices in the scope of the data infrastructure as defined in this Section.

- Quality of Service (QoS):
  Any technology that manages data traffic to reduce packet loss, latency and jitter on a network. QoS controls and manages network resources by setting priorities for specific types of data on the network.
- Server:
  Computer that manages access to centralized resources or services within a network.
- Service Level Agreement (SLA):
  Commitment between a service provider and a client which specifies the service provided, with respect to different measurable aspects (e.g. availability, performance...). In particular, a Data Quality Service Level Agreement (DQ SLA), is an agreement that specifies data consumers expectations in term of data validity rules (e.g. completeness, timeliness...), and the corresponding level of acceptability. Service provider supports are usually part of the SLA (e.g. response time, action...).
- Service Level Definition (SLD):
  Specification of the service provided, with respect to different measurable aspects.
- Telemetry:
  Collection of data (e.g. measurements) at remote points and their transmission to a receiving equipment for monitoring, through one way data flow.
- Voyage Data Recorder (VDR):
  Data recording system designed for vessels required to comply with the requirement of SOLAS (IMO Res.A.861(20)).
- Zigbee:
  (One among other) communication protocol used for wireless connection (defined in IEEE 802.15.4).

2.2 Data Infrastructures

2.2.1 Data infrastructures are usually constituted by:

- One or more acquisition LAN, which perform the collection and transfer of data.
- Ship network, which enables transmission of data from acquisition LAN to end server.

Note 1: Data infrastructures are usually connected to an other on board ship network.

- Ship-shore communication system, which enables transmission of data from ship to shore.

Note 2: Data infrastructures are usually connected to an other on board ship-shore communication system.

- Data server, which can be cloud, shore or ship based. The server hosts data, supports multiple functionalities such as control, sharing and availability to data consumer.
- Data management policies or organisation: policies or organisation ensuring proper data sharing, maintenance, quality assurance and uniform data management.

Note 3: Data infrastructures should be supported by qualified organisations, process and technologies to ensure data quality management and access to reliable data (refer to [10.3]).

2.3 Acquisition LAN

2.3.1 For the purpose of this Section, the term “acquisition LAN” refer to devices, and to the corresponding Local Area Network, designed to collect or share data from different data producers and that may ensure their transmission to a server.

Note 1: Multiple acquisition LAN, provided by different suppliers may be fitted on a single ship.

2.3.2 The acquisition LAN is usually constituted by:

- Data logger: network device fitted with computational capabilities, internal storage and acting as a gateway to connect different types of networks or devices.
- Purposely installed network devices which ensure data transfer and communication (e.g. “L2 switch”, “Zigbee to TCP/IP Modbus Gateway”...).
- Data producers, which can be:
  - purposely installed (e.g. sensors)
  - other on board systems (e.g. Alarm Monitoring System, VDR...).
- Devices interconnection (e.g. wired / wireless).
- Power sources.

Note 1: The acquisition LAN may be very simple, for example when data infrastructure only collect data from existing other on board system such as Alarm Monitoring Systems (AMS).

2.4 Data logger

2.4.1 A data logger may be constituted by:

- Data acquisition interface, which ensures acquisition of data from various data sources (i.e. analogue / digital, batch / streaming).
- Gateway, which ensure the interface, communication and data flow between different networks.
- Buffer, which ensures temporary data storage.

- Embedded data processing capabilities.
- Data communication and network capabilities.
- Administration management functions.

3 Documentation to be submitted

3.1 General

3.1.1 The documents to be submitted for granting additional class notation **DATA-INFRA** or **DATA-INFRA-STAND** are listed in Tab 1.

Further documentation may be requested for approval or for information by the Society on a case-by-case basis.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Description	References in the Section
INFRASTRUCTURE DESCRIPTION			
1	I	Infrastructure definition: - Data infrastructure SLD - Data Quality SLD - Supported standards	[4.1]
2	I	Data Producer Inventory	[4.2]
3	I	Data Consumer Inventory	[4.3]
4	A	Architecture	[4.4]
5	I	Data quality framework	[10.3]
SHIP NETWORK AND COMMUNICATION			
6	I	Bandwidth calculation **(2)**	[8.1]
INSTALLATION AND TESTING			
7	I	Ship-shore communication subscription	[11.2]
8	A	Testing protocols	
9	I	Onboard documentation: - User's manual - Installation manual - Maintenance manual - Sensors maintenance plan	
10	I	Identification of personnel in charge of network management and maintenance	

(1) A : To be submitted for approval; I : To be submitted for information
(2) On request of the Society

4 Infrastructure description

4.1 General

4.1.1 Objectives and boundaries

A general description of the data infrastructure is to be provided, with overall goals and objectives for the ship, or ship management.

Description of systems covered by the data infrastructure, with identification of the boundaries between purposely installed system, and other on board systems are to be provided (see Fig 1).

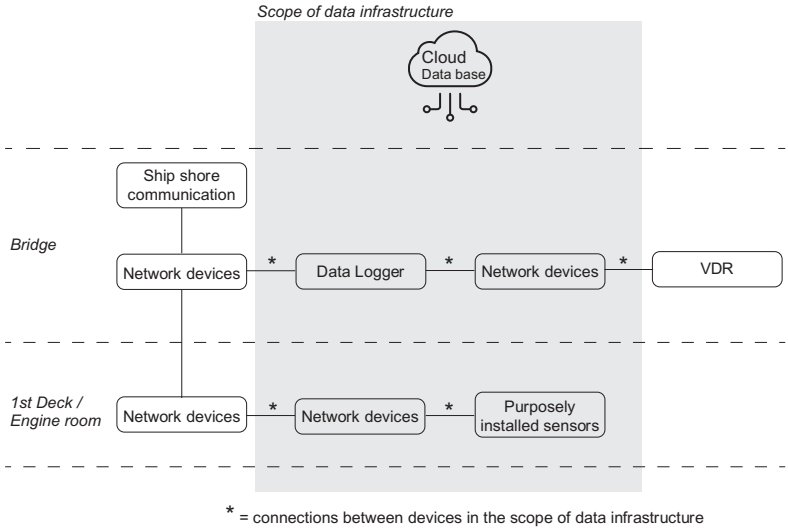
The data infrastructure usually relies on other on board ship network devices, or on other on board ship-shore communication system, for the transmission of data.

Note 1: By definition, other on board ship network devices are not covered by the requirements defined in this document.

However, depending on the architecture the supplier may install additional devices in order to support the data infrastructure. In that case following are to be submitted:

- documentation on additional ship network devices, if any,
- documentation on additional ship-shore communication devices, if any.

Figure 1 : Example of data infrastructure boundary diagram



4.1.2 Data infrastructure Service Level Definition (SLD)

A data infrastructure Service Level Definition (SLD) is to be provided with a list of indicators qualifying the expected performance or reliability of the data infrastructure.

The data infrastructure SLD is a supplier input, therefore the list of indicators, where the indicator is assessed (e.g. cloud, on board) and the corresponding targets are the responsibility of the supplier. An example of data infrastructure SLD is given in Tab 2.

Note 1: When applicable, the indicators are to be monitored, refer to [10.4].

Note 2: The SLD may be considered as a basis for Service Level Agreement between the data infrastructure supplier and the Owner.

Note 3: When services do not meet targets, customer support, remediation processes, responsibilities and escalation plan (e.g."inform IT team support, then inform software manager") should be defined.

4.1.3 Data Quality Service Level Definition (DQ SLD)

Data Quality Service Level Definition (DQ SLD) is to be provided with a list of data quality dimensions setting up the expected quality of data. Corresponding targets are to be specified (and business rules when available).

The DQ SLD is a supplier input and therefore the list of dimensions covered, along with corresponding targets, is the responsibility of the supplier. An example of DQ SLD is provided in Tab 3.

Note 1: The DQ SLD is part of data management (refer to [10]).

Note 2: When applicable, indicators are to be monitored by the infrastructure, refer to [10.4].

4.1.4 Data standards

For the assignment of the notation **DATA-INFRA-STAND**, data standards supported by the data infrastructure are to be specified and comply with additional requirements given in [6], [9] and [10].

Table 2 : Example of data infrastructure SLD

Topic	Measure	Metric	Target
System performance	Data retention time (cloud)	Estimated storage time for database, backup and log (cloud)	5 years
	Data latency /freshness (cloud)	Average latency between data producer and availability in the (cloud) data base	for sensors: 15min
	Timestamp accuracy	Average latency between data producer and data time stamping	for sensors: average 1ms
Reliability	Server availability (cloud)	Monthly uptime (%): $\frac{\text{Maximum available minutes} - \text{Downtime}}{\text{Maximum available minutes}}$	99%
	Back up frequency of (cloud) database	Frequency	once a day
	Recovery time (cloud)	Expected time to recover the system from catastrophic failure	24h

Table 3 : Example of DQ SLD

DQ Dimension	Business Rule	Measure	Target
Completeness	Database fields should be complete	% of displayed values that are not “Null” or “NaN”	> 90%
Uniqueness	ID or TAG should be unique for a data element	% of unique element	> 95%
Validity	Data element (physical sensor values) should be inside the sensor “range” defined in metadata	% of values inside sensor range	> 85%
	Data element should be of the correct type	% of value with the correct ‘type’	> 80%
	Data element should be of the correct format	% of correct format	> 77%
	Transmission error should be as low as possible	% of message transmission error	> 80%
Timeliness	Data element (sensor) present in the database has been refreshed during the last 6h	% of element not refreshed	< 10%
	Data element timestamp should be correct	% without incorrect or missing timestamp	> 90%
Accuracy	Sensor value should not present a slope or a drift in values (not physical behavior)	% of value with a drift in the median value (over the past 2month)	< 10%
	Sensors calibration should be up to date	% of sensors calibrated	> 95%

4.2 Data Producer Inventory

4.2.1 An inventory of the data producers is to be provided (see Tab 4):

- data producers, with indication of:
  - data producer name, with ID or TAG
  - “purposely installed” (e.g. sensors) or “other on board systems” (e.g. “organisation logbook”)
  - source system producing the data (e.g. sensors, VDR...)
  - on board location, when applicable.
- list of data collected and transferred, with indication of:
  - data ID or TAG
  - data or parameter description
  - data type
  - data unit
  - calibration period, for purposely installed data sources
  - acquisition interval with signal processing if any (e.g. instant, average, maximum)
  - transmission interval
  - acquisition interval.

Table 4 : Example of Data Producer Inventory

Data producer name / #TAG #ID	Purposely installed / Other onboard system	Onboard location	Data Description	Data TAG / ID	Data type	Unit	Source calibration period	Signal processing	Transmission time
Sensor #ME1	Purposely installed	Engine room Main diesel generator Generator Rotor shaft							
			bearing temperature	254032 _temp	scalar	°C	yearly	15min / maximum value	hour
AMS #AMS34	Other onboard system	Bridge							
			latitude	lat	scalar	geodetic system	Not Applicable	5min / instant	hour
			longitude	long	scalar	geodetic system	Not Applicable	5min / instant	hour
Bridge #report2	Other onboard system	Bridge							
			Noon reports content	org_2	string	Not applicable	Not Applicable	event driven / instant	event driven

4.3 Data Consumer Inventory

4.3.1 A general inventory of expected data consumer is to be provided (see Tab 5). Inventory may include but is not limited to:

- data consumer name
- type of data consumer (e.g. visualization, analytic, models for optimization...)
- corresponding smart function, when applicable

Note 1: smart function are defined in NR675, Sec 1.

- general description.

Table 5 : Example of Data Consumer Inventory

Data consumer	Visualization / Analytic / Models	Smart function (see NR675)	Description
Current vessel position	Visualization	–	Display current vessel position (AIS) on a world map
Vessels voyages	Visualization / Analytic	–	Display vessel past voyage on a world map. Detailed information on previous voyages are accessible
Swell	Visualization / Analytic	–	Swell height, swell direction, swell spectra
Diesel Engine Analysis	Visualization / Analytic	MH	Diesel engine RPM and efficiency analysis
Noon report visualization	Visualization	–	(Read) access to noon report

4.4 Architecture

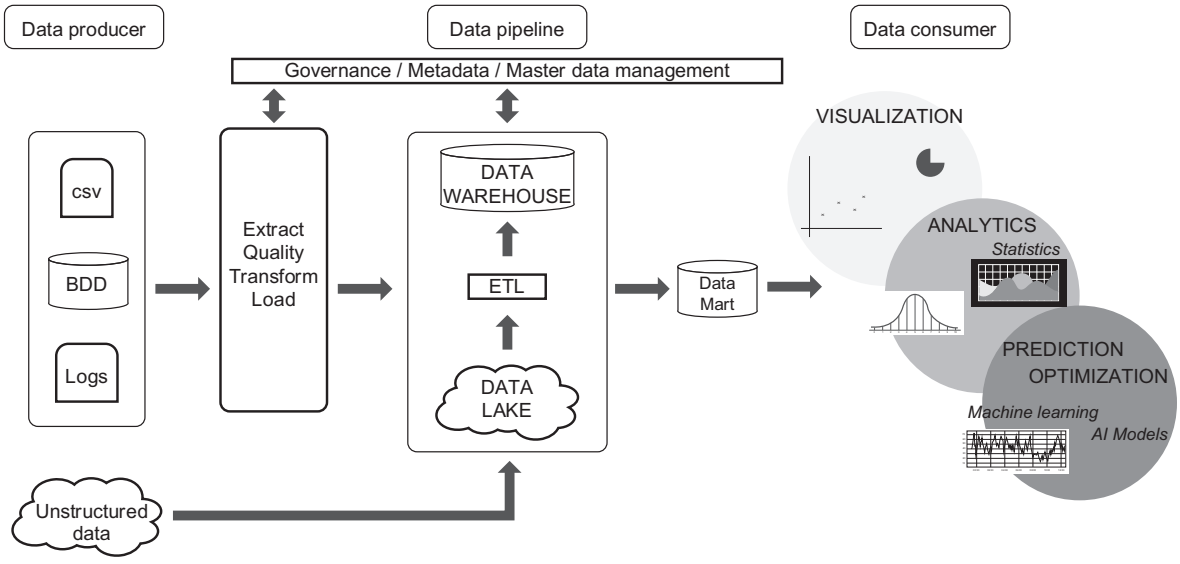
4.4.1 Data flow

The data-flow architecture is to be submitted (see Fig 2), with:

- A general data flowchart, from data producers to intermediate and final repositories. When applicable, data consumers may be considered.

Note 1: It is recommended to indicate general database architecture (e.g. Data Warehouse, Data Lakes...) with specification of the product/API used (e.g. SQL, MongoDB...).

Figure 2 : Example of data flow



4.4.2 Acquisition LAN

A detailed scheme or diagram detailing the acquisition LAN is to be provided (see Fig 3), with:

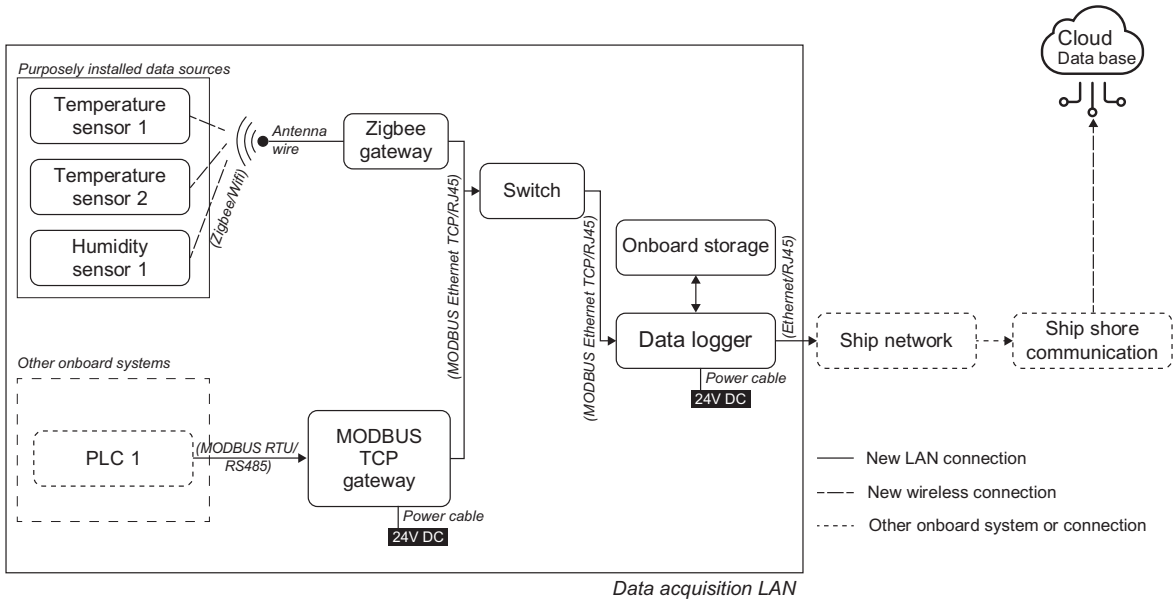
- identification of data producers:
  - purposely installed
  - other on board systems connected to data infrastructure

Note 1: Data producers are detailed in the Data Producer Inventory

- identification of network devices:
  - purposely installed (e.g. data logger, switch)
  - other on board network devices at the interface of the acquisition LAN
- connection between different devices, with indication of physical connection, direction of the communication (bidirectional or one way), and protocol (e.g. Modbus Ethernet TCP / RJ45, Zigbee / Wi Fi…)
- power sources

Note 2: It is to be noted that each solution may differ from one to another, therefore a clear definition of data flow and infrastructure is to be provided with identifications of boundaries between purposely installed devices and other on board systems.

Figure 3 : example of acquisition LAN architecture



4.4.3 Data logger specifications

Technical documentation of the data logger is to be provided, with:

- general description
- connectivity specification:
  - number of ports with indication of the connection type (e.g. Ethernet RJ45, Wi-Fi 5GHz, field buses …)
  - supported protocols (e.g. TCP/IP, MODBUS TCP/IP, HTTPS...)
  - maximum number of devices that can be connected, when applicable
  - maximum input rate under which the equipment can perform its functions
- power supply
- data processing functions (e.g. “max”, ”min”...).

4.4.4 On board data server specifications

When data server is located on board, general description of server capability is to be provided. Technical documentation is to be provided, that may include, but is not limited to, the following:

- connectivity specification
- power supply, when applicable
- processing performance (e.g. number of source, response time...) for request-response services for data input, data output, and streaming services may be requested by the Society on a case-by-case basis.

4.4.5 On board buffer specifications

On board buffer capacity is to be provided, with estimation of the maximum buffering time (e.g. estimation in days) based on a common ship usage and at full use of the available inputs. Design scalability (refer to [5.1.3]) of the data infrastructure is to be considered in the calculation (e.g. 20% increase).

4.4.6 Purposely installed network or ship-shore communication devices specification

When additional devices are added by the data infrastructure supplier to the ship network or to the ship-shore communication system, they are in the scope of this section and their documentations are to be submitted.

5 Requirements for acquisition LAN

5.1 General

5.1.1 Component

Purposely installed data infrastructure components are to be type approved products (as indicated in Pt C, Ch 2, Sec 1, [4]). They are to be approved on the basis of the applicable requirements of the Rules and in particular the ones defined in Part C, Chapter 3. Tab 6 list the requirements regarding components' type approval.

Table 6 : Type approval requirements

Notation	Type approved products	
	Software	Hardware
DATA INFRA	yes	yes
DATA INFRA-STAND	yes	yes

5.1.2 Data communication links

Data links are to comply with following requirements:

- Characteristics of data link are to prevent overloading in any operational condition of system.
- Data link are to be self-checking, detecting failures on the link itself and data communication failures on nodes connected to the link. Detected failures are to initiate an alarm.

Especially, wireless data links are to comply with following requirements:

- Recognized international wireless communication system protocols are to be employed, incorporating message integrity: fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message
- The internal wireless system within the vessel are to comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements. Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

5.1.3 Scalability

The acquisition LAN is to be designed and the corresponding devices are to be chosen, in order to ensure as far as possible scalability, such as: input/output channel expansion, increase of storage capability, computational resources, compatibility between devices, support of multiple data transmission protocols.

Scalability is to be considered during the design stage.

5.1.4 Availability

High availability of the data infrastructure is to be ensured, especially:

- supporting software are to be fault tolerant
- acquisition LAN devices are to restart automatically (i.e. without intervention of personnel) after loss of power supply or interruption
- in case of a device communication loss, re-initialization and re-establishment of the connection is to be automatically performed.

Note 1: Availability of the data infrastructure may be part of the infrastructure SLD (e.g. 99,9% availability).

5.1.5 Network separation

The acquisition LAN and the corresponding devices are to be separated from ship's essential services networks.

5.1.6 Separation with other on board systems

In no case, the presence of purposely installed devices (e.g. data logger, gateway...) for the collection of other on board systems data are to impact the availability, the functionality or to interfere with these other on board systems.

Especially, purposely installed collection devices used to collect information, and the corresponding supervision interface, are to use strong separated and safe logical environments (e.g. data diode). So that the system is not to be able to alter the origin data, software or hardware, purposefully or not purposefully.

Risk analysis or technical specification may be requested by the Society on a case-by-case basis, to justify the separation with other on board systems. Especially, purposely installed collection devices are to be located, and mounted, at a distance from the other on board systems, in order to avoid any perturbation of the other on board systems or instrumentation.

5.1.7 Back-up

Back up and restore are to be available for all purposely installed devices.

Procedures for diagnostic, re-installation and restoration of equipment, system or solution are to be available on board to the attention of responsible personnel.

5.1.8 Integrated system

Integrated systems are to comply with requirements stated in Pt C, Ch 3, Sec 3, [7.7].

5.2 Data producer

5.2.1 Purposely installed sensors design

Sensors are to be approved on the basis of the applicable requirements of this Section and of Part C, Chapter 3.

Sensors characteristics (e.g. precision, range, accuracy…) are to be appropriate with regard to the physical parameter to be monitored, and when applicable to the data consumers (e.g. optimization model).

Note 1: Sensors metadata should be available in the information model (refer to [10].

Note 2: When the data infrastructure aims to support data-driven data consumers, the requirements of stakeholders in charge of algorithms development are to be considered during sensor selection, and data infrastructure design (e.g. sampling time). Indeed sensors characteristics such as precision or range may have an impact on models, on the confidence interval of the prediction... thus limiting performances (e.g. numbers of false negatives).

5.2.2 Purposely installed sensor location

Sensors are to be located such as they provide a reliable measurement of the physical parameter to be monitored. Manufacturers or international standards specifications are to be considered.

Note 1: The position of sensors with regard to the physical parameter to be monitored is the responsibility of the designer and it should be confirmed after installation during deployment phase by the mean of inspections or measurements.

5.2.3 Purposely installed sensor calibration

When applicable, sensor calibration information (or certificate) are to be available in the data infrastructure or integrated. This is part of the information model (refer to [10]).

When applicable, the sensors are to be selected and installed in such a way that a periodical on-site recalibration can be carried out.

5.2.4 Purposely installed sensors on board identification

Sensors are to be installed with permanent means of identification.

5.3 Data logger

5.3.1 Computer based system

Data loggers are computer based systems and are to comply with requirements of Pt C, Ch 3, Sec 3, as Category I system.

In addition, the following documentation is to be submitted for information:

- software functional description and associated hardware description
- test program for on board tests, including wireless network testing.

5.3.2 Functions

Data loggers computational resources and internal memory are to be sufficient to ensure data acquisition, network connectivity, and to support functions listed in [6]:

- management functions
- communication and data input / output functions
- data processing functions
- data buffering functions
- log management functions.

5.3.3 Continuity of operation

Data loggers are to be able to detect and handle the loss or interruption of communication (e.g. timeout), and to ensure continuous operation of data acquisition and data storage, without loss or overwritten of data.

5.3.4 Integrity

Data loggers are to ensure integrity of recorded information. The process for writing data or files is to be at system level.

Administration profiles, or operators profiles are not to have other access right than read only.

Operators with backup rights, are not to have read access rights.

5.3.5 Alarm and status reporting

Data loggers are to be fitted with a status reporting interface with indication of the system status (e.g. normal, abnormal).

Detected failures are to initiate an alarm. A no-fault condition is to be positively indicated (e.g. green LED lighted).

5.3.6 Connection to ship network

When data loggers are connected to the ship network, a wired, Ethernet interface which enables a minimum transmission rate of 100 Mbps (fast Ethernet), is to be provided.

5.3.7 Direct access

An on board direct connection to data logger is to be provided (e.g. console port) for debugging or maintenance purpose.

5.3.8 Buffer

Data logger are to be provided with non-volatile, buffering storage capacity of sufficient size to avoid loss of collected data during network issue.

A data buffer able to store the following data on board for a minimum of 30 days is to be provided:

- management data, as listed in [6.4]
- collected data, based on a full usage of acquisition LANs, as listed in [6.4]
- error log, as listed in [6.5].

Procedure for emergency extraction of data are to be available on board with detailed information and identification of the location of the equipment on board

Note 1: Depending of the architecture, the on board storage may be an external unit, integrated in the data logger or in the server.

6 Data logger functions

6.1 Administration management functions

6.1.1 Configuration management

Configuration management of the data logger is to be allowed and accessible through Human Machine Interface (e.g. HTTP access, local access...)

6.1.2 System clock management

When the Data logger is responsible to timestamp the data, it is to be fitted with clock management function capability, and is to be synchronized with reference clock.

Note 1: UTC time synchronization of the data logger can be performed through Network Time Protocol (NTP).

In case of loss of clock synchronization, an alarm is to be raised and logged.

Note 2: It is recommended that to perform data timestamping on board ship to minimize impact of the instability of ship shore communication. Refer to [10] for time management definition.

6.2 Input / output communication functions

6.2.1 Errors detections

When applicable, application protocols are to integrate means to ensure message integrity and detect transmission errors (e.g. “tokens”...).

6.2.2 Proprietary solutions

In case of proprietary solutions, general specification of protocols, data types, format, naming, error codes... are to be available.

6.2.3 Additional requirements for DATA-INFRA-STAND

For the assignment of the notation **DATA-INFRA-STAND**, standardized solutions are to support at least one of the following protocols and data exchange formats:

- ISO 19847 and ISO 19848 standards for format and transmission of shipboard machinery or equipment data
- OPC UA as relay of IEC 61162 sentences, when interfacing with Maritime navigation and radio communication equipment and systems, and ISO 19847.

Other solution may be considered by the Society on a case-by-case basis.

6.3 Data processing functions

6.3.1 Processing functions supported by the data logger are to be listed for information.

When data logger enables the deployment of expert system, such as Machine Learning algorithm this is to be clearly specified.

Note 1: Data processing may also be performed on other acquisition LAN device (edge computing) to reduce volume of data transferred across the network and increase reliability of information.

6.3.2 For the assignment of the notation **DATA-INFRA-STAND**, standardized solutions are to be able to support "calculation data" field specified in ISO 19848.

6.4 Data logging

6.4.1 The data logger is to be able to log the following data:

- device management data, such as:
  - history of access, with username and date time
  - history of changes to software (e.g. data management, software parameters change, data format, database…)
- data to be transmitted, in order to prevent loss of data during network or communication issues, such as:
  - raw data
  - processed data, as described in [6.3].

6.5 Error log management functions

6.5.1 Failure detection

Data loggers are to be self-checking and be able to detect faults, malfunctions or interruptions of its different parts. Especially, they are to be able to detect the following:

- loss of power supply, (or low battery when applicable)
- loss of communication or network failures
- software abnormal operation
- processor failure (e.g. overheating)
- failure of data collection interface
- failure of on board storage device (e.g. access)
- on board storage capacity nearly complete or over reading (e.g. warning at 90% full storage)
- loss of UTC synchronization.

6.5.2 Error logging

Data logger are to be able to log:

- errors listed in [6.5.1]
- transmission errors (e.g. header error, checksum error...)
- other element identified in the data quality framework [10.3], when applicable

Sufficient information (e.g. datetime, system...) are to be available in the log to enable analysis, reconstruction, review and examination of the time sequence of operations.

6.5.3 Log transmission and access

Logs are to be accessible during inspections or surveys.

Note 1: it is recommended that data loggers support external error logging, for example by the mean of SYSLOG protocol (refer to RFC5424).

7 Ship network configuration

7.1 General

7.1.1 Data infrastructure is to be appropriately designed and configured for the onboard ship network. Especially QoS tools and strategies are to be implemented to ensure minimum packet loss or latency and enough bandwidth for data transmission.

In no case, the presence of the data infrastructure and corresponding data consumers, is to lead to congestion, or failure of the ship network or disruption of on board services.

Note 1: QoS should be provided with means to:

- manage data transfer priority level,
- provide information on communication system status (e.g. connectivity, estimated transfer rate...),
- identify network congestion, leak and manage traffic (e.g. delay, packet loss, timeouts...) such as bandwidth monitoring, ping analysis...
- log error and provide analysis tools.

7.2 On board data server

7.2.1 When a server is installed on board, the server is to be appropriately designed to provide sufficient input/output processing performance to handle data volume based on the estimated usage of acquisition LANs.

7.2.2 When a server is installed on board, and when its reliability or performance relies on specific environmental conditions (e.g. room temperature), this is to be clearly specified. The server is to be installed in a place where these environmental conditions are ensured.

7.2.3 Depending of the architecture, data loggers may be integrated in the server. In that case, requirements for data logger apply (refer to [5.3] and [6]).

8 Ship-shore communication configuration

8.1 General

8.1.1 The ship-shore communication system is to be appropriately designed and configured to handle reliable data transfer.

A bandwidth calculation report, demonstrating that ship-shore communication subscription is sufficient to ensure reliable transmission of data, or to support data consumers, may be requested by the Society on a case-by-case basis. QoS tools and strategies are to be implemented with appropriate priority levels or traffic quota.

In no case the presence of the data infrastructure is to lead to failure or congestion of the communication system. Especially it must not:

- lead to disruption of essential services on board
- endanger the reception and transmission of distress messages and other communications covered by the Rules and/or Statutory regulations (e.g. digital cordless telephone (DCT), public address).

9 Server

9.1 General

9.1.1 Data management function

The data server is to be provided with means to access and manage (e.g. creation, suppression...) data. Especially:

- access to collected data, to metadata are to be provided, with filtering capability
- access to data and information model (refer to [10.1])
- time synchronization is to be ensured
- database alias management function is to be supported.

9.1.2 Access right management and logging

Access right management is to be defined (e.g. read, write) for different roles: administrators, users, data consumers...

When coming from authorized sources, modification to the data base or data model are to be logged in the system with datetime and information on modification performed.

9.1.3 Input-Output

Server input and output functions capability are to be specified:

- request-response data transport service (e.g. REST API such as HTTP, HTTPS...)
- streaming data service (e.g. Broker and Publisher functions of MQTT Protocol)
- file transport service (e.g. FTP, SFTP...).

9.1.4 Additional requirements for DATA-INFRA-STAND

For the assignment of the notation **DATA-INFRA-STAND**, standardized solutions are to support at least one of the following protocols and data exchange formats:

- ISO 19847 and ISO 19848 standards for format and transmission of shipboard machinery or equipment data
- OPC UA as relay of IEC 61162 sentences, when interfacing with Maritime navigation and radio communication equipment and systems, and ISO 19847.

Other solution (e.g. API) may be considered by the Society on a case by case basis.

9.1.5 Backup

Database are to be regularly backup to ensure recovery in case of lost data.

Note 1: Backup frequencies and recovery time may be part of the data infrastructure SLD.

Backup files are to be stored on a separated storage medium.

10 Data management

10.1 Data model

10.1.1 A data model is to be defined to support interoperability between connected systems, with definition of ontology (data property, object property) and metadata. The model is to be documented.

Note 1: Data model may rely on existing data standards (e.g. RFC 8428 (SenML)...) for improved interoperability.

Ontology is to be specified, with definition of data properties and object properties (e.g. Unified Modeling Language diagram).

10.1.2 A data catalog with specification of data naming rules is to be provided.

Note 1: A data catalog should be defined to support ISO 19848 Data Channel definition.

10.1.3 For the assignment of the notation **DATA-INFRA-STAND**, standardized solutions are to implement ISO 19847, ISO 19848, OPC-UA or IEC 61162 as applicable.

10.2 Data format

10.2.1 Data exchange format are to be specified (e.g. XML, JSON) and support the data model specified in [10.1].

10.2.2 For the assignment of the notation **DATA-INFRA-STAND**, standardized solutions are to comply with requirements of ISO 19847 or ISO 19848. Especially, they are to be able to export data under XML format with standard character encoding (e.g. UTF-8, ASCII...).

Note 1: it is recommended to support also JSON or CSV formats.

10.3 Data quality framework

10.3.1 A data quality framework is to be implemented to ensure the reliability of data. A general description of the data quality framework is to be provided.

Note 1: This description, may include, but is not limited to:

- general data quality strategy (e.g. scope, objectives...), with general specification of data quality target or maturity assessment
- definition of business rules and corresponding data quality rules
- description of data quality monitoring and assessment framework, with
  - data quality dimensions (e.g. completeness, timeliness...), corresponding metric and acceptability thresholds. Especially data quality monitoring related to sensors faults should be considered (e.g. missing value, low or no batteries, calibration expired, above/below range, slope exceed, constant value, detection limit, spatial or internal inconsistencies…)
  - tools or processes, for data quality inspection and monitoring (e.g. on line KPI, manual inspection...)
  - tools or processes, for reporting data quality performances and data quality incidents
  - tool or processes for the investigation of data that does not comply with quality criteria (e.g. root cause analysis)
  - integration policies for data that does not comply with quality criteria (e.g error correction, error flagging, cleansing...)
- sustainment process
- overall data governance
- data standards (international or company standards)
- Service Level Agreement (SLA) for data integrated from an external data supplier.

10.3.2 Time management

Definition of the timestamp accuracy is to be provided (e.g. latency). Definition of what is considered as a ‘current’ (or ‘now’) value in the database is to be specified with regard to the capabilities of the data infrastructure.

Note 1: For example, a system composed by a sensor which send messages over RS485 to a data logger with NTP synchronization, and timestamp the data at the reception of the message on the data logger have an average uncertainty of around 1ms.

Note 2: Definition of the average time between the data producer and the time stamp may be part of the DQ SLD.

10.4 Monitoring

10.4.1 Performance monitoring

The indicators specified in the data infrastructure SLD (refer to [4.1.2]) are to be monitored.

10.4.2 Data quality monitoring

The indicators specified in the DQ SLD (refer to [4.1.3]) are to be monitored.

10.4.3 SLD report

The data infrastructure is to be able to generate a report, which provides an overview data infrastructure SLD and DQ SLD indicators on a given period, with indication of the monitored values and their corresponding targets. The summary should display the worst indicator condition recorded on an aggregated period of time (e.g. worst indicator recorded for each quarter). When a threshold has been exceeded it is to be specified in the report.

Note 1: When exceeding thresholds, it is recommended to indicate actions taken in response.

11 Installation and testing

11.1 Data logger type approval

11.1.1 Data loggers are subject to acceptance testing. Acceptance tests are generally to be carried out at the manufacturer’s facilities before the shipment of the equipment, when requested.

Testing protocols are to be agreed with the Society prior to testing, and are to include, but are not limited to:

- testing as described in Pt C, Ch 3, Sec 6, [3]
- test of data logger functions described in [6].

11.2 On board testing

11.2.1 Ship-shore communication subscription is to be checked, and is to be in accordance with documentation.

11.2.2 The documentation listed in Tab 1, items 9 and 10 is to be available on board.

11.2.3 Testing protocols are to be such that, tests are to be performed in the expected conditions of operations of the ship:

- All data producers are to be connected.
- The network bandwidth is to be restraint to simulate the other ship system usage. The priority level are to be correctly defined.
- Ship-shore communication is to be restraint to simulate the other ship system usage. The priority level are to be correctly defined.

11.2.4 A complete test program is to be submitted, and testing protocols are to be agreed with the Society prior to testing.

The testing protocols are to include, but are not limited to:

- General testing to be carried out to check that data producers can be accessed. Check of main hardware and software functionalities with all systems integrated are to be performed.
- The system is able to monitor data infrastructure SLD and Data Quality SLD, and to produce the SLD report.
- Black out is to be simulated to demonstrate capability of data infrastructure to restart automatically.
- Data flow is implemented from data source to final data base server. Synchronization between systems repositories is to be checked.
- Acquisition LAN testing:
  - data acquisition and wireless communications are to be tested according to Pt C, Ch 3, Sec 6, [4]
  - for analog sensors, signal calibration, tip set point adjustment are to be performed
  - sensors and equipment calibration are to be checked, when applicable

    Record of calibration and maintenance are to be checked, by the mean of data infrastructure or integrated.
  - UTC synchronization of data logger is ensured.
- Buffer and backup testing:
  - data listed in [6.4] are available on board
  - system is able to recover from backup.
- Errors simulation (refer to [6.5.1]):
  - corresponding alarm is raised and displayed on board
  - ship to shore outage is to be simulated
  - data listed in [6.5] are logged in the system
  - error log can be inspected on board.
- Data server:
  - collected data are available with correct timestamp
  - data stored in the server are same as data recorded on board
  - information model and metadata are accessible
  - server is able to answer to data request, with filtering, aggregation capability.

CHAPTER 5
MONITORING EQUIPMENT

Section 1 Hull Stress and Motion Monitoring (MON-HULL)

Section 2 Shaft Monitoring (MON-SHAFT)

Section 3 Real-time Emission Reporting (REALTIME)

Section 1 Hull Stress and Motion Monitoring (MON-HULL)

1 General

1.1 Application

1.1.1 The additional class notation **MON-HULL** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.6.2] to ships equipped with a Hull Stress Monitoring System (hereafter referred to as Hull Monitoring System for easy reference), complying with the requirements of this Section.

The class notation **MON-HULL** is not applicable to High Speed Craft.

1.1.2 A Hull Monitoring System is a system which:

- provides real-time data to the Master and officers of the ship on hull girder longitudinal stresses and vertical accelerations the ship experiences while navigating and during loading and unloading operations in harbour
- allows the real-time data to be condensed into a set of essential statistical results. The set is to be periodically updated, displayed and stored on a removable medium.

  Extra information may be added in view of later exploitation by the Owner, for instance as an element in the exploitation of the ship or as an addition to its logbook.

Note 1: The information provided by the Hull Monitoring System is to be considered as an aid to the Master. It does not replace his own judgement or responsibility.

1.1.3 The Hull Monitoring System is to be able to ensure the following main functions:

- acquisition of data: hull girder longitudinal strains and vertical accelerations at bow
- data processing: conversion in physical units, scaling, consistency checking, statistical processing and storage of results
- display management, handling of alarms and warnings
- detection of faults and malfunctions.

Note 1: The additional resources needed for the later onshore exploitation of the recorded results are not considered as part of the Hull Monitoring System.

1.2 Documentation

1.2.1 The documents according to Tab 1 are to be submitted to the Society.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	A	Description and metrological characteristics of the sensors and associated conditioning units
2	A	Diagram and functional scheme of the system
3	A	Sensors calibration procedures and certificates including calibration values and tolerances
4	A	Location of sensors
5	A	Detection of faults and malfunctions of the system
6	I	Principles and algorithm used for the data processing
7	I	User's manuals (installation and maintenance manual, using manual)
8	I	List of data to be transmitted to VDR, if any
(1) A: to be submitted for approval I: to be submitted for information		

2 Sensors design

2.1 General

2.1.1 The Hull Monitoring System is to be based on sensors designed to carry out the following measurements:

- measurements of the longitudinal strains in the main deck: the sensors will be located at one or several transversal sections where the maximum hull girder stress can be expected during navigation, loading or unloading. At least one transversal section will be equipped with two sensors located symmetrically at Port and Starboard
- measurements of the vertical acceleration at the bow.

2.2 Measurements ranges and tolerances

2.2.1 Stress measurements of hull girder are related to the still water and wave and dynamic bending moments acting on the ship. For steel ships, a deformation range from –2000 micro-strain to +2000 micro-strain should be assumed.

The measurement uncertainty (including strain transducers parameters, calibration, resolution of acquisition system, etc.) is to be less than +/– 20 micro-strain or +/– 5% of the reading, whichever is the greater.

The typical bandwidth should be 0 Hz to 1,0 Hz.

2.2.2 Acceleration measurements at the bow are related to the vertical motion (heave and pitch) of the ship and the first mode of the vertical vibration of the hull girder. Depending of the size of the ship, an acceleration range from -20 m/s^2 to +20 m/s^2 should be assumed.

The measurement uncertainty is to be less than +/- 0.2 m/s^2 or +/- 5% of the reading, whichever is the greater.

The typical bandwidth should be 0,02Hz to 1,0Hz.

2.3 On-site calibration of sensors

2.3.1 The sensors are to be selected and installed in such a way that a periodical on-site recalibration can be carried out without extra equipment.

When this operation is impossible, the Manufacturer is to declare the period and procedure of calibration.

2.4 Environmental and EMC requirements

2.4.1 The sensors and the associated conditioning units are to comply with the applicable requirements concerning electromagnetic compatibility and protection against environmental conditions. The installation is to be compliant with Pt C, Ch 3, Sec 5.

2.4.2 The electrical equipment installed in hazardous areas are to be compliant to requirements of Pt C, Ch 2, Sec 2, [6] and Pt C, Ch 2, Sec 3, [10].

3 System design

3.1 General

3.1.1 The Hull Monitoring system is to include at least:

- sensors and conditioning units
- a computer with the sufficient resources to perform the required tasks in real time (e.g. warnings and alarms are to be given out immediately)
- a display unit readable at a distance of at least 1 m
- a data storage unit with a removable medium, allowing for the statistical data to be exploited later
- as option, a data storage unit to record time data series from sensors (see [3.5.1])
- an UPS with 30 minutes autonomy (see [3.8.1]).

3.1.2 The system is to be designed to detect, as far as possible the faults and the malfunctions of the system (e.g.):

- failure of main source of power
- data out of range
- data remaining strictly constant (failure of a transducer)
- system stops or hangs (the implementation of a Watchdog is recommended).

Note 1: The detection of faults and malfunctions will trigger a visual and audible alarm.

3.2 Data processing

3.2.1 The system is to be designed in order to measure and process the stresses induced by still water and dynamic hull girder loads as defined in Pt B, Ch 5, Sec 4 and the accelerations which result from the ship motions as defined in Pt B, Ch 5, Sec 3.

3.2.2 Data processing is to be carried with the provision of the following requirements:

- analogue low-pass filters are to be used in accordance with the required bandwidth
- the sampling frequency is to be at least 20 times the low-pass filtering frequency
- the processing ranges of stress and acceleration are to be fixed in accordance with the calculated stress and acceleration limits for the ship, and will allow possible overshooting
- the signals are to be processed through a cyclic statistical procedure. The procedure (e.g. peak value, N/10 and N/3 averages, RMS value, mean value, etc.) will allow to record a set of statistical data for an off-line exploitation and to display real time values for an on-line exploitation
- the recording duration per cycle is to be adapted to produce results that are not to deviate by more than 10% from one wave encounter to the next in steady navigation conditions. The recording duration per cycle is not to be less than 10 minutes.

3.2.3 The information (still water bending moments or stresses) from loading calculator is to be exported to the Hull Monitoring System during loading and unloading.

The measured still water hull girder stresses is to be checked against the predicted values from the loading calculator.

3.2.4 The system is to switch from port to sea conditions, and vice versa.

3.2.5 Provision is to be made for a connection to a Voyage Data Recorder. The Manufacturer of the Hull Monitoring System is to declare which information would be forwarded to the Voyage Data Recorder.

The physical connection of the Hull Monitoring System to the Voyage Data Recorder is to be compliant with IEC 61162.

3.3 Data displaying

3.3.1 The hull girder stresses and the vertical accelerations are to be displayed in real time (e.g. maximum values and current values). This information is to be declared as “default condition” and displayed at power up or reset.

In sea conditions, statistical data may be displayed on the same page without possibility of mix-up with the real time data.

3.3.2 When a visual alarm/warning is emitted in accordance with [3.4], the corresponding information is superimposed on the above “default condition” displayed.

3.3.3 When the system detects a fault or a malfunction, the corresponding status is to be displayed.

3.4 Alarms

3.4.1 The alarms and warnings levels are to be settled in accordance with the following:

- the alarm levels are to be fixed to 80% of the maximum values obtained from the requirements on the basis of which the hull structure is approved
- the warning levels are always to be less than the alarm levels defined above.

3.4.2 The alarms and warning associated with each limit defined in [3.4.1] are to be clearly distinguishable from those relevant to faults and malfunctions.

3.4.3 When the system detects a fault or a malfunction, the alarms and warnings are to be inhibited and a visual an audible fault/malfunction alarm is to be emitted.

3.5 Data storage

3.5.1 The time data series are to be stored either by the recording device which is part of the Hull Monitoring System, or by an integrated bridge system, if available.

The storage media used shall have a sufficient capacity to store at least 1 year of time data.

3.5.2 The data storage recording device suitable for accumulating statistical information for feedback purposes is to be able to store at least 30 days of statistical data depending of ship's operation.

Statistical data are to be recorded in text format easily readable on a PC.

3.5.3 The data storage recording devices are to be:

- entirely automatic, apart from the replacement of the removable storage support
- such that they do not interrupt or delay the processing of the data.

3.5.4 The recorded data (time and statistical) must be time dated.

3.6 Exploitation of stored data

3.6.1 The exploitation of the recorded statistical data according to [3.5.2] is let to the responsibility of the owner.

3.7 Checking facility

3.7.1 The Hull Monitoring System is to include an auto-checking facility so that the verification of the System can be carried out without the need of external devices.

3.8 Power supply

3.8.1 The Hull Monitoring System is to be supplied by the main source of power of the ship through an uninterruptible 30 minutes autonomy power source.

4 Installation and testing

4.1 General

4.1.1 The components of the hull monitoring system including data processing, storage, display units and UPS are to be type approved in accordance with Pt C, Ch 3, Sec 6 (see also [2.4.1]).

The design of the display unit installed on the bridge is to be compliant to requirements of IEC 60945.

4.2 Installation of sensors

4.2.1 Attention is drawn to the possible existence of local strains induced by temperature gradients in the hull structure.

The strain sensors are to be located in areas free from these temperature gradients.

If a temperature compensation device is implemented, the Manufacturer is to demonstrate its effectiveness on site. When measurement systems are based on strain gauges, temperature compensated strain gauges are to be used.

4.2.2 Stain transducers are to be installed on the hull taking into account the influence of local stresses which may corrupt the global hull strain values.

4.3 Testing of Hull Monitoring System

4.3.1 The first on-site calibration of the measuring system of hull stresses is to be based on an approved loading case in still water.

The differences between the readings obtained from the Hull Monitoring System and the approved values are to be less than 10 N/mm^2 or 10% of the reading, whichever is the greater.

4.3.2 This first on-site calibration of the Hull Monitoring System is to be surveyed by the society.

Section 2 Shaft Monitoring (MON-SHAFT)

1 General

1.1 Applicability of MON-SHAFT notation

1.1.1 The additional class notation **MON-SHAFT** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.7.3], to ships fitted with oil or water lubricated systems for tailshaft bearings, or to ships fitted with pods, complying with the applicable requirements of this Section.

1.1.2 The assignment of this notation allows a reduced scope for complete tailshaft surveys; see Pt A, Ch 2, Sec 2, [5.5.3].

1.1.3 The requirements of this section apply in addition to those listed in Pt C, Ch 1, Sec 7, [2.4].

1.1.4 Applicable requirements for oil lubricated shafts are given in Article [2].

1.1.5 Applicable requirements for closed loop system fresh water lubricated shaft and open systems water lubricated shafts are given in Article [3].

1.1.6 Applicable requirements for pods shafts are given in Article [4].

1.2 Documentation to be submitted

1.2.1 The plans and documents to be submitted for the additional class notations **MON-SHAFT** are listed in Tab 1 for oil lubricated shafts, in Tab 2 for water lubricated shafts and in Tab 3 for pods.

Table 1 : Documentation to be submitted for oil lubricated shafts

No.	A/I **(1)**	Documents
1	A	Shaft line arrangement
2	A	Oil sealing gland
3	I	Onboard procedure for measurement of bearing wear, oil sealing gland seals replacement and lubricating oil analysis, including records
(1) A= to be submitted for approval; I = to be submitted for information		

Table 2 : Documentation to be submitted for water lubricated shafts

N°	A/I **(1)**	Documents
1	A	Shaft line arrangement
2	A	Sealing gland
3	A	Water lubrication piping diagram
4	I	Arrangement and procedure to measure the bearing wear
5	A	Shaft alignment calculation (see [3.1.6])
6	I	Onboard procedure for sealing gland seals replacement and, where relevant, lubricating fresh water analysis, including records
(1) A= to be submitted for approval; I = to be submitted for information		

Table 3 : Documentation to be submitted for pods

N°	A/I **(1)**	Documents
1	A	Shaft line arrangement
2	A	Bilge arrangement in pod
3	I	Onboard procedure for: - collecting temperature and vibration data and their analysis, limits values, and - lubricating oil analysis - recording above data.
(1) A= to be submitted for approval; I = to be submitted for information		

2 Requirements for oil lubricated shafts

2.1 Arrangement

2.1.1 Oil sealing glands design is to be approved by the Society. Seals replacement is to be possible without shaft withdrawal.

2.1.2 The aftmost bearing is to be fitted with a temperature monitoring system.

2.1.3 The aftmost bearing is to be arranged with facilities for measurement of bearing wear.

2.2 Lubricating oil analysis

2.2.1 Analysis frequency

Provisions are to be made to analyse stern bearing lubricating oil on a regular basis; in any event, the interval between two subsequent analyses is not to exceed six months.

2.2.2 Records

Provisions are to be made to make the lubricating oil analysis documentation available on board, showing in particular the trend of the parameters measured according to [2.2.3].

2.2.3 Content of analysis

Each analysis is to include the following parameters:

- Water content
- Chloride content
- Bearing material and metal particle content
- Oil ageing (resistance to oxidation).

The oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

2.2.4 Additional data to be recorded

In addition to the results of the oil sample analysis, provisions are to be made to record the following data on a regular basis:

- Oil consumption
- Bearing temperatures.

3 Requirements for water lubricated shafts

3.1 General requirements

3.1.1 Bearing material is to be approved by the Society.

3.1.2 The tailshaft is to be made of a corrosion-resistant material or protected against corrosion by a continuous liner or cladding.

3.1.3 The bearings are to be arranged with facilities for measuring the bearing wear while the ship is afloat. The relevant procedure including the maximum permissible wear will have to be submitted.

3.1.4 Sensors are to be provided for the aft bearing and any other bearings not accessible when the ship is afloat, giving alarm in case of bearing wear exceeding a predetermined threshold. An alarm is to be activated in the event of failure of the position sensor circuit.

3.1.5 Alternatively, arrangements are to be made for endoscopic examination of the tailshaft surface in particular in way of the bearings with the shaft in place. The relevant procedure will have to be submitted to the Society.

3.1.6 Where required by Pt C, Ch 1, Sec 7, [3.3.1], the shaft alignment calculations are to be performed for both initial conditions (new bearings) and conditions of maximum permissible wear according to the bearing manufacturer's recommendations and deemed satisfactory by the Society.

3.1.7 Sealing glands design is to be approved by the Society. Replacement of seals is to be possible without withdrawal of tailshaft.

3.2 Additional requirements for forced water lubrication systems

3.2.1 The water pumping system is to include:

- Two pumps
- A filtering system designed in accordance with bearing and pump manufacturer requirements
- Two independent flow sensors allowing permanent flow monitoring and activating an alarm in case of low flow.

3.2.2 The operating restrictions of the propulsion installation in case of low flow alarm are to be stated.

3.2.3 Filters are to be cleaned or replaced in accordance with manufacturer recommendations. Records of cleaning and replacement of filters are to be available on board.

3.2.4 Unless otherwise justified, an interlock arrangement is to be provided to prevent the propulsion starting if sufficient water flow is not established.

3.2.5 Specific requirements for closed loop forced systems

a) Low and high level alarms are to be fitted on water tank. Operating restrictions of the propulsion installation in case of low/high level alarms are to be stated

b) Provisions are to be made to analyse chloride content as well as presence of bearing material and other particles within fresh water piping system on a regular basis.The interval between two subsequent analyses is not to exceed six months. The water analysis records are to be available on board.

3.3 Data to be recorded

3.3.1 Provisions are to be made to record the following data on a regular basis and keep the records available on board:

- Water flow
- Bearings wear
- Failure alarms.

4 Requirements for pod

4.1 Arrangement

4.1.1 The propeller bearing and the thrust bearing are to be fitted with a temperature monitoring system.

4.1.2 The shaft line bearings are to be fitted with a vibration monitoring system.

4.1.3 The pod is to be fitted with an automatic bilge pumping system.

4.2 Lubricating oil analysis

4.2.1 Analysis frequency

Provisions are to be made to analyse propeller and thrust bearings lubricating oil on a regular basis; in any event, the interval between two subsequent analyses is not to exceed six months.

4.2.2 Records

Provisions are to be made to make the lubricating oil analysis documentation available on board, showing in particular the trend of the parameters measured according to [4.2.3].

4.2.3 Content of analysis

Each analysis is to include the following parameters:

- Water content
- Chloride content
- Bearing material and metal particle content
- Oil ageing (resistance to oxidation).

The oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

4.3 Additional data to be recorded

4.3.1 In addition to the results of the oil sample analysis, provisions are to be made to record the following data on a regular basis:

- Oil consumption
- Bearing temperatures
- Vibration data
- Automatic bilge pumping system.

Section 3 Real-time Emissions Reporting (REALTIME)

1 General

1.1 Scope

1.1.1 This Section addresses the digital solutions which collect the data from the ship and calculate the emissions which fall in the scope of international or regional reporting schemes. Data collection from the ship and the access to the data by the users on board and on shore through the dedicated digital interfaces are covered.

1.2 Application

1.2.1 This Section applies to ships fitted with two digital solutions as follows:

a) an onboard computer based system, further referred to as Onboard Digital Solution (ODS), performing on board the collection of data necessary for the calculation of the emissions, defined in [1.3.1], based on manual inputs. ODS is to be available for the onboard users to monitor regularly the emissions and to obtain a relevant decision-support;

b) a shore digital solution, further referred to as Shore Digital Solution (SDS), is available for the shore users to monitor regularly the emissions, to access the supporting evidences, to facilitate reporting and to obtain a relevant decision-support based on the data acquired from the ODS.

The SDS performs the calculation of the emissions according to the reporting schemes defined in [2].

The corresponding onboard computer based system and the shore digital solution are to comply with the requirements of this Section. ODS and SDS can be the same web-based software with an offline mode.

1.2.2 Ships complying with the requirements of this Section may be assigned the additional class notation **REALTIME( )**, as defined in [3].

1.2.3 The Onboard Digital Solution (ODS) is to comply with:

- the requirements for inputs and functions listed in [5]
- initial survey requirements for the assignment of the notation **REALTIME( )** listed in [7].

The software of the ODS is to be of a type approved by the Society as per the requirements of [4] and [5].

1.2.4 The Shore Digital Solution (SDS) is to comply with:

- the requirements for functions listed in [6]
- initial survey requirements for the assignment of the notation **REALTIME( )** listed in [7].

The software of the SDS is to be of a type approved by the Society as per the requirements of [4] and [6].

1.3 Definitions

1.3.1 The following definitions are used in the present Section:

- Applicant: digital solution's manufacturer applying for the Type Approval.
- Carbon Intensity Indicator (CII): a ship's performance indicator by which it is possible to measure the carbon intensity of the ship for a calendar year, as defined in the IMO Guidelines listed in [2.2.1].
- Continuous CII: a ship's carbon intensity indicator which is calculated for a period of time between the commencement of a calendar year and the exact time defined by the system or the operator. Continuous CII is based on available IMO DCS data without extrapolation.
- Bunker Delivery Note (BDN): a document issued by a party supplying bunkers to a receiving ship. The BDN is to comply with MARPOL Annex VI.
- Digital solution: a computer based system that incorporates functions for collection, transmission, analysis and visualisation of data, as well as the relevant calculations.
- Reporting period: a calendar year from 1 January to 31 December inclusive, unless specified otherwise by the applicable regulation.
- UN/LOCODE: United Nations code for trade and transport locations available from the United Nations Economic Commission for Europe (UNECE).

2 Reporting schemes

2.1 General

2.1.1 The following reporting schemes are considered for the purpose of this Section:

- CII reporting scheme based on IMO Carbon Intensity Indicator and ship rating scheme (see [2.2.1])
- EU ETS reporting scheme based on EU Monitoring, Reporting and Verification Maritime regulation (MRV regulations) and European Emission trading system (see [2.3.1] and [2.4.1])
- Fuel EU reporting scheme based on MRV regulations and Fuel EU Maritime regulations (see [2.3.1]and [2.5.1])

Details of the requested reporting documents are provided in Tab 1.

Table 1 : Reporting schemes

<table>
<tr><th>Reporting scheme</th><th>Template</th><th>Annual report</th><th>Voyage report</th><th>Port list</th><th>Correction and/or emission factors</th><th>Company level reporting</th><th>Boundary factors</th></tr>
<tr><td>CII reporting scheme (see [2.2])</td><td colspan="3">• CII Guidelines, G1, MEPC.336(76)
• 2022 Guidelines for administration verification of ship fuel oil consumption data and operational carbon intensity, MEPC.348(78)</td><td>–</td><td>• CII reduction factor guidelines, G3, MEPC.338(76)
• CII Guidelines, G5, MEPC.355(78)</td><td>–</td><td>• CII reference line guidelines, G2, MEPC.353(78)
• CII rating guidelines, G4, MEPC.354(78)</td></tr>
<tr><td>EU ETS reporting scheme (see [2.3] and [2.4])</td><td>Based on EU MRV regulations</td><td colspan="5">EU MRV regulations
Directive (EU) 2023/959
Regulation (EU) 2023/2297
Decision (EU) 2023/2895</td><td>–</td></tr>
<tr><td>FuelEU reporting scheme (see [2.5])</td><td colspan="3">EU MRV regulations
EU Regulation 2023/1805</td><td colspan="4">EU Regulation 2023/1805</td></tr>
</table>

2.2 Reference documents for CII reporting scheme

2.2.1 The IMO Guidelines to be used as reference for the calculation of emissions at the ship level relevant for CII calculation and ship rating are the following:

- Guidelines on operational carbon intensity indicators and the calculation methods (CII Guidelines, G1)
- Guidelines on the reference lines for use with operational carbon intensity indicators (CII reference line guidelines, G2)
- Guidelines on the operational carbon intensity reduction factors relative to reference line (CII reduction factor guidelines, G3)
- Guidelines on the operational carbon intensity rating of ships (CII rating guidelines, G4)
- Interim Guidelines on correction factors and voyage adjustments for CII calculations (CII Guidelines, G5)
- 2022 Guidelines for administration verification of ship fuel oil consumption data and operational carbon intensity (IMO Resolution MEPC.348(78))
- Interim Guidance on the use of biofuels under Regulations 26, 27 and 28 of MARPOL Annex VI (DCS and CII) (MEPC.1/Circ.905)
- Amendments to the 2022 Guidelines for administration verification of ship fuel oil consumption data and operational carbon intensity (Resolution MEPC.348(78) and Resolution MEPC.389(81)).

2.3 Reference documents for EU MRV regulations

2.3.1 The documents to be used as reference for the calculation of emissions at the ship level relevant for EU MRV regulations are the following:

- Regulation (EU) 2023/2776 amending Regulation (EU) 2015/757 as regards to the rules for monitoring greenhouse gas emissions and other relevant information from maritime transport
- European Regulation Reg (EU) 2023/2449 laying down rules for the application of Regulation (EU) 2015/757 of the European Parliament and of the Council as regards to the templates for monitoring plans, emissions reports, partial emissions reports, documents of compliance, and reports at company level, and repealing Commission Implementing Regulation (EU) 2016/1927

- Commission Delegated Regulation (EU) 2023/2849 of 12 October 2023 supplementing Regulation (EU) 2015/757 of the European Parliament and of the Council as regards the rules for reporting and submission of the aggregated emissions data at company level
- Commission Implementing Decision (EU) 2023/2895 of 19 December 2023 laying down the list of islands and ports referred to in Article 12(3-d) of Directive 2003/87/EC of the European Parliament and of the Council and the list of transnational public service contracts or transnational public service obligations referred to in Article 12(3-c) of that Directive.

2.4 Reference documents for EU ETS reporting scheme

2.4.1 In addition to the document listed in [2.3], the documents to be used as reference for the calculation of emissions at the ship level relevant for EU ETS reporting scheme are the following:

- European Regulation Reg (EU) 2023/957 amending Regulation (EU) 2015/757 in order to provide for the inclusion of maritime transport activities in the EU Emissions Trading System and for the monitoring, reporting and verification of emissions of additional greenhouse gases and emissions from additional ship types
- Directive (EU) 2023/959 which extends the EU Emission Trading System to maritime
- Regulation (EU) 2023/2297 which gives the list of neighbouring container transhipment ports.

2.5 References documents for FuelEU reporting scheme

2.5.1 In addition to the documents listed in [2.3.1], the documents to be used as reference for the calculation of emissions at the ship level relevant for FuelEU reporting scheme are the following:

- European Regulation Reg (EU) 2023/1805 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC.

3 Classification notations

3.1 Notation REALTIME( )

3.1.1 In accordance with the requirements of [1.2] and Pt A, Ch 1, Sec 2, [6.6], ships complying with the requirements of this Section may be assigned the additional class notation **REALTIME( )**.

The notation **REALTIME( )** is completed between brackets by one or a combination of notations **CII**, **EU ETS** and **FuelEU** indicating the considered reporting schemes defined in [2].

For example:

REALTIME(EU ETS)

REALTIME(CII, EU ETS, FuelEU)

3.1.2 The assignment of the additional class notation **REALTIME( )** excludes any statutory certification of the reports under the reporting schemes and is not to be construed as a statutory certification activity according to the applicable regulations.

3.1.3 The additional class notations **REALTIME( )** is assigned independently from any IMO DCS, EU MRV or EU ETS statutory certification activity.

3.2 Documentation to be submitted

3.2.1 The documentation to be submitted for assigning the notation **REALTIME( )** is listed in Tab 2.

Table 2 : Documentation to be submitted for the notation REALTIME( )

No.	A/I **(1)**	Description
1	I	Type Approval Certificate of the ODS and the SDS (see [4])
2	I	• Monitoring Plan approved as per the reporting scheme, as applicable as per [2], or • Ship Energy Efficiency Management Plan (SEEMP) Part II and Part III specifying the data collection and reporting
3	I	List of computer based systems involved in onboard functions to calculate the emissions. For each system, the list is to include: a) functional designation b) manufacturer
(1) A = to be submitted for approval ; I = to be submitted for information		

4 Type approval of ODS and SDS software

4.1 Type approval of ODS and SDS software

4.1.1 The software of ODS and SDS are to be type approved in accordance with the Society's type approval scheme described in Rule Note NR320, which consists of the following steps:

- documentation review (see [4.1.5])
- type test of software functionalities for deployment on board and on shore, if applicable
- issuance of a Type Approval Certificate which will be given a time validity of maximum 2 years.

The type approval of the hardware for ODS and SDS is not required.

4.1.2 When the ODS and the SDS require a specific software configuration or the definition of installation parameters, they are to be identified and listed with indication of their values or settings in the documentation submitted to the Society.

4.1.3 The Type Approval Certificate of the ODS and the SDS is to list the regulations (e.g. EU directives) used for the evaluation as per [2].

4.1.4 The type tests and relevant datasets are to be prepared by the Applicant as per the considered notation defined in [3]:

- for the notation **REALTIME(CII)**: the scenario datasets as in [4.2.1], [4.2.2], [4.2.3] and the boundary dataset as in [4.2.4] are to be provided
- for the notation **REALTIME(EU ETS)**: the scenario datasets as in [4.3.1], [4.3.2], [4.3.3] and the port dataset as in [4.3.4] are to be provided
- for the notation **REALTIME(FuelEU)**: the scenario datasets as in [4.3.1], [4.3.2], [4.3.3], the port dataset as in [4.3.4], and the boundary dataset as in [4.3.5] are to be provided.

When the test datasets of Tab 3 including the simulated entries and the corresponding calculation results are considered satisfactory, the Society endorses the test datasets.

Table 3 : Test datasets for type approval

Notation	Scenario dataset	Port dataset	Boundary dataset
REALTIME(CII)	[4.2.1], [4.2.2], [4.2.3]	–	[4.2.4]
REALTIME(EU ETS)	[4.3.1], [4.3.2], [4.3.3]	[4.3.4]	–
REALTIME(FuelEU)	[4.3.1], [4.3.2], [4.3.3]	[4.3.4]	[4.3.5]

4.1.5 Documentation to be submitted

The documentation to be submitted for approval of the software of SDS and ODS is listed in Tab 4.

Table 4 : Documentation to be submitted for the approval of the software of SDS and ODS

No.	A/I **(1)**	Description
1	I	List of the reporting regulations (e.g. IMO Resolutions and Circulars, EU Regulations and Directives) to be complied with by the ODS and the SDS
2	A/I	Documentation as required in Pt C, Ch 3, Sec 3 for the computer based systems forming the ODS
3	I	Software Quality Plan as per Pt C, Ch 3, Sec 3, [4.1.2]
4	I	Description of the SDS architecture with functional diagrams, data flow, process description, location of the hosting servers
5	I	Description of the communication method between the ODS and the SDS including the data transfer procedures
6	I	Manual describing the coordinated use of the ODS and the SDS in the framework of the emission reporting by each type of user and describing the overall digital reporting process where the perimeter for the application is defined
7	A	For each reporting scheme, description of the methods and tables of parameters per fuel used for calculating the annual and voyage emissions and models used to provide the quality assurance of the data
8	I	Description of the data transfer procedures to send the data ashore for reporting and database sharing purpose
9	I	Table listing the types of user accounts with corresponding access rights
10	I	List of manual data entries in the digital interface of the ODS described in [5.1]
11	A	Templates of reports generated as described in [6.1.6]
12	I	List of alerts and notifications generated for onboard and shore users
13	I	Test program for onboard tests (including wireless network testing) in the scope of [7.1]
(1) A = to be submitted for approval; I = to be submitted for information		

4.2 Datasets for CII reporting scheme

4.2.1 For the notation **REALTIME(CII)**, scenario datasets are to be developed as per Tab 5, for the three types of vessels subject to correction factors as defined in IMO Guidelines listed in [2.2.1]. A scenario dataset is to include a simulated record of activities and consumption for a duration of 1 calendar year with a resolution of 1 day, i.e. corresponding to daily reports, and is to include:

a) consumption of more than one fuel type

b) activities subject to voyage exemptions and with correction factors, e.g. ship-to-ship transfers of fuel

c) electrical power consumption subject to correction factors, e.g. power supply for refrigerated containers.

4.2.2 For the notation **REALTIME(CII)**, a collection of scenario datasets is to cover:

a) all types of fuels covered by the applicable regulations, including:
- diesel or gas oil
- light fuel oil (LFO)
- heavy fuel oil (HFO)
- propane and butane liquefied petroleum gas (LPG)
- liquefied natural gas (LNG)
- methanol
- ethanol
- biofuel.

b) all types of exemptions and activities eligible for correction factors as per [2.2].

4.2.3 For the notation **REALTIME(CII)**, a collection of scenario datasets is to be submitted, as per Tab 5, with a calculation of:

a) CII and the corresponding Rating

b) Continuous CII and the corresponding Rating.

Note 1: YYYY is a reference year.

Table 5 : Scenario test dataset for CII

	Attained Indicator / Rating							
	Continuous CII and corresponding rating				CII and corresponding rating			
	with correction factors		without correction factors		with correction factors	without correction factors		
Vessel type	until 1 Jul. YYYY	until 1 Oct. YYYY	until 1 Jul. YYYY	until 1 Oct. YYYY	YYYY	YYYY	YYYY+1	YYYY+2
Tanker								
Gas carrier, e.g. LNG carrier								
Ship carrying refrigerated containers								

4.2.4 For the notation **REALTIME(CII)**, the boundary dataset is to include the required CII and the CII Rating boundaries calculated for each category of ships listed below as per Tab 6 based on the applicable regulations as per IMO Guidelines listed in [2.2].

a) Bulk carrier

b) Gas carrier 65,000 DWT and above

c) Gas carrier less than 65,000 DWT

d) Tanker

e) Container ship

f) General cargo ship

g) Refrigerated cargo carrier

h) Combination carrier

i) LNG carrier 100,000 DWT and above

j) LNG carrier less than 100,000 DWT

k) Ro-ro cargo ship (vehicle carrier)

l) Ro-ro cargo ship

m) Ro-ro passenger ship

n) Cruise passenger ship.

Table 6 : Boundary test dataset for REALTIME(CII)

2019 Reference CII:	
Vessel type:	

CII values	YYYY	YYYY+1	YYYY+2
Inferior CII Rating boundary			
Upper CII Rating boundary			
Required CII			
Lower CII Rating boundary			
Superior CII Rating boundary			

4.3 Datasets for EU ETS and FuelEU reporting schemes

4.3.1 For the notations **REALTIME(EU ETS)** and **REALTIME(FuelEU)**, the scenario datasets are to be developed for all types of vessels subject to correction factors as listed in reporting schemes.

Note 1: e.g. 5% allowance reduction for ice class ships as per Directive 2023/959 of the EU ETS reporting scheme.

Each scenario dataset is to include a simulated record of activities and fuel consumption for a duration of 1 calendar year with a resolution of 1 day, i.e. corresponding to daily reports, and is to include:

a) consumption of multiple fuel types

b) carriage of passengers, if applicable

c) voyages subject to exemptions or correction factors, e.g. voyages into or out of the MRV or ETS coverage zone, use of wind-assisted propulsion (applicable only to FuelEU):
   - at least 3 voyages between EU (European Union) / EEA (European Economic Area) and non-EU/EEA ports
   - at least 3 voyages between EU/EEA ports
   - berthing in EU/EEA ports.

d) activities subject to a special regime, e.g. stop in a neighbouring transshipment port, stop for refuelling, for repairs, voyages between ports within outermost region of a member state.

4.3.2 For the notations **REALTIME(EU ETS)** and **REALTIME(FuelEU)**, the collection of scenario datasets is to cover:

a) all types of fuels covered by the applicable regulations, including, but not limited to:
   - diesel or gas oil
   - light fuel oil (LFO)
   - heavy fuel oil (HFO)
   - propane and butane liquefied petroleum gas (LPG)
   - liquefied natural gas (LNG)
   - methanol
   - ethanol
   - biofuel
   - biofuel blends.

b) all types of exemptions and activities eligible for correction factors, as per the template prescribed by the reporting scheme.

4.3.3 For the notations **REALTIME(EU ETS)** and **REALTIME(FuelEU)**, the collection of scenario datasets as per Tab 7 is to be submitted, as per the template prescribed by the reporting scheme, with a calculation of the annual and voyage emissions at the ship and company levels, if applicable.

4.3.4 For the notations **REALTIME(EU ETS)** and **REALTIME(FuelEU)**, the port dataset is to include the list of the ports with the UN/LOCODE and the attribution to the MRV or ETS coverage zone.

4.3.5 For the notation **REALTIME(FuelEU)**, the boundary dataset is to include the required emission boundaries calculated as per the applicable regulations, e.g. the limit on Green House Gases (GHG) intensity required by FuelEU regulation. At least two consecutive phases of the boundary evolution are to be indicated, for example, from 1 January 2025 and from 1 January 2030 as in the FuelEU regulation.

Table 7 : Scenario test dataset for EU ETS and FuelEU

		Continuous EU ETS or FuelEU indicators				Annual EU ETS or FuelEU indicators			
		with correction factors		without correction factors		with correction factors	without correction factors		
Vessel type GRT > 3000	**REALTIME** Notations	until 1 Jul. YYYY	until 1 Oct. YYYY	until 1 Jul. YYYY	until 1 Oct. YYYY	YYYY	YYYY	YYYY+1	YYYY+2
Tanker	**EU ETS** and **FuelEU**								
IA Ice classed Gas carrier									
Container ship									
Any vessel with wind-assisted propulsion	**FuelEU**								

5 Onboard Digital Solution (ODS)

5.1 Requirements for inputs

5.1.1 Means of a manual entry for the following fuel consumption and fuel storage data are to be provided:

a) information from Bunker Delivery Note (BDN) and periodic stocktakes of fuel tanks

b) information from bunker fuel tank monitoring on board, e.g. Custody Transfer Measurement System (CTMS) readings for the quantity of the liquefied gas in storage, if applicable

c) bunker fuel tank monitoring on board

d) fuel tank soundings or fuel flow meter measurements for applicable combustion processes

e) direct CO2 emission measurements

f) type and characteristics of the fuel consumed

g) status of measuring equipment, e.g. operational, out of order, out of calibration validity period

h) selected technique for soundings, e.g. manual dip tape, tank radar, gauging sensor

i) comments from the users.

5.1.2 Means of a manual entry for the following voyage related data are to be provided:

a) Departure and arrival: time and the location as a UN/LOCODE port name or geographic coordinates

b) Mass of the transported cargo, if applicable

c) Number of passengers, if applicable

d) Distance travelled

e) Activity status information such as ballast voyage, laden voyage, etc.

5.1.3 Means of manual upload for the documented evidence with an indication of its type as a metadata including:

a) proof of cargo carriage, e.g. bills of lading

b) proof of bunkering, e.g. BDNs

c) proof of voyage activities and itinerary, e.g. ship's log book extracts

d) proof of passenger carriage, if applicable

e) proof of sustainability for biofuel, if applicable.

5.2 Requirements for functions

5.2.1 The ODS is to provide the following dashboards and reports:

a) summaries of bunker transfers and voyages

b) dashboard for data discrepancy alerts for the inconsistencies automatically detected in the manually reported data.

Note 1: The automatic consistency checks can include the detection of outliers on the basis of the engine's SFOC (Specific Fuel Oil Consumption) diagramme, fuel energy to displacement ratios, maximum fuel tank capacity, cross-check of the values established by different methods of measurement (soundings, BDN, flowmeter readings), etc.

5.2.2 The ODS is to provide the following functions:

a) indicate the last date and UTC time of synchronisation with the database of the SDS and maintain a log of such synchronisations

b) export data to non-encrypted delimited text file easily readable on a Personal Computer

c) store a minimum of 5 years of the manual entries and the calculation results

5.2.3 The ODS is to be configured to the ship specific parameters, which are to be accessible in a single aggregated presentation in the digital user interface.

5.2.4 Access to the ODS is to be password protected and all users are to be identified, as a minimum with their names and their roles, when logged in. Each modification for the comments for the onboard records is to be digitally signed when completed by an authorized signature.

5.2.5 Means of encrypted data exchange with the SDS are to be provided. The exchanges are to be done automatically on a daily basis.

5.2.6 The ODS is to have a test mode which:

- allows filling records for a reporting period with a simulated test dataset from a database file
- is clearly indicated in the user interface when active
- does not compromise the normal operational entries
- generates the same type of outputs as the normal operational mode
- exports to an external portable storage device the test outputs resultant from processing the test dataset.

6 Shore Digital Solution (SDS)

6.1 Requirements for functions

6.1.1 Means of automatic encrypted data exchange with the ODS are to be provided.

6.1.2 Means of access to the tabulated summaries and trends are to be provided for the different type of users defined by the manufacturer (e.g. shipowner, verifier, charterer).

6.1.3 The SDS is to be configured to produce reports in compliance with the applicable EU MRV and EU ETS Directives as per Tab 1. The corresponding regulation and the version of the SDS software are to be displayed to users.

6.1.4 The SDS is to provide the following dashboards and reports:

a) dashboard with the provisional emissions estimates based on available data presented as a daily trend over a period specified by the user

b) dashboard with the voyage emissions estimates based on available data

c) dashboard with the annual emission report for a past closed reporting period, if data are available.

6.1.5 The SDS functions are to include:

- dashboard and report defined in [5.2.1]
- items defined in [5.2.2]
- dashboards defined in [6.1.4]
- granting a full or a partial access to the data according to the user's profile
- submitting the reported data between the users according to the user's profile
- for the notations **REALTIME(CII)** and **REALTIME(FuelEU)**, displaying boundaries defined by the regulations in Tab 1
- for the notations **REALTIME(CII)** and **REALTIME(FuelEU)**, generating notifications for crossing the boundaries and the margins of the boundaries, if defined by the regulations in Tab 1, e.g. by the FuelEU regulation. Boundary margins are typically to be set at ≥ 5%.

6.1.6 The SDS is to provide the following functions:

a) generation of reports for annual and voyage emissions estimates

b) provide comparison of the present emission profile to the historical data for a period selected by the user

c) provide comparison of the present fuel consumption to the historical data for a period selected by the user

d) calculate the fuel consumption based on independent models and provide an automatic comparison between the estimates produced by these models

e) dashboard with the annual and provisional emissions estimates of a fleet of vessels at the company level, if applicable, e.g. EU ETS allowance calculation

f) provide access to the documented evidence recorded by means described in [5.1.3] in relation to a selected voyage.

6.1.7 Access to the SDS is to be password protected and all users are to be identified with a name, a position and an organisation, when logged in.

6.1.8 The reports generated by the SDS are to comply with the applicable reporting schemes and are to be in the formats prescribed by the these regulations, including the digital formats directly importable into the reporting platforms, e.g. xml format importable into the EMSA\Thetis MRV platform.

6.1.9 The reports generated by the SDS are to indicate the digital signature and comments of the user responsible for the reporting.

6.1.10 The SDS is to have a test mode which:

- handles the test outputs from the ODS
- is clearly indicated in the user interface when active
- does not compromise the normal operational entries
- generates the same type of outputs as in the normal operational mode.

7 Initial Survey

7.1 Onboard Digital Solution (ODS)

7.1.1 At the time of the initial survey, the ODS software version is to be shown to the Surveyor and the following documents are to be presented to the Surveyor:

- Description of the ship specific parameters entered in the ODS (e.g. IMO number, type of ship, GT, DWT)
- ODS Manufacturer's declaration of compliance of the software version to the Type approval Certificate
- ODS Manufacturer's declaration confirming that the software version complies with the up-to-date version of the regulations for the reporting scheme covered.

7.1.2 Onboard function tests are to be witnessed by the Surveyor, including wireless network testing, if applicable.

During the onboard test, the system is to be operated to:

a) create manual entries as described in [5.1]

b) access dashboards as described in [5.2.1]

c) demonstrate integration into the ship’s communication network, including wireless network testing where applicable

d) check the Type Approval Certificate with regards to the applicable regulations as per [2] and confirm the software version.

7.2 Shore Digital Solution (SDS)

7.2.1 At the time of the initial survey, the SDS software version is to be shown to the Surveyor and the following documents are to be presented to the Surveyor:

- Description of the ship specific parameters entered in the SDS (e.g. IMO number, type of ship, GT, DWT)
- SDS Manufacturer's declaration of compliance of the software version to the Type approval Certificate
- SDS Manufacturer's declaration confirming that the software version complies with the up-to-date version of the regulations for the reporting scheme covered.

7.2.2 A remote test is to be witnessed by a Surveyor.

During the remote test, the SDS is to be accessed by means of an external internet connection to:

a) demonstrate access for the different types of defined user categories

b) confirm availability of the items described in [6.1.3] and [6.1.5]

c) load sample of dataset from the ODS in a test mode; confirm that the SDS receives the dataset for calculation.

CHAPTER 6
COMFORT ON BOARD AND HABITABILITY

Section 1 COMF Notations - General Requirements

Section 2 COMF Notations - Additional Requirements for Ships of Less than 1600 GT

Section 3 COMF Notations - Additional Requirements for Crew Areas - Ships Greater than or Equal to 1600 GT

Section 4 COMF Notations - Additional Requirements for Passenger Areas - Ships Greater than or Equal to 1600 GT

Section 5 COMF Notations - Additional Requirements for Yachts

Section 6 Habitability

Section 1 COMF Notations - General Requirements

Symbols

dB : Decibel, unit of sound pressure level compared to the reference pressure level ($2\ 10^{-5}$ Pa)

dB(A) : (A) weighted global value of the sound pressure level

R.M.S. : Root Mean Square

1 General

1.1 Application

1.1.1 The additional class notations **COMF-NOISE** and **COMF-VIB** are assigned, in accordance with Pt A, Ch 1, Sec 2, [6.7] to ships complying with the requirements in this Section and with the following specific requirements applicable according to the type and size of the ship:

- Ships of less than 1600 GT (such as fishing ships, tugs, small passenger ships excluding yachts and pleasure crafts): see Ch 6, Sec 2
- Ships greater than or equal to 1600 GT (such as tankers, container ships, large fishing vessels, cruise ships, ferries, ...): see Ch 6, Sec 3 and Ch 6, Sec 4, as applicable.
- Yachts: see Ch 6, Sec 5.

The notations **COMF-NOISE** and **COMF-VIB** are to be completed as follows:

- **COMF-NOISE x**: Comfort with regard to noise criteria applicable to specified ship category

  with x = **1**, **2** or **3**, "**1**" corresponding to the most comfortable level for both passenger and crew spaces
- **COMF-VIB x**: Comfort with regard to vibration criteria applicable to specified ship category

  with x = **1**, **2** or **3**, the overall frequency weighted R.M.S. velocity criteria, "**1**" corresponding to the most comfortable level for both passenger and crew spaces, or

  with x = **1PK**, **2PK** or **3PK**, for the single amplitude peak velocity criteria, "**1PK**" corresponding to the most comfortable level for both passenger and crew spaces.

The requirements corresponding to those additional class notations are given in Ch 6, Sec 2 to Ch 6, Sec 5 for each concerned ship type.

The assignment of **COMF-NOISE** and **COMF-VIB** to passenger ships is to be done separately for passenger and crew spaces:

- **COMF Pax** deals with passenger comfort:

  COMF-NOISE-Pax x and **COMF-VIB-Pax x** may be granted accordingly with different grades
- **COMF Crew** deals with crew comfort:

  COMF-NOISE-Crew x and **COMF-VIB-Crew x** may be granted accordingly with different grades.

Note 1: For ships intended with in-service assessment, the notations **COMF** may be completed by **-SIS** as defined in Pt A, Ch 1, Sec 2, [6.7.1].

1.1.2 High speed crafts which do not have the same kind of behaviour in the concerned fields (vibrations and noise) are not covered by these Rules.

1.2 Basic principles

1.2.1 Measurement specialist

Granting of the comfort grade is made on the basis of measurements performed during sea trials or in service by an acoustic and vibration specialist, referred as the Measurement Specialist within this Chapter.

The Measurement Specialist is an acoustic and vibration specialist from an approved service supplier in accordance with NR533, or a qualified Surveyor from the Society.

1.2.2 The granting of the comfort grade of a ship cannot be made on the basis of the measurements performed on any other ship of the considered series.

1.2.3 These Rules take into account various International Standards, and are deemed to preserve their general principles.

1.3 Regulations, Standards

1.3.1 Noise

The present Chapter refers to the following standards applicable to noise:

- IMO Resolution MSC.338(91), "Adoption of amendments to the international convention for the safety of life at sea, 1974"
- IMO Resolution MSC.337(91), "Adoption of the code on noise levels on board ships"
- ISO 2923:1997, "Acoustics - Measurements of noise on board vessels"
- ISO 80000-8:2007, "Quantities and Units - Part 8: Acoustics"
- IEC Publication 61672:2003, "Electroacoustics-Sound level meters"
- IEC Publication 61260-1:2014, IEC 61260-2:2017 and IEC 61260-3:2016, "Octave, half-octave and third octave band filters"
- IEC Publication 60942:2003, "Electroacoustics - Sound calibrators"
- ISO 16283-1:2014, "Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation"
- ISO 16283-2:2015, "Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 2: impact sound insulation"
- ISO 717, "Acoustics - Rating of sound insulation in buildings and of building elements", namely:
  - ISO 717-1:1996, Part 1, "Airborne sound insulation in buildings and interior elements"
  - ISO 717-2:1996, Part 2, "Impact sound insulation"
- IEC Publication 60268-16:2004, "Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index"
- ISO 1996, "Acoustics - Description, measurements and assessment of environmental noise", namely:
  - ISO 1996-1:2016, Part 1, "Basic quantities and assessment procedure"
  - ISO 1996-2:2017, Part 2, "Determination of environmental noise levels"
- ISO 3382-1:2009, "Acoustics - Measurement of room acoustic parameters", namely:
  - Part 1, "Performance spaces"
  - Part 2, "Reverberation time in ordinary rooms".

1.3.2 Vibration

The present Chapter refers to the following standards applicable to vibration:

- ISO 2041:2009, "Vibration and shock - Vocabulary"
- ISO 20283-5:2016, "Mechanical vibration - Measurement of vibration on ships - Part 5: Guidelines for measurement, evaluation and reporting of vibration with regard to habitability on passenger and merchant ships"
- ISO 2631-1:2010, "Mechanical vibration and shock- Evaluation of human exposure to whole-body vibration"
- ISO 8041:2005, "Human response to vibration - Measuring instrumentation".

1.4 Definitions

1.4.1 In addition to the definitions given by IMO for crew spaces and SOLAS for passenger spaces, the following definitions are used in the present Chapter for the concerned ships:

- Passenger public spaces
  - Type A public space

    closed rooms normally manned at sea or recreational spaces where noise is generally high (discotheques)
  - Type B public space

    closed rooms permanently manned at sea where noise may be moderately high (restaurants, bars, cinemas, casinos, lounges, fitness rooms, gymnasiums and other closed sport areas).
  - Type C public space

    closed rooms permanently manned at sea requiring relatively low background noise (lecture rooms, libraries, theatres)
  - Type D public space

    closed rooms intermittently used at sea or passages which do not require very low background noise (halls, atriums, shops, corridors, staircases).
- Passenger cabins
  - Cabins are dealt with separately. Distinction between passenger cabins categories is to be made on the basis of Owner's specifications.
- Workshops other than those forming part of machinery spaces
  - Workshops other than those forming part of machinery spaces are enclosed workshops that are separated from the engine room with bulkheads, which may include access doors of the equivalent acoustic insulating properties as the bulkhead. Workbenches and workstations located inside the machinery space are not to be considered as "workshops other than those forming part of machinery spaces".

1.5 Document to be submitted

1.5.1 Prior to any sea trials, documents are to be submitted in relation with ship categories listed in Tab 1.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Document
1	I	General arrangements
2	A	Measurement program: • Measurement procedures • loading conditions • propulsion operating conditions • other equipment to be run • weather conditions
(1) A = to be submitted for approval ; I = to be submitted for information		

2 Conditions of attribution

2.1 Measurements

2.1.1 Measurements aiming at giving the comfort class notation have to be performed under the conditions specified in [3].

2.1.2 Instrumentation

a) General

Measurement and calibration equipment are to meet the requirements of:

- ISO 2923, IEC 61672-1, IEC 61260 and IEC 60942 for noise, and
- ISO 20283-5 or ISO 6954:1984 and ISO 8041 for vibration.

Sound insulation measurement is to be carried out according to ISO 16283-1.

Impact noise measurement is to be carried out according to ISO 16283-2.

Noise and vibration calibrators are to be verified at least every year by a national standard laboratory or a competent laboratory accredited according to ISO/IEC 17025:2017.

b) Noise measurements

Measuring equipment is to be verified at least every two years by a national standard laboratory or a competent laboratory accredited according to ISO/IEC 17025:2017.

The instrumentation has to be calibrated in situ before the tests and verified after. The deviation shall not exceed 0,5 dB.

c) Vibration measurements

The instrumentation has to include at least a transducer (accelerometer or velocity transducer) with an appropriate amplifier, and a FFT analyser. Measuring equipment is to be verified at least every two years. The instrumentation has to be calibrated in situ before the tests and verified after.The deviation shall not exceed 5%.

Should the vibration measurements be performed on a soft floor, the use of a transducer mounted on an appropriate three-spike plate is recommended. A rigid plate with the person standing on the plate and the accelerometer rigidly fixed on may be used.

2.1.3 Data processing and analysis

a) For noise level

The nominal noise level is evaluated with LAeq,T value.

LAeq,T (dB (A) re. 20µPa) is the equivalent continuous A weighted sound pressure level, T greater than 15 seconds.

Results are to be given in global values (dB (A)) calculated in octave bands from 31,5 Hz to 8 kHz.

Note 1: "octave band" means band of sound covering a range of frequencies such that the highest is twice the lowest

b) For vibration level

The criterion of vibration is to be expressed either in terms of overall frequency-weighted R.M.S. velocity (mm/s) from 1 to 80Hz as defined by ISO 20283-5, or single frequency amplitude peak velocity from 1 Hz to 100 Hz as defined by ISO 6954:1984 with a conversion factor $C_F = 1$, which leads to:

$$\text{crest factor} = C_F \times \sqrt{2}$$

$$\text{Maximum repetitive value} = \sqrt{2} \times \text{R.M.S. value}$$

Measurements are to be rounded to the nearest tenth of mm/s or mm/s^2 as applicable.

c) For sound insulation

The criterion of sound insulation is to be expressed in terms of apparent weighted sound reduction index (R'w) in dB, measured in accordance with ISO 16283-1 and then calculated in accordance with the method specified in ISO 717-1.

d) For impact noise

The criterion of impact noise is to be expressed in terms of weighted normalized impact sound pressure level (L'n,w) in dB, measured in accordance with ISO 16283-2 and then calculated in accordance with the method specified in ISO 717-2.

2.1.4 When it is not possible for the Measurement Specialist to follow or to carry out all the required measurements, the specialist designated by the shipyard carries out the full measurement and spot-check is to be performed by the Measurement Specialist.

This spot-check consists of a cross-comparison between:

- a sample of at least 10% of the measurements provided by the shipyard/external specialist (see Note 1),
- and the corresponding readings obtained during the spot-check measurements.

This procedure enables the validation by the Society of the entire set of measurements provided by the shipyard/external specialist.

Note 1: The maximum deviations allowed during the cross-comparison are 2 dB(A) for noise measurements and 0,5 mm/s for vibration measurements for both single amplitude peak velocity and overall frequency weighted rms readings.

2.1.5 Measurement report

When the measurements are carried out by an approved service supplier, the measurement report is to be submitted to the Society for approval.

2.2 Determination of comfort rating number

2.2.1 The notation is completed by a grade **1**, **2** or **3** which represents the comfort level achieved for the assignment of the notation, the grade 1 corresponding to the most comfortable (highest) class notation.

Regarding vibration, the notation is completed either by a grade **1**, **2** or **3** or by a grade **1PK**, **2PK** or **3PK** according to the vibration criteria used for the assessment.

2.2.2 Noise and vibration levels are measured at several locations for different categories of space onboard the ship. The comfort class grade is assigned provided that none of the measured levels exceeds the corresponding rule limits taking into account the following tolerances:

a) For the measurements of noise levels:
   - For cabins:
     - No more than 18% of the total number of measurements are to exceed the rule criterion.
     - No more than 2% of the total number of measurements (with a minimum of 1 cabin) are to exceed the rule criterion by 3,0 dB(A).
     - No measurement is to exceed the rule criterion by more than 5,0 dB(A).
   - For other spaces:
     - No more than 25% of the total number of measurements are to exceed the rule criterion.
     - No more than 5% of the total number of measurements with a minimum of 1 cabin) are to exceed the rule criterion by 3,0 dB(A).
     - No measurement is to exceed the rule criterion by more than 5,0 dB(A).

b) For the measurements of apparent sound reduction indexes R'w:
   - No more than 20% of the total number of measurements are to be lower than the rule criterion.
   - No more than 10% of the total number of measurements (with a minimum of 1 partition or floor) are to be lower than 1 dB below the rule criterion.
   - No measurement is to be lower than 2 dB below the rule criterion.

c) For the measurements of weighted normalized impact sound pressure level $L'_{n,w}$:
   - No more than 20% of the total number of measurements are to exceed the rule criterion.
   - No more than 10% of the total number of measurements (with a minimum of 1 partition or floor) are to exceed the rule criterion by 1 dB.
   - No measurement is to exceed the rule criterion by more than 2 dB.

d) No more than 20% of the vibration level measurements in all passenger and crew spaces are to exceed:
   - the overall frequency weighted R.M.S. velocity rule criterion by more than 0,3 mm/s
   - the single amplitude peak velocity rule criterion from 5 Hz to 100 Hz by more than 0,5 mm/s
   - the single amplitude acceleration rule criterion from 1 Hz to 5 Hz by more than 17,0 mm/s^2.

2.3 Measuring locations

2.3.1 The list of measuring points is to be prepared prior to the tests and submitted to the Society. This list may be adjusted during the tests and covers:

- noise level at harbour conditions (yacht only)
- noise level at sea conditions
- vibration level at sea conditions
- sound insulation measurements
- impact noise measurements.

3 Testing conditions

3.1 General

3.1.1 This Article gives the conditions to be fulfilled during measurements. Additional details of these conditions may be taken from International Standards, respectively:

- IMO Resolution MSC.337(91), ISO 2923 for noise
- ISO 20283-5 and ISO 6954:1984 for vibrations.

3.1.2 Prior to the tests, possible divergence on the required conditions may be accepted by the Society. If any, it is to be clearly mentioned in the report.

3.1.3 The measurement program is to be submitted before the trials (see [1.5.1]). During the tests, some additional measurements may be decided upon request of the Measurement Specialist.

3.1.4 During measurements, rooms have to be fully completed (outfitting, furniture, covering...).

3.2 Harbour test conditions

3.2.1 Part of the noise measurement tests is to be conducted at quay or at anchorage (impact noises and sound insulation indexes between rooms). For these specific tests, no particular conditions concerning output, loading conditions, water depth, weather conditions are required.

3.3 Sea trial conditions

3.3.1 During the sea trials, propeller output is to correspond to the specified open sea steady heading nominal continuous rating of the propulsion (NCR). If NCR is not specified, at least 80% of maximum continuous rating of the propulsion (MCR) will be considered.

In particular, ships which are frequently operated by means of a Dynamic Positioning system (DP system) shall require additional measurements to be performed in DP mode. The Owner, Shipyard and Society shall agree on a process to simulate the operation of the DP thruster system under conditions which would approximate station-holding at, or above, 40 per cent of maximum thruster power for design environmental conditions that the ship operates in.

The list of machine and equipment to be run during the tests is, at least, to include (if present) the following:

- generating sets
- air conditioning and machinery ventilation
- evaporators
- anti rolling devices
- compressors and chillers
- cold rooms
- waste treatment units
- swimming pool with pumps
- jacuzzi and thalasso therapy equipment
- laundry with the entire equipment running.

3.3.2 Any other frequently used equipment (more than 1/3 of the time at sea) is to be run at its normal operating conditions (if practicable).

3.3.3 Standard test conditions correspond to the loading condition defined for sea trials. Nevertheless, for cargo ships which are operated over a wide range of drafts, the readings may significantly differ from test condition to another loading condition. Should this particular case occur, additional measurements may be required.

3.3.4 Tests have to be conducted within sea and weather condition 3 or less. Measurements carried out with worst weather conditions may be accepted at the sight of the results.

3.3.5 The tests have to be performed in deep water, with a water depth greater than 5 times the mean draft. However, for ships usually operating in coastal waters, measurements may be taken with conditions corresponding to normal service conditions.

3.3.6 Ship course has to be kept constant, with rudder angle less than 2 degrees portside or starboard, for the duration of the measurement. If ship manoeuvring is needed, measurements must be stopped until recovery of steady heading.

Section 2 COMF Notations - Additional Requirements for Ships of less than 1600 GT

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to ships of less than 1600 GT. They are additional to the applicable requirements of Ch 6, Sec 1.

2 COMF-NOISE

2.1 Measurement procedure

2.1.1 Measuring conditions

Tests have to be conducted in the conditions described in Ch 6, Sec 1, [3.3]. Air conditioning is to be in normal operation. Doors and windows have to be closed, unless they have to be kept open in normal use.

It may happen that the measurements in accommodation spaces cannot be performed with HVAC in normal operation (as defined in Ch 6, Sec 1, [3.3]).

In such case, additional measurements should be done at quay and taken into account in the final results as follows:

$$LAeq = 10 \cdot Log_{10}\left(10^{\frac{LAeq1}{10}} + 10^{\frac{LAeq2}{10}}\right)$$

where:

LAeq1 : Equivalent continuous A weighted sound pressure level measured at quay with HVAC in normal operation.

LAeq2 : Equivalent continuous A weighted sound pressure level measured in sailing conditions without HVAC in normal operation.

2.1.2 Measuring positions

a) Noise measurements

Measurements are to be taken at a height between 1,2 and 1,6 m from the deck and at a distance above 1,0 m from any boundary surface of the room. In cabins and offices, one measurement will be performed in the middle of the space. Additional measurements should be performed in other locations if appreciable sound level differences inside the room occur.

On open deck, measurements are to be taken at 2 m at least from the existing noise sources (e.g. inlet/outlet of ventilation).

Noise is to be measured in all accommodation spaces (cabins, public spaces, mess rooms and offices) in the wheelhouse, in the engine control room and in all workspaces specified in Tab 1, if any. On passenger ships having relatively large public rooms (salons or restaurants), noise measurements are to be carried out in different locations (to get a representative description of the noise), each measuring points covering less than 20 m^2.

b) Sound insulation measurements

The selection of insulation measuring locations is to be representative of the different types of insulation provided in Tab 2 and Tab 3 (a minimum of two measurements of each type is required).

2.2 Noise levels

2.2.1 Noise levels corresponding to the noise grade **x** are provided in Tab 1.

2.3 Sound insulation measurements

2.3.1 Between two adjacent accommodation spaces, apparent weighted sound reduction index is to be greater than the requirements given in Tab 2 and Tab 3. Measurements are to be performed in situ, ship at quay or at anchorage.

Table 1 : Noise level requirements

Locations	LAeq,T in dB(A)		
	grade = 1	grade = 2	grade = 3
Wheelhouse	63,0	64,0	65,0
Passenger cabins	50,0	54,0	58,0
Crew cabins	55,0	58,0	60,0
Offices	60,0	63,0	65,0
Galleys **(1)**	72,0	73,0	75,0
Public spaces (type B), mess rooms **(2)**	60,0	63,0	65,0
Passages and type D spaces **(2)**	65,0	68,0	70,0
Engine control room or switchboard room (if continuously manned at sea) **(1)**	75,0	75,0	75,0
Open public areas **(3) (4)**	70,0	73,0	75,0
Workshops other than those forming part of machinery spaces **(1)**	85,0	85,0	85,0

(1) Equipment switched on but not in use.
(2) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].
(3) Measurement carried out with a microphone windscreen.
(4) A tolerance of 5,0 dB(A) may be accepted for measurements at less than 3 m from a ventilation inlet/outlet.

Table 2 : Apparent weighted sound reduction indexes R'w in dB for passenger areas

Locations	grade = 1	grade = 2	grade = 3
Cabin to cabin	40	38	36
Corridor to cabin	38	36	34
Stairs to cabin	50	50	50
Public spaces to cabin	53	50	48
Note 1: When the area of the tested partition is less than 10 m^2, a minimum value of 10 m^2 is to be considered for the calculation of index R'w.			

Table 3 : Apparent weighted sound reduction indexes R'w in dB for crew areas

Locations	grade = 1	grade = 2	grade = 3
Cabin to cabin	37	35	32
Corridor to cabin	35	32	30
Stairs to cabin	35	32	30
Public spaces to cabin	45	44	42
Note 1: When the area of the tested partition is less than 10 m^2, a minimum value of 10 m^2 is to be considered for the calculation of index R'w.			

3 COMF-VIB

3.1 Measurement procedure

3.1.1 Measuring conditions

Tests are to be conducted under the conditions described in Ch 6, Sec 1, [3.3].

3.1.2 Measuring positions

Measurements are to be taken in vertical direction. In cabins, offices or other small size rooms, measurements are to be taken on the floor in the centre of the room. For larger rooms, several measuring points may be required.

Vibrations are to be measured in all accommodation spaces (cabins, public spaces and mess rooms, offices), in the wheelhouse, in the engine control room and in all workspaces specified in Tab 4, Tab 5 and Tab 6, if any. On passenger ships having relatively large public rooms (salons or restaurants), vibration measurements are to be carried out in different locations (to get a representative description of the vibration), each measuring points covering less than 20 m^2.

In addition to vertical direction, measurements in transverse and longitudinal directions are to be performed on one point of each deck. This point is not to be located in way of nodal points of vibration modes.

3.2 Vibration levels

3.2.1 Vibration levels corresponding to the grade **x** are provided in Tab 4 in accordance to ISO 20283-5 (the limits listed below are applicable for any directions).

3.2.2 Vibration levels corresponding to the grade **x** are provided in Tab 5 and Tab 6 in accordance to ISO 6954:1984 (the limits listed below are applicable for any directions).

Table 4 : Overall frequency weighted R.M.S. vibration levels

Locations	Vibration velocity (mm/s) values from 1 Hz to 80 Hz		
	grade = 1	grade = 2	grade = 3
Wheelhouse	3,5	4,0	4,5
Passenger cabins	3,0	3,2	3,5
Crew cabins			
Offices	3,5	4,0	4,5
Galleys	5,0	5,5	6,0
Public spaces (type B), mess rooms **(1)**	3,0	3,2	3,5
Passages and type D spaces **(1)**	3,0	4,0	5,0
Engine control room or switchboard room (if continuously manned at sea)	4,0	4,5	5,0
Open public areas	3,5	4,0	4,5
Other workspaces	4,0	5,0	6,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].			

Table 5 : Single amplitude peak vibration levels from 5 Hz to 100 Hz

Locations	Vibration velocity (mm/s peak) values from 5 Hz to 100 Hz		
	grade = 1PK	grade = 2PK	grade = 3PK
Wheelhouse	3,0	4,0	5,0
Passenger cabins	2,0	2,5	3,0
Crew cabins			
Offices	3,0	3,5	4,0
Galleys	5,0	5,5	6,0
Public spaces (type B), mess rooms **(1)**	3,0	3,5	4,0
Passages and type D spaces **(1)**			
Engine control room or switchboard room (if continuously manned at sea)	4,0	5,0	6,0
Open public areas	4,0	5,0	6,0
Other workspaces	4,0	5,0	6,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].			

Table 6 : Single amplitude peak vibration levels from 1 Hz to 5 Hz

Locations	Acceleration (mm/s^2 peak) values from 1 Hz to 5 Hz		
	grade = 1PK	grade = 2PK	grade = 3PK
Wheelhouse	96,0	125,0	157,0
Passenger cabins	64,0	80,0	96,0
Crew cabins			
Offices	96,0	111,0	125,0
Galleys	157,0	172,0	188,0
Public spaces (type B), mess rooms **(1)**	96,0	111,0	125,0
Passages and type D spaces **(1)**			
Engine control room or switchboard room (if continuously manned at sea)	125,0	157,0	188,0
Open public areas	125,0	157,0	188,0
Other workspaces	125,0	157,0	188,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].			

Section 3 COMF Notations - Additional Requirements for Crew Areas - Ships Greater than or Equal to 1600 GT

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to crew areas of ships greater than or equal to 1600 GT. They are additional to the applicable requirements of Ch 6, Sec 1.

2 COMF-NOISE

2.1 Measurement procedure

2.1.1 Measuring conditions

Tests are to be conducted in the conditions described in Ch 6, Sec 1, [3.3]. Air conditioning is to be in normal operation. Doors and windows are to be closed, unless they are to be kept open in normal use.

It may happen that the measurements in accommodation spaces cannot be performed with HVAC in normal operation (as defined in Ch 6, Sec 1, [3.3]).

In such case, additional measurements should be done at quay and taken into account in the final results as follows:

$$LAeq = 10 \cdot Log_{10}\left(10^{\frac{LAeq1}{10}} + 10^{\frac{LAeq2}{10}}\right)$$

where:

LAeq1 : Equivalent continuous A weighted sound pressure level measured at quay with HVAC in normal operation.

LAeq2 : Equivalent continuous A weighted sound pressure level measured in sailing conditions without HVAC in normal operation.

2.1.2 Measuring positions

a) Noise measurements

Measurements are to be taken at a height between 1,2 and 1,6 m from the deck and at a distance above 1,0 m from any boundary surface of the room. In cabins and offices, one measurement will be performed in the middle of the space. Additional measurements should be performed in other locations if appreciable sound level differences inside the room occur.

On open deck, measurements are to be taken at 2,0 m at least from the existing noise sources (e.g. inlet/outlet of ventilation).

Measurements are to be carried out in a minimum of 60% of the rooms on each cabins deck (including hospital). When the engine casing is integrated in the accommodation area, noise levels are to be measured in each adjacent room.

For the location and number of measuring points in crew cabins within passenger ships, refer to Ch 6, Sec 4.

In addition, noise is to be measured in all workspaces and public spaces specified in Tab 1and Tab 2. In the wheelhouse, three points are to be measured (centreline and both sides).

For large rooms exceeding 20 m^2 (mess rooms, recreation rooms...), noise measurements are to be performed every 20 m^2.

b) Sound insulation measurements

The selection of sound insulation measuring locations is to be representative of the different types of insulation provided in Tab 3 (a minimum of two measurements of each type is required).

2.2 Noise levels

2.2.1 Noise levels corresponding to the noise grade **x** are provided in Tab 1 or Tab 2, as applicable.

2.3 Sound insulation measurements

2.3.1 Between two adjacent accommodation spaces, apparent weighted sound reduction index R'w is to be greater than the requirements given in Tab 3. Measurements are to be performed in situ, ship at quay or at anchorage.

Table 1 : Noise level requirements for ships from 1600 GT to 10000 GT

Locations	LAeq,T in dB(A)		
	grade = 1	grade = 2	grade = 3
Wheelhouse	60,0	63,0	65,0
Radio room **(1)**	55,0	57,0	60,0
Cabins	52,0	55,0	60,0
Offices	57,0	60,0	65,0
Public spaces, mess rooms	57,0	60,0	65,0
Hospital	56,0	58,0	60,0
Engine control room or switchboard room (if continuously manned at sea) **(2)**	70,0	73,0	75,0
Open recreation areas **(3)** **(4)**	70,0	73,0	75,0
Galleys **(2)**	72,0	72,0	75,0
Workshops other than those forming part of machinery spaces **(2)**	85,0	85,0	85,0
Staircases and passages in crew areas	70,0	73,0	75,0

(1) Equipment switched on but not emitting.
(2) Equipment switched on but not in use.
(3) Measurement carried out with a microphone windscreen.
(4) A tolerance of 5 dB(A) may be accepted for measurements at less than 3 m from a ventilation inlet/outlet.

Table 2 : Noise level requirements for ships greater than 10000 GT

Locations	LAeq,T in dB(A)		
	grade = 1	grade = 2	grade = 3
Wheelhouse	60,0	63,0	65,0
Radio room **(1)**	55,0	57,0	60,0
Cabins	50,0	52,0	55,0
Offices	55,0	57,0	60,0
Public spaces, mess rooms	55,0	57,0	60,0
Hospital	53,0	54,0	55,0
Engine control room or switchboard room (if continuously manned at sea) **(2)**	70,0	73,0	75,0
Open recreation areas **(3)** **(4)**	70,0	73,0	75,0
Galleys **(2)**	72,0	72,0	75,0
Workshops other than those forming part of machinery spaces **(2)**	85,0	85,0	85,0
Staircases and passages in crew areas	70,0	73,0	75,0

(1) Equipment switched on but not emitting.
(2) Equipment switched on but not in use.
(3) Measurement carried out with a microphone windscreen.
(4) A tolerance of 5 dB(A) may be accepted for measurements at less than 3 m from a ventilation inlet/outlet.

Table 3 : Apparent weighted sound reduction indexes R'w in dB

Locations	grade = 1	grade = 2	grade = 3
Cabin to cabin	37	35	32
Corridor to cabin	35	32	30
Stairs to cabin	35	32	30
Public spaces to cabin	45	44	42
Note 1: When the area of the tested partition is less than 10 m^2, a minimum value of 10 m^2 is to be considered for the calculation of index R'w.			

3 COMF-VIB

3.1 Measurement procedure

3.1.1 Measuring conditions

Tests are to be conducted under the conditions described in Ch 6, Sec 1, [3.3].

3.1.2 Measuring positions

Measurements are to be taken in vertical direction. In cabins, offices or other small size rooms, measurements are to be taken on the floor in the centre of the room. For larger rooms, several measuring points may be required.

Measurements are to be carried out in a minimum of 60% of the rooms on each cabins deck (including hospital).

For the location and number of measuring points in crew cabins within passenger ships, refer to Ch 6, Sec 4.

Vibrations are to be measured in all workspaces and public spaces specified in Tab 4, Tab 5 or Tab 6. In the wheelhouse, three points are to be measured (centreline and both sides).

In addition to vertical direction, measurements in transverse and longitudinal directions are to be performed on one point on each deck. This point is not to be located in way of nodal points of vibration modes.

3.2 Vibration levels

3.2.1 Vibration levels corresponding to the vibration grade **x** are provided in Tab 4 in accordance to ISO 20283-5 (the limits listed below are applicable for any directions).

3.2.2 Vibration levels corresponding to the vibration grade **x** are provided in Tab 5 and Tab 6 in accordance to ISO 6954:1984 (the limits listed below are applicable for any directions).

Table 4 : Overall frequency weighted R.M.S vibration levels

Locations	Vibration velocity (mm/s) values from 1 Hz to 80 Hz		
	grade = 1	grade = 2	grade = 3
Wheelhouse	2,8	3,0	3,2
Radio room			
Cabins	2,8	3,0	3,2
Offices	3,0	3,5	4,0
Public spaces, mess rooms	3,0	3,2	3,5
Hospital	2,8	3,0	3,2
Engine control room or switchboard room (if continuously manned at sea)	4,0	4,5	5,0
Open recreation areas	–	–	–
Galleys	5,0	5,5	6,0
Workspaces			
Staircases and passages in crew areas	5,0	5,5	6,0

Table 5 : Single amplitude peak vibration levels from 5 Hz to 100 Hz

Locations	Vibration velocity (mm/s peak) values from 5 Hz to 100 Hz		
	grade = 1PK	grade = 2PK	grade = 3PK
Wheelhouse	2,0	3,0	4,0
Radio room			
Cabins	3,0	3,5	4,0
Offices	3,0	4,0	5,0
Public spaces, mess rooms	3,0	3,5	4,0
Hospital	2,0	3,0	4,0
Engine control room or switchboard room (if continuously manned at sea)	4,0	4,5	5,0
Open recreation areas	–	–	–
Galleys	5,0	5,5	6,0
Workspaces			
Staircases and passages in crew areas	5,0	5,5	6,0

Table 6 : Single amplitude peak vibration levels from 1 Hz to 5 Hz

Locations	Acceleration (mm/s² peak) values from 1 Hz to 5 Hz		
	grade = 1PK	grade = 2PK	grade = 3PK
Wheelhouse	96,0	103,0	111,0
Radio room			
Cabins	89,0	96,0	100,0
Offices	96,0	111,0	125,0
Public spaces, mess rooms	96,0	111,0	125,0
Hospital	89,0	96,0	125,0
Engine control room or switchboard room (if continuously manned at sea)	125,0	141,0	157,0
Open recreation areas	–	–	–
Galleys	157,0	172,0	188,0
Workspaces			
Staircases and passages in crew areas	157,0	172,0	188,0

Section 4 COMF Notations - Additional Requirements for Passenger Areas - Ships Greater than or Equal to 1600 GT

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to passenger areas of ships greater than or equal to 1600 GT. They are additional to the applicable requirements of Ch 6, Sec 1.

2 COMF-NOISE

2.1 Measurement procedure

2.1.1 Measuring conditions

Tests have to be conducted in the conditions described in Ch 6, Sec 1, [3.3]. Air conditioning is to be in normal operation. Doors and windows have to be closed, unless they have to be kept open in normal use.

It may happen that the measurements in accommodation spaces cannot be performed with HVAC in normal operation (as defined in Ch 6, Sec 1, [3.3]).

In such case, additional measurements should be done at quay and taken into account in the final results as follows:

$$LAeq = 10 \cdot Log_{10}\left(10^{\frac{LAeq1}{10}} + 10^{\frac{LAeq2}{10}}\right)$$

where:

LAeq1 : Equivalent continuous A weighted sound pressure level measured at quay with HVAC in normal operation.

LAeq2 : Equivalent continuous A weighted sound pressure level measured in sailing conditions without HVAC in normal operation.

2.1.2 Measuring positions

a) Noise measurements

Measurements are to be taken at a height between 1,2 and 1,6 m from the deck and at a distance above 1,0 m from any boundary surface of the room. In cabins and offices, one measurement will be performed in the middle of the space. Additional measurements should be performed in other locations if appreciable sound level differences inside the room occur.

On open decks, measurements are to be taken at 2,0 m at least from the existing noise sources (e.g. inlet/outlet of ventilation).

In cabins, measurements are to be carried out at the centre of the cabin.

In order to define the location and number of measuring points, the length of the ship is divided in two parts:

- From the aft part of the ship to the front bulkhead of the casing:
  - minimum of 35% of cabins
  - all public spaces and open decks.

  For large public rooms (lounges, restaurants…) measurements are to be carried out in different locations, each measuring point covering less than 50 m^2.
- From the front bulkhead of the casing to the fore end of the ship:
  - minimum of 15% of cabins
  - all public spaces and open decks.

  For large public rooms (lounges, restaurants…) measurements are to be carried out in different locations, each measuring point covering less than 100 m^2.

Note 1: The Society may accept a lower number of measuring points or a modification of the points distribution for specific cases.

Note 2: The number of measuring points should not exceed 250.

b) Sound insulation measurements

The selection of insulation measuring locations is to be representative of the different types of insulation provided in Tab 1 (a minimum of two measurements of each type is required).

c) Impact measurements

The selection of impact measuring locations is to be representative of the different deck coverings implemented on the ship and as provided in Tab 3 (a minimum of two measurements of each deck covering is required). These measurements are dedicated to passenger cabins only.

Table 1 : Apparent weighted sound reduction indexes R'w in dB

Locations	grade = 1	grade = 2	grade = 3
Cabin to cabin (top level)	45	42	40
Cabin to cabin (standard)	41	38	36
Cabin to cabin with communication door (top level)	44	41	39
Cabin to cabin with communication door (standard)	40	37	35
Corridor to cabin (top level)	42	40	37
Corridor to cabin (standard)	38	36	34
Stairs to cabin	48	45	45
Public spaces to cabin	53	50	48
Discotheques and show rooms to cabin	64	62	60
Note 1: When the area of the tested partition is less than 10 m^2, a minimum value of 10 m^2 is to be considered for the calculation of index R'w.			

2.2 Noise levels

2.2.1 Noise levels corresponding to the noise grade **x** are provided in Tab 2.

Table 2 : Noise level requirements

Locations	LAeq,T in dB (A)		
	grade = 1	grade = 2	grade = 3
Passenger top level cabins	45,0	47,0	50,0
Passenger standard cabins	49,0	52,0	55,0
Restaurants, cafeterias and type B spaces **(1)**	55,0	57,0	60,0
Public shop, passages (type D) **(1)**	60,0	63,0	65,0
Passenger spaces (type A) **(1)**	65,0	68,0	72,0
Passenger spaces (type C) **(1)**	53,0	56,0	59,0
Outside installations (swimming pools, sport decks...) **(2)** **(3)**	65,0	70,0	75,0
Beauty center and spas (massage parlor, rest room, hairdressing salon, ...) **(4)**	53,0	56,0	59,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1]. **(2)** A tolerance of 5 dB (A) may be accepted for measurements at less than 3 m from ventilation inlet/outlet. **(3)** Measurement carried out with a windscreen microphone protection. **(4)** Equipment not processing.			

2.3 Sound insulation measurements

2.3.1 Between two adjacent accommodation spaces, acoustic insulation is to be greater than the requirements given in Tab 1. Measurements are to be performed in situ, ship at quay or at anchorage.

2.4 Impact measurements

2.4.1 For cabins below public spaces, the weighted normalized impact sound pressure level is to be lower than the requirements given in Tab 3. Measurements are to be performed in situ, ship at quay or at anchorage.

Table 3 : Weighted normalized impact sound pressure level L'n,w

Locations	L'n,w in dB
Cabin below public spaces covered with soft materials	50
Cabin below public spaces covered with hard materials (wood, marble, tiles, etc)	60
Cabin below sport rooms or dance floors	45

3 COMF-VIB

3.1 Measurement procedure

3.1.1 Measuring conditions

Tests are to be conducted under the conditions described in Ch 6, Sec 1, [3.3].

3.1.2 Measuring positions

Measurements are to be taken in vertical direction. In cabins, offices or other small size rooms, measurements are to be taken on the floor in the centre of the room. For larger rooms, several measuring points may be required.

In order to define the location and number of measuring points, the length of the ship is divided in two parts:

- From the aft part of the ship to the front bulkhead of the casing:
  - minimum of 20% of cabins
  - all public spaces and open decks.

  For large public rooms (lounges, restaurants, …) measurements are to be carried out in different locations, each measuring point covering less than 80 m^2.
- From the front bulkhead of the casing to the fore end of the ship:
  - minimum of 10% of cabins
  - all public spaces and open decks.

  For large public rooms (lounges, restaurants, …) measurements are to be carried out in different locations, each measuring point covering less than 150 m^2.

Note 1: The Society may accept a lower number of measuring points or a modification of the points distribution for specific cases.

Note 2: The number of measuring points should not exceed 250.

In addition to vertical direction, measurements in transverse and longitudinal directions are to be performed every 3 decks, with one measuring point in the fore part of the ship, one in the middle part and one in the aft part. These points are not to be located in way of nodal points of vibration modes.

3.2 Vibration levels

3.2.1 Vibration levels corresponding to the vibration grade **x** are provided in Tab 4 in accordance to ISO 20283-5 (the limits listed below are applicable for any directions).

3.2.2 Vibration levels corresponding to the vibration grade **x** are provided in Tab 5 and Tab 6 in accordance to ISO 6954:1984 (the limits listed below are applicable for any directions).

Table 4 : Overall frequency weighted R.M.S. vibration levels

Locations	Vibration velocity (mm/s) values from 1 Hz to 80 Hz		
	grade = 1	grade = 2	grade = 3
Passenger top level cabins	1,7	2	2,2
Passenger standard cabins	2,0	2,5	3,0
Restaurants, cafeterias and type B spaces **(1)**	2,2	2,5	3,0
Public shops, passages (type D) **(1)**	4,0	4,5	5,0
Passenger spaces (type A) **(1)**			
Passenger spaces (type C) **(1)**	2,0	2,5	3,0
Outside installations (swimming pools, sport decks, ...)	3,0	3,5	4,0
Beauty center and spas (massage parlor, rest room, hairdressing salon, ...) **(2)**	2,0	2,5	3,0

(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].
(2) Equipment not processing.

Table 5 : Single amplitude peak vibration levels from 1 Hz to 5 Hz

Locations	Acceleration (mm/s² peak) values from 1 Hz to 5 Hz		
	grade = 1PK	grade = 2PK	grade = 3PK
Passenger top level cabins	48,0	64,0	80,0
Passenger standard cabins	64,0	80,0	96,0
Restaurants, cafeterias and type B spaces **(1)**	80,0	96,0	111,0
Public shops, passages (type D) **(1)**	125,0	125,0	125,0
Passenger spaces (type A) **(1)**			
Passenger spaces (type C) **(1)**	64,0	80,0	96,0
Outside installations (swimming pools, sport decks, ...)	96,0	125,0	125,0
Beauty center and spas (massage parlor, rest room, hairdressing salon, ...) **(2)**	64,0	80,0	96,0

(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].
(2) Equipment not processing.

Table 6 : Single amplitude peak vibration levels from 5 Hz to 100 Hz

Locations	Vibration velocity (mm/s peak) values from 5 Hz to 100 Hz		
	grade = 1PK	grade = 2PK	grade = 3PK
Passenger top level cabins	1,5	2,0	2,5
Passenger standard cabins	2,0	2,5	3,0
Restaurants, cafeterias and type B spaces **(1)**	2,5	3,0	3,5
Public shops, passages (type D) **(1)**	4,0	4,0	4,0
Passenger spaces (type A) **(1)**			
Passenger spaces (type C) **(1)**	2,0	2,5	3,0
Outside installations (swimming pools, sport decks, ...)	3,0	4,0	4,0
Beauty center and spas (massage parlor, rest room, hairdressing salon, .) **(2)**	2,0	2,5	3,0

(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].
(2) Equipment not processing.

Section 5 COMF Notations - Additional Requirements for Yachts

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to yachts. They are additional to the applicable requirements of Ch 6, Sec 1.

2 COMF-NOISE

2.1 Measurement procedure

2.1.1 Measuring conditions

For noise level measurements in harbour conditions, machinery and chiller should be run under normal harbour conditions. HVAC and machinery ventilation must be in operation and at nominal rate all over the ship.

Tests in sea trial conditions are to be conducted in the conditions described in Ch 6, Sec 1, [3.3]. Air conditioning is to be in normal operation. Doors and windows are to be closed, unless they are to be kept open in normal use.

It may happen that the measurements in accommodation spaces cannot be performed with HVAC in normal operation (as defined in Ch 6, Sec 1, [3.3]).

In such case, additional measurements should be done at quay and taken into account in the final results as follows:

$$LAeq = 10 \cdot Log_{10}\left(10^{\frac{LAeq1}{10}} + 10^{\frac{LAeq2}{10}}\right)$$

where:

LAeq1 : Equivalent continuous A weighted sound pressure level measured at quay with HVAC in normal operation.

LAeq2 : Equivalent continuous A weighted sound pressure level measured in sailing conditions without HVAC in normal operation.

2.1.2 Measuring positions

a) Noise measurements

Measurements are to be taken at a height between 1,2 and 1,6 m from the deck and at a distance above 1,0 m from any boundary surface of the room. In cabins and offices, one measurement will be performed in the middle of the space. Additional measurements should be performed in other locations if appreciable sound level differences inside the room occur.

On open deck, measurements are to be taken at 2,0 m at least from the existing noise sources (e.g. inlet/outlet of ventilation).

The noise measurements are to be performed in all crew and passenger spaces, each measuring point covering less than 15 m^2.

b) Sound insulation measurements

The selection of insulation measuring locations is to be representative of the different types of insulation provided in Tab 1 and Tab 3 (a minimum of two measurements of each type is required).

c) Impact measurements

The selection of impact measuring locations is to be representative of the different deck coverings implemented on the ship (a minimum of two measurements of each deck covering is required).

These measurements are dedicated to passenger cabins only.

2.2 Noise levels

2.2.1 Noise levels corresponding to the noise grade **x** are provided in Tab 2.

2.3 Sound insulation measurements

2.3.1 Between two adjacent accommodation spaces, acoustic insulation is to be greater than the requirements given in Tab 1 and Tab 3. Measurements are to be performed in situ, ship at quay or at anchorage.

2.4 Impact measurements

2.4.1 For cabins below public spaces, impact noise index is to be lower than the requirements given in Tab 4. Measurements are to be performed in situ, ship at quay or at anchorage.

Table 1 : Apparent weighted sound reduction indexes R'w in dB for passenger areas

Locations	grade = 1	grade = 2	grade = 3
Cabin to cabin	45	42	40
Corridor to cabin	42	40	37
Stairs to cabin	48	45	45
Public spaces to cabin	55	53	50
Public spaces designed for loud music to cabin	64	62	60
Note 1: When the area of the tested partition is less than 10 m^2, a minimum value of 10 m^2 is to be considered for the calculation of index R'w.			

Table 2 : Noise level requirements

Locations	LAeq,T in dB (A)					
	Harbour			Sea		
	grade = 1	grade = 2	grade = 3	grade = 1	grade = 2	grade = 3
Wheelhouse	–	–	–	65,0	65,0	65,0
Passengers cabins	40,0	45,0	50,0	50,0	54,0	58,0
Lounges	45,0	50,0	55,0	55,0	58,0	62,0
Open recreation areas **(1)**	55,0	60,0	65,0	75,0	80,0	85,0
Crew cabins	45,0	50,0	55,0	55,0	58,0	60,0
Public spaces (type B), mess rooms **(2)**	55,0	58,0	60,0	60,0	63,0	65,0
Passages and type D spaces **(2)**	60,0	63,0	65,0	65,0	68,0	72,0
(1) Measurement carried out with a windscreen microphone protection. **(2)** For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].						

Table 3 : Apparent weighted sound reduction indexes R'w in dB for crew areas

Locations	grade = 1	grade = 2	grade = 3
Cabin to cabin	37	35	32
Corridor to cabin	35	32	30
Stairs to cabin	35	32	30
Public spaces to cabin	45	45	45
Note 1: When the area of the tested partition is less than 10 m^2, a minimum value of 10 m^2 is to be considered for the calculation of index R'w.			

Table 4 : Weighted normalized impact sound pressure level

Locations	L'n,w in dB
Cabin below public spaces covered with soft materials	50
Cabin below public spaces covered with hard materials (wood, marble, tiles, etc)	60
Cabin below sport rooms or dance floors	45

3 COMF-VIB

3.1 Measurement procedure

3.1.1 Measuring conditions

Tests are to be conducted under the conditions described in Ch 6, Sec 1, [3.3].

3.1.2 Measuring positions

Measurements are to be taken in vertical direction. In cabins, offices or other small size rooms, measurements are to be taken on the floor in the centre of the room. For larger rooms, several measuring points may be required.

Measurements are to be performed in all crew and passenger spaces, each measuring point covering less than 15 m^2.

In addition to vertical direction, measurements in transverse and longitudinal directions are to be performed on one point on each deck. This point is not to be located in way of nodal points of vibration modes.

3.2 Vibration levels

3.2.1 Vibration levels corresponding to the vibration grade **x** are provided in Tab 5 in accordance to ISO 20283-5 (the limits listed below are applicable for any directions).

3.2.2 Vibration levels corresponding to the vibration grade x are provided in Tab 6 and Tab 7 in accordance to ISO 6954:1984 (the limits listed below are applicable for any directions).

Table 5 : Overall frequency weighted R.M.S vibration levels

Locations	Vibration velocity (mm/s) values from 1 Hz to 80 Hz					
	Harbour			Sea		
	grade = 1	grade = 2	grade = 3	grade = 1	grade = 2	grade = 3
Wheelhouse	–	–	–	2,5	3,5	4,5
Passengers cabins	1,0	1,5	2,0	2,0	2,5	3,0
Lounges	1,0	1,5	2,0	2,0	2,5	3,0
Open recreation areas	2,0	2,5	3,0	3,0	4,0	4,5
Crew cabins	2,0	2,5	3,0	2,5	3,0	3,5
Public spaces (type B), mess rooms **(1)**	2,0	2,5	3,0	2,5	3,0	3,5
Passages and type D spaces **(1)**	2,0	3,0	4,0	3,0	4,0	5,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].						

Table 6 : Single amplitude peak vibration levels from 5 Hz to 100 Hz

Locations	Vibration velocity (mm/s peak) values from 5 Hz to 100 Hz					
	Harbour			Sea		
	grade = 1PK	grade = 2PK	grade = 3PK	grade = 1PK	grade = 2PK	grade = 3PK
Wheelhouse	–	–	–	2,5	3,5	5,0
Passengers cabins	1,0	1,5	2,5	2,0	2,5	3,0
Lounges	1,0	1,5	2,5	3,0	3,5	4,0
Open recreation areas	2,0	3,0	4,0	3,5	4,5	5,0
Crew cabins	1,5	2,0	2,5	2,0	2,5	3,0
Public spaces (type B), mess rooms **(1)**	2,0	2,5	3,0	3,0	3,5	4,0
Passages and type D spaces **(1)**	2,0	3,0	4,0	3,0	4,0	5,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].						

Table 7 : Single amplitude peak vibration levels from 1 Hz to 5 Hz

Locations	Acceleration (mm/s² peak) values from 1 Hz to 5 Hz					
	Harbour			Sea		
	grade = 1PK	grade = 2PK	grade = 3PK	grade = 1PK	grade = 2PK	grade = 3PK
Wheelhouse	–	–	–	80,0	111,0	144,0
Passengers cabins	32,0	48,0	80,0	64,0	80,0	96,0
Lounges	32,0	48,0	80,0	96,0	111,0	125,0
Open recreation areas	64,0	96,0	125,0	111,0	144,0	157,0
Crew cabins	48,0	64,0	78,0	64,0	80,0	96,0
Public spaces (type B), mess rooms **(1)**	64,0	80,0	96,0	96,0	111,0	128,0
Passages and type D spaces **(1)**	64,0	96,0	125,0	96,0	125,0	157,0
(1) For the definition of type A to type D public spaces, refer to Ch 6, Sec 1, [1.4.1].						

4 COMF +

4.1 Application

4.1.1 Optional **COMF +** notation represents an advanced comfort rating with additional performance index requirements.

Note 1: The present Article may also be applied, after special study, to passenger ships.

4.1.2 Prior to the **COMF+** notation assessment, **COMF-NOISE** notation is to be granted.

4.1.3 The following **COMF+** performance indexes can be granted separately:

- **COMF+** Sound insulation index
- **COMF+** Impact index
- **COMF+** Emergence
- **COMF+** Intermittent noise
- **COMF+** Intelligibility.

4.2 Data processing and analysis

4.2.1 Results are to be given on a table in global values (dB(A) or dB for insulation measurements).

4.3 Measurement procedure

4.3.1 Measuring conditions

Tests are to be conducted in the conditions described in Ch 6, Sec 1, [3.3] and [2.1.1].

Specific additional conditions are described in the relevant **COMF+** index requirements.

4.3.2 Measuring positions

The location of the measuring positions is selected in accordance with [2.1.2] for **the following** indexes:

- **COMF+** Sound insulation index
- **COMF+** Impact index
- **COMF+** Emergence.

4.4 COMF + Sound insulation index

4.4.1 Sound insulation between discotheques, show lounge and passenger cabins

Due to the potential low frequency noise, transmitted through floors or bulkheads, the sound insulation index requirement is to be considered as the sum of the R'w index + the adaptation term C as described in ISO 717-1.

The adaptation term C added to the R'w index is to be above the insulation level given in Tab 8.

Table 8 : Sound insulation indexes R'w+C

Locations	grade = 1	grade = 2	grade = 3
Discotheques and show rooms to cabin	64	62	59

4.5 COMF + Impact index

4.5.1 Due to the potential low frequency noise, transmitted through the floor, the impact noise index requirement is to be considered as the sum of the L'n,w index + the adaptation term C_I as described in ISO 717-2.

The adaptation term C_I added to the L'n,w index is to be below any impact comfort class requirements listed in [2.4.1].

4.6 COMF + Emergence

4.6.1 When the noise level contains audible annoying tonal components, an objective assessment should be carried out as described in ISO 1996-2:2007 Annex D.

A prominent tone in one-third-octave band is established when its level exceeds the time-average sound pressure levels of both adjacent one-third-octave bands by some constant level difference.

Note 1: "one-third-octave band" means band of sound covering a range of frequencies such that the highest is the cube root of two times the lowest.

The constant level difference varies with the frequency and shall not exceed:

- 15 dB in the low-frequency one-third-octave bands (25 Hz to 125 Hz)
- 8 dB in middle-frequency bands (160 Hz to 400 Hz)
- 5 dB in high-frequency bands (500 Hz to 10 000 Hz).

4.7 COMF + intermittent noise

4.7.1 Machinery and systems having an intermittent operation are not to increase the noise level in cabins, with regard to ambient noise, by more than 5 dB(A) during daytime (from 7 am to 10 pm) and 3 dB(A) during night time (from 10 pm to 7 am).

4.7.2 The shipyard is to propose an intermittent noise measuring program including:

- the complete procedure of measurements
- the exhaustive list of system which includes, when applicable:
  - swimming pool/Jacuzzi equipment and piping during filling/emptying/re-circulating
  - dishwasher/pulper
  - high pressure deck washing piping systems
  - hydraulic power pack
  - evaporators
  - stabiliser systems
  - steam dump valve
  - laundry/garbage equipment
- the ambient noise considered for each system (i.e. noise at quay or at sea conditions).

Anchoring, mooring, thrusters, safety alarms, emergency equipment are excluded from the list of machinery systems concerned by this paragraph.

This program is to be submitted to the Society prior to the trials.

4.8 COMF + intelligibility

4.8.1 In spaces with audience expected, like theatres, conference rooms, etc..., the STIPA (Speech Transmission Index for Public Address system) is to be above 0,60 (for each public space, measurements are to be carried out in different locations, each measuring point covering less than 40 m^2).

The Society may accept a lower number of measuring points or a modification of the point distribution for specific cases.

Note 1: The evaluation of the STIPA has been standardised in IEC 60268-16.

4.8.2 For other specified spaces, the reverberation time (RT), in seconds, is to be lower than the requirements of:

- Tab 9 for restaurants, bars, lounges and casinos
- Tab 10 for cabins, lecture rooms and libraries.

4.8.3 An Intelligibility noise measuring program is to be submitted to the Society, prior to measurement test.

Table 9 : Reverberation time requirements for restaurants, bars, lounges and casinos

Volume V, in m^3	RT, in s
$V \leq 50$	0,50
$50 < V \leq 100$	0,60
$100 < V \leq 200$	0,70
$200 < V \leq 500$	0,80
$500 < V \leq 1000$	0,90
$1000 < V \leq 2000$	1,00
$2000 < V \leq 3000$	1,10
$V > 3000$	1,20

Table 10 : Reverberation time requirements for cabins, lecture rooms and libraries

Volume V, in m^3	RT, in s
$V \leq 50$	0,45
$50 < V \leq 100$	0,50
$100 < V \leq 200$	0,55
$200 < V \leq 500$	0,60
$500 < V \leq 1000$	0,70
$1000 < V \leq 2000$	0,80
$V > 2000$	0,90

Section 6 Habitability

1 General

1.1 Scope

1.1.1 This Section covers the requirements for crew accommodation and recreational facilities stated in the MLC Convention 2006 (called "the MLC Convention" in this Section), Regulation 3.1, in so far as the following aspects are concerned:

- accommodation design
- vibration
- noise
- indoor climate
- lighting.

This Section does not cover the requirements of Regulation 3.2 of the Convention: Food and catering.

1.1.2 In accordance with the requirements of Pt A, Ch 1, Sec 2, [6.7.6], the additional class notation **HABITABILITY** may be assigned, upon request of the Shipowner, to ships found to be in compliance with both the criteria of the MLC Convention and the provisions of this Section.

1.2 Equivalences and alternatives

1.2.1 National requirements

In case of a discrepancy between the national regulations and the provisions of the present Section, the former always takes precedence. However, the Society reserves the right to call for the necessary adaptation to preserve the intention of this Section.

1.2.2 Technical alternatives

When authorized by the Administration, the Society will consider alternative arrangements and criteria for compliance with this Section, proposed by the interested parties always on behalf of the Owner, provided that their relevance has been demonstrated through sound engineering analysis or service experience.

2 Accommodation

2.1 General

2.1.1 Documents to be submitted

Location and general arrangement of crew accommodation spaces are to be submitted, at a scale not less than 1/100, deck by deck, and adequately detailing the:

- use of various spaces
- type of cabins (ratings, officers)
- surfaces of spaces
- number of persons (crew/passengers) on board
- disposition of furniture and fittings, and
- sanitary arrangements.

2.2 General design requirements

2.2.1 The headroom *in all seafarer accommodation where full and free movement is necessary shall be not less than 203 centimetres*, however subject to [1.2] if this condition is not fulfilled.

2.2.2 *The accommodation shall be adequately insulated* (refer to [2.2.7]).

2.2.3 *In ships other than passenger ships, sleeping rooms shall be situated above the load line amidships or aft, except that in exceptional cases, where the size, type or intended service of the ship* makes this impossible, *sleeping rooms may be located in the fore part of the ship, but in no case forward of* the rule vertical extension of *the collision bulkhead.*

2.2.4 *In passenger ships and in special purpose ships,* the Society *may, on condition that satisfactory arrangements are made for lighting and ventilation, permit the location of sleeping rooms below the load line, but in no case shall they be located immediately beneath working alleyways.*

2.2.5 *There shall be no direct openings into sleeping rooms from cargo and machinery spaces or from galleys, storerooms, drying rooms or communal sanitary areas; that part of a bulkhead separating such places from sleeping rooms and external bulkheads shall be efficiently constructed of steel or other approved substance and be* adequately *watertight and gas-tight.*

2.2.6 *The materials used to construct internal bulkheads, panelling and sheeting, floors and joinings shall be* adequate *for the purpose* according to the referred standards.

2.2.7 The design and construction shall be as follows:

a) *External bulkheads of sleeping rooms and mess rooms should be adequately insulated. All machinery casings and all boundary bulkheads of galleys and other spaces in which heat is produced should be adequately insulated where there is a possibility of resulting heat effects in adjoining accommodation or passageways. Measures should also be taken to provide protection from heat effects of steam or hot-water service pipes or both.* In general, insulation materials with thermal conductivity factor K value of 0,036 W/m·K or equivalent are to be used for external boundaries.

b) *Sleeping rooms, mess rooms, recreation rooms and alleyways in the accommodation space should be adequately insulated to prevent condensation.*

c) *The bulkhead surfaces and deckheads should be of material with a surface easily kept clean. No form of construction likely to harbour vermin should be used.*

d) *The bulkhead surfaces and deckheads in sleeping rooms and mess rooms should be capable of being easily kept clean and light in colour with a durable, non-toxic finish.*

e) *The decks in all seafarer accommodation should be of* steel or equivalent *material and of approved construction and should provide a non-slip surface impervious to damp and easily kept clean.*

f) *Where the floorings are made of composite materials, the joints with the sides should be profiled to avoid crevices.*

2.3 Sleeping rooms

2.3.1 *In ships other than passenger ships, an individual sleeping room shall be provided for each seafarer; in the case of ships of less than 3000 gross tonnage or special purpose ships, exemptions from this requirement may be granted*, subject to [1.2].

2.3.2 *Separate sleeping rooms shall be provided for men and for women.*

2.3.3 *A separate berth for each seafarer shall in all circumstances be provided.*

2.3.4 *The minimum inside dimensions of a berth shall be at least 198 centimetres by 80 centimetres.*

2.3.5 *In single berth seafarers' sleeping rooms, the floor area shall not be less than:*

- *4,5 square metres in ships of less than 3000 gross tonnage*
- *5,5 square metres in ships of 3000 gross tonnage or over but less than 10000 gross tonnage*
- *7,0 square metres in ships of 10000 gross tonnage or over.*

2.3.6 *However, in order to provide single berth sleeping rooms on ships of less than 3000 gross tonnage, passenger ships and special purpose ships,* a reduced floor area may be allowed, subject to [1.2].

2.3.7 *In ships of less than 3000 gross tonnage other than passenger ships and special purpose ships, sleeping rooms may be occupied by a maximum of two seafarers; the floor area of such sleeping rooms shall not be less than 7 square metres.*

2.3.8 *On ships other than passenger ships and special purpose ships, sleeping rooms for seafarers who perform the duties of ships' officers, where no private sitting room or day room is provided, the floor area per person shall not be less than:*

- *7,5 square metres in ships of less than 3000 gross tonnage*
- *8,5 square metres in ships of 3000 gross tonnage or over but less than 10000 gross tonnage*
- *10,0 square metres in ships of 10000 gross tonnage or over.*

2.3.9 *The master, the chief engineer and the chief navigating officer shall have, in addition to their sleeping rooms, an adjoining sitting room, day room or equivalent additional space.*

Ships of less than 3000 gross tonnage may be exempted by the Society *from this requirement*, subject to [1.2].

2.3.10 *For each occupant, the furniture shall include a clothes locker of minimum 475 litres and a drawer or equivalent space of not less than 56 litres. If the drawer is incorporated in the clothes locker, then the combined minimum volume of the clothes locker shall be 500 litres. It shall be fitted with a shelf and be able to be locked by the occupant.*

2.3.11 *Each sleeping room shall be provided with a table or desk, which may be of the fixed, drop-leaf or slide-out type, and with* adequate *seating accommodation.*

2.3.12 Sleeping room arrangements shall be as follows:

a) In the case of seafarers performing the duty of petty officers, there should be no more than two persons per sleeping room.

b) Space occupied by berths and lockers, chests of drawers and seats should be included in the measurement of the floor area. Small or irregularly shaped spaces which do not add effectively to the space available for free movement and cannot be used for installing furniture should be excluded.

c) Berths should not be arranged in tiers of more than two; in the case of berths placed along the ship's side, there should be only a single tier where a sidelight is situated above a berth.

d) The lower berth in a double tier should be not less than 30 centimetres above the floor; the upper berth should be placed approximately midway between the bottom of the lower berth and the lower side of the deckhead beams.

e) The framework and the lee-board, if any, of a berth should be of approved material (as per standards used in shipbuilding industry)*, hard, smooth, and not likely to corrode or to harbour vermin.*

f) If tubular frames are used for the construction of berths, they should be completely sealed and without perforations which would give access to vermin.

g) Each berth should be fitted with a comfortable mattress with cushioning bottom or a combined cushioning mattress, including a spring bottom or a spring mattress. The mattress and cushioning material used should be made of approved material (as per standards used in shipbuilding industry)*. Stuffing of material likely to harbour vermin should not be used.*

h) When one berth is placed over another, a dust-proof bottom should be fitted beneath the bottom mattress or spring bottom of the upper berth.

i) The furniture should be of smooth, hard material not liable to warp or corrode.

j) Sleeping rooms should be fitted with curtains or equivalent for the sidelights.

k) Sleeping rooms should be fitted with a mirror, small cabinets for toilet requisites, a book rack and a sufficient number of coat hooks.

2.4 Sleeping rooms - Special arrangements for passenger ships and special purpose ships

2.4.1 *On passenger ships and special purpose ships, the floor area of sleeping rooms for seafarers not performing the duties of ships' officers shall not be less than:*

- *7,5 square metres in rooms accommodating two persons*
- *11,5 square metres in rooms accommodating three persons*
- *14,5 square metres in rooms accommodating four persons.*

2.4.2 *On special purpose ships, sleeping rooms may accommodate more than four persons. The floor area of such sleeping rooms shall not be less than 3,6 square metres per person.*

2.4.3 *On passenger ships and special purpose ships, the floor area for seafarers performing the duties of ships' officers where no private sitting room or day room is provided, the floor area per person for junior officers shall not be less than 7,5 square metres and for senior officers not less than 8,5 square metres. Junior officers are understood to be at the operational level, and senior officers at the management level.*

2.5 Mess rooms

2.5.1 *Mess rooms shall be located apart from the sleeping rooms and as close as practicable to the galley.*

Ships of less than 3000 gross tonnage may be exempted by the Society *from this requirement*, subject to [1.2].

2.5.2 *Mess room facilities* are normally separate. They may be common, subject to [1.2] and taking account of shipowners' representatives information and *factors such as the size of the ship and the distinctive cultural, religious and social needs of the seafarers.*

2.5.3 *Where separate mess room facilities are to be provided to seafarers, then separate mess rooms should be provided for:*

- *master and officers, and*
- *petty officers and other seafarers.*

2.5.4 Mess room arrangements shall be as follows:

a) On ships other than passenger ships, the floor area of mess rooms for seafarers should be not less than 1,5 square metres per person of the planned seating capacity.

b) In all ships, mess rooms should be equipped with tables and appropriate seats (34 cm minimum breadth)*, fixed or movable, sufficient to accommodate the* specified *number of seafarers likely to use them at any one time.*

c) *There should be available at all times when seafarers are on board:*

- *a refrigerator, which should be conveniently situated and of sufficient capacity for the number of persons using the mess room or mess rooms*
- *facilities for hot beverages, and*
- *cool water facilities.*

d) *Where available pantries are not accessible to mess rooms, adequate lockers for mess utensils and proper facilities for washing utensils should be provided.*

e) *The tops of tables and seats should be of damp-resistant material.*

2.6 Sanitary facilities and accommodation

2.6.1 *All seafarers shall have convenient access on the ship to sanitary facilities,* to be provided separate *for men and for women.*

2.6.2 *There shall be sanitary facilities within easy access of the navigation bridge and the machinery space or near the engine room control centre.*

Ships of less than 3000 gross tonnage may be exempted by the Society *from this requirement*, subject to [1.2].

2.6.3 *In all ships a minimum of one toilet, one wash basin and one tub or shower or both for every six persons or less who do not have personal facilities shall be provided at a convenient location.*

2.6.4 *With the exception of passenger ships, each sleeping room shall be provided with a washbasin having hot and cold running fresh water, except where such a washbasin is situated in the private bathroom provided.*

2.6.5 *In passenger ships normally engaged on voyages of not more than four hours' duration, consideration may be given to special arrangements or to a reduction in the number of facilities required*, subject to [1.2].

2.6.6 *Hot and cold running fresh water shall be available in all wash places.*

2.6.7 *Sanitary accommodation intended for the use of more than one person should comply with the following:*

a) *floors should be of approved durable material* (as per standards used in shipbuilding industry)*, impervious to damp, and should be* provided with draining arrangements

b) *bulkheads should be of steel or other approved material* (as per standards used in shipbuilding industry) *and should be watertight up to at least 23 centimetres above the level of the deck*

c) *the accommodation should be sufficiently lit, heated and ventilated*

d) *toilets should be situated convenient to, but separate from, sleeping rooms and wash rooms, without direct access from the sleeping rooms or from a passage between sleeping rooms and toilets to which there is no other access; this requirement does not apply where a toilet is located in a compartment between two sleeping rooms having a total of not more than four seafarers, and*

e) *where there is more than one toilet in a compartment, they should be* screened, as a minimum, from 23 cm above ceiling up to deck minus 10 cm.

2.7 Hospital accommodation

2.7.1 *Ships carrying 15 or more seafarers and engaged in a voyage of more than three days' duration shall provide separate hospital accommodation to be used exclusively for medical purposes.*

This requirement may be exempted *for ships engaged in coastal trade*, subject to [1.2].

The accommodation will, in all weathers, be easy of access, provide comfortable housing for the occupants and be appropriate *to their receiving prompt and proper attention.*

2.7.2 The following design and construction provisions are to be considered regarding the hospital accommodation:

a) *The hospital accommodation should be designed so as to facilitate consultation and the giving of medical first aid and to help prevent the spread of infectious diseases* without requiring separate ventilation.

b) *The arrangement of the entrance, berths, lighting, ventilation, heating and water supply should be designed to* allow for *the comfort and facilitate the treatment of the occupants.*

c) *Sanitary accommodation should be provided for the exclusive use of the occupants of the hospital accommodation, either as part of the accommodation or in close proximity thereto. Such sanitary accommodation should comprise a minimum of one toilet, one washbasin and one tub or shower.*

2.8 Miscellaneous

2.8.1 *Appropriately situated and furnished laundry facilities shall be available.*

The laundry facilities provided for seafarers' use should include:

a) washing machines

b) drying machines or adequately heated and ventilated drying rooms, and

c) irons and ironing boards or their equivalent.

2.8.2 *All ships shall have a space or spaces on open deck to which* all off duty seafarers can have simultaneous access.

2.8.3 *All ships shall be provided with separate offices or a common ship's office for use by deck and engine departments.*

Ships of less than 3000 gross tonnage may be exempted from this requirement, subject to [1.2].

2.8.4 *Ships regularly trading to mosquito-infested ports shall be fitted with appropriate devices* unless directly provided by air conditioning systems.

2.8.5 Appropriate seafarers' recreational facilities, amenities and services, as adapted to meet the special needs of seafarers who must live and work on ship, shall be provided on board in accordance to the shipowner's specifications.

3 Vibration prevention

3.1 General

3.1.1 Documents to be submitted

Documents to be submitted regarding vibration prevention are detailed in Tab 1.

3.1.2 Standards of relevance

- ISO 2041:2009, “Vibration and shock - Vocabulary”
- ISO 6954:2000, “Mechanical vibration - Guidelines for measurements, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships”
- ISO 2631-1:2010, “Mechanical vibration and shock- Evaluation of human exposure to whole-body vibration”
- ISO 8041:2005, “Human response to vibration - Measuring instrumentation”.

3.2 Design requirements

3.2.1 Scope

Seafarers shall not to be exposed to excessive vibration level.

Table 1 : Vibration prevention - Documents to be submitted

No.	Documents
1	General arrangements
2	List of measuring points: • vibration level at sea conditions
3	Measurement program: • loading conditions • propulsion operating conditions • other equipment in operation • weather conditions • measuring instrument calibration sheets

3.2.2 Criteria

The vibration criterion is based on the guideline levels given by ISO 6954:2000. It shall be expressed in terms of overall frequency-weighted r.m.s. velocity (mm/s) from 1 to 80 Hz as defined by the standard. The highest value in any direction shall be used for the evaluation, using the guidance given in Tab 2.

3.2.3 Maximum vibration levels

Maximum vibration levels are detailed in Tab 2.

Table 2 : Maximum overall frequency-weighted r.m.s. velocity

Location	Frequency range	Maximum vibration velocity
Accommodation and recreation spaces	1 to 80 Hz	6,0 mm/s
Catering facilities		

3.3 Testing

3.3.1 General

Measurements are to be performed under attendance of a Surveyor during building stage, sea trials or in service, as relevant.

3.3.2 Instrumentation

Measurement and calibration equipment is to comply with ISO 6954 and ISO 8041. The instrumentation is to:

- include at least a transducer (accelerometer or velocity transducer) with an appropriate amplifier, and a FFT (Fast Fourier Transform) analyser
- be calibrated in situ, before and after the tests.

Should the vibration measurements be performed on a soft floor, a tripod mount is to be used.

3.3.3 Measuring positions

The list of measuring points is to be prepared prior to the tests (see [3.1.1]). This list is to be submitted to the Society and may be adjusted during the tests. Measurements may be performed in locations such as corridors, sanitary spaces, when vibration levels are expected to be high.

Measurements are to be taken in vertical direction. In cabins, offices or other small size rooms, measurements are to be taken on the floor in the centre of the room. For larger rooms, several measuring points may be required and are to be chosen taking account of the local structure (measurements of the different existing types of stiffened panels). Vibrations are to be measured throughout accommodation space (typical cabins, mess rooms, typical offices).

In addition to vertical direction, measurements in transverse and longitudinal directions are to be performed on one point of each deck.

3.3.4 Test conditions

a) Vibration level measurement is to be carried out according to the requirements of ISO 6954:2000.

b) Sea trial conditions:

1) During sea trials, propeller output is to correspond to the operating condition specifications of the ship. In particular, ships which are frequently operated by means of a Dynamic Positioning system (DP system) may require additional measurements to be performed in DP mode according to a specification taking account of the duration of transients.

2) Any other frequently used equipment (more than 1/3 of the time at sea) is to be run at its normal operating conditions (as far as practicable). The list of machine and equipment to be run during the tests is normally to include the following:
   - generating sets
   - air conditioning and machinery ventilation
   - evaporators
   - anti-rolling devices
   - compressors, chillers
   - cold rooms
   - waste treatment units
   - swimming pool with pumps
   - jacuzzi and thalassotherapy equipment
   - laundry with the entire equipment running: drying (spin dryer or tumble dryer) and washing machines (for measurements inside laundry, equipment is to be stopped).

3) Standard test conditions correspond to the loading condition defined for sea trials. Nevertheless, for cargo ships operating over a wide range of draughts, the readings obtained in the test conditions may significantly differ from those in another loading condition. The Society will determine whether it requires measurements for a loading condition other than the sea trial conditions.

4) The meteorological conditions such as wind (Beaufort 4 maximum), rain (moderate) as well as sea state (1 m significant wave height maximum) should normally be accepted as not influencing the measurements.

5) The tests are to be performed in deep water, with a water depth greater than 5 times the mean draught. However, for ships usually operating in coastal waters, measurements may be taken with conditions declared to correspond to normal service conditions.

6) Ship course is to be kept constant, with rudder angle less than 2 degrees portside or starboard, for the duration of the measurement. If ship manoeuvring is needed, measurements must be stopped until recovery of heading.

3.3.5 Test report framework

The measurement report shall be submitted to the Society for review. The details listed hereafter shall be provided in the vibration test report:

a) General information
- testing company / names of the involved personnel
- name of the surveyors
- name of the ship
- IMO number of the ship
- name of the Owner
- name of the Shipyard
- classification Society name and ship register number
- date of the test
- all deviation from the approved test plan

b) Ship's main data
- hull: tonnage / length between perpendiculars / breadth moulded / maximum draught
- machinery: main engine data / auxiliary engine data / gear data / propulsion data / service speed / installed propulsion power

c) Test main conditions
- test site location
- environmental conditions: sea height / wind state
- speed of the ship
- aft and fore draughts
- test machinery conditions
- machinery ventilation condition
- HVAC condition

d) Measuring equipment data
- ID / manufacturer / serial number
- last calibration dates / calibration certificates

e) Results
- measurement locations (additionally indicated on appropriate drawings)
- location and orientation of transducers
- measurement duration
- results of the measurements
- all deviation from the vibration level requirements given in Tab 2.

4 Noise prevention

4.1 General

4.1.1 Documents to be submitted

Documents to be submitted regarding noise prevention are detailed in Tab 3.

Table 3 : Noise prevention - Documents to be submitted

No.	Documents
1	General arrangements
2	List of measuring points: • noise level at sea conditions • insulation measurements • impact measurements
3	Measurement program: • loading conditions • propulsion operating conditions • other equipment in operation • weather conditions • measuring instrument calibration sheets

4.1.2 Regulations, standards of relevance

- IMO Resolution MSC.337(91), "Adoption of the code on noise levels onboard ships"
- ISO 2923:1997, "Acoustics - Measurements of noise on board vessels"
- ISO 80000-8:2007, "Quantities and units of acoustics"
- IEC Publication 61672:2003, "Electroacoustics-Sound level meters"
- IEC Publication 61260-1:2014, IEC 61260-2:2017 and IEC 61260-3:2016, "Octave, half-octave and third octave band filters"
- IEC Publication 60942:2003, "Electroacoustics - Sound calibrators"
- ISO 16283-1:2014, "Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation"
- ISO 717-1:1996, "Acoustics - Rating of sound insulation in buildings and of building elements", namely:

  Part 1, "Airborne sound insulation in buildings and interior elements"
- IEC Publication 60268-16:2004, "Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index".

4.2 Design requirements

4.2.1 Scope

Seafarers shall not be exposed to excessive noise level.

4.2.2 Criteria

The noise levels are based on the IMO Resolution MSC.337(91): Adoption of the code on noise levels on board ships.

Consideration should be given to the acoustic insulation between accommodation spaces in order to make rest and recreation possible even if activities are taking place in adjacent spaces, e.g. music, talking, cargo-handling, etc.

4.2.3 Maximum noise levels

Maximum noise levels are detailed in Tab 4.

Table 4 : Maximum equivalent continuous A-weighted noise level LAeq

Location	Noise limit LAeq, in dB(A)	
	Ships < 10000 GT	Ships ≥ 10000 GT
Accommodation and recreation spaces		
Cabins and hospital	60,0	55,0
Mess rooms	65,0	60,0
Recreation rooms	65,0	60,0
Open recreation spaces	75,0	75,0
Offices	65,0	60,0
Catering facilities		
Galley without food processing equipment operating	75,0	75,0
Serveries and pantries	75,0	75,0
Note 1: For other workspaces, refer to IMO Resolution MSC.337(91).		

4.2.4 Sound insulation index

Building specifications should normally include provisions applicable to the erection of materials and in the construction of accommodation spaces to reduce sound transmission. The airborne sound insulation properties for bulkheads and decks within the accommodation shall comply at least with the following weighted sound reduction index (Rw) according to ISO Standard 717-1:

- cabin to cabin:

  Rw = 35
- mess rooms, recreation rooms to cabins and hospitals:

  Rw = 45
- corridor to cabin:

  Rw = 30
- cabin to cabin with communicating door:

  Rw = 30

4.3 Testing

4.3.1 General

Measurements are to be performed under attendance of a Surveyor during building stage, sea trials or in service, as relevant.

4.3.2 Instrumentation

Measurement and calibration equipment is to comply with ISO 2923, IEC 61672, IEC 61260 and IEC 60942. The instrumentation is to be calibrated in situ, before and after the tests.

4.3.3 Measuring positions

a) The list of measuring points is to be prepared prior to the tests (see [4.1.1]). This list is to be submitted to the Society and may be adjusted during the tests. Measurements may be performed in locations such as corridors, sanitary spaces, where noise levels are expected to be high.

b) Noise measurements

One measurement should be made in the middle of the space. The microphone should be moved slowly horizontally and/or vertically over a distance of 1 m. Additional measurements may be performed in other locations if appreciable sound level differences inside the room occur.

On open decks, measurements should be taken in areas provided for the purpose of recreation. The measurements are to be taken at 2 m at least from the existing noise sources (e.g. inlet/outlet of ventilation).

c) Sound insulation measurements

The selection of insulation measuring locations is to be representative of the different types of insulation provided in [4.2.4] (one measurement of each type is normally to be performed).

4.3.4 Test conditions

a) Noise level measurement is to be carried out according to the requirements of ISO 2923. Sound insulation measurement is to be carried out according to ISO 140-4, ISO 140-13 and ISO 140-14.

b) Harbour test conditions

Noise measurement tests for the determination of insulation indexes between rooms is to be conducted at quay or at anchorage in a condition as near as possible to dead ship condition. For these tests, no particular condition concerning output, loading, water depth or weather conditions are required.

c) Sea trial conditions

1) During sea trials, propeller output is to correspond to the operating condition specifications of the ship. In particular, ships which are frequently operated by means of a Dynamic Positioning system (DP system) may require additional measurements to be performed in DP mode according to a specification taking account of the duration of transients.

2) Any other frequently used equipment (more than 1/3 of the time at sea) is to be run at its normal operating conditions (as far as practicable). The list of machine and equipment to be run during the tests is, at least, to include (when appropriate) the following:

- generating sets
- air conditioning and machinery ventilation
- evaporators
- anti-rolling devices
- compressors, chillers
- cold rooms
- waste treatment units
- swimming pool with pumps
- jacuzzi and thalassotherapy equipment
- laundry with the entire equipment running: drying (spin dryer or tumble dryer) and washing machines (for measurements inside laundry, equipment is to be stopped).

3) Standard test conditions correspond to the loading condition defined for sea trials. Nevertheless, for cargo ships operating over a wide range of draughts, the readings obtained in the test conditions may significantly differ from those in another loading condition. The Society will determine whether it requires measurements for a loading condition other than the sea trial conditions.

4) The meteorological conditions such as wind (Beaufort 4 maximum), rain (moderate) as well as sea state (1 m significant wave height maximum), should normally be accepted as not influencing the measurements.

5) The tests are to be performed in deep water, with a water depth greater than 5 times the mean draught. However, for ships usually operating in coastal waters, measurements may be taken with conditions declared to correspond to normal service conditions.

6) Ship course is to be kept constant, with rudder angle less than 2 degrees portside or starboard, for the duration of the measurement. If ship manoeuvring is needed, measurements must be stopped until recovery of heading.

4.3.5 Test report framework

The measurement report shall be submitted to the Society for review. The details listed hereafter shall be provided in the noise test report:

a) General information
- testing company / names of the involved personnel
- name of the surveyors
- name of the ship
- IMO Number of the ship
- name of the Owner
- name of the Shipyard
- classification Society name and ship register number
- date of the test
- all deviation from the approved test plan

b) Ship's main data
- hull: tonnage / length between perpendiculars / breadth moulded / maximum draught
- machinery: main engine data / auxiliary engine data / gear data / propulsion data / service speed / installed propulsion power

c) Test main conditions
- test site location
- environmental conditions: sea height / wind state
- speed of the ship
- aft and fore draughts
- test machinery conditions
- machinery ventilation condition
- HVAC condition

d) Measuring equipment data
- ID / manufacturer / serial number
- last calibration dates / calibration certificates

e) Results
- measurement locations (additionally indicated on appropriate drawings)
- measurement duration
- results of the measurements
- all deviation from the noise level requirements given in [4.2.3] and [4.2.4].

5 Ventilation, heating and air conditioning

5.1 General

5.1.1 Documents to be submitted

The following documentation relating to the design philosophy of the HVAC system shall be submitted to the Society for information:

a) general arrangement of air distribution and location of all relevant interacting components such as cooling and heating coils, means for temperature and relative humidity regulation, dampers, data analysis including methods, software and instrumentation

b) actual measurement locations and transducer positions, to be indicated on appropriate drawings.

5.1.2 Regulations, standards of relevance

- ASHRAE (American Society of Heating Refrigerating and Air Conditioning Engineers)
- ISO 7730:1994(E).
- ISO 7726 (E) (1998)
- NEBB (1998).

5.2 Design requirements

5.2.1 Central HVAC (Heating, Ventilation and Air-Conditioning) performance requirements

a) The HVAC system including the condensing unit capacity and the interacting components shall be provided with efficient means to condition the air in compliance with the requirements of the MLC Convention (Reg 3.1) and ISO 7730:1994(E).

b) Air-conditioning systems, whether of a centralized or an individual unit type, should be designed to maintain the air at a satisfactory temperature and a satisfactory relative humidity and ensure a sufficiency of air changes in all air conditioned spaces as per Tab 5, taking into account the specified ambient conditions at sea.

c) Indoor climate criteria for the notation **HABITABILITY** apply only to the manned spaces.

d) A “manned” space is considered herein as a space occupied by a seafarer at least for twenty (20) minutes or longer at a time.

5.2.2 Monitoring and control

a) The HVAC system shall be capable of providing return air temperatures as those indicated in Tab 5.

b) The temperature and relative humidity shall be sufficiently maintained and controlled in each concerned space, whereas the overall system shall be capable of providing and maintaining the room temperature and relative humidity as indicated in Tab 5.

Table 5 : Air temperature, relative humidity and air exchange requirements

Item	Description	Requirement
1	Air temperature	22°C to 25°C
2	Relative humidity	30% minimum to 70% maximum
3	Air exchange rate	six (6) complete changes-per-hour

5.3 Testing

5.3.1 Test plan

a) Along with the design details of the HVAC system, a test plan shall be submitted to the Society for review.

b) The test plan shall include the necessary documentation and data enabling the Surveyor to verify the compliance with the indoor climate criteria set in this Section and to identify the spaces where measurements are to be performed:

1) HVAC system design specifications

2) schematics / layout drawings of the HVAC system

3) general arrangement drawings of the ship's accommodations indicating the concerned spaces.

c) The personnel running the test are to be qualified for performing ambient environmental testing, and the relevant qualifications documentation is to be included in the test report.

d) Details of measuring and analysis equipment (e.g., manufacturer, type and serial number, accuracy, sampling frequency, and resolution) shall be provided.

Documentation establishing compliance with minimum requirements for instruments entailed for such purpose in accordance with international recognized standards is to be included.

e) The equipment calibration and data collection process of the indoor climate tests shall be done under attendance of a Surveyor.

f) Copies of the relevant instrumentation reference calibration certificates, together with the results of field setup and calibration checks before and after the field tests, shall be provided.

g) The performance test of the entire system shall be conducted in accordance with recognized practice and standards from an organization that establishes and maintains HVAC system industry standards, procedures and specifications.

h) A table format shall be submitted with all the relevant information on the concerned spaces being subjected to physical measurements, as indicated in Tab 6, including any deviations from the approved test plan.

i) Specific locations are to be identified as “Measurement locations” and the test conditions are to be based on an international recognized standard.

j) A preset return air temperature shall be maintained by a temperature controller for each concerned zone when HVAC systems do not make provision for individual adjustment within a specific space.

Table 6 : Physical measurements

Item	Description
1	Measurement position
2	Number of people present in the space at the time of measurement
3	Measurement period
4	Time at start and end of measurement
5	Air temperature **(1)** **(2)**
6	Relative humidity **(3)**
7	Outdoor wind speed and direction
8	Ambient outdoor air temperature
9	Outdoor humidity
10	Barometric pressure corresponding to indoor measurement periods
(1) Minimum, maximum, and average values. **(2)** As per [5.3.2], item k). **(3)** As per [5.3.2], item l).	

5.3.2 Test report

a) A test report shall be submitted to the Society after completion of the test.

b) The report on the test results for air temperature and relative humidity shall include the items listed in Tab 8, and shall document the spaces or areas where measurements were performed.

c) The test report shall detail the environmental conditions under which the tests were performed, the ship being at sea, with the equipment functioning in the design operational mode. See Tab 7.

d) All doors and windows are to be kept closed (except those to be left open) and the spaces being tested are to be furnished according to the space accommodation intended design; whereas, for cooling mode, the test should be performed on a clear day.

e) The data shall be gathered every five (5) minutes for air temperature and relative humidity and every three (3) minutes for air velocity, during a period of two (2) hours. Entry and exit to and from the space being tested should be kept to a minimum and shall be mentioned in the report.

f) Whether for cooling or heating tests and, as far as practicable, within those zones having high sensitivity to time of day, the measurements in one same space should be performed in the system demanding the most conditions possible during the day or the night, as applicable.

g) When selecting indoor climate measurement locations, accurate representative sample of data shall be used, reproducing at the best the actual conditions in manned spaces. Attention shall be paid to areas to be identified as specific with respect to the conditions of radiation or absorption of heat that substantially affect the indoor climate.

h) The same criteria apply for gathering data in spaces covering large portions of the ship and, when the area extends from one side to the other, the selection of areas shall normally include portside, starboard and amidships, as well as fore and aft sections of the space.

i) Measurements shall be done for each space commonly manned, such as bridge, radio room, officer's mess, gymnasium, library, etc.; whereas for cabins, a representative sample, including the worst case locations, of at least 20% of each type of cabin shall be selected for measurement.

j) Air temperature and relative humidity measuring instrumentation shall be set up approximately in the middle of the space being tested.

k) Air temperature shall be simultaneously measured at approximately 100 mm, 1100 mm and 1700 mm above the deck.

l) Relative humidity shall be measured at a height of approximately 1700 mm above the deck.

5.3.3 Walkthrough verification inspection and spot check measurements

a) A walkthrough verification inspection covering at least 10% of all the manned spaces not included in the test is to be done to assess the indoor climatic qualities of those spaces and the potential impact on the areas, subject to physical measurements in accordance with Tab 9.

b) One copy of the report shall be provided to the Society for filing and one copy shall be included in the final indoor climate test report.

Table 7 : Test conditions

Item	Description
1	Climate
2	Loading condition
3	Number of seafarers and total number of persons on board during testing
4	Machinery operating conditions
5	Navigation conditions: a) ship course and speed versus wind speed and direction b) ambient outdoor air temperature and humidity c) barometric pressure d) latitude and longitude
6	Weather conditions and meteorological data
7	Sea state
8	Special activities **(1)**
(1) Conditions during the test that might affect results.	

Table 8 : Test results

Item	Description
1	Transducer measurement positions
2	Measurement locations **(1)**
3	Reaction time to load variations
4	Data analysis **(2)**
5	Data acquisition and instruments **(3)**
(1) Indoor climate measurements shall be in accordance with the requirements of an international recognized standard. **(2)** Methods, software and instrumentation to be used for data analysis. **(3)** The instrumentation shall meet the characteristics of instruments for measuring physical quantities characterizing an environment specified in ISO 7726:1998(E).	

Table 9 : Ventilation, heating and air conditioning - Manned spaces not included in the test

Item	Description
1	Name and number of space
2	Walkthrough verification inspection results
3	Spot measurement results **(1)**
(1) When appropriate.	

6 Lighting

6.1 General

6.1.1 Documents to be submitted

Documents to be submitted regarding lighting are detailed in Tab 10.

Table 10 : Lighting - Documents to be submitted

No.	Documents
1	Single line diagram of main lighting system
2	Single line diagram of emergency lighting system
3	Layout diagram of main lighting system
4	Layout diagram of emergency lighting system
5	Average illumination level calculations per room (EN13032-1)

6.1.2 Regulations, standards of relevance

- IEC 61892-2
- IEC 60598 and 60092-306.

6.1.3 Illumination level

Illumination level is the luminous flux per unit area at any point on a surface exposed to incident light, measured in luxes.

6.2 Design requirements

6.2.1 General

General lighting illumination levels in accommodation areas are to be at least as per Tab 11, unless specific requirements from concerned authorities. The average lighting illumination levels mentioned in the present sub-article are stated as maintained average illuminance, which is understood as the average lighting illumination level at the time where maintenance is to be carried out.

Different light colours will be used, when required.

6.2.2 Emergency lighting

The emergency lighting level shall, as a minimum, be equal to 30% of the general lighting level required in Tab 11.

Table 11 : General lighting illumination levels

Area	Normal lighting **(1)**		
	Average illuminance E (lux)	Minimum illuminance E (lux)	Maximum illuminance E (lux)
General outdoor areas	50	20	100
General indoor areas, corridors, accommodation, hectic.	100	40	200
Stairways	150	60	300
Offices	500	250	750
Laundry and mess area	300	120	600
Hospital	300	120	360
WC and sanitary room	100	–	–
Sanitary room mirror	200	–	–
Cabin general illumination	100	–	–
Cabin reading desk	300	–	–
Cabin head bed light	120	–	–

(1) Lighting levels shall be checked through measurements performed one metre above the floor level in general areas and at actual work places where appropriate levels are required.

Note 1: The number of measured points in each area is to be in accordance with IEC 61892-2.

6.2.3 Escape lighting

The escape lighting system shall, as a minimum, provide a lighting illumination level meeting the values given in Tab 12.

6.3 Testing

6.3.1 On board testing of lighting systems is to be done in the presence of a Surveyor. Illumination levels are to be measured according to IEC 61892-2. Deviations of measured values from Tab 11 and Tab 12 are to be documented in the report provided to the Society.

Table 12 : Escape lighting illumination levels

Area	Normal lighting **(1)**	
	Average illuminance E (lux)	Minimum illuminance E (lux)
General outdoor escape routes	5	1
General indoor escape routes, corridors, accommodation, etc.	5	1
Stairways escape routes	5	1
Offices	10	1
Laundry and mess area	5	1
Hospital	300	120
Hospital spotlight	1000	500

(1) Lighting levels shall be checked through measurements performed one metre above the floor level in general areas and at actual work places where appropriate levels are required.

Note 1: The number of measured points in each area is to be in accordance with IEC 61892-2.

CHAPTER 7
REFRIGERATING INSTALLATIONS (REF)

Section 1 General Requirements

Section 2 Additional Requirements for Notation REF-CARGO

Section 3 Additional Requirements for Notation REF-CONT

Section 4 Additional Requirements for Notation REF-STORE

Section 1 General Requirements

1 General

1.1 Application

1.1.1 The following additional class notations are assigned, in accordance with Pt A, Ch 1, Sec 2, [6.9], to ships with refrigerating installations complying with the applicable requirements of this Chapter:

- **REF-CARGO** for installations related to carriage of cargo
- **REF-CONT** for installations related to carriage of refrigerated containers
- **REF-STORE** for installations related to preservation of ship's domestic supplies.

1.1.2 The requirements of this Chapter apply to refrigerating installations on ships, including fixed and permanently installed mechanical refrigerating installations and cargo holds in different types of ships and services rendered on board, such as precooling of cargo, storage of cargo, air conditioning, conservation of consumable goods on board, and cold preservation of other substances etc. These requirements apply only to ships having one of the additional class notations listed in [1.1.1] and are related to the capability of the installation to keep the required temperature of the stored products, including the precooling of the product when so required.

1.1.3 The additional class notations **REF-CARGO** and **REF-STORE** may be completed by the following:

- **PRECOOLING** for refrigerating plants having enough cooling capabilities for lowering the temperature of the embarking cargo, reaching the required temperature for its preservation in a time lapse agreed with the Society as suitable for the specific product, reducing to the minimum practically possible the impact on the refrigerated space temperature or to any cargo already stored in the refrigerated space.
- **QUICKFREEZE** for refrigerating plants of fishing vessels and fish factory ships where the design and equipment of such plants have been recognised as suitable to permit quick-freezing of fish in specified conditions.

  Other types of refrigerating means and preservation methods not mentioned in this Chapter may be considered by the Society on a case-by-case basis.

The additional class notations **REF-CARGO** may be completed by **AIRCONT** for ships fitted with a controlled atmosphere plant on board.

1.2 Temperature conditions

1.2.1 Cargo space conditions

The minimum temperature range for which the notation is granted is to be mentioned in the notation. For design temperatures to be considered for designing the plant, see [2.1.1] and [2.1.2].

This indication is to be completed by the mention of any operational restriction such as maximum sea water temperature, geographical or seasonal limitations, etc., as applicable.

1.3 Definitions

1.3.1 Direct cooling system

Direct cooling system is a system where the refrigeration is obtained by direct expansion of the refrigerant in coils fitted on the walls and ceilings of the refrigerated chambers.

1.3.2 Indirect cooling system

Indirect cooling system is a system where the refrigeration is obtained by brine or other secondary refrigerant, circulating through pipe grids or coils fitted on the walls and ceilings of the refrigerated chambers. The secondary refrigerant is cooled down in a closed loop transferring the heat through a heat exchanger comprised in the refrigerant gas compression / condensing unit.

1.3.3 Air cooling system

Air cooling system is a system where air is circulated by mechanical means through a direct or indirect cooled heat exchanger.

1.3.4 Refrigerant

Refrigerant is a compound fluid in a liquid or gaseous state which can absorb heat from the environment or products when evaporated, thus being capable to move heat from one place to another in a closed loop or system, with the use of mechanical components such as compressors, condensers and evaporators.

Note 1: Absorption systems are not considered for the purpose of **REF** notations.

1.3.5 Brine

Brine is a cooling media constituted by a liquid solution of industrial salts or other elements, normally used for removing heat from closed spaces through an indirect cooling system. In general, the word brine is also used in this Chapter to cover other types of secondary refrigerants, such as those refrigerants based on glycol/water mixtures.

1.3.6 Refrigerating unit

A refrigerating unit includes the compression / condensing unit considered as an integral part of a refrigeration system whose purpose is to lower air and/or product temperatures.

When the installation includes a secondary refrigerant (brine), the refrigerating unit is also to include a brine cooler (evaporator) and a pump.

Special requirements may apply for refrigerating installations arranged in cascade using two refrigerant gases with different saturation temperatures.

1.3.7 Refrigerated chamber

A refrigerated chamber is any space which is directly or indirectly refrigerated by one or more refrigerating units such as a cargo space, a quickfreeze tunnel, or other refrigerated service spaces such as those used for storing goods in galleys or other locations on board. Spaces cooled by HVAC refrigerating systems are not considered as refrigerated chambers.

2 Design criteria

2.1 Reference conditions

2.1.1 Design temperature

Unless otherwise indicated in the specification, refrigerating plants are to be designed for the following design temperatures:

- Frozen cargo: minus 20°C
- Fish: minus 20°C
- Fruit: 0°C
- Bananas: 12°C.

2.1.2 Environmental conditions

Unless otherwise indicated in the ship specification, the following environmental conditions are to be considered for the heat transfer and balance calculations and for the running rate of the refrigerating machinery:

- Sea water temperature: 32°C
- Outside air temperature: 35°C
- Relative humidity of air at 35°C: 80%.

For the determination of heat transfer through outside walls liable to be exposed to sun radiation, the outside air temperature is to be taken as equal to 45°C.

2.1.3 Operating conditions

The refrigerating plant inclusive of all machinery, equipment and accessories is to operate satisfactorily under the conditions indicated in Tab 1.

Table 1 : Operating conditions

Length of ship (m)		< 100	< 200	≤ 300	> 300
Permanent list		15°	15°	15°	15°
Roll		± 22,5°	± 22,5°	± 22,5°	± 22,5°
Pitch		± 10°	± 7,5°	± 5°	± 3°
Trim	Aft	5°	2,5°	1,5°	1°
	Forward	2°	1°	0,5°	0,3°

3 Documentation

3.1 Refrigerating installations

3.1.1 Plans to be submitted

The plans listed in Tab 2 are to be submitted as applicable.

The listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

Plans of equipment which are type approved by the Society need not be submitted, provided the types and model numbers are made available.

3.1.2 Calculations to be submitted

The calculations listed in Tab 3 are to be carried out in accordance with criteria agreed with the Society and are to be submitted.

3.2 Controlled atmosphere installations

3.2.1 The plans listed in Tab 4 are to be submitted.

3.3 Ships assigned with the notation QUICKFREEZE

3.3.1 For the ships assigned with the notation **QUICKFREEZE**, the heat balance calculation report of the quick freezing plant is to be submitted for approval. It is to include the following information:

- the number of quick freeze tunnels or cells,
- their capacities,
- the power required, and
- the justification of the suitability of the plant for the temperature ranges and time stipulated to cool down the product.

Table 2 : Documents to be submitted

No.	A/I **(1)**	Document
1	I	Detailed specification of the plant (refrigerating machinery and insulation) including the design parameters and ambient conditions
2	I	General arrangement of refrigerated spaces including: • the intended purpose of spaces adjacent to refrigerated spaces • the arrangement of air ducts passing through refrigerated spaces • the arrangement of steelwork located in refrigerated spaces or in insulated walls • the individual volume and the total volume of the refrigerated spaces
3	A	Drawings showing the thickness and methods of fastening of insulation on all surfaces in refrigerated spaces, including: • insulation material specification • hatch covers • doors • steel framing (pillars, girders, deck beams) • bulkhead penetrations • etc.
4	A	Drawing showing the arrangement of the draining system, size of the pipes and syphon sealing means
5	A	Cooling appliances in refrigerated spaces (coil grids, air coolers with air ducts and fans, etc.)
6	I	Characteristic curves of fans (capacity, pressure, power consumption)
7	A	Distribution of the thermometers and description of remote thermometer installation, if any, including: • detailed description of the apparatus with indication of the method and instruments adopted, measuring range, degree of accuracy and data regarding the influence of temperature variations on connection cables • electrical diagram of apparatus, with indication of power sources installed, characteristics of connection cables and all data concerning circuit resistance • drawings of sensing elements and their protective coverings and indicators, with specification of type of connections used
8	A	General arrangement and functional drawings of piping (refrigerant system, brine system if any, sea water system, defrosting system, etc.)
9	I	Characteristic curves of circulating pumps for refrigerant or brine (capacity, pressure, power consumption, etc.)
10	I	General arrangement of refrigerating machinery spaces (main data regarding prime movers for compressors and pumps, including source of power, are to be included in this drawing)
11	A	Electrical wiring diagram
12	A	Compressor main drawings (sections and crankshaft or rotors) with characteristic curves giving the refrigerating capacity
13	A	Drawings of main items of refrigerant system and pressure vessels, such as condensers, receivers, oil separators, evaporators, gas containers, etc.
14	A	Remote control, monitoring and alarm system (if any)
15	A	Air refreshing and heating arrangement for fruit cargo
16	I	Operation manual for the refrigerating plant and for refrigerated containers, as applicable
17	I	Type and specification of the pressure relief valves
(1)	A : To be submitted for approval; I : To be submitted for information	

Table 3 : Calculations to be submitted

No	A/I **(1)**	Item
1	A	Detailed calculation of the heat balance of the plant. The calculation is to include: • the minimum internal temperatures for which the classification is requested • the most unfavourable foreseen ambient conditions • the compressor capacity and power rated required for the specific gas • the heat load mentioned in the specification • the mass flow of gas and the pressure/temperature parameters given by the designer in the most unfavourable foreseen ambient conditions • the condenser capacity for the temperatures given by the designer and those required in this Chapter • the characteristics of heat exchangers and heat transfer given by the designer • the pumps characteristic curves for condensing water and brine circulation • the characteristics of the products to be stored including mass and volume occupied by the product in the refrigerated space
2	I	Result of duct air flow calculations
(1) A : To be submitted for approval; I : To be submitted for information		

Table 4 : Documents to be submitted

No	A/I **(1)**	Item
1	I	Description of the installation
2	I	Location of spaces covered and gas-tight subdivisions
3	I	Design overpressure
4	A	Details and arrangement of inert gas generating equipment for atmosphere control when applicable
5	A	Piping diagrams, including installation details
6	A	Details and arrangement of ventilation and gasfreeing system for controlled atmosphere zone
7	A	Instrumentation and automation plans
8	I	Instruction manual for inert gas generation, ventilation and gas-freeing equipment
9	I	Cargo space sealing arrangement
(1) A : To be submitted for approval; I : To be submitted for information		

4 General technical requirements

4.1 Refrigeration of chambers

4.1.1 Refrigerating systems

Refrigeration of the chambers may be achieved by one of the following systems:

- direct cooling system
- indirect cooling system
- air cooling system.

4.1.2 Cold distribution

a) The chambers may be refrigerated either by means of grids distributed on their walls or by means of air circulation on air coolers.

b) Grids and/or air coolers may be supplied either by brine or by a direct expansion system depending on the type of refrigerating system.

4.2 Defrosting

4.2.1 Availability

a) Means are to be provided for defrosting air cooler coils, even when the refrigerated chambers are loaded to their maximum. Air coolers are to be fitted with trays and gutterways for gathering condensed water.

b) The defrosting system is to be designed so that defrosting remains possible even in the case of failure of an essential component such as a compressor, a circulation pump, a brine heater or a heating resistance.

4.2.2 Draining

Arrangements are to be made to drain away the condensate even when the refrigerated chambers are loaded to their maximum. See [5.8] for specific requirements.

4.3 Prime movers and sources of power

4.3.1 Number of power sources

a) The motive power for each refrigerating unit is to be provided by at least two distinct sources. Each source is to be capable of ensuring the service of the plant under the conditions stated in [2.1.1], [2.1.2] and [2.1.3], without interfering with other essential services of the ship. For small plants, see also [4.7].

b) Where the refrigerating units are driven by internal combustion engines, one power source for each refrigerating unit may be accepted.

4.3.2 Electric motors

Where the prime movers of refrigerating units are electric motors, the electrical power is to be provided by at least two distinct generating sets.

4.3.3 Steam prime movers

Where steam prime movers are used in refrigerating units they are to be connected to at least two different boilers.

Furthermore, the exhaust steam is to be led to the main and auxiliary condensers.

4.4 Pumps

4.4.1 Minimum number of condenser pumps

a) At least one standby condenser circulating pump is to be provided; this pump is to be ready for use and its capacity is not to be less than that of the largest pump that it may be necessary to replace.

b) One of the condenser circulating pumps may be one of the ship's auxiliary pumps, provided its capacity is sufficient to serve the refrigerating plant working at maximum power without interfering with essential services of the ship.

4.4.2 Plants with intermediate cooling media

a) Where an intermediate cooling medium is used, at least one standby brine circulating pump is to be provided; this pump is to be ready for use and its capacity is not to be less than that of the largest pump that it may be necessary to replace.

b) The same provision applies to any other type of plants in which the circulation of refrigerant is ensured by pumps.

4.5 Sea connections

4.5.1 Number and location of sea connections

a) The cooling water is normally to be taken from the sea by means of at least two separate sea connections.

b) The sea connections for the refrigerating plant are to be distributed, as far as practicable, on both sides of the ship.

4.5.2 Connections to other plants

Where the circulating pump(s) of the refrigerating plant is/are connected to the same circuit as other pumps, precautions are to be taken in the design and arrangement of piping so that the working of one pump does not interfere with another.

4.5.3 Dry dock conditions

In order to keep the refrigerating plant running when the ship is in dry dock, means are to be provided to supply cooling water from an external source permanently flanged and duly identified in the circuit drawings.

4.6 Refrigerating machinery spaces

4.6.1 Arrangement

Refrigerating machinery spaces are to be provided with efficient means of ventilation and drainage and, unless otherwise allowed by the Society, are to be separated from the refrigerated spaces by means of gas-tight bulkheads.

Ample space is to be provided around the refrigerating machinery to permit easy access for routine maintenance and to facilitate overhauls, particularly in the case of condensers and evaporators.

4.6.2 Dangerous refrigerants in machinery spaces

Use of dangerous refrigerants in machinery spaces may be permitted in accordance with Pt C, Ch 1, Sec 16, [2.2.4].

4.7 Exemptions for small plants

4.7.1 Consideration may be given to waiving the requirements in [4.3.1], [4.3.2] and [4.3.3] above on power source duplication for refrigerating plants serving spaces having a volume below 400 m^3, depending on the service provided by the refrigerating systems.

4.8 Personnel safety

4.8.1 Means are to be provided to monitor the presence of personnel in refrigerated cargo spaces and to promptly detect any possible need for help from outside the space.

5 Refrigerated chambers

5.1 Construction of refrigerated chambers

5.1.1 Bulkheads surrounding refrigerated chambers

a) Generally, the bulkheads of refrigerated chambers are to be of metallic construction; however, the bulkheads between two refrigerated spaces intended to contain cargoes of the same nature or having no contaminating effect need not be metallic.

b) The bulkheads are to be gas-tight.

c) Steels intended to be used for the construction of refrigerated chambers are to comply with the applicable provisions of Pt B, Ch 4, Sec 1 for low temperature steels.

5.1.2 Closing devices

a) The closing devices of the accesses to refrigerated chambers, such as doors, hatch covers and plugs for loading or surveying are to be as far as possible gas-tight.

b) The ventilators of refrigerated chambers, if any, are to be fitted with gas-tight closing devices.

5.2 Penetrations

5.2.1 Penetration of pipes and ducts

Penetrations of pipes through watertight, gas-tight or fire-resistant decks and bulkheads are to be achieved by fitting glands suitable for maintaining the tightness and fire-resisting characteristics of the pierced structures.

5.2.2 Penetration of electrical cables

Where electrical wiring passes through refrigerated chambers, the relevant requirements of Part C, Chapter 2 are to be complied with.

5.3 Access to refrigerated spaces

5.3.1 Doors and hatches

a) Refrigerated chambers are to be arranged for easy emergency escape. The escape ways are to be provided with emergency lights. Evacuation of injured personnel is to be possible even when cargo is loaded using stretchers or other means for small area chambers acceptable by the Society.

b) Access doors and hatches to refrigerated chambers are to be provided with means of opening from both sides.

c) Refrigerated chambers are to be fitted with at least one local alarm call button close to the access.

5.3.2 Manholes

Manholes on the tank top of refrigerated chambers are to be surrounded by an oil-tight steel coaming of at least 100 mm height.

5.4 Insulation of refrigerated chambers

5.4.1

a) The insulating material is to be non-hygroscopic. The insulating boards are to have satisfactory mechanical strength. Insulating materials and binders, if any, are to be odourless and so selected as not to absorb any of the odours of the goods contained in refrigerated chambers. The materials used for linings are to comply with the same provisions.

b) Polyurethane and other plastic foams used for insulation are to be of a self-extinguishing type according to a standard acceptable by the Society. In general, these foams are not to be used without a suitable protective coating.

c) The insulation together with its coating is normally to have low flame spread properties according to an accepted standard.

d) Plastic foams of a self-extinguishing type, suitably lined, may also be used for insulation of piping and air ducts.

e) When it is proposed to use foam prepared in situ, the detail of the process is to be submitted for examination before the beginning of the work.

5.5 Protection of insulation

5.5.1 Insulation extension

The insulation and the lining are to be carefully protected from all damage likely to be caused by the goods contained in the chamber or by their handling.

5.5.2 Insulation strength

The insulation lining and the air screens with their supports are to be of sufficient strength to withstand the loads due to the goods liable to be carried in the refrigerated chambers.

5.5.3 Removable panels

a) A sufficient number of removable panels are to be provided in the insulation, where necessary, to allow inspection of the bilges, bilge suctions, bases of pillars, vent and sounding pipes of tanks, tops of shaft tunnels and other structures and arrangements covered by the insulation.

b) Where the insulation is covered with a protective lining, certain panels of this lining are to be provided with a suitable number of inspection openings fitted with watertight means of closing.

5.6 Miscellaneous requirements

5.6.1 Refrigerated chambers adjacent to oil or fuel tanks

a) An air space of at least 50 mm is to be provided between the top of fuel and lubricating oil tanks and the insulation, so designed as to allow leaks to drain to the bilges. Such air space may be omitted provided multiple sheaths of an odourless oil-resisting material are applied to the upper surface of tank tops. The total required thickness of sheathing depends on the tank construction, on the composition used and on the method of application.

b) In general, the sides of fuel and lubricating oil tanks are to be separated from refrigerated spaces by means of cofferdams. The cofferdams are to be vented, the air vents fitted for this purpose are to be led to the open and their outlets are to be fitted with wire gauze which is easily removable for cleaning or renewal. The cofferdams may be omitted provided that multiple sheaths of an odourless oil-resisting material are applied on the tank side surface facing the refrigerated chambers. The total required thickness of this sheathing depends on the composition used and on the method of application.

5.6.2 Refrigerated chambers adjacent to high temperature spaces

The insulation of the walls adjacent to fuel bunker tanks or to any space where an excessive temperature may arise, by accident or otherwise, is to be made of mineral wool or any equivalent material and suitable for the refrigerated space or chamber and adjacent spaces.

5.6.3 Wooden structures

Wooden beams and stiffeners are to be insulated and strips of suitable insulating material are to be fitted between them and the metallic structures.

5.6.4 Metal fittings

All metal fittings (bolts, nuts, hooks, hangers, etc.) necessary for fitting of the insulation are to be galvanised or made in a corrosion-resistant material.

5.6.5 Equipment below the insulation

Arrangements are to be made whilst building in order to facilitate the examination in service of parts such as bilge suctions, scuppers, air and sounding pipes and electrical wiring which are within or hidden by the insulation.

5.7 Installation of the insulation

5.7.1

a) Before laying the insulation, steel surfaces are to be suitably cleaned and covered with a protective coating of appropriate composition and thickness.

b) The thickness of the insulation on all surfaces together with the laying process are to be in accordance with the approved drawings.

c) The insulating materials are to be carefully and permanently installed; where they are of slab form, the joints are to be as tight as possible and the unavoidable crevices between slabs are to be filled with insulating material. Bitumen is not to be used for this purpose.

d) Joints of multiple layer insulations are to be staggered.

e) In applying the insulation to the metallic structures, any paths of heat leakage are to be carefully avoided.

5.8 Drainage of refrigerated spaces

5.8.1 General

All refrigerated cargo spaces and trays under air coolers are to be fitted with means suitable for their continuous and efficient drainage.

5.8.2 Drain pipes

a) Drain pipes from refrigerating space cooler trays are to be fitted with liquid sealed traps provided with non-return valves which are easily accessible, even when the chamber is fully loaded.

b) Threaded plugs, blank flanges and similar means of closing of drain pipes from refrigerated spaces and trays of air coolers are not permitted.

c) Where means of closing of drain pipes are required by the Owner, these are to be easily checked and the controls are to be located in an accessible position on a deck above the full load waterline.

5.8.3 Drain tanks

a) Where the draining from cargo spaces is led to a closed drain tank, the size of the tank is to be such as to be able to collect all the waters produced during defrosting operations.

b) Drain tanks are to be provided with appropriate venting and sounding arrangements.

c) When two or more refrigerated spaces are connected to the same drain tank, the common lines are to be fitted with check valves to prevent the possibility of passage of water from one refrigerated space to another.

5.8.4 Scuppers

a) Scuppers from the lower holds and from trays of air coolers installed on the inner bottom are to be fitted with liquid seals and non-return devices.

b) Scuppers from 'tweendeck refrigerated spaces and from trays of air coolers installed above the inner bottom are to be fitted with liquid seals, but not necessarily with non-return devices.

c) Where scuppers from more than one refrigerated space or tray are led to a common header or common tank, in addition to the liquid seal on each pipe, a sufficient number of non-return devices are to be provided, so arranged as to prevent lower compartments from being flooded by drains from higher compartments.

d) Water seals are to be of sufficient height and readily accessible for maintenance and filling with anti-freezing liquid.

e) Valves, scuppers and drain pipes from other non-refrigerated compartments are not to be led to the bilges of refrigerated spaces.

6 Refrigerants

6.1 General

6.1.1 Permissible refrigerants

Refrigerants are to comply with the requirements of Pt C, Ch 1, Sec 16, [2.2] and with applicable international and national regulations.

For restrictions on the selection of refrigerants, see Pt C, Ch 1, Sec 16, [2.2.1] and Pt C, Ch 1, Sec 16, [2.2.3].

6.1.2 Use of ammonia as refrigerant

In general, ammonia (R717) may be used only in indirect system refrigerating plants.

The use of direct cooling with ammonia may however be accepted in specific cases subject to special approval by the Society.

For specific requirements relative to the use of ammonia as refrigerant, see Pt C, Ch 1, Sec 16, [2.3].

6.2 Rated working pressures

6.2.1 Pressure parts design pressure

a) The design pressure of the installation or parts thereof is not to be less than their maximum working pressure, either in operation or at rest, whichever is the greater. No safety valve is to be set at a pressure higher than the maximum working pressure.

b) In general, the design pressure of the low pressure side of the system is to be at least the saturated vapour pressure of the refrigerants at 40°C. Due regard is to be paid to the defrosting arrangement which may increase the pressure on the low pressure system.

c) The design pressure of the high pressure side of the installation is to be taken as the maximum of:

   1) the pressure setting of the pressure relieving device at the compressor discharge (whether the device is integral or not) when the compressor is running at a dead head or shut off discharge condition.

   2) the condenser maximum allowable working pressure, or the effective saturated vapour pressure at 50°C, whichever is the highest.

6.2.2 Design pressure

In general, the design pressure for high and low pressure parts of refrigerating systems is to be taken not less than the values indicated in the manufacturer's documentation.

7 Refrigerating machinery and equipment

7.1 General requirements for prime movers

7.1.1

a) The diesel engines driving the compressors are to satisfy the relevant requirements of Pt C, Ch 1, Sec 2.

b) The electric motors driving the compressors, pumps or fans are to satisfy the relevant requirements of Pt C, Ch 1, Sec 4.

7.2 Common requirements for compressors

7.2.1 Casings

The casings of compressors are to be designed for the design pressure of the high pressure side of the system in line with [6.2].

7.2.2 Cooling

a) Air-cooled compressors are to be designed for an air temperature of 45°C.

b) For sea water cooling, a minimum inlet temperature of 32°C is to be applied. Unless provided with a free outlet, the cooling water spaces are to be protected against excessive overpressure by safety valves or equivalent overpressure protecting devices.

7.2.3 Safety devices

a) Stop valves are to be provided on the compressor suction and discharge sides.

b) A safety valve or equivalent overpressure protecting device is to be arranged between the compressor and the delivery stop valve.

c) Overpressure protection is to consist of both a pressure relief valve and a pressure control device which automatically stops the machine in the event of overpressure. Details of the design of this device are to be submitted to the Society.

d) Compressors arranged in parallel are to be provided with check valves in addition to the isolation valve in the discharge line of each compressor. Alternatively, the discharge valve is to be of the non-return type and provided with positive means for closing.

e) Means are to be provided to indicate the correct direction of rotation.

7.3 Reciprocating compressors

7.3.1 Crankcase

a) When subjected to refrigerant pressure, compressor crankcases are to be either:

- designed to withstand the rated working pressure of the high pressure side; or
- fitted with safety valves designed to lift at a pressure not exceeding 0,8 times the crankcase test pressure including seals. In this case, arrangements are to be made for the refrigerant to discharge to a safe place; or
- protected against overpressure by means of devices ensuring a similar protection.

b) An oil level sight glass is to be fitted in the crankcase.

c) Means are to be provided to heat the crankcase when the compressor is stopped.

7.3.2 Hydraulic lock

Reciprocating compressors having cylinder bores of 50 mm and above are to be provided with means to relieve high pressure due to hydraulic lock. Alternatively means to prevent the possibility of refrigerants entering the cylinders may be considered.

7.4 Screw compressor bearings

7.4.1 Whenever the bearing surfaces are locally hardened, details of the process are to be submitted to the Society. In any case, the process is to be limited to the bearing area and is not to be extended to the fillets.

7.5 Pressure vessels

7.5.1 General

The general requirements of Pt C, Ch 1, Sec 16, [2.1.2] are applicable.

7.5.2 Refrigerant receivers

a) The receivers are to have sufficient capacity to accumulate liquid refrigerant during maintenance and repairing.

b) Each receiver is to be fitted with suitable level indicators. Glass gauges, if any, are to be of the flat plate type and are to be heat resistant. All level indicators are to be provided with shut-off devices.

c) Each receiver that may be isolated from the system is to be provided with an adequate overpressure safety device.

7.5.3 Evaporators and condensers

a) All parts of evaporators and condensers are to be accessible for routine maintenance; where deemed necessary, efficient means of corrosion control are to be provided.

b) When condensers and evaporators of the "coil-in-casing" type cannot be readily dismantled owing to their dimensions, a suitable number of inspection openings not smaller than 230x150 mm^2 are to be provided on their shells.

c) Condensers connected to more than one circulating water pump capable of delivering a pressure which may exceed the design pressure of the condenser are to be duly protected by a safety valve.

Flooded evaporators served by a pump are to be protected by a safety valve opening at a pressure not higher than:

- the "Shut In" condition of the pump, and
- the maximum pressure that may occur in the evaporator when shut off from the circuit. This pressure is to be determined based on the refrigerant thermodynamic characteristics.

7.5.4 Brine tanks

a) Brine tanks which are not atmospheric tanks and can be shut off are to be protected against excessive pressure due to thermal expansion of the brine by safety valves or by an interlocking device blocking the shut-off valves in open position.

b) In general, brine tanks are not to be galvanised at their side in contact with brine. Where they are galvanised and are of a closed type, they are to be provided with a suitable vent arrangement led to the open for toxic gases. The vents are to be fitted with easily removable wire gauze diaphragms and their outlets are to be located in positions where no hazard for the personnel may arise from the gases. Where brine tanks are not of a closed type, the compartments in which they are located are to be provided with efficient ventilation arrangements.

7.5.5 Air coolers

a) Where finned-tube or multi-plate type air coolers are used, the distance between the fins or plates is not to be less than 10 mm, at least on the air inlet side. For the purpose of this requirement, the air inlet side means 1/4 of the length of the cooler measured in the direction of the air flow.

b) Air coolers are to be made of corrosion-resistant material or protected against corrosion by galvanising.

c) Air coolers are to be provided with drip trays and adequate drains.

7.5.6 Insulation

Pressure vessels are to be thermally insulated to minimise the condensation of moisture from the ambient atmosphere. The insulation is to be provided with an efficient vapour barrier and is to be protected from mechanical damage.

7.6 General requirements for piping

7.6.1 General

The general requirements of Pt C, Ch 1, Sec 16, [2.1.3] are applicable.

7.6.2 Piping arrangement

a) Pipelines are to be adequately supported and secured so as to prevent vibrations. Approved type flexible hoses may be used where necessary to prevent vibrations.

b) Provision is to be made for allowing thermal expansion and contraction of the piping system under all operating conditions. Approved type flexible hoses may be used where necessary for this purpose.

c) Pipe insulation is to be protected from mechanical damage and is to be provided with an efficient vapour barrier which is not to be interrupted in way of supports, valves, fittings, etc.

7.7 Accessories

7.7.1 Oil separators

Oil separators with drains are to be fitted on the refrigerant lines. When a wire gauze is fitted, this is to be of material which cannot be corroded by the refrigerant.

7.7.2 Filters

a) Efficient filters are to be fitted at the suction of positive displacement compressors and on the high pressure side of reducing valves. The filters of compressors may be incorporated in the crankcases, provided their filtering area is sufficient.

b) Filters are to be fitted with a wire gauze strainer which cannot be corroded by the refrigerant and allowing a sufficient flow area for the fluid. Filters are to be provided with isolating means and a by-pass so arranged that the filter can be cleaned without interrupting the operation of the plant.

7.7.3 Dehydrators

An efficient dehydrator is to be fitted on systems using authorized halocarbon refrigerants.

The dehydrator is to be so designed and arranged that the drying product can be replaced without any disassembling of the pipes.

7.8 Refrigerating plant overpressure protection

7.8.1 General

a) The refrigerant circuits and associated pressure vessels are to be protected against overpressure by safety valves or equivalent arrangement. However, inadvertent discharge of refrigerant to the atmosphere is to be prevented.

Rupture discs are not allowed for flammable or toxic refrigerants.

b) The safety devices are to be in such number and so located that there is no possibility that any part of the system may be isolated from a safety device. Where it is necessary to be able to isolate one of these devices from the system for maintenance purposes, the valves may be duplicated provided a change-over valve is arranged in such a way that when one device is isolated it is not possible to shut off the other. Due attention has to be paid to the discharge of the isolated safety device when connected to a common manifold.

c) Pressure vessels connected by pieces of pipe without valves may be considered as a single pressure vessel from the point of view of overpressure protection, provided that the interconnecting pipe does not prevent effective venting of the vessels.

7.8.2 Safety valves

a) Safety valve discharges are to be led to a safe place above the deck. Discharge pipes are to be designed in such a way that the ingress of water, snow, dirt or debris affecting the operation of the system can be prevented. In the case of the refrigerant R717 (ammonia), the discharge pipe outlet is to be as high as possible on the ship and fitted with an automatic water-spray system, which is to be automatically activated when the presence of ammonia is detected. An alarm is to be provided on deck to warn of the ammonia discharge.

b) Refrigerant pumps are to be fitted with safety valves at the discharge side. The valves may discharge at the pump suction side or at another suitable location.

c) After setting, safety valves are to be suitably protected against the possibility of inadvertent change of setting.

d) Safety valves are to lift at a pressure not higher than 0,8 times the test pressure of the protected components.

8 Specific requirements for direct and indirect refrigerating systems

8.1 Specific requirements for refrigerating systems

8.1.1 Direct expansion system

a) Refrigerating systems where the refrigerant expands directly in the coils within the refrigerated chambers may be considered by the Society only for application in chambers of small capacity and at the specific request of the Owner.

b) For the acceptance of such a system by the Society, special consideration is to be given to the following:

- the proposed refrigerant
- the use of coil pipes having butts welded circumferentially within refrigerated chambers, to prevent leakages of gas within the chambers themselves
- the effective protection of chamber cooling coils within the chambers from shocks and external mechanical damage.

c) Coils within each refrigerated space are to be arranged in at least two sections, and the number of sections in each refrigerated space is to be clearly indicated on the plan to be submitted for approval. Each section is to be fitted with valves or cocks so that it can be shut off.

8.1.2 Brine systems

a) Each brine pump is to be connected to the brine tanks and to the valve manifolds controlling the brine pipes. Each brine pipe is to be fitted with a stop valve on the delivery, and a regulating valve is to be fitted on the return pipe.

b) All regulating valves are to be located in positions accessible at any time.

c) Brine pipes are not to be galvanised on the inside.

d) The thickness of the brine pipes is to be not less than 2,5 mm; in the case of pipes with threaded joints, the thickness at the bottom of the thread is not to be less than the above value.

e) Steel pipe cooling coils and their associated fittings are to be externally protected against corrosion by galvanising or other equivalent method.

f) Plastic pipes may be used for brine systems in accord- ance with the provisions of Pt C, Ch 1, App 3

g) For brine tanks, see [7.5.4].

8.2 Specific requirements for air cooling systems and distribution and renewal of air in cargo spaces

8.2.1 Rated circulation

The air circulation system is to be so designed as to ensure as uniform as possible a distribution of air in refrigerated spaces.

8.2.2 Refrigerated air circulation systems

a) For air coolers, see [7.5.5].

b) Air coolers are to be designed for a maximum temperature difference between cooling medium and cooling air at the air cooler inlet of about 5°C for fruit cargoes and about 10°C for deep frozen cargoes.

c) Air coolers may be operated either by brine circulation or by direct expansion of the refrigerant.

d) The coils are to be divided into two sections, each capable of being easily shut off (see Ch 7, Sec 2, [1.2.1]). As an alternative, two fin fan cooler modules may be accepted.

e) Means for defrosting the coils of the air coolers are to be provided. Defrosting by means of spraying with water is to be avoided.

f) Provision is to be made for heating the drains. In automated plants, the heating equipment is to be controlled by the defrosting program.

g) Fans and their motors are to be arranged so as to allow easy access for inspection and repair and/or removal of the fans and motors themselves when the chambers are loaded with refrigerated cargo. Where duplicate fans and motors are fitted and each fan is capable of supplying the quantity of air required, it is sufficient that easy access for inspection is provided.

h) The air circulation is to be such that delivery and suction of air from all parts of the refrigerated chambers are ensured.

i) The air capacity and the power of the fans are to be in proportion to the total heat to be extracted from the refrigerated chamber, due regard being given to the nature of the service.

j) When excess cooling capacity is required in order to cool or freeze all or part of the cargo from the ambient temperature to the minimum anticipated temperature, the air capacity is to be adequate to the increased heat to be extracted, in accordance with the specifications approved by the Owner.

8.2.3 Air refreshing

a) When refrigerated cargoes include goods which, under certain conditions, emit gases, odours or humidity, an efficient system is to be provided for air refreshing in the space concerned. Air inlets and outlets in such systems are to be provided with closing devices.

b) The position of air inlets is to be such as to reduce to a minimum the possibility of contaminated air entering the refrigerated spaces.

9 Instrumentation, alarm, monitoring

9.1 General

9.1.1 Automation safety equipment

The automation safety equipment is to be of the fail-safe type and is to be so designed and installed as to permit manual operation. In particular, manual operation of the compressors is to be ensured provided that the circuit is in condition of accepting the manual operation.

In this regard, the installation, including its automatic control system, is to be designed so that the automatic operation of the installation can be safely overridden. The capability of the installation to run in manual mode is to be clearly indicated in the design and operational philosophy and duly verified on board.

9.1.2 Regulation devices

Regulation devices such as motor-operated valves or thermostatic expansion valves are to be such that they can be isolated, thus allowing the plant to be manually operated should the need arise.

9.2 Instrumentation, alarm and monitoring arrangement

9.2.1 Compressors

Tab 5 summarises the minimum control and monitoring requirements for refrigerating compressors.

9.2.2 Refrigerating systems

Tab 6 summarises the minimum control and monitoring requirements for refrigerating systems.

Table 5 : Refrigerating compressors

Item	Indicator	Function			Comments
			Alarm	Automatic shutdown	
Refrigerant suction	pressure	low		X	At saturated temperature and including intermediate stages
Refrigerant discharge	pressure	high		X	
Refrigerant suction	temperature				For installations over 25 kW only
Refrigerant discharge	temperature				
Lubricating oil	pressure	low		X	
Lubricating oil	temperature				For installations over 25 kW only
Cooling water	temperature				For installations over 25 kW only
Cumulative running hours	hours				All screw compressors and installations over 25 kW only
Note 1: Shut-off is also to activate an audible and visual alarm.					

Table 6 : Refrigerating systems

Item	Indicator	Function			Comments
			Alarm	Automatic shutdown	
Air in refrigerated space	temperature	high	X		
Air fan		failure	X		
Chamber temperature	temperature		X		
Secondary refrigerant suction	pressure	low		X	
Secondary refrigerant discharge	pressure	high		X	
Lubricating oil	pressure	low		X	
Bilge level in refrigerated space		high	X		
Note 1: Shut-off is also to activate an audible and visual alarm.					

10 Material tests, inspection and testing, certification

10.1 Material testing

10.1.1 The materials for the construction of the parts listed below are to be tested in compliance with the requirements of NR216 Materials and Welding:

- compressor crankshafts, couplings, connecting rods and piston rods
- compressor liners, cylinder heads and other parts subjected to pressure
- steel and copper tubing for evaporator and condenser coils and for pressure piping in general
- oil separators, intermediate receivers and other pressure vessels included in the gas circuit
- condensers and evaporators of shell type (tube or welded plate).

10.2 Shop tests

10.2.1 Individual pieces of equipment

Shop tests are to be carried out on pumps, fans, electric motors and internal combustion engines forming parts of refrigerating installations, following procedures in accordance with the requirements applicable to each type of machinery. The relevant running data (capacity, pressure head, power and rotational speed, etc.) are to be recorded for each item.

10.2.2 Refrigerating unit

a) At least one refrigerating unit of each type installed on board is to be subjected to shop tests in order to ascertain its refrigerating capacity in the most unfavourable ambient/environmental temperature conditions given in Pt C, Ch 1, Sec 1, Tab 1 and Pt C, Ch 1, Sec 1, Tab 2, and/or in other temperature conditions when so required by the Society.

b) Where the complete unit cannot be shop tested the compressors may be tested detached from the installation according to procedures approved by the Society.

10.3 Pressure tests at the workshop

10.3.1 Strength and leak tests

Upon completion, all parts included in the suction and delivery branches of the refrigerant circuit are to be subjected to a strength and leak test.

The strength test is the resistance test of a pressure retaining item or section of piping tested between two pipe or tube connections carried out with a suitable fluid. The leak test is a test carried out with a gaseous fluid on the circuit after being assembled at room temperature.

The components to be tested and the test pressure are indicated in Tab 7.

10.3.2 Condensers

Circulating water sides of condensers are to be subjected to a hydrostatic test at a pressure equal to 1,5 times the design pressure, but in no case less than 0,1 N/mm^2.

10.3.3 Brine system

a) Brine coils of air coolers are to be subjected to a hydrostatic test at a pressure equal to 1,5 times the design pressure, but in no case less than 0,7 N/mm^2.

b) Cast iron casings for brine evaporators are to be subjected to a hydrostatic test at a pressure equal to 1,5 times the design pressure, but in no case less than 0,1 N/mm^2.

c) Steel casings for brine evaporators fitted on the suction side of the compressors are to be subjected to a hydrostatic test at a pressure not less than 0,2 N/mm^2.

d) Open brine tanks are to be tested by filling them completely with water.

Table 7 : Test pressures for the refrigerating installation components

Component	Test pressure **(1)**	
	Strength test	Leak test
Compressor cylinder blocks, cylinder covers, stop valves, pipes and other components (condensers, receivers, etc.) of the high pressure part of the circuit	1,5 P_1	P_1
Compressor crankcases subjected to refrigerant pressure and • designed to withstand the rated working pressure of the high pressure side • fitted with safety valves in accordance with [7.3.1], item a)	 1,5 P_1 1,5 P_2	 P_1 P_2
Stop valves, pipes and other components of the low pressure part of the circuit	1,5 P_2	P_2
(1) P_1 and P_2 are the design pressures for high and low pressure parts of refrigerating systems as defined in [6.2.2].		

10.4 Thermometers and manometers

10.4.1

a) All thermometers recording the temperature of refrigerated spaces, the air temperature at the inlet and outlet of air coolers and the temperature at various points in the refrigerant circuit or in the brine circuit are to be carefully calibrated by the Manufacturer. The Society reserves the right to require random checks of the calibration.

b) The accuracy of manometers and other measuring instruments is also to be checked before the commencement of the tests required in [10.5].

10.5 Shipboard tests

10.5.1 Pressure tests

After installation on board, and before operating, the plant is to be subjected to a test at the maximum working pressure determined as indicated in [6.2.1].

However, all pressure piping portions which have welded joints made on board are to be subjected to a strength test at a pressure equal to 1,5 times the rated working pressure before being insulated.

10.5.2 Tests of the ventilation system

a) After installation, the ventilation system is to be tested and the pressure, air capacity in cubic metres per minute, maximum rotational speed and power absorbed by the fans are to be recorded.

b) The distribution of air in the various refrigerated spaces is to be checked.

10.5.3 Operational tests

a) Upon completion of the installation, each refrigerating plant is to be subjected to an operational test on board in order to check the proper operation of the machinery and the refrigerating capacity of the plant by means of a heat balance test.

b) Before starting the actual test, the Surveyor will check at random that thermometers, pressure gauges and other instruments are in good working order, calibrated and arranged as directed in each case by the Society.

c) All the refrigerating machinery is to be put into service and all chambers, closed and empty, are to be simultaneously cooled to the minimum expected temperature, i.e. the temperature required to be entered in the notation, or a lower temperature determined so that a difference of at least 20°C can be maintained between the average external temperature and the temperature in the refrigerated spaces. The expected temperature is to be maintained for a period of time sufficient to remove all the heat from the insulation. Further, cooling is to be continued until the chamber temperature can be maintained substantially constant without any adjustment of the output of the machinery or with regular on-off operation of the working compressors.

d) Following this, the heat balance test may be commenced. The duration of the test may be 6 hours or, where necessary, even longer. Air cooler fans are to run at their normal output throughout the test.

e) The regulation of the refrigerating capacity of the plant may be effected by reducing the number of running compressors, by varying their rotational speed or even by running them intermittently.

f) Means of control where the load in the cylinders is varied or the gas is returned from the delivery side to the suction side are not permitted.

g) The following data are to be recorded in the course of the test:

- Temperatures in the refrigerated spaces, external air temperature and sea water temperature (in particular, at the outlet and inlet of the condensers). The external surfaces S of the walls corresponding to the temperature differences ΔT measured between the inside and outside of the refrigerated spaces are to be detailed as well as the products: $S \cdot \Delta T$
- Absorbed power and speed of the compressors and the temperatures and pressures which determine the running conditions of the refrigerating machinery. The recorded data, through comparison with the thermodynamic cycle considered for the preparation of the cold production curves of the compressors, are to enable the corrections (superheating, undercooling) necessary for determination of the actual refrigerating capacity F
- Absorbed power of the motors driving the fans F_V and brine pumps F_P
- Temperatures and pressures at various locations along the refrigerant and brine circuits.
- Air temperatures at the inlet and outlet of air coolers.

The calculation of the overall heat transfer coefficient k is required when the total volume of the holds exceeds 400 m^3.

The purpose of the test being to check the capabilities of the plant for the extreme climatic conditions considered, the following formula permits to determine the coefficient k:

$$F = k\,\Sigma(S \,.\, \Delta T) + F_V + F_P + F_C$$

where F_C is a correcting term which is to be introduced for other heat exchanges between the tested plant and the environment.

h) In the course of the heat balance test, the above data are to be recorded at one-hour intervals. Before starting the actual test, the data may be recorded at 4-hour intervals, except for the external air and sea water temperatures, which are to be recorded at one-hour intervals at least for the last twelve hours of the test.

i) Special cases, e.g. when the test is carried out with very low external atmospheric temperatures which would require the temperature within the refrigerated cargo spaces to be brought down below the above specified values, or where the compressors are driven by constant speed prime movers, or where refrigerating plants of banana and fruit carriers are tested in winter time, or the minimum temperature required for classification is not the same for all the spaces will be specially considered by the Society.

10.6 Defrosting system

10.6.1 The defrosting arrangements are also to be subjected to an operational test.

Instructions regarding the procedure to be followed for the operational test of the refrigerating plant on board will be given by the Society in each case.

Section 2 Additional Requirements for Notation REF-CARGO

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable for the assignment of the additional class notation **REF-CARGO**. They are additional to the applicable requirements of Ch 7, Sec 1.

1.1.2 These requirements are applicable independently of the number of refrigerated holds. Where only certain holds are fitted with a refrigerating plant for which the notation is requested, the number and the location of these holds will be indicated in a memorandum.

1.2 Refrigeration of cargo spaces

1.2.1 Cooling appliances, including brine coils, if any, are to be divided into two distinct systems capable of working separately in each refrigerated space; each of them is to be able to keep the cargo in a satisfactory cold condition. Each section is to be fitted with valves or cocks or similar devices so that it can be shut off.

All manually operated valves, whether shut off valves, redundant expansion valves, solenoid valves or thermostatic expansion valves, are to be located outside of the refrigerated chamber.

1.2.2 Consideration may be given to waiving the requirements in [1.2.1] on cooling system duplication for refrigerating plants serving spaces having volume below 200 m^3.

1.3 Heating

1.3.1 Where it is intended to carry cargoes which may be adversely affected by low temperatures during cold seasons or in certain geographical areas, efficient means are to be provided for heating the spaces concerned.

2 Refrigerated cargo spaces

2.1 Insulation

2.1.1 Protection of insulation

In addition to the requirement in Ch 7, Sec 1, [5.5.1], the floors of refrigerated spaces to about 600 mm beyond the projection of the hatchway outline are to be covered with a hard wood sheathing about 50 mm thick, or with a protection of similar efficiency.

2.1.2 Insulation strength

In addition to the requirement in Ch 7, Sec 1, [5.5.2], where insulations are to support fork-lift trucks, they are to be submitted to a strength test performed on a sample in conditions representative of the service conditions.

2.1.3 Cargo battens

a) Cargo battens of 50x50 mm, spaced at approximately 400 mm, are to be fitted to the vertical boundaries of refrigerated cargo spaces.

b) Floors of refrigerated cargo spaces are to be similarly fitted with battens of 75x75 mm spaced at approximately 400 mm; over the insulation of the top of shaft tunnels, cargo battens are to be of hard wood.

c) The arrangement of the cargo battens is to be such that free circulation of air is not impaired and cargo cannot come in contact with the insulation or with the brine coils, if any.

d) Battens on the floors of refrigerated spaces may be omitted in the case of hanging cargoes.

3 Instrumentation

3.1 Thermometers in cargo spaces

3.1.1 Number of thermometers

Each refrigerated space with a volume not exceeding 400 m^3 is to be fitted with at least 2 thermometers or temperature sensors. Where the volume exceeds 400 m^3, this number is to be increased by one for each additional 400 m^3.

3.1.2 Direct reading thermometers

The tubes intended to contain thermometers are to have a diameter not less than 50 mm and are to be carefully isolated from the ship's structure. If they pass through spaces other than those they serve, they are to be insulated when passing through those spaces. Joints and covers of such tubes are to be insulated from the plating to which they are attached and installed on open decks so that water will not collect and freeze in them when measuring temperatures.

3.1.3 Electric thermometer apparatus for remote reading

The apparatus is to provide the temperature indications with the accuracy required in [3.1.5] in conditions of vibrations and inclinations expected on board and for all ambient temperatures, up to 50°C, to which indicating instruments and connection cables may be exposed.

3.1.4 Distant electric thermometer sensors

a) Sensing elements are to be placed in refrigerated spaces where they are not liable to be exposed to damage during loading and unloading operations and well clear of heat sources such as, for instance, electric lamps, etc.

b) Sensing elements in air coolers are to be placed at a distance of at least 900 mm from coils or fan motors.

c) When arranged in ducts, they are to be placed at the centre of the air duct section, as far as possible.

d) Sensing elements are to be protected by a corrosion-resistant impervious covering. Conductors are to be permanently secured to sensing elements and to indicating instruments and connected accessories. Plug-and-socket connections are allowed only if they are of a type deemed suitable by the Society.

e) All sensing elements are to be easily accessible.

3.1.5 Accuracy

a) Direct reading thermometers are to permit reading with an accuracy of 0,1°C for temperatures between 0°C and 15°C. Temperatures given by remote reading are to have an accuracy of:

- ± 0,3°C (at 0°C) for the carriage of fruit and vegetables, and
- ± 0,5°C (at 0°C) for the carriage of frozen products.

b) The instrumental error, to be ascertained by means of calibration by comparison with a master-thermometer with officially certified calibration, is not to exceed the following values:

- ± 0,15°C, in the range - 3°C to + 3°C
- ± 0,25°C, in all other ranges of the scale.

c) In general, the scale range is to be within -30°C and +20°C; in any case it is to be ±5°C greater than the range of application of the instrument.

d) In the graduated scale, the space between each degree centigrade is not to be less than 5 mm.

3.1.6 Data-logger

a) When a data-logger is installed, at least one sensing element for each refrigerated space, both in the space itself and in its air circulating system, is to be connected to another independent indicating instrument, approved by the Society. The data-logger is to register to 0,1 of a degree. Indicating instruments are to be fed by two independent power sources. If they are fed by the network on board through a transformer and rectifier unit, a spare unit is also to be provided and is to be easily replaceable aboard. If they are fed by storage batteries, it will be sufficient to arrange easily changeable batteries.

b) A prototype apparatus is to be checked and tested by a Surveyors at an independent recognised laboratory, or at the Manufacturer's facilities, to verify by means of suitable tests that the degree of accuracy corresponds to the above provisions.

c) The capacity of the apparatus to withstand stipulated vibrations, impacts and temperature variations and its non-liability to alterations due to the salt mist atmosphere, typical of conditions on board, are to be verified.

4 Additional requirements for AIR-CONT notation

4.1 General

4.1.1 Applicability

a) The following requirements apply to ships with permanently installed equipment capable of generating and controlling relative humidity and/or oxygen concentration in the cargo holds for which the notation **AIRCONT** is requested.

b) The **AIRCONT** notation will be not granted to ships using portable apparatus for the generation of the controlled atmosphere or to ships with permanently installed apparatus serving less than 50% of the allowable cargo space.

4.1.2 Operational performance

a) Normally, the displacement of the oxygen from the spaces which are intended to operate under controlled atmosphere is obtained by an inert gas. The most commonly used inert gases are:
   - carbon dioxide (CO_2)
   - nitrogen (N_2)

b) The oxygen content in air controlled spaces is to be maintained between 10% and 2% of the volume, with an accuracy of at least 0,2%, unless otherwise specified and agreed with the Society.

c) Where carbon dioxide is used for controlling the atmosphere, the plant is to be capable of controlling and maintaining a concentration of CO_2 in all or in any of the controlled spaces between 10% and 0,2% in volume. The selected CO_2 content is to be maintained with an accuracy of at least 0,2%.

d) Where nitrogen (N_2) is used to control the atmosphere, and unless otherwise specified and agreed with the Society, the generating plant is to be capable of supplying at least:
   - 0,05 m^3/h of nitrogen with 4% oxygen content for each cubic meter of the total cargo space which is intended for controlled atmosphere, at normal operating temperature
   - 0,025 m^3/h of nitrogen with 2% oxygen content for each cubic meter of the total cargo space which is intended for controlled atmosphere, at normal operating temperature
   - For different oxygen content, intermediate values may be interpolated.

4.1.3 Operating and safety manual

An operating and safety manual covering at least the items listed below is to be provided on board:

- principal information on the use of controlled atmosphere
- complete description of the controlled atmosphere installation on board
- hazards of low oxygen atmospheres and consequential effects on human life
- countermeasures when exposed to low oxygen atmospheres
- instructions for operation, maintenance and calibration of all gas detectors
- instructions for use of portable oxygen analysers with alarm for personal protection
- prohibition of entry to spaces under controlled atmospheres
- loading instructions prior to injection of gas
- procedure for checking security of controlled atmosphere zones, doors and access hatches prior to injection of gas
- gas-freeing procedure for all controlled atmosphere zones
- procedure for checking atmosphere of controlled atmosphere zones before entry.

4.2 Controlled atmosphere cargo spaces and adjacent spaces

4.2.1 Air-tightness of controlled atmosphere

a) The controlled atmosphere zones are to be made air-tight. Particular attention is to be paid to sealing of hatches, plugs and access doors in each controlled atmosphere zone. Double seals are to be fitted to each opening.

b) Openings for pipes, ducts, cables, sensors, sampling lines and other fittings passing through the decks and bulkheads are to be suitably sealed and made air-tight.

c) The liquid sealed traps from bilges and drains from the cooler trays are to be deep enough, so that, when filled with an anti-freeze mixture, the liquid will neither evaporate nor freeze.

   The liquid column is to be capable of withstanding the design pressure in each controlled atmosphere zone taking account of the ship motion and angles of trim mentioned in Pt C, Ch 1, Sec 1, Tab 1.

d) Air refreshing inlets and outlets are to be provided with isolating arrangements.

4.2.2 Controlled atmosphere zone protection

a) Means are to be provided to protect controlled atmosphere zones against the effect of overpressure or vacuum.

b) One pressure/vacuum valve is to be fitted in each controlled atmosphere zone, set for the design conditions of the zone.

c) The proposed pressure/vacuum valves for the various zones are to be of adequate size to release any excess pressure when the gas generating unit is delivering at its maximum capacity to a single cargo space or compartment and to relieve the vacuum at maximum cooling rate.

d) Pressure/vacuum valve discharges are to be located at least 2 m above the open deck and 10 m away from any ventilation inlet and opening to accommodation spaces, service spaces, machinery spaces and other similar manned spaces. Connecting piping is to be arranged to preclude the ingress of water, dirt or debris which may cause the equipment to malfunction.

e) Arrangements for the protection of cargo spaces or compartments against over or under pressure other than those referred to above will be the subject of special consideration.

4.2.3 Gas freeing

a) The arrangements for gas freeing of controlled atmosphere zones are to be capable of purging all parts of the zone to ensure a safe atmosphere.

b) Cargo air cooling fans and the air refreshing arrangements may be used for gas freeing operations.

c) Gas freeing outlets are to be led to a safe place in the atmosphere 2 m above the open deck and 10 m away from air inlets and openings to accommodation spaces, service spaces, machinery spaces and similar manned spaces.

4.2.4 Ventilation of adjacent zones

a) Deckhouses and other adjacent spaces, or other spaces containing gas piping where gas leakage may create an oxygen deficient atmosphere, which need to be entered regularly, are to be fitted with a positive pressure type mechanical ventilation system with a capacity of at least 10 air changes per hour capable of being controlled from outside these spaces.

b) Adjacent spaces not normally entered are to be provided with a mechanical ventilation system which can be permanent or portable to free the gas space prior to entry. Where portable ventilators are used, at least two units capable of ensuring at least 2 air changes per hour in the largest of such spaces are to be kept on board.

c) Ventilation inlets are to be arranged so as to avoid re-cycling any gas.

d) For container carriers with containers under controlled atmosphere which have arrangements to vent low oxygen air from each container under controlled atmosphere into the cargo space, venting arrangements are to be in accordance with the applicable requirements of these Rules.

4.3 Gas systems

4.3.1 General requirements

a) Means are be provided to reach and maintain the required oxygen and/or carbon dioxide levels in the controlled atmosphere zones. This may be accomplished by use of stored gas, portable or fixed gas generating equipment or other equivalent arrangements.

b) The gas system is to have sufficient capacity to compensate for any gas loss from the controlled atmosphere zones and to maintain a positive pressure in all such zones.

c) Gas systems utilising compressors are to be provided with two or more compressors and prime movers. Each compressor is to be sized so that, with one compressor out of operation, the system is able to maintain the O_2 content in all designated cargo spaces within the specified range. Alternatively, one compressor and prime mover may be accepted provided that:

- the compressor is capable of delivering the rated capacity, and
- spares for the compressor and prime mover are carried to enable any failure of the compressor and prime mover to be rectified on board.

d) Air inlets are to be located such as to ensure that contaminated air is not drawn into the compressors.

e) Where it is intended to supply gas by means of stored gas bottles, the arrangements are to be such that depleted bottles may be readily and safely disconnected and replaced by charged bottles.

4.3.2 Carbon dioxide generation

Carbon dioxide generating equipment is subject to special consideration by the Society.

4.3.3 Passive components of nitrogen generators

The passive components of nitrogen generators, such as membranes or carbon molecular sieves, need not be duplicated.

4.3.4 Gas supply

a) Gas systems are to be designed so that the pressure which they can exert on any controlled atmosphere zone will not exceed the design pressure of the zone.

b) During initial operation, arrangements are to be made to vent the gas outlets from each generator to the atmosphere. All vents from gas generators are to be led to a safe location on the open deck.

c) Where gas generators use positive displacement compressors, a pressure relief device is to be provided to prevent excess pressure being developed on the discharge side of the compressor.

d) Suitable arrangements are to be provided to enable the supply mains to be connected to an external supply

e) Where nitrogen (N_2) is used:

- means of controlling inadvertent release of nitrogen into controlled atmosphere zones, such as lockable non-return valves, are to be provided.
- the nitrogen delivery line is to be fitted with a safety valve capable of discharging the rated capacity of the nitrogen generation unit at shut-in conditions with maximum discharge pressure/no flow.
- filters are to be fitted in the delivery line.
- oxygen and nitrogen exhaust lines are to be led to discharge in safe locations on open deck.

4.3.5 Segregation

a) Fixed gas generating equipment, gas bottles or portable gas generators are to be located in a compartment reserved solely for their use. Such compartments are to be separated by a gas-tight bulkhead and/or deck from accommodation, machinery, service and control spaces. Access to such compartments is only to be from the open deck.

b) Gas piping systems are not to be led through accommodation, service and machinery spaces or control stations.

4.3.6 Protection of cargo spaces against overpressure

a) Means to protect the cargo spaces from overpressure are to be provided. These means may be:
   - in the case of external gas supply, a shut-off valve automatically operated in the event of overpressure fitted at the connection with the external supply
   - a vent valve, connected to the cargo hold inlet valve, ensuring that the inlet of nitrogen is allowed when the vent valve is open.

b) Nitrogen outlets to the atmosphere are to be directed vertically upward and are to be located in segregated positions which are not likely to discharge into manned areas.

4.3.7 Ventilation

a) The gas supply compartment is to be fitted with an independent mechanical extraction ventilation system providing a rate of at least 20 air changes per hour based on the total empty volume of the compartment.

b) Ventilation ducts from the gas generator/supply compartment are not to be led through accommodation, service and machinery spaces or control stations.

c) The air exhaust ducts are to be led to a safe location on the open deck.

4.4 Miscellaneous equipment

4.4.1 Humidification equipment

Where a humidification system is fitted, the following requirements are to be complied with:

a) the supply of fresh water for humidification is to be such as to minimise the risk of corrosion and contamination of the cargo

b) in order to prevent damage or blockage in the humidification system caused by water freezing, the air, steam or water pipelines in the cargo chambers are to be installed so as to facilitate drainage and to be provided with suitable heating arrangements.

4.4.2 Electrical equipment

In addition to the applicable requirements of Part C, Chapter 2 of the Rules, the following are to be complied with:

a) the electrical power for the controlled atmosphere plant is to be provided from a separate feeder circuit from the main switchboard

b) under seagoing conditions, the number and rating of service generators are to be sufficient to supply the cargo refrigeration machinery and controlled atmosphere equipment in addition to the ship's essential services, when any one generating set is out of action.

4.5 Gas detection and monitoring equipment

4.5.1 General

a) The indicators and alarms required in this Section are all to be given at a suitable refrigerated cargo control station.

b) The pressure in each controlled atmosphere zone is to be monitored and an alarm initiated when the pressure is too high or too low.

c) Direct read-out of the gas quality within any controlled atmosphere zone is to be available to the operating staff on demand.

4.5.2 Oxygen and carbon dioxide detection

a) All cargo spaces intended for controlled atmosphere are to be fitted with means for measuring the oxygen and carbon dioxide content.

   The values are to be automatically logged at regular intervals (generally every hour) for the entire period in which the cargo space is kept under controlled atmosphere.

b) Gas analysers are to be calibrated automatically once every 24 hours. An alarm is to be initiated if accuracy is outside tolerance limits.

c) Each normally manned space adjacent to cargo spaces, intended to be operated under controlled atmosphere, is to be fitted with at least one means to measure the oxygen content.

d) When humidification equipment is installed in each of the controlled atmosphere zones, an alarm is to be initiated when the relative humidity falls below or exceeds the predetermined set values.

4.5.3 Sampling and analysing system

a) At least two analysers for oxygen and carbon dioxide having a tolerance of ± 0,1 per cent by volume are to be provided to determine the content of the circulated gas within the controlled atmosphere zones.

b) When a sampling system with sequential analysing is fitted, the sampling lines are to be able to operate at any value of pressure or vacuum at which the controlled air system may operate in the cargo space. Common sampling lines for different media (oxygen, carbon dioxide, etc.) are allowed.

c) Two separate sampling points are to be located in each controlled atmosphere zone and one sampling point in each of the adjacent spaces. The arrangements are to be such as to prevent water condensing and freezing in the sampling lines under normal operating conditions. Filters are to be provided at the inlet to sampling point lines.

d) Arrangements of the gas sampling points are to be such as to facilitate representative sampling of the gas in the space.

e) Where gas is extracted from the controlled atmosphere zones via a sampling tube to analysers outside the space, the sample gas is to be discharged safely to the open deck.

f) Sampling by means of portable equipment will be subject to special consideration.

g) The sampling frequency is to be at least once per hour.

4.5.4 Alarm for gas release

An audible and visual alarm is to be automatically operated for at least 60 seconds before the gas release in the cargo spaces is initiated. The alarm is to be interlocked with the gas inlet valve, in such a way that the valve cannot be opened until the alarm has been given.

4.6 Instrumentation, alarm and monitoring arrangement

4.6.1 Tab 1 summarises the minimum control and monitoring requirements for controlled atmosphere plants.

Table 1 :

Item	Indicator	Function			Comments
			Alarm	Automatic shut-down	
Oxygen content	percentage	low	X		Cargo spaces
		high	X		
		< 21%	X		Manned spaces adjacent to cargo spaces
Carbon dioxide content	percentage		X		Cargo spaces
Atmospheric pressure	pressure	high	X	X **(1)**	
Gas generation		failure	X		Failure of any one of the generating equipment
Gas release		release	X		To be operated for at least 60 seconds before release
Liquid seal level		low	X		Where installed
Ventilation		failure	X		
Sampling line flow		failure	X		
Logging		failure	X		
(1) Automatic closing of inlet valve of externally supplied gas.					

4.7 Safety

4.7.1 Access to controlled atmosphere zones

a) Controlled atmosphere zones are to be clearly labelled with “Caution” and “Danger” signs to alert personnel.

b) Entry hatch and manhole covers and doors leading to controlled atmosphere zones and adjacent spaces are to be fitted with acceptable security type locks and warning notices informing about the low oxygen atmosphere. Warning notices are to be posted at all openings to spaces under controlled atmosphere to prevent inadvertent opening while the space is under the controlled atmosphere.

c) All doors and access hatches to controlled atmosphere zones which may be under pressure are to open outwards and are to be fitted with means to prevent injury or damage during opening.

4.7.2 Safety equipment

a) At least 10 portable oxygen monitors with alarms are to be provided on board.

b) At least two portable oxygen sensors are to be provided to sample the oxygen level in all controlled atmosphere zones and adjacent spaces for use prior to entry into such zones or spaces.

c) A means of two-way communication is to be provided between the cargo spaces under controlled atmosphere and the gas release control station. If portable radiotelephone apparatus is adopted to comply with this requirement, at least three sets are to be provided on board. This equipment is to be in addition to that required by SOLAS Chapter III, Regulation 6.

d) Two self-contained breathing apparatuses equipped with built-in radio communication and a lifeline with a belt are to be provided on board together with fully charged spare air bottles with a total free air capacity of 3600 litres for each breathing apparatus. This equipment is to be in addition to that required by SOLAS Chapter II-2, Regulation 17.

4.8 Tests and trials

4.8.1 General

Controlled atmosphere system trials are to be carried out on board before the system is put into service, as indicated below.

4.8.2 Tightness tests

a) Piping

1) The gas supply mains and branches are to be pressure and leak tested. The test pressures are to be 1,5 and 1,0 times the design pressure, respectively.

2) All gas sampling lines are to be leak tested using a vacuum or overpressure method.

b) Air-tightness in controlled atmosphere

1) Air-tightness of each controlled atmosphere zone is to be tested and the results entered on the certificate. The measured leakage rate of each zone is to be compared with the specified value.

2) Either a constant pressure method or a pressure decay method is to be used to determine the degree of air-tightness.

3) If the constant pressure method is used, the test is to be carried out at the design pressure of the controlled atmosphere zones.

4) If the pressure decay method is used, the time for the pressure to drop from 350 Pa to 150 Pa is to be measured and the leakage is to be calculated using the following formula:

$$Q = 7{,}095 \cdot \frac{V}{t}$$

where:

Q : Air leakage, in m^3/h

V : Volume of zone, in m^3

t : Time, in seconds

7,095 : Constant for 200 Pa pressure decay.

5) During this test, the adjacent zones are to be kept at atmospheric pressure.

4.8.3 Gas system performance

The capability of the gas system to supply gas according to the specified flow rate and conditions is to be verified by tests.

4.8.4 Gas freeing

The gas freeing arrangements are to be tested to demonstrate that they are effective.

4.8.5 Safety, alarms and instrumentation

a) The control, alarm and safety systems are to be tested to demonstrate overall satisfactory performance of the control engineering installation. Testing is also to take account of the electrical power supply arrangements.

b) Locking arrangements of all controlled atmosphere zones and adjacent spaces where gas may accumulate, provision of warning notices at all entrances to such spaces, communication arrangements and operation of alarms, controls, etc. are to be examined.

c) The provision of portable gas detectors and personnel oxygen monitors is to be verified. Suitable calibrated instruments to measure the levels of O_2, CO_2 and humidity, gas pressure and gas flow to the controlled atmosphere zones are to be provided for testing. Their accuracy is to be verified.

5 Additional requirements for notations PRECOOLING and QUICKFREEZE

5.1 General

5.1.1 Applicability

The following requirements apply to ships for which either the **PRECOOLING** or **QUICKFREEZE** notation is requested. The requirements of this Section are additional to those in Ch 7, Sec 1.

5.1.2 Conditions of assignment

The notations **PRECOOLING** and **QUICKFREEZE** are assigned in connection with the maximum time necessary to cool the products loaded from the ambient temperature down to the storage temperature mentioned in the class certificate. This time is to be indicated in the contract specification and entered in the notation after approval of the heat balance of the installation for the specified temperatures.

Number of tunnels or cells to be in service is to be noted in the class certificate along with:

- refrigeration capacity
- electric power supply capacity.

5.1.3 Additional requirements for PRECOOLING notation

a) Unless otherwise specified for special cargoes, the rate of cold air circulation within each space is not normally to be less than 70 changes per hour. Lower values may be accepted locally for zones with lesser ventilation. However, for any zone, in any right parallelepiped having 1 m^2 of ceiling surface as a base and the height of the space, the rate of circulation is not to be less than 40 changes per hour; moreover, the average rate of circulation is not to be less than 60 changes per hour in any parallelepiped with the same height and based on 50 m^2 of ceiling surface.

b) For a system with horizontal air circulation, the average and local rates of circulation are not to be less than those mentioned above for vertical circulation.

c) Unless duly justified, the local and average rates of circulation of refrigerated air are to be checked for the empty spaces.

5.2 Shipboard tests

5.2.1 Additional requirement for PRECOOLING notation

For the notation **PRECOOLING**, during the ventilation system tests the conditions stated in [5.1.3] are to be verified. The detailed procedure of the test is to be previously submitted to the Society.

Section 3 Additional Requirements for Notation REF-CONT

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable for the assignment of the additional class notation **REF-CONT**. They are additional to the applicable requirements of Ch 7, Sec 1.

1.1.2 Containers

Refrigerated containers are not covered by the class notation and accordingly no specific requirements for the containers are contained in these Rules.

2 Ships supplying electrical power to self-refrigerated containers

2.1 Electrical equipment

2.1.1 In addition to the applicable requirements of Part C, Chapter 2 of the Rules, the following are to be complied with:

a) the electrical power for the controlled atmosphere plant is to be provided from a separate feeder circuit from the main switchboard

b) under seagoing conditions, the number and rating of service generators are to be sufficient to supply the cargo refrigeration machinery and controlled atmosphere equipment in addition to the ship's essential services, when any one generating set is out of action.

2.2 Installation of containers

2.2.1 The loading of refrigerated containers is to be restricted to locations where proper ventilation and cooling of the refrigerating equipment may be ensured.

Section 4 Additional Requirements for Notation REF-STORE

1 General

1.1 Application

1.1.1 For the assignment of the additional class notation **REF-STORE**, and in addition to the applicable requirements of Ch 7, Sec 1, the additional requirements of Ch 7, Sec 2 are to be complied with, with the exception of those of Ch 7, Sec 2, [1.3] and Ch 7, Sec 2, [2.1].

CHAPTER 8
NAVIGATION IN COLD ENVIRONMENT

Section 1 ICE Class Notations - General Requirements

Section 2 ICE Class Notations - Hull and Stability

Section 3 ICE Class Notations - Machinery

Section 4 COLD Notations - Cold Weather Conditions

Section 1 ICE Class Notations - General Requirements

1 General

1.1 Application

1.1.1 The following additional class notations are assigned in accordance with Pt A, Ch 1, Sec 2, [6.10] to ships strengthened for navigation in ice and complying with the relevant requirements of Ch 8, Sec 1, Ch 8, Sec 2 and Ch 8, Sec 3:

- **ICE CLASS IA SUPER**
- **ICE CLASS IA**
- **ICE CLASS IB**
- **ICE CLASS IC**
- **ICE CLASS ID**
- **YOUNG ICE 1**
- **YOUNG ICE 2**

1.1.2 The ice strengthening requirements in Ch 8, Sec 1, Ch 8, Sec 2 and Ch 8, Sec 3, excepting those for ships with the additional class notation **ICE CLASS ID**, **YOUNG ICE 1** or **YOUNG ICE 2**, are equivalent to those stated in the Finnish-Swedish Ice Class Rules 2010, as amended, applicable to ships trading in the Baltic Sea in winter or equivalent ice conditions.

1.1.3 As a guidance, Tab 1 provides relation between the additional class notations **YOUNG ICE 1** and **YOUNG ICE 2** and the associated ice conditions compatible with the strengthening requirements in Ch 8, Sec 2, [7].

Table 1 : Ice conditions for YOUNG ICE 1 and YOUNG ICE 2

Notation	Ice forming stage	Ice concentration
YOUNG ICE 1	Young ice (gray or whitish) having a maximum thickness of 30 cm	Open ice (concentration between 6 and 3/10th)
YOUNG ICE 2		Very open ice (concentration less than 3/10th)

1.2 Owner's responsibility

1.2.1 It is the responsibility of the Owner to decide which ice class notation is the most suitable in relation to the expected service conditions of the ship.

Nevertheless, it is to be noted that a ship assigned with **ICE CLASS IA SUPER** is not to be considered as a ship suitable for navigation in ice in any environmental condition, such as an icebreaker.

1.3 Documents to be submitted

1.3.1 The plans relevant to shell expansion and fore and aft part structures are to define (see [2.2]) the maximum draught LWL, the minimum draught BWL (both draughts at midship, fore and aft ends), and the borderlines of fore, midship and aft regions defined in Ch 8, Sec 2, [1.2].

2 Ice class draughts and ice thickness

2.1 Definitions

2.1.1 Upper ice waterline

The Upper Ice Waterline (UIWL) is the envelop of highest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

2.1.2 Lower ice waterline

The Lower Ice Waterline (LIWL) is the envelop of lowest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

2.1.3 Ice belt

The ice belt is that portion of the side shell which is to be strengthened. Its vertical extension is defined in Ch 8, Sec 2, Tab 1.

2.2 Draught limitations in ice

2.2.1 Maximum draught

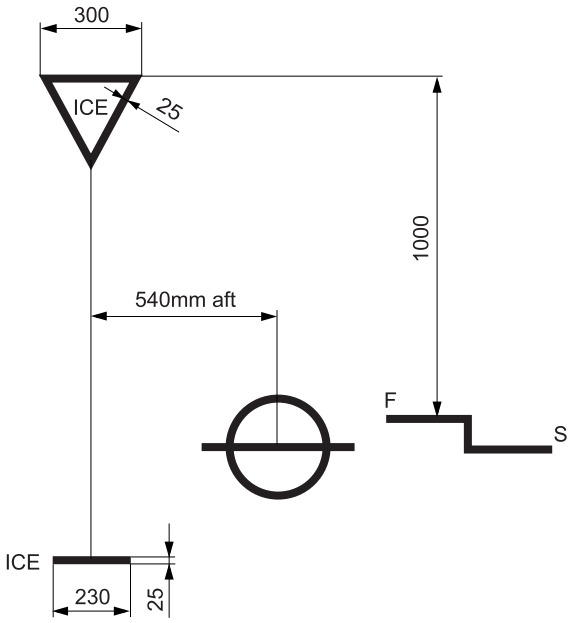
The draught and trim limited by the UIWL are not to be exceeded when the ship is navigating in ice.

The salinity of the sea water along the intended route is to be taken into account when loading the ship.

2.2.2 Minimum draught

The ship is always to be loaded down at least to the draught of LIWL amidships when navigating in ice. Any ballast tank situated above the LIWL and needed to load down the ship to this waterline is to be equipped with devices to prevent the water from freezing.

Figure 1 : Ice class draught marking



Note 1: The upper edge of the warning triangle is to be located vertically above the "ICE" mark, 1000 mm higher than the summer load line in fresh water but in no case higher than the deck line. The sides of the triangle are to be 300 mm in length.

Note 2: The ice class draught mark is to be located 540 mm abaft the centre of the load line ring or 540 mm abaft the vertical line of the timber load line mark, if applicable.

Note 3: The marks and figures are to be cut out of 5 - 8 mm plate and then welded to the ship's side. The marks and figures are to be painted in a red or yellow reflecting colour in order to make the marks and figures plainly visible even in ice conditions.

Note 4: The dimensions of all figures are to be the same as those used in the load line mark.

Note 5: The upper horizontal line above the triangle represents the ship deck line.
The lower horizontal line below the triangle represents the UIWL.

2.2.3 Minimum forward draught

In determining the LIWL, due regard is to be paid to the need to ensure a reasonable degree of ice going capability in ballast. The highest point of the propeller is to be submerged and if possible at a depth of at least h_i below the water surface in all loading conditions. The minimum forward draught is to be at least equal to the value T_{AV}, in m, given by the following formula:

$$T_{AV} = (2 + 0{,}00025\Delta_1)h_i$$

where:

Δ_1 : Displacement of the ship, in t, determined from the waterline on the UIWL, as defined in [2.2.1]. Where multiple waterlines are used for determining the UIWL, the displacement must be determined from the waterline corresponding to the greatest displacement.

h_i : Ice thickness, in m, as defined in [2.3].

The draught T_{AV} need not, however, exceed 4 h_i.

2.2.4 Indication of maximum and minimum draughts in ice

Restrictions on draughts when operating in ice are to be documented and kept on board readily available to the master.

The maximum and minimum ice class draughts fore, amidships and aft are to be specified in the documents submitted for approval to the Society and stated on the Certificate of Classification.

If the summer load line in fresh water is anywhere located at a higher level than the UIWL, the ship's sides are to be provided with a warning triangle and with a draught mark at the maximum permissible ice class draught amidships, according to Fig 1.

The purpose of the warning triangle is to provide information on the draught limitation of the ship when it is sailing in ice for masters of icebreakers and for inspection personnel in ports.

2.3 Ice thickness

2.3.1 Height of the ice load area

a) An ice strengthened ship is assumed to operate in open sea conditions corresponding to an ice level with a thickness not exceeding the value h_i.

b) The design ice load height h of the area under ice pressure at any time is assumed to be only a fraction of the ice thickness.

c) The values for h_i and h, in m, are given in Tab 2.

Table 2 : Ice load height

Notation	h_i (m)	h (m)
ICE CLASS IA SUPER	1,0	0,35
ICE CLASS IA	0,8	0,30
ICE CLASS IB	0,6	0,25
ICE CLASS IC **ICE CLASS ID**	0,4	0,22
YOUNG ICE 1 **YOUNG ICE 2**	0,3	0,19

3 Output of propulsion machinery

3.1 Required engine output for ICE CLASS IA SUPER, ICE CLASS IA, ICE CLASS IB and ICE CLASS IC

3.1.1 The engine output, P, is the total maximum output the propulsion machinery can continuously deliver to the propeller(s). If the output of the machinery is restricted by technical means or by any regulations applicable to the ship, P is to be taken as the restricted output. If additional power sources are available for propulsion power (e.g. shaft motors), in addition to the power of the main engine(s), they are also to be included in the total engine output.

The engine output is to be not less than that determined according to [3.1.3] and in no case less than 1000 kW for ice class **ICE CLASS IA**, **ICE CLASS IB** and **ICE CLASS IC**, and not less than 2800kW for **ICE CLASS IA SUPER**.

No minimum engine output is required for notations **ICE CLASS ID**, **YOUNG ICE 1** and **YOUNG ICE 2**.

3.1.2 Definitions

The dimensions of the ship, defined below, are measured on the maximum ice class draught of the ship as defined in [2.2.1]. For the symbol definitions, see also Fig 2.

L : Length of the ship between the perpendiculars, in m

L_{BOW} : Length of the bow, in m

L_{PAR} : Length of the parallel midship body, in m

B : Maximum breadth of the ship, in m

T : Actual ice class draught of the ship, in m, according to [3.1.3]

A_{wf} : Area of the waterline of the bow, in m^2

α : Angle of the waterline at B/4, in deg

ϕ_1 : Rake of the stem at the centreline, in deg, taken equal to 90 if the ship has a bulbous bow

ϕ_2 : Rake of the bow at B/4, in deg

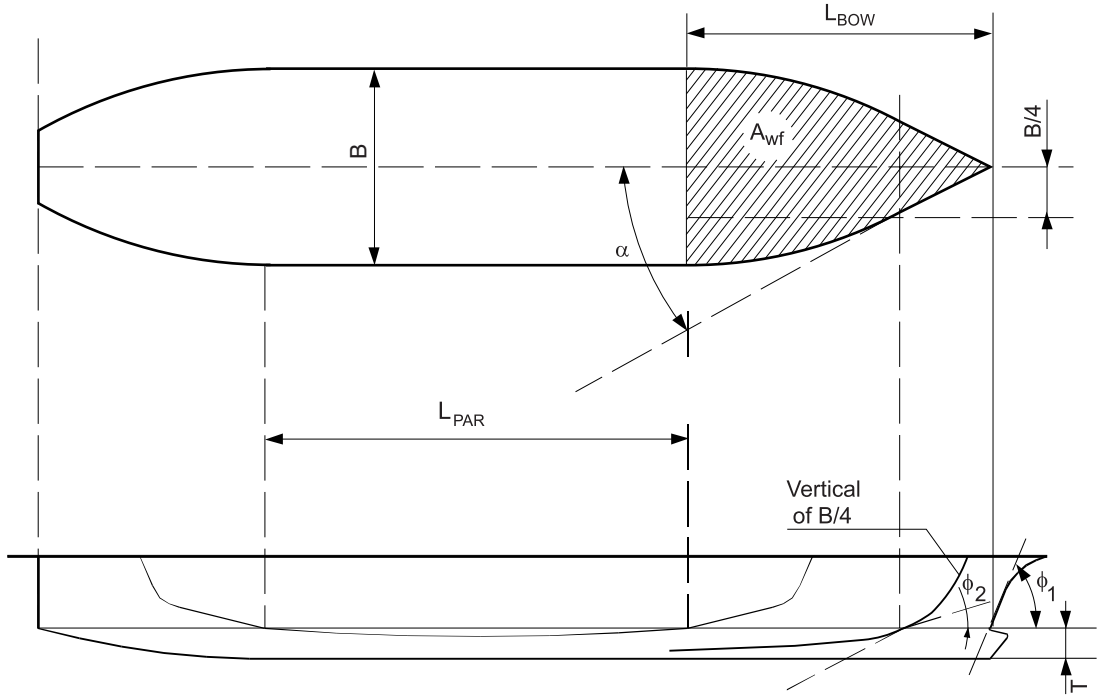
ψ : Flare angle, in deg, taken equal to arctan (tan ϕ_2 /sin α)

D_P : Diameter of the propeller, in m

H_M : Thickness of the brash ice in mid-channel, in m

H_F : Thickness of the brash ice layer displaced by the bow, in m.

Figure 2 : Determination of the geometric quantities of the hull



3.1.3 Minimum required power

The engine output requirement P is to be calculated for two draughts. Draughts to be used are the maximum draught amidship referred to as UIWL and the minimum draught amidship referred to as LIWL, as defined in [2.2]. In the calculation the ship's parameters which depend on the draught are to be determined at the appropriate draught, but L and B are to be determined only at the UIWL. The engine output is to be not less than the greater of these two outputs. These two outputs, in kW, are to be determined by the following formula:

$$P = K_C \frac{\left(\frac{R_{CH}}{1000}\right)^{3/2}}{D_P}$$

where:

K_C : Coeficient as defined in Tab 3

R_{CH} : Ice resistance of the ship in a channel with brash ice and a consolidated layer, in N, taken equal to:

$$R_{CH} = C_1 + C_2 + C_3(H_F+H_M)^2(B+ C_\psi H_F)C_\mu + C_4 L_{PAR} H_F^2 + C_5\left(\frac{LT}{B^2}\right)^3 \frac{A_{wf}}{L}$$

with

$$20 \geq \left(\frac{LT}{B^2}\right)^3 \geq 5$$

C_1 : Coefficient taking into account a consolidated upper layer of the brash ice and to be taken:

- for **ICE CLASS IA SUPER**:

$$C_1 = \frac{f_1 B L_{PAR}}{\frac{2T}{B}+1} + (1+0{,}021\phi_1)(f_2 B + f_3 L_{BOW} + f_4 B L_{BOW})$$

- for **ICE CLASS IA**, **ICE CLASS IB** and **ICE CLASS IC**:

$C_1 = 0$

C_2 : Coefficient taking into account a consolidated upper layer of the brash ice and to be taken:

- for **ICE CLASS IA SUPER**:

$$C_2 = (1+0{,}063\phi_1)(g_1 + g_2 B) + g_3\left(1+1{,}2\frac{T}{B}\right)\frac{B^2}{L^{0,5}}$$

- for **ICE CLASS IA**, **ICE CLASS IB** and **ICE CLASS IC**:

$C_2 = 0$

C_ψ : Coefficient equal to:

- if $\psi \leq 45°$, $C_\psi = 0$
- otherwise, $C_\psi = 0{,}047\ \psi - 2{,}115$

C_μ : Coefficient equal to:

$C_\mu = 0{,}15 \cos \phi_2 + \sin \psi \sin \alpha$

without being less than 0,45

H_F : $0{,}26 + (H_M B)^{0,5}$

H_M : Coefficient defined in Tab 4

$C_3 = 845\ kg/m^2s^2$

$C_4 = 42\ kg/m^2s^2$

$C_5 = 825\ kg/s^2$

$f_1 = 23\ N/m^2$

$f_2 = 45{,}8\ N/m$

$f_3 = 14{,}7\ N/m$

$f_4 = 29\ N/m^2$

$g_1 = 1530\ N$

$g_2 = 170\ N/m$

$g_3 = 400\ N/m^{1,5}$

Table 3 : Values of K_C for conventional propulsion systems

Number of propellers	Controllable pitch propellers or electric or hydraulic propulsion machinery	Fixed pitch propellers
1 propeller	2,03	2,26
2 propellers	1,44	1,60
3 propellers	1,18	1,31
Note 1: These K_c values apply for conventional propulsion systems. Other methods may be used for determining the required power for advanced propulsion systems (see [3.1.4]).		

Table 4 : Values of H_M

Notation	H_M
ICE CLASS IA SUPER **ICE CLASS IA**	1,0
ICE CLASS IB	0,8
ICE CLASS IC	0,6

3.1.4 Other methods of determining K_C or R_{CH}

The Society may for an individual ship, in lieu of the K_C or R_{CH} values defined above, approve the use of K_C values based on more exact calculations or R_{CH} values based on model tests. Such approval will be given on the understanding that it can be revoked if experience of the ship's performance in practice warrants this.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels.

The values of H_M are those defined in Tab 4. A 0,1 m thick consolidated layer of ice for ice class **ICE CLASS IA SUPER** is to be considered.

Section 2 ICE Class Notations - Hull and Stability

Symbols

LIWL : Lower ice waterline, defined in Ch 8, Sec 1, [2.1]

UIWL : Upper ice waterline, defined in Ch 8, Sec 1, [2.1]

b : Breadth of an elementary plate panel, as defined in Pt B, Ch 1, Sec 3

h : Height, in m, of load area defined in [3.2.1]

ℓ : Span of stiffeners or primary supporting members, as defined in Pt B, Ch 4, Sec 6, [1]

s : Stiffener spacing, as defined in Pt B, Ch 4, Sec 6, [1.2.1]

S : Primary supporting member spacing, as defined in Pt B, Ch 4, Sec 6, [1.2.2]

p : Design ice pressure, in N/mm^2, defined in [3.2.2]

R : Minimum yield stress value of the material, in N/mm^2, taken equal to:

- for steel: $R = R_{eH}$ as defined in Pt B, Ch 4, Sec 1, [2]
- for aluminium: $R = R'_{p0,2}$ as defined in Pt B, Ch 4, Sec 1, [4]

t_c : Abrasion and corrosion addition, in mm, to be taken equal to 2 mm; where a special surface coating, shown by experience to be capable of withstanding the abrasion of ice, is applied, a lower value may be accepted by the Society on a case-by-case basis

α : Angle of the waterline at B/4, in deg

ϕ_1 : Rake of the stem at the centreline, in deg, taken equal to 90 if the ship has a bulbous bow

ϕ_2 : Rake of the bow at B/4, in deg

ψ : Flare angle, in deg, taken equal to arctan (tan ϕ /sin α).

1 General

1.1 Application

1.1.1 For the purpose of the assignment of the notations **ICE CLASS IA SUPER**, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC** and **ICE CLASS ID**, the ship is divided into three regions defined in [1.2].

1.1.2 The area to be strengthened are defined in [1.3] depending on the ice notation.

1.1.3 Additional class notation ICE CLASS ID

Strengthening of ships with additional class notation **ICE CLASS ID** is that of bow region, rudder and steering arrangements of additional class notation **ICE CLASS IC**.

1.1.4 Additional class notations YOUNG ICE 1 and YOUNG ICE 2

Ships with the additional class notation **YOUNG ICE 1** or **YOUNG ICE 2** are to comply with the requirements defined in [7].

The other articles of this Section are not applicable to notations **YOUNG ICE 1** and **YOUNG ICE 2**.

The miscellaneous requirements listed in Ch 8, Sec 3, [3] are also to be complied with.

1.2 Hull regions

1.2.1 Bow region

The bow region is the region from the stem to a line parallel to and 0,04L aft of the forward borderline of the part of the hull where the waterlines run parallel to the centerline.

The overlap over the borderline need not exceed:

- 6 m for the notations **ICE CLASS IA SUPER** and **ICE CLASS IA**
- 5 m for the notations **ICE CLASS IB**, **ICE CLASS IC** and **ICE CLASS ID**.

1.2.2 Midbody region

The midbody region is the region from the aft boundary of the bow region to a line parallel to and 0,04 L aft of the aft borderline of the part of the hull where the waterlines run parallel to the centerline.

The overlap over the borderline need not exceed:

- 6 m for the notations **ICE CLASS IA SUPER** and **ICE CLASS IA**
- 5 m for the notations **ICE CLASS IB** and **ICE CLASS IC**.

1.2.3 Stern region

The stern region is the region from the aft boundary of the midbody region to the stern.

1.3 Ice strengthened area

1.3.1 General

The vertical extension of the ice strengthened area (see Fig 1) is defined in:

- Tab 1 for plating (ice belt)
- Tab 2 for ordinary stiffeners and primary supporting members.

Figure 1 : Ice strengthened area and regions

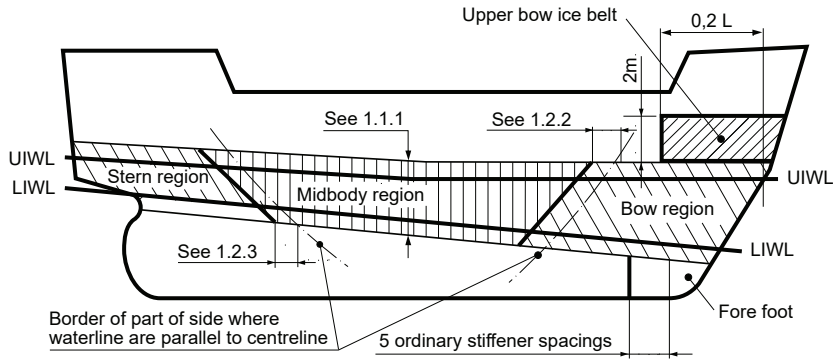


Table 1 : Vertical extension of ice strengthened area for plating (ice belt)

Notation	Hull region	Vertical extension of ice strengthened area, in m	
		Above UIWL	Below LIWL
ICE CLASS IA SUPER	Bow	0,60	1,20
	Midbody		
	Stern		1,00
ICE CLASS IA	Bow	0,50	0,90
	Midbody		0,75
	Stern		
ICE CLASS IB **ICE CLASS IC** **ICE CLASS ID**	Bow	0,40	0,70
	Midbody		0,60
	Stern		
YOUNG ICE 1 **YOUNG ICE 2**	Bow	0,40	0,50

Table 2 : Vertical extension of ice strengthening for ordinary stiffeners and primary supporting members

Notation	Hull region	Vertical extension of ice strengthened area, in m	
		Above UIWL	Below LIWL
ICE CLASS IA SUPER	Bow	1,20	Down to tank top or below top of floors
	Midbody		2,00
	Stern		1,60
ICE CLASS IA **ICE CLASS IB** **ICE CLASS IC** **ICE CLASS ID**	Bow	1,00	1,60
	Midbody		1,30
	Stern		1,00
YOUNG ICE 1 YOUNG ICE 2	Bow	0,40	0,50
Note 1: Where an upper bow ice belt is required (see [4.2.1]), the ice-strengthened part of the framing is to be extended at least to the top of this ice belt. **Note 2:** Where the ice strengthened area extends beyond a deck, the top or bottom plating of a tank or tank top by not more than 250 mm, it may be terminated at that deck, top or bottom plating of the tank or tank top.			

1.3.2 Fore foot

The fore foot is the area below the ice belt extending from the stem to a position five ordinary stiffeners spacings aft of the point where the bow profile departs from the keel line (see Fig 1).

1.3.3 Upper bow ice belt

The upper bow ice belt is the area extending from the upper limit of the ice belt to 2 m above and from the stem to a position at least 0,2 L aft of the forward perpendicular (see Fig 1).

2 Structure design principles

2.1 General framing arrangement

2.1.1 The frame spacings and spans in this Section are normally assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members the span (or spacing) is defined as the chord length between span (or spacing) points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element (stringer, web frame, deck or bulkhead).

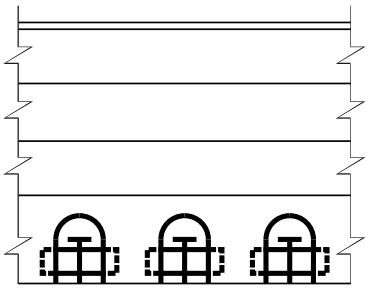
2.1.2 The effective breadth of the attached plate to be used for calculating the combined section modulus of the stiffener, stringer and web frame and attached plate is to be taken as specified in Pt B, Ch 4, Sec 6, [1.3].

2.1.3 The requirements for the section modulus and shear area of the stiffeners and the primary supporting members in [4.3] and [4.4] are with respect to effective member cross section as calculated in Pt B, Ch 4, Sec 6, [1.4].

2.1.4 Within the ice-strengthened area defined in [1.3], all stiffeners are to be effectively attached to all the supporting structures. A longitudinal stiffener is to be attached by brackets to all the supporting web frames and bulkheads. When a transverse stiffener terminates at a stringer or a deck, a bracket or a similar construction is to be fitted. Brackets are to have at least the same thickness as the web plate of the stiffener and the edge is to be appropriately stiffened against buckling.

When a stiffener is running through the supporting structure, both sides of the web plate of the stiffener are to be connected to the structure (by direct welding or collar plate, see example in Fig 2).

Figure 2 : End connection of stiffener - Two collar plates



2.1.5 Within the ice-strengthened area defined in [1.3], all stiffeners are to be attached to the shell by double continuous welds; no scalloping is allowed (except when crossing shell plate butts.

2.1.6 Within the ice-strengthened area defined in [1.3], the web thickness of the frames is to be at least the maximum of the following:

- $\frac{h_w \sqrt{R_{eH}}}{C}$

  where h_w is the web height and C is equal to 805 for profiles and 282 for flat bars

- half of the net thickness of the shell plating. For the purpose of calculating the web thickness of frames, the required thickness of the shell plating is to be calculated according to [4.2.2] using the yield strength R_{eH} of the frames

- 9 mm.

Where there is a deck, top or bottom plating of a tank, tanktop or bulkhead in lieu of a frame, the plate thickness of it is to be calculated as above, to a depth corresponding to the height of the adjacent frames. In such a case, the material properties of the deck, top or bottom plating of the tank, tank top or bulkhead and the frame height h_w of the adjacent frames are to be used in the calculations, and the constant C is to be taken equal to 805.

2.1.7 Within the ice-strengthened area defined in [1.3], asymmetrical frames and frames which are not at right angles to the shell (web less than 90 degrees to the shell) are to be supported against tripping by brackets, intercoastals, stringers or similar, at a distance not exceeding 1300 mm.

For frames with spans greater than 4 m, the extent of antitripping supports is to be applied to all regions and for all ice classes.

For frames with spans less than or equal to 4 m, the extent of antitripping supports is to be applied to all regions for **ICE CLASS IA SUPER**, to the bow and midbody regions for I**CE CLASS IA**, and to the bow region for **ICE CLASS IB**, I**CE CLASS IC** and **ICE CLASS ID**.

Direct calculation methods may be applied to demonstrate the equivalent level of support provided by alternative arrangements.

2.2 Transverse framing arrangement

2.2.1 Upper end of transverse framing

The upper end of the strengthened part of a main ordinary stiffener and intermediate ice ordinary stiffener is to be attached to a deck, top or bottom plating of a tank or an ice stringer as required in [4.4.1].

Where an intermediate ordinary stiffener terminates above a deck or an ice stringer which is situated at or above the upper limit of the ice belt, the part above the deck or stringer is to have the scantlings required for a non-ice strengthened ship. The upper end is to be connected to the adjacent main ordinary stiffeners by a horizontal member of the same scantlings as the main ordinary stiffener.

2.2.2 Lower end of transverse framing

The lower end of the strengthened part of a main ordinary stiffener and intermediate ice ordinary stiffener is to be attached to a deck, top or bottom plating of a tank, tank top or an ice stringer as required in [4.4.1].

Where an intermediate ordinary stiffener terminates below a deck, top or bottom plating of a tank, tank top or an ice stringer which is situated at or below the lower limit of the ice belt, the lower end is to be connected to the adjacent main ordinary stiffeners by a horizontal member of the same scantlings as the ordinary stiffeners.

2.3 Bilge keels

2.3.1 The connection of bilge keels to the hull is to be so designed that the risk of damage to the hull, in the event of a bilge keel being ripped off, is minimised.

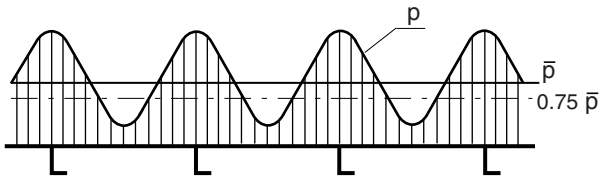
For this purpose, it is recommended that bilge keels are cut up into several shorter independent lengths.

3 Design loads

3.1 General

3.1.1 Because of the different flexural stiffness of plating, ordinary stiffeners and primary supporting members, the ice load distribution is to be assumed to be as shown in Fig 3.

Figure 3 : Ice load distribution on ship side



3.1.2 The formulae and values given in this Section may be substituted by direct analysis if they are deemed by the Society to be invalid or inapplicable for a given structural arrangement or detail. Otherwise, direct analysis is not to be used as an alternative to the analytical procedures prescribed by explicit requirements.

Direct analyses are to be carried out using the load patch (p, h and ℓ_a). The pressure to be used is 1,8p. The load patch is to be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized. In particular, the structure is to be checked with load centred at the UIWL, 0,5 h_i below the LIWL, and positioned several vertical locations in between. Several horizontal locations are also to be checked, especially the locations centred at the mid-span or mid-spacing. Further, if the load length ℓ_a cannot be determined directly from the arrangement of the structure, several values of ℓ_a are to be checked using corresponding values for c_a.

Acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, are lower than the yield point R_{eH}. When the direct calculation is using beam theory, the allowable shear stress is not to be larger than 0,9 τ_Y, where:

$$\tau_Y = \frac{R_{eH}}{\sqrt{3}}$$

3.1.3 If scantlings obtained from the requirements of this Section are less than those required for a ship that has not been ice strengthened, the latter are to be used.

3.2 Ice loads

3.2.1 Height of load area

The height of the area under ice pressure, h, at any particular point of time is to be obtained, in m, from Ch 8, Sec 1, Tab 2 depending on the additional class notation assigned to the ship.

3.2.2 Design ice pressure

The value of the design ice pressure p, in N/mm^2, to be considered for the scantling check, is obtained from the following formula:

$p = c_d\, c_p\, c_a\, p_o$

where:

c_d : Coefficient taking account of the influence of the size and engine output of the ship, to be obtained from the following formula:

$$c_d = \frac{A\ f + B}{1000}$$

without being more than 1.

A, B : Coefficients defined in Tab 3

f : Coefficient to be obtained from the following formula:

$$f = \frac{\sqrt{\Delta\ P}}{1000}$$

Δ : Displacement, in t, at the maximum ice class draught (see Ch 8, Sec 1, [2.1.1])

P : Actual continuous output of propulsion machinery, in kW (see Ch 8, Sec 1, [3]) available when sailing in ice. If additional power sources are available for propulsion power (e.g. shaft motors) in addition to the power of the main engine(s), they shall also be included in the total engine output used as the basis for hull scant-ling calculations. The engine output used for the calculation of the hull scantlings shall be clearly stated on the shell expansion drawing.

c_p : Factor that reflects the magnitude of the load expected in the hull area in question relative to the bow area, defined in Tab 5

c_a : Coefficient taking account of the probability that the full length of the area under consideration will be under pressure at the same time, to be obtained from the following formula:

$$c_a = \left(\frac{\ell_0}{\ell_a}\right)^{\frac{1}{2}}$$

without being taken less than 0,35 or greater than 1,0

p_o : Nominal ice pressure, in N/mm^2, to be taken equal to 5,6.

ℓ_0 : Distance, in m, taken equal to 0,6

ℓ_a : Distance, in m, defined in Tab 4

Table 3 : Coefficients A, B

Hull region	Condition	A	B
Bow	f ≤12	30	230
	f > 12	6	518
Midbody Stern	f ≤ 12	8	214
	f > 12	2	286

Table 4 : Distance ℓ_a

Structure	Type of framing	ℓ_a
Shell plating	Transverse	Spacing of ordinary stiffeners
	Longitudinal	1,7 spacings of ordinary stiffeners
Ordinary stiffeners	Transverse	Spacing of ordinary stiffeners
	Longitudinal	Span of ordinary stiffeners
Vertical primary supporting members		Two spacings of vertical primary supporting members
Ice stringers		Span of stringers

Table 5 : Coefficient c_p

Hull region	ICE CLASS IA SUPER	ICE CLASS IA	ICE CLASS IB	ICE CLASS IC	ICE CLASS ID	YOUNG ICE 1	YOUNG ICE 2
Bow	1,0	1,0	1,0	1,0	1,0	0,6	0,3
Midbody	1,0	0,85	0,70	0,50	not applicable		
Stern	0,75	0,65	0,45	0,25	not applicable		

4 Hull scantlings

4.1 Gross scantlings

4.1.1 All scantlings referred to in this Article are gross, i.e. they include margin for corrosion and abrasion.

4.2 Plating

4.2.1 General

The plating thickness is to be ice strengthened according to [4.2.2] within the strengthened area for plating defined in [1.3].

In addition, the plating thickness is to be strengthened in the following cases:

- For the notation **ICE CLASS IA SUPER**, the fore foot region is to be ice-strengthened in the same way as the bow region
- For the notations **ICE CLASS IA SUPER** or **ICE CLASS IA**, on ships with an open water service speed equal to or exceeding 18 knots, the upper bow ice belt is to be ice-strengthened in the same way as the midbody region. A similar strengthening of the bow region is to be considered for a ship with a lower service speed, when on the basis of the model tests, for example, it is evident that the ship will have a high bow wave.

4.2.2 Plating thickness in the ice belt

The thickness of the shell plating is to be not less than the value obtained, in mm, from the following formulae:

- for transverse framing:

$$t = 0,667b\sqrt{\frac{F_1 p_{PL}}{R_{eH}}} + t_c$$

- for longitudinal framing:

$$t = 0,667b\sqrt{\frac{p}{F_2 R_{eH}}} + t_c$$

where:

p_{PL} : Ice pressure on the shell plating to be obtained, in N/mm^2, from the following formula: $p_{PL} = 0,75\ p$

F_1 : Coefficient to be obtained from the following formula:

$$F_1 = 1,3 - \frac{4,2}{\left[\frac{h}{b}10^3 + 1,8\right]^2}$$

without being taken greater than 1,0

F_2 : Coefficient to be obtained from the following formulae:

- for $h/b \leq 10^{-3}$:

$$F_2 = 0,6 + 0,4\frac{b}{h}10^{-3}$$

- for $10^{-3} < h/b < 1,8.10^{-3}$:

$$F_2 = 1,4 - 0,4\frac{h}{b}10^3$$

4.3 Stiffeners

4.3.1 General

Stiffeners are to be strengthened according to [4.3.2] within the ice strengthened area for stiffeners defined in [1.3].

Where less than 15% of the span ℓ of the stiffener is situated within the ice-strengthening zone for stiffeners as defined in Tab 2, their scantlings may be determined according to Pt B, Ch 7, Sec 5 or NR600, as applicable.

4.3.2 Scantlings of transverse stiffeners

The section modulus Z, in cm^3 and the effective shear area A_{shr}, in cm^2, of transverse stiffeners are to be not less than the values obtained from the following formulae:

$$Z = \frac{7 - 5(h/\ell)}{7m_0} \frac{psh\ell}{R_{eH}} 10^3$$

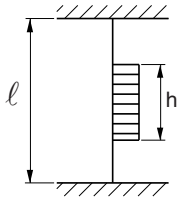
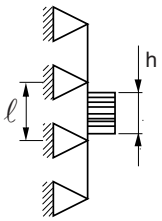
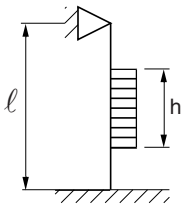
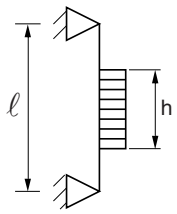
$$A_{shr} = \frac{\sqrt{3}F_3phs}{2R_{eH}}10$$

where:

F_3 : Coefficient which takes into account the maximum shear force versus the load location and the shear stress distribution and to be taken equal to 1,20

m_0 : Coefficient defined in Tab 6.

Table 6 : Coefficient m_0

Boundary condition	Example	m_0	Boundary condition	Example	m_0
Type 1 	Frames in a bulk carrier with top wing tanks	7,0	Type 3 	Continuous stiffeners between several decks or stringers	5,7
Type 2 	Stiffeners extending from the tank top to a single deck	6,0	Type 4 	Stiffeners extending between two decks only	5,0
Note 1: The boundary conditions are those for the main and intermediate stiffeners. **Note 2:** Load is applied at mid-span.					

4.3.3 Scantlings of longitudinal stiffeners

The section modulus Z, in cm^3 and the effective shear area A_{shr}, in cm^2, of longitudinal stiffeners with or without brackets are to be not less than the values obtained from the following formulae:

$$Z = \frac{F_4ph\ell^2}{m_1R_{eH}}10^6$$

$$A_{shr} = \frac{\sqrt{3}F_4F_5ph\ell}{2R_{eH}}10^4$$

where:

F_4 : Coefficient, taking account of the load distribution on adjacent stiffeners, to be obtained from the following formula:

$$F_4 = 1 - 0{,}2\frac{h}{s}10^3$$

F_5 : Coefficient which takes into account the pressure definition and maximum shear force versus load location and also shear stress distribution and to be taken equal to 2,16

m_1 : Boundary condition coefficient for the stiffener considered, to be taken equal to 13,3 for a continuous beam with brackets; where the boundary conditions deviate significantly from those of a continuous beam with brackets, e.g. in an end field, a smaller boundary condition coefficient may be required.

Note 1: In calculating the actual shear area of longitudinal stiffeners, the area of the brackets is not to be taken into account.

4.4 Primary supporting members

4.4.1 Ice stringers

The section modulus Z, in cm^3 and the effective section area A_{shr}, in cm^2, of an ice stringer are to be not less than the values obtained from the following formulae:

$$Z = \frac{F_6 F_7 p h \ell^2}{m_S R_{eH}} 10^6$$

$$A_{shr} = \frac{\sqrt{3} F_6 F_7 F_8 p h \ell}{2 R_{eH}} 10^4$$

where:

h : Height, in m, of load area defined in [3.2.1], without the product p.h being taken less than 0,15 MN/m.

m_S : Boundary condition coefficient for the ordinary stiffener considered, to be taken equal to 13,3 for a continuous beam; where the boundary conditions deviate significantly from those of a continuous beam, e.g. in an end field, a smaller boundary condition coefficient may be required. In such a case, for girders without brackets, a value of m = 11,0 is to be used

F_6 : Factor that takes into account the distribution of load to the transverse frames, to be taken equal to:

- for ice stringers within the ice belt, $F_6 = 0,90$
- for ice stringers outside the ice belt, $F_6 = 0,80 (1 - h_S / \ell_S)$

F_7 : Factor that takes into account the design point of girders to be taken equal to 1,80

F_8 : Factor that takes into account the maximum shear force versus load location and the shear stress distribution to be taken equal to 1,20

h_S : Distance to the ice belt as defined in Tab 1, in m

ℓ_S : Distance to the adjacent ice stringer, in m.

4.4.2 Vertical primary supporting member checked through simplified model

For vertical primary supporting members which may be represented by the structure model represented in Fig 4, the section modulus Z, in cm^3, and the effective shear area A_{shr}, in cm^2, are to be not less than the values obtained from the following formulae:

$$Z = \frac{M}{R_{eH}} \left(\frac{1}{1 - (\nu A_{Sh1} / A_a)^2} \right)^{\frac{1}{2}} 10^3$$

$$A_{shr} = 10 \frac{\sqrt{3} F_9 \alpha Q}{R_{eH}}$$

where:

F : Load transferred to a vertical primary supporting member from a stringer or from longitudinal ordinary stiffeners, to be obtained, in kN, from the following formula:

- for load transferred from a longitudinal stiffener, $F = F_{10}\ p\ h\ s$
- for load transferred from a stringer, $F = F_{10}\ p\ h\ S\ 10^3$

F_{10} : Factor that takes into the design point of girders to be taken equal to:

- for vertical primary supporting members within the ice belt, $F_{10} = 1,80$
- for vertical primary supporting members outside the ice belt,

  $F_{10} = 1,80 (1 - h_S / \ell_S)$, where h_S and ℓ_S are to be taken as defined in [4.4.1]

F_9 : Factor that takes into account the shear force distribution to be taken equal to 1,1

Q : Maximum calculated shear force, in kN, under the ice load F

M : Maximum calculated bending moment, in kN.m, under the ice load F to be taken equal to $M = 0,193\ F\ell$

ν : Coefficient defined in Tab 7

α : Coefficient defined in Tab 7

p : Design ice pressure, in N/mm^2, defined in [3.2.2], where the value of c_a is to be calculated assuming ℓ_a equal to $2\ S_{wf}$

S_{wf} : Distance between web frames, in m

h : Height, in m, of load area defined in [3.2.1], without the product p.h being taken less than 0,15 MN/m.

A_{Sh1} : Required shear area, in cm^2

A_a : Actual cross-sectional area, in cm^2 of the vertical primary supporting member, to be taken equal to $A_F + A_W$.

Figure 4 : Reference structure model

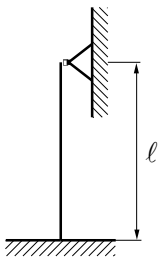


Table 7 : Coefficients α,ν

A_F / A_W	α	ν
0,20	1,23	0,44
0,40	1,16	0,62
0,60	1,11	0,71
0,80	1,09	0,76
1,00	1,07	0,80
1,20	1,06	0,83
1,40	1,05	0,85
1,60	1,05	0,87
1,80	1,04	0,88
2,00	1,04	0,89
Note 1: A_F : Cross-sectional area of the face plate A_W : Cross-sectional area of the web		

5 Other structures

5.1 Application

5.1.1 The requirements in [5.3] and [5.4] do not apply for the assignment of the **ICE CLASS ID**.

5.2 Fore part

5.2.1 Stem

The stem may be made of rolled, cast or forged steel or of shaped steel plates (see Fig 5).

The plate thickness of a shaped plate stem and, in the case of a blunt bow, any part of the shell where $\alpha \geq 30°$ and $\psi \geq 75°$, is to be not less than that calculated in [4.2.2] assuming that:

- s is the spacing of elements supporting the plate, in m
- p_{PL}, in N/mm², is taken equal to p, defined in [3.2.2], with ℓ_a being the spacing of vertical supporting elements, in m.

The stem and the part of a blunt bow defined above are to be supported by floors or brackets spaced not more than 600 mm apart and having a thickness at least half that of the plate.

The reinforcement of the stem is to be extended from the keel to a point 0,75 m above the UIWL or, where an upper fore ice belt is required (see [1.3]), to the upper limit of the latter.

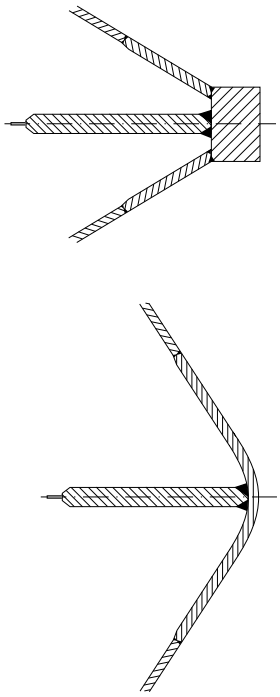
5.3 Aft part

5.3.1 In order to avoid very high load on propeller blade tips, the minimum distance between propeller(s) and hull (including stern frame) should not be less than h_i as defined in Ch 8, Sec 1, Tab 2.

5.3.2 On twin and triple screw ships, the ice strengthening of the shell and framing is to be extended to the tank top for at least 1,5 m forward and aft of the side propellers.

5.3.3 Shafting and sterntubes of side propellers are generally to be enclosed within plated bossings. If detached struts are used, their design, strength and attachment to the hull are to be examined by the Society on a case-by-case basis.

Figure 5 : Example of suitable stems



5.4 Deck strips and hatch covers

5.4.1 Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area calculated in [4.4.1], respectively. In the case of very long hatches, the product ph is to be taken less than 0,30 but in no case less than 0,20.

Special attention is to be paid when designing weather deck hatch covers and their fittings to the deflection of the ship sides due to ice pressure in way of very long hatch openings.

5.5 Sidescuttles and freeing ports

5.5.1 Sidescuttles are not to be located in the ice belt.

5.5.2 Freeing ports are to be given at least the same strength as is required for the shell in the ice belt.

6 Hull outfitting

6.1 Rudders and steering arrangements

6.1.1 The scantlings of the rudder post, rudder stock, pintles, steering gear, etc. as well as the capacity of the steering gear are to be determined according to Pt B, Ch 12, Sec 1 in the two following conditions:

- Maximum ahead service speed
- Reference speed indicated in Tab 8, with the coefficients r_1 and r_2, as defined in Pt B, Ch 12, Sec 1, [2.1.2] taken equal to 1,0 irrespective of the rudder type profile.

Within the ice strengthened zone, the thickness of rudder plating and diaphragms is to be not less than that required for the shell plating of the stern region.

Table 8 : Reference speed

Notation	Reference speed (knots)
ICE CLASS IA SUPER	20
ICE CLASS IA	18
ICE CLASS IB	16
ICE CLASS IC **ICE CLASS ID**	14

6.1.2 For the notations **ICE CLASS IA SUPER** or **ICE CLASS IA**, the rudder stock and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means.

6.2 Bulwarks

6.2.1 If the weather deck in any part of the ship is situated below the upper limit of the ice belt (e.g. in way of the well of a raised quarter deck), the bulwark is to be reinforced at least to the standard required for the shell in the ice belt.

7 Additional class notations YOUNG ICE 1 and YOUNG ICE 2

7.1 Area to be strengthened

7.1.1 Region

For the purpose of the assignment of the notations **YOUNG ICE 1** and **YOUNG ICE 2**, only the bow region of the ship, as defined in [1.2.1], is to be strengthened.

7.1.2 Vertical extension

The vertical extension of the ice strengthened area is defined in Tab 1 for plating (ice belt) and in Tab 2 for ordinary stiffeners and primary supporting members

7.2 Design loads

7.2.1 Height of the ice load area

A ship strengthened for assignment of additional class notation **YOUNG ICE 1** or **YOUNG ICE 2** is assumed to operate in conditions corresponding to ice thickness not exceeding the value h_i.

The design ice load height h of the area under ice pressure at any time is assumed to be only a fraction of the ice thickness.

The values for h_i and h, in m, are given in Ch 8, Sec 1, Tab 2.

7.2.2 Ice loads

The design ice pressure p, in N/mm², is to be calculated according to [3.2], with the nominal ice pressure, p_0, to be taken equal to 3,0.

7.3 Plating

7.3.1 General

If the scantlings obtained from [7.3.2] are less than those required for the unstrengthened ship, the latter are to be used.

The scantling formulae defined in [7.3.2] are based on simply supported boundary conditions to take into account non-homogeneous ice loads. Different boundary conditions will be considered on a case-by-case basis.

7.3.2 Plating thickness in the ice belt

The thickness of the shell plating made of steel or aluminium is to be not less than the value obtained, in mm, from the following formulae:

- for transverse framing:

$$t = 0,0274b\sqrt{\frac{F_1 p_{pl} 10^3}{R}} + t_c$$

- for longitudinal framing:

$$t = 27,4\sqrt{\frac{p_{pl} h(2b10^{-3} - h)10^3}{F_2 R}} + t_c$$

where:

p_{pl} : Ice pressure on the shell plating, in N/mm², to be taken equal to 0,75 p

F_1 : Coefficient to be obtained from the following formula:

$$F_1 = 1,3 - \frac{4,2}{\left[\frac{h}{b}10^3 + 1,8\right]^2}$$

without being taken greater than 1,0

F_2 : Coefficient to be obtained from the following formulae:

- for $h/b \leq 10^{-3}$:

$$F_2 = 0,6 + 0,4\frac{b}{h}10^{-3}$$

- for $10^{-3} < h/b < 1,8.10^{-3}$:

$$F_2 = 1,4 - 0,4\frac{h}{b}10^3$$

t_c : Abrasion and corrosion addition, in mm, to be taken equal to 2 mm for steel and aluminium; where a special surface coating, shown by experience to be capable of withstanding the abrasion of ice, is applied, a lower value may be accepted by the Society on a case-by-case basis.

7.4 Stiffeners and primary supporting members

7.4.1 General

If the scantlings obtained from [7.4.2] and [7.4.3] are less than those required for the unstrengthened ship, the latter are to be used.

The scantling formulae defined in [7.4.2] and [7.4.3] are based on simply supported boundary conditions to take into account non-homogeneous ice loads. Direct calculation approach may be considered for different boundary conditions, by considering the loads and allowable stresses defined in Article [3] to a beam or a FE model.

Where less than 15% of the span ℓ of a stiffener or a primary supporting member is located within the ice-strengthening zone defined in [7.1], their scantlings may be determined according to the applicable requirements for the unstrengthened ship or by direct calculation.

The effective shear section of welded connections between secondary stiffeners and primary supporting members is to be not less than the A_{shr} values calculated in [7.4.2] or [7.4.3], as relevant. When these criteria cannot be fulfilled, brackets or collar plates are to be fitted.

7.4.2 Scantlings of transverse members

The section modulus Z, in cm^3, and the effective shear area A_{shr}, in cm^2, of transverse stiffeners and primary supporting members within the ice belt and subject to ice loads are to be not less than the values obtained from the following formulae:

- For stiffeners:

$$Z = \frac{phs(2\ell - h)10^3}{8R}$$

$$A_{shr} = \frac{10psh}{0,6R}$$

- For primary supporting members:

$$Z = \frac{phS(2\ell - h)10^6}{8R}$$

$$A_{shr} = \frac{pSh}{0,6R}10^4$$

7.4.3 Scantlings of longitudinal members

The section modulus Z, in cm^3, and the effective shear area A_{shr}, in cm^2, of longitudinal stiffeners and primary supporting members within the ice belt and subject to ice loads are to be not less than the values obtained from the following formulae:

$$Z = \frac{ph\ell^2 10^6}{8R}$$

$$A_{shr} = \frac{5ph\ell}{0,6R}10^3$$

7.5 Sidescuttles and freeing ports

7.5.1 Sidescuttles are not to be located in the ice belt.

7.5.2 Freeing ports are to be given at least the same strength as the one required for the shell in the ice belt.

Section 3 ICE Class Notations - Machinery

Symbols

c : Chord length of blade section, in m

$c_{0,7}$: Chord length of blade section at 0,7R propeller radius, in m

CP : Controllable pitch

D : Propeller diameter, in m

d : External diameter of propeller hub (at propeller plane), in m

D_{limit} : Limit value for propeller diameter, in m

EAR : Expanded blade area ratio

F_b : Maximum backward blade force during the ship's service life, in kN. See Tab 3

F_{ex} : Ultimate blade load resulting from blade loss through plastic bending, in kN. See Tab 3

F_f : Maximum forward blade force during the ship's service life, in kN. See Tab 3

F_{ice} : Ice load, in kN

$(F_{ice})_{max}$: Maximum ice load during the ship's service life, in kN

FP : Fixed pitch

H_{ice} : Thickness of maximum design ice block entering the propeller, in m

I_e : Equivalent mass moment of inertia of all parts on engine side of the component under consideration, in kg·m^2

I_t : Equivalent mass moment of inertia of the whole propulsion system, in kg·m^2

k : Shape parameter for Weibull distribution

LIWL : Lower ice waterline, in m

m : Slope for SN curve in log/log scale

M_{BL} : Blade bending moment, in kN·m

MCR : Maximum continuous rating

n : Rotational propeller speed in bollard condition, in rev/s. If not known, n is to be taken equal to the values given in Tab 7

n_n : Nominal rotational propeller speed at MCR in free running open water condition, in rev/s

N_{class} : Reference number of impacts per nominal propeller rotational speed per ice class

N_{ice} : Total number of ice loads on propeller blade during the ship's service life

N_R : Reference number of load for equivalent fatigue stress (10^8 cycles)

N_Q : Number of propeller revolutions during a milling sequence

$P_{0,7}$: Propeller pitch at 0,7 R radius, in m. if not known, $P_{0,7}$ is to be taken equal to 0,7 $P_{0,7n}$

$P_{0,7n}$: Propeller pitch at 0,7 R radius at MCR in free running open water condition, in m

Q : Torque, in kN·m

Q_{emax} : Maximum engine torque, in kN·m. If not known, Q_{emax} is to be taken equal to the values given in Tab 10

Q_{max} : Maximum torque on the propeller resulting from propeller/ice interaction, in kN·m. See Tab 3

Q_{max}^n : Maximum torque on the propeller resulting from propeller/ice interaction reduced to the rotational speed in question, in kN·m

Q_{motor} : Electric motor peak torque, in kN·m

Q_n : Nominal torque at MCR in free running open water condition, in kN·m

Q_{peak} : Maximum of the response torque Q_r , in kN·m, see Tab 3

Q_r : Response torque along the propeller shaft line, in kN.m

Q_{sex} : Maximum spindle torque due to blade failure caused by plastic bending, in kN·m.

Q_{smax} : Maximum spindle torque of the blade during the ship's service life, in kN·m. See Tab 3

Q_{vib} : Vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC), in kN·m

R : Propeller radius, in m

r : Blade section radius, in m

T : Propeller thrust, in kN

T_b : Maximum backward propeller ice thrust during the ship's service life, in kN. See Tab 3

T_f : Maximum forward propeller ice thrust during the ship's service life, in kN. See Tab 3

T_n : Nominal propeller thrust at MCR in free running open water condition, in kN

T_r : Maximum response thrust along the shaft line, in kN. See Tab 3

t : Maximum blade section thickness

Z : Number of propeller blades

α_1 : Phase angle of propeller ice torque for blade order excitation component, in degrees

α_2 : Phase angle of propeller ice torque for twice the blade order excitation component, in degrees

α_i : Duration of propeller blade/ice interaction expressed in rotation angle, in degrees

$\gamma_{\varepsilon 1}$: Reduction factor for fatigue; scatter effect (equal to one standard deviation)

$\gamma_{\varepsilon 2}$: Reduction factor for fatigue; test specimen size effect

γ_v : Reduction factor for fatigue; variable amplitude loading effect

γ_m : Reduction factor for fatigue; mean stress effect

ρ : Reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles

$\sigma_{0,2}$: Minimum yield or 0,2% proof strength of blade material, in MPa, to be specified on the drawing.

σ_{exp} : Mean fatigue strength of blade material at 10^8 cycles to failure in sea water, in MPa

σ_{fat} : Equivalent fatigue ice load stress amplitude for 10^8 stress cycles, in MPa

σ_{fl} : Characteristic fatigue strength for blade material, in MPa

σ_{ref1} : Reference stress, in MPa:

$\sigma_{ref1} = 0,6\ \sigma_{0,2} + 0,4\ \sigma_u$

σ_{ref2} : Reference stress, in MPa:

$\sigma_{ref2} = 0,7\ \sigma_u$ or

$\sigma_{ref2} = 0,6\ \sigma_{0,2} + 0,4\ \sigma_u$, whichever is less

σ_{st} : Maximum stress resulting from F_b or F_f , in MPa

σ_u : Ultimate tensile strength of blade material, in MPa, to be specified on the drawing.

$(\sigma_{ice})_{bmax}$: Principal stress caused by the maximum backward propeller ice load, in MPa

$(\sigma_{ice})_{fmax}$: Principal stress caused by the maximum forward propeller ice load, in MPa

$(\sigma_{ice})_{max}$: Maximum ice load stress amplitude, in MPa.

φ : Rotation angle, in deg, from when the first impact occurs.

1 Requirements for propulsion machinery of the class notation ICE CLASS IA SUPER, ICE CLASS IA, ICE CLASS IB and ICE CLASS IC

1.1 Scope

1.1.1 These regulations apply to propulsion machinery covering open- and ducted-type propellers with controllable pitch or fixed pitch design for the class notations **ICE CLASS IA SUPER**, **ICE CLASS IA**, **ICE CLASS IB** and **ICE CLASS IC**.

The given loads are the expected ice loads for the whole ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers.

However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

The regulations also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice interaction and loads on the trhruster body/ice interaction.

The given azimuthing thruster body loads are the expected ice loads during the ship's service life under normal operational conditions. The local strength of the thruster body shall be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads.

However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially)

The thruster global vibrations caused by blade order excitation on the propeller may cause significant vibratory loads.

1.2 Design ice conditions

1.2.1 In estimating the ice loads of the propeller for ice classes, different types of operation as given in Tab 1 were taken into account. For the estimation of design ice loads, a maximum ice block size is determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice}.2H_{ice}.3H_{ice}$.

The thickness of the ice block (H_{ice}) is given in Tab 2.

Table 1 : Types of operation

Notation	Operation of the ship
ICE CLASS IA SUPER	Operation in ice channels and in level ice The ship may proceed by ramming
ICE CLASS IA **ICE CLASS IB** **ICE CLASS IC**	Operation in ice channels

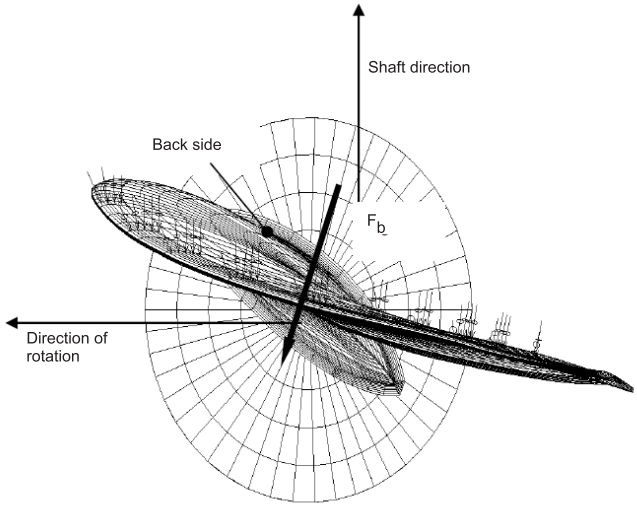
Table 2 : Thickness of the ice block (H_{ice})

ICE CLASS IA SUPER	ICE CLASS IA	ICE CLASS IB	ICE CLASS IC
1,75 m	1,5 m	1,2 m	1,0 m

Table 3 : Definition of loads

	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line. See Fig 1	Design force for strength calculation of the propeller blade
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0,7R chord line	Design force for strength calculation of the propeller blade
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade	When designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust	Is used for estimating of the response thrust T_r T_b can be used as an estimate of excitation in axial vibration calculations. However, axial vibration calculations are not required by the rules
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust	Is used for estimating of the response thrust T_r T_f can be used as an estimate of excitation in axial vibration calculations. However, axial vibration calculations are not required by the rules
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade	Is used for estimating of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge appear in the root area. The force is acting on 0,8R. The spindle arm is 2/3 of the distance between the axis of blade rotation and leading/trailing edge (whichever is the greater) at the 0,8R radius	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure does not lead to damage to other components
Q_{peak}	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller	Design torque for propeller shaft line components
T_r	Maximum response thrust along shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller	Design thrust for propeller shaft line components
F_{ti}	Maximum response force caused by ice block impacts on the thruster body or the propeller hub	Design load for thruster body and slewing bearings.
F_{tr}	Maximum response force on the thruster body caused by ice ridge/ thruster body interaction	Design load for thruster body and slewing bearings

Figure 1 : Direction of the backward blade force resultant taken perpendicular to chord line at radius 0,7R



Ice contact pressure at leading edge is shown with small arrows

1.3 Materials

1.3.1 Materials exposed to sea water

Materials of components exposed to sea water, such as propeller blades, blade bolts, propeller hubs, and thruster body, are to have an elongation of not less than 15% on a test specimen, the gauge length of which is five times the diameter. A Charpy V impact test is to be carried out for materials other than bronze and austenitic steel. An average impact energy value of 20 J taken from three tests is to be obtained at minus 10ºC. For nodular cast iron, average impact energy of 10 J at minus 10ºC is required accordingly.

1.3.2 Materials exposed to sea water temperature

Materials exposed to sea water temperature shall be of ductile material. An average impact energy value of 20 J taken from three tests is to be obtained at minus 10ºC. This requirement applies to the propeller shaft, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. This does not apply to surface hardened components, such as bearings and gear teeth. The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts. The average impact energy for nodular cast iron is to be a minimum of 10 J at minus 10ºC.

1.4 Design loads

1.4.1 The given loads are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction. The presented maximum loads are based on a worst case scenario that occurs once during the service life of the ship. Thus, the load level for a higher number of loads is lower. The values of the parameters in the formulae in this section shall be given in the units shown in the symbol list. If the highest point of the propeller is not at a depth of at least h_i below the water surface when the ship is in ballast condition, the propulsion system shall be designed according to ice class **ICE CLASS IA** for ice classes **ICE CLASS IB** and **ICE CLASS IC**

1.4.2 Design loads on propeller blades

F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead. F_b and F_f originate from different propeller/ice interaction phenomena, not acting simultaneously. Hence they are to be applied to one blade separately.

a) Maximum backward blade force F_b for open propellers

- when $D \leq D_{limit}$

$$F_b = 27(nD)^{0,7}\left(\frac{EAR}{Z}\right)^{0,3} D^2$$

- when $D > D_{limit}$

$$F_b = 23(nD)^{0,7}\left(\frac{EAR}{Z}\right)^{0,3} DH_{ice}^{1,4}$$

where:

$D_{limit} = 0,85\ H_{ice}^{1,4}$

n : nominal rotational speed (at MCR in free running condition) of a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) of an FP propeller.

b) Maximum forward blade force F_f for open propellers

- when $D \le D_{limit}$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2$$

- when $D > D_{limit}$

$$F_f = 500\left(\frac{EAR}{Z}\right)D\frac{1}{\left(1-\frac{d}{D}\right)}H_{ice}$$

where:

$$D_{limit} = \frac{2}{\left(1-\frac{d}{D}\right)}H_{ice}$$

c) Loaded area on the blade for open propellers

Load cases 1-4 have to be covered, as given in Tab 4 below, for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 also has to be covered for FP propellers.

d) Maximum backward blade ice force F_b for ducted propellers

- when $D \le D_{limit}$

$$F_b = 9,5(nD)^{0,7}\left(\frac{EAR}{Z}\right)^{0,3}D^2$$

- when $D > D_{limit}$

$$F_b = 66(nD)^{0,7}\left(\frac{EAR}{Z}\right)^{0,3}D^{0,6}H_{ice}^{1,4}$$

where:

$D_{limit} = 4\ H_{ice}$

n : nominal rotational speed (at MCR in free running condition) of a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) of an FP propeller.

e) Maximum forward blade ice force F_f for ducted propellers

- when $D \le D_{limit}$

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2$$

- when $D > D_{limit}$

$$F_f = 500\left(\frac{EAR}{Z}\right)D\frac{1}{\left(1-\frac{d}{D}\right)}H_{ice}$$

where:

$$D_{limit} = \frac{2}{\left(1-\frac{d}{D}\right)}H_{ice}$$

f) Loaded area on the blade for ducted propellers

Load cases 1 and 3 have to be covered as given in Tab 5 for all propellers, and an additional load case (load case 5) for an FP propeller, to cover ice loads when the propeller is reversed.

g) Maximum blade spindle torque Q_{smax} for open and ducted propellers

The spindle torque Q_{smax} around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as in Tab 4 and Tab 5. The larger of the obtained torques is used as the dimensioning torque. If the above method gives a value which is less than the default value given by the formula below, the default value shall be used:

$Q_{smax} = 0,25\ F\ c_{0,7}$

where:

F : Either F_b or F_f , whichever has the greater absolute value.

h) Load distributions for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in Fig 2, is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{max}} \geq \frac{F}{(F_{ice})_{max}}\right) = e^{\left[-\left(\frac{F}{(F_{ice})_{max}}\right)^{k} \ln(N_{ice})\right]}$$

where:

k : Shape parameter of the spectrum

The shape parameter k = 0,75 is to be used for the ice force distribution of an open propeller

The shape parameter k = 1,0 is to be used for that of a ducted propeller blade

N_{ice} : Number of load cycles in the load spectrum (see item i))

F_{ice} : Random variable for ice loads on the blade:

$0 \leq F_{ice} \leq (F_{ice})_{max}$

i) Number of ice loads

The number of load cycles per propeller blade in the load spectrum shall be determined according to the formula:

$N_{ice} = k_1\, k_2\, k_3\, N_{class}\, n_n$

where:

k_1 : Propeller location factor:

- for a center propeller and bow first operation: $k_1 = 1,0$
- for a wing propeller and bow first operation: $k_1 = 2$
- for a pulling propeller (wing and center): $k_1 = 3$
- for a bow propeller or stern first operation: $k_1 = 3$

k_2 : Submersion factor:

- for $f < 0$:
  $k_2 = 0,8 - f$
- for $0 \leq f \leq 1$:
  $k_2 = 0,8 - 0,4\, f$
- for $1 < f \leq 2,5$:
  $k_2 = 0,6 - 0,2\, f$
- for $f > 2,5$:
  $k_2 = 0,1$

with:

f : Immersion function:

$$f = \frac{h_0 - H_{ice}}{\frac{D}{2}} - 1$$

h_0 : Depth of the propeller centreline at the lower ice waterline (LIWL) of the ship.

k_3 : Propulsion machinery type factor:

- for a fixed propulsor:
  $k_3 = 1,0$
- for an azimuthing propulsor:
  $k_3 = 1,2$

N_{class} : Reference number of loads:

- for **ICE CLASS IA Super**:
  $N_{class} = 9 \cdot 10^6$
- for **ICE CLASS IA**:
  $N_{class} = 6 \cdot 10^6$
- for **ICE CLASS IB**:
  $N_{class} = 3,4 \cdot 10^6$
- for **ICE CLASS IC**:
  $N_{class} = 2,1 \cdot 10^6$

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

Figure 2 : Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$) used for fatigue design

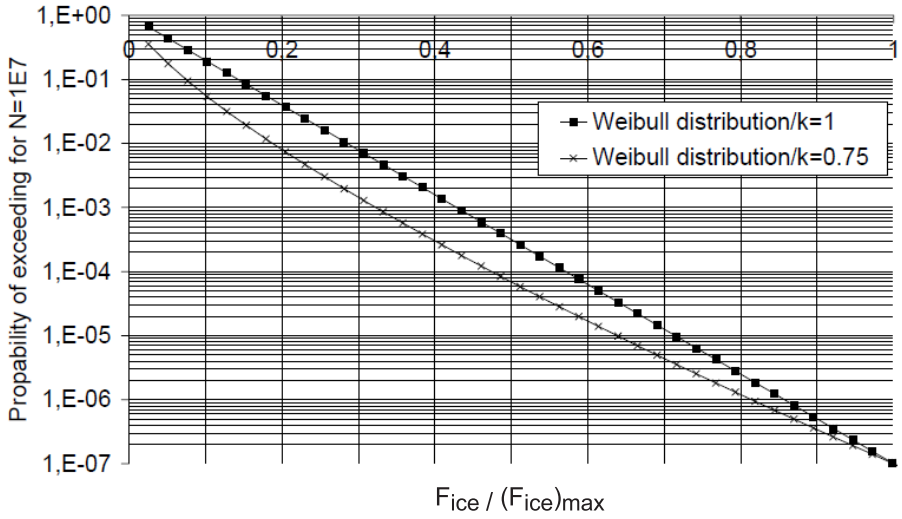
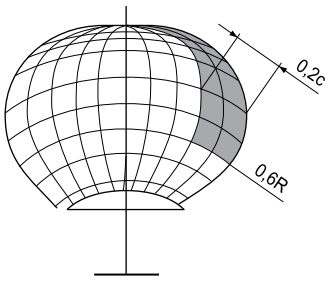
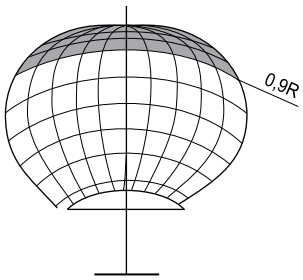
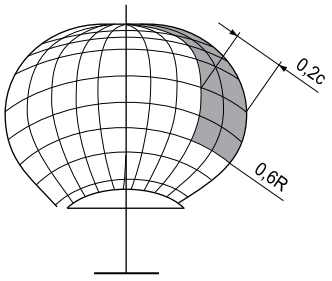


Table 4 : Load cases for open propellers

	Force	Loaded Area	Right-handed propeller blade seen from behind
Load Case 1	F_b	Uniform pressure applied on the blade back (suction side) to an area from 0,6R to the tip and from the leading edge to 0,2 times the chord length	
Load Case 2	50% of F_b	Uniform pressure applied on the blade back (suction side) of the blade tip area outside 0,9R radius	
Load Case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6R to the tip and from the leading edge to 0,2 times the chord length	

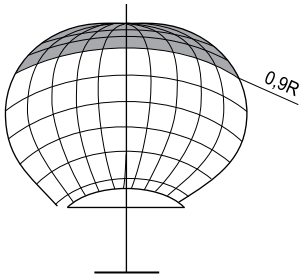
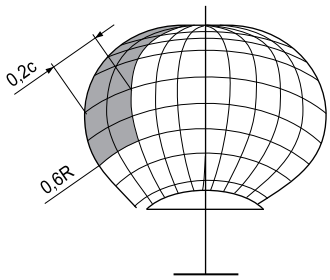
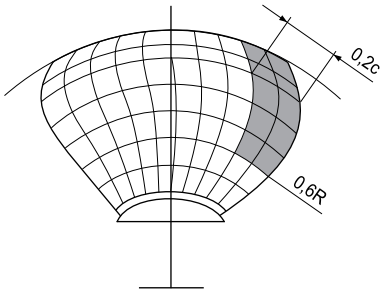
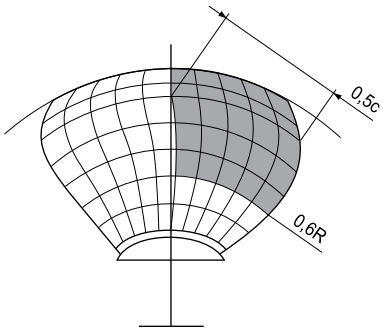
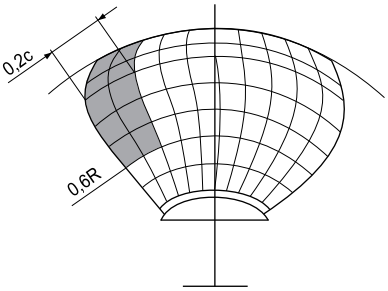
	Force	Loaded Area	Right-handed propeller blade seen from behind
Load Case 4	50% of F_f	Uniform pressure applied on the blade face (pressure side) of the blade tip area outside 0,9R radius	
Load Case 5	60% of F_f or F_b, whichever is greater	Uniform pressure applied on the blade face (pressure side) to an area from 0,6R to the tip and from the trailing edge to 0,2 times the chord length	

Table 5 : Load cases for ducted propellers

	Force	Loaded Area	Right-handed propeller blade seen from behind
Load Case 1	F_b	Uniform pressure applied on the blade back (suction side) to an area from 0,6R to the tip and from the leading edge to 0,2 times the chord length	
Load Case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6R to the tip and from the leading edge to 0,5 times the chord length	
Load Case 5	60% of F_f or F_b, whichever is greater	Uniform pressure applied on the blade face (pressure side) to an area from 0,6R to the tip and from the trailing edge to 0,2 times the chord length	

1.4.3 Axial design loads for open and ducted propellers

a) Maximum ice thrust on propeller T_f and T_b for open and ducted propellers.

The maximum forward and backward ice thrusts are:

$T_f = 1,1\ F_f$

$T_b = 1,1\ F_b$

b) Design thrust along the propulsion shaft line for open and ducted propellers

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward direction loads shall be taken as the design load for both directions. The factors 2,2 and 1,5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction: $T_r = T + 2,2\ T_f$

In a backward direction: $T_r = 1,5\ T_b$

If the hydrodynamic bollard thrust, T, is not known, T is to be taken equal to the values given in Tab 6.

Table 6 : Hydrodynamic bollard thrust T

Propeller type	T
CP propellers (open)	$1,25\ T_n$
CP propellers (ducted)	$1,1\ T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0,85\ T_n$
FP propellers driven by diesel engine (ducted)	$0,75\ T_n$

Table 7 : Rotational propeller speed n, at MCR in bollard condition

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0,85 n_n$

1.4.4 Torsional design loads

a) Design ice torque on propeller Q_{max} for open propellers:

- when $D \le D_{limit}$

$$Q_{max} = 10,9\left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}(nD)^{0,17}D^3$$

- when $D > D_{limit}$

$$Q_{max} = 20,7\left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}(nD)^{0,17}D^{1,9}H_{ice}^{1,1}$$

where:

$D_{limit} = 1,8\ H_{ice}$

b) Design ice torque on propeller Q_{max} for ducted propellers:

- when $D \le D_{limit}$

$$Q_{max} = 7,7\left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}(nD)^{0,17}D^3$$

- when $D > D_{limit}$

$$Q_{max} = 14,6\left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}(nD)^{0,17}D^{1,9}H_{ice}^{1,1}$$

where:

$D_{limit} = 1,8\ H_{ice}$

c) Design torque for non-resonant shaft line:

When there is not any relevant first blade order torsional resonance in the operational speed range or in range 20% above and 20% below the maximum operating speed (bollard condition), the following estimation of the maximum torque is to be used:

- for directly coupled two stroke diesel engines without flexible coupling:

$$Q_{peak} = Q_{emax} + Q_{vib} + Q_{max}\frac{I_e}{I_t}$$

- for other plants :

$$Q_{peak} = Q_{emax} + Q_{max}\frac{I_e}{I_t}$$

All the torques and the inertia moments are to be reduced to the rotation speed of the component being examined.

d) Design torque for shaft lines having resonances:

When there is a first blade order torsional resonance in the operational speed range or in the range 20% above and 20% below the maximum operating speed (bollard condition), the design torque (Q_{peak}) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. There are two alternative ways of performing the dynamic analysis:

- time domain calculation for estimated milling sequence excitation (see item e)
- frequency domain calculation for blade orders sinusoidal excitation (see item f)

The frequency domain analysis is generally considered conservative compared to the time domain simulation, provided that there is a first blade order resonance in the considered speed range.

e) Time domain calculation of torsional response:

Time domain calculations are to be calculated for the MCR condition, MCR bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained.

The load sequence given in this chapter, for a case where a propeller is milling an ice block, is to be used for the strength evaluation of the propulsion line. The given load sequence is not intended for propulsion system stalling analyses.

The following load cases are intended to reflect the operational loads on the propulsion system, when the propeller interacts with ice, and the respective reaction of the complete system. The ice impact and system response causes loads in the individual shaft line components. The ice torque Q_{max} is to be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} is to be calculated using the relevant speed according to item a) or item b).

Diesel engine plants without an elastic coupling are to be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in the time domain. The engine firing pulses is to be included in the calculations and their standard steady state harmonics can be used.

When there is a blade order resonance just above the MCR speed, calculations are to cover rotational speeds up to 105% of the MCR speed.

The propeller ice torque excitation for shaft line transient dynamic analysis in the time domain is defined as a sequence of blade impacts which are of half sine shape. The excitation frequency shall follow the propeller rotational speed during the ice interaction sequence. The torque due to a single blade ice impact as a function of the propeller rotation angle is then defined using the formula:

- when $\varphi = 0, ..., \alpha_i$ plus integer revolutions:

$$Q(\varphi) = C_q\, Q_{max} \sin\left[\varphi\,(180/\alpha_i)\right]$$

- when $\varphi = \alpha_i, ..., 360°$ plus integer revolutions:

$$Q(\varphi) = 0$$

where:

α_i : Duration of propeller blade/ice interaction given in Tab 8 and represented in Fig 3.

C_q : Ice impact magnification parameter given in Tab 8.

The total ice torque is obtained by summing the torque of single blades, while taking into account of the phase shift 360°/Z (see Fig 4 and Fig 5). At the beginning and end of the milling sequence (within the calculated duration) linear ramp functions are to be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see examples of different Z numbers in Fig 4 and Fig 5.

The number of propeller revolutions during a milling sequence are to be obtained with the formula:

$N_Q = 2\ H_{ice}$

The number of impacts is $Z \cdot N_Q$ for blade order excitation.

A dynamic simulation is to be performed for all excitation cases at the operational rotational speed range. For a fixed pitch propeller propulsion plant, a dynamic simulation must also cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.

When a speed drop occurs until the main engine is at a standstill, this indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process must be used.

For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. When this is not the case, the response torques must be obtained using the formula:

$$Q_{peak} = Q_{emax} + Q_{rtd}$$

where Q_{rtd} is the maximum simulated torque obtained from the time domain analysis.

f) Frequency domain calculation of torsional response:

For frequency domain calculations, blade order and twice-the-blade-order excitation are to be used. The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived. With these assumptions, the propeller ice torque $Q_F(\varphi)$, in kN·m, is equal to:

$$Q_{max}[C_{q0} + C_{q1}\sin(ZE_0\varphi + \alpha_1) + C_{q2}\sin(2ZE_0\varphi + \alpha_2)]$$

where:

C_{q0} : Mean torque parameter, see Tab 9

C_{q1} : First blade order excitation parameter, see Tab 9

C_{q2} : Second blade order excitation parameter, see Tab 9

E_0 : Number of ice blocks in contact, see Tab 9.

The design torque for the frequency domain excitation case is to be obtained using the formula:

$$Q_{peak} = Q_{emax} + Q_{vib} + (Q^n_{max}C_{q0})\frac{I_e}{I_t} + Q_{rf1} + Q_{rf2}$$

where:

C_{rf1} : First blade order torsional response from the frequency domain analysis

C_{rf2} : Second blade order torsional response from the frequency domain analysis.

All the torque values have to be scaled to the shaft revolutions for the component in question.

g) Guidance for torsional vibration calculation:

The aim of time domain torsional vibration simulations is to estimate the extreme torsional load during the ship's service life. The simulation model can be taken from the normal lumped mass elastic torsional vibration model, including damping.

For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller.

The calculations should cover variation of phase between the ice excitation and prime mover excitation.

This is extremely relevant to propulsion lines with directly driven combustion engines. Time domain calculations shall be calculated for the MCR condition, MCR bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation.

The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

Figure 3 : Schematic ice torque due to a single blade ice impact

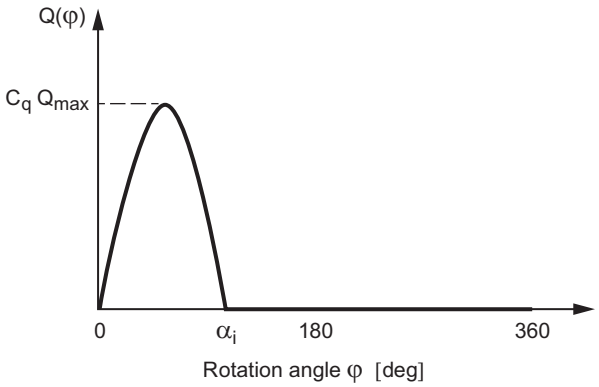


Table 8 : Parameters C_q and α_i

Torque excitation	Propeller/ice interaction	C_q	α_i			
			Z = 3	Z = 4	Z = 5	Z = 6
Case 1	Single ice block	0,75	90	90	72	60
Case 2	Single ice block	1,0	135	135	135	135
Case 3	Two ice blocks (phase shift 360/2Z deg.)	0,5	45	45	36	30
Case 4	Single ice block	0,5	45	45	36	30

Figure 4 : Propeller ice torque excitation for 3 and 4 blades

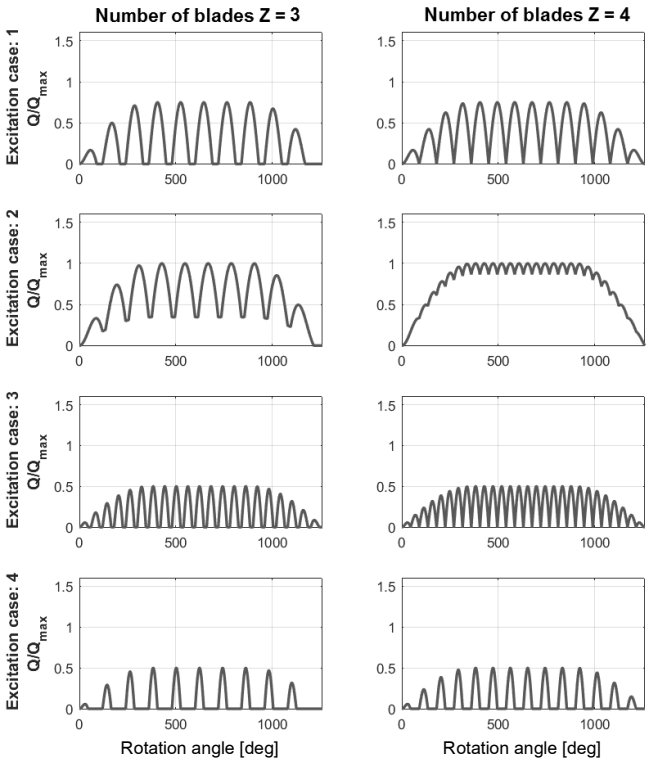


Figure 5 : Propeller ice torque excitation for 5 and 6 blades

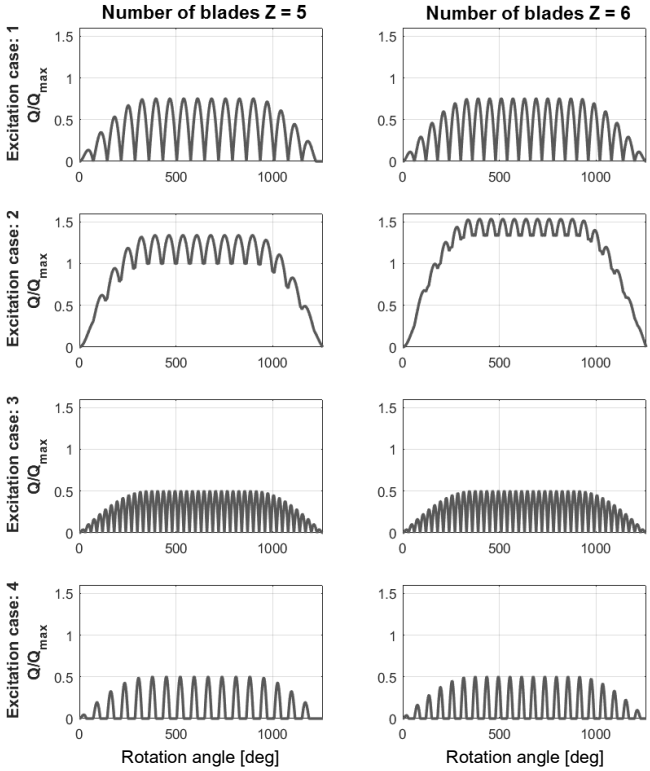


Table 9 : Coefficients for frequency domain excitation calculation (Z)

	Torque excitation	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Z = 3	Case 1	0,375	0,36	–90	0	0	1
	Case 2	0,7	0,33	–90	0,05	–45	1
	Case 3	0,25	0,25	–90	0	0	2
	Case 4	0,2	0,25	0	0,05	–90	1
Z = 4	Case 1	0,45	0,36	–90	0,06	–90	1
	Case 2	0,9375	0	–90	0,0625	–90	1
	Case 3	0,25	0,25	–90	0	0	2
	Case 4	0,2	0,25	0	0,05	–90	1
Z = 5	Case 1	0,45	0,36	–90	0,06	–90	1
	Case 2	1,19	0,17	–90	0,02	–90	1
	Case 3	0,3	0,25	–90	0,048	–90	2
	Case 4	0,2	0,25	0	0,05	–90	1
Z = 6	Case 1	0,45	0,36	–90	0,05	–90	1
	Case 2	1,435	0,1	–90	0	0	1
	Case 3	0,30	0,25	–90	0,048	–90	2
	Case 4	0,2	0,25	0	0,05	–90	1

Table 10 : Default prime mover maximum torque Q_{emax}

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	0,75 Q_n

1.4.5 Blade failure load

a) Bending force, F_{ex}

The ultimate load resulting from blade failure as a result of plastic bending around the blade root is to be calculated with the formula as follows:

$$F_{ex} = \frac{300ct^2\sigma_{ref1}}{0,8D - 2r}$$

where:

c, t, r : Actual chord length, maximum thickness and radius, respectively, of the cylindrical root section of the blade which is the weakest section outside the root fillet typically located at the point where the fillet terminates at the blade profile.

The ultimate load may be obtained alternatively by means of an appropriate stress analysis reflecting the non-linear plastic material behaviour of the actual blade. In such a case, the blade failure area may be outside the root section. The ultimate load is assumed to be acting on the blade at the 0,8R radius in the weakest direction of the blade. A blade is regarded as having failed if the tip is bent into an offset position by more than 10% of propeller diameter D.

b) Spindle torque, Q_{sex}

The maximum spindle torque due to a blade failure load acting at 0,8R is to be determined. The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation, the maximum spindle torque will occur (Fig 6 illustrates the spindle torque values due to blade failure loads across the entire chord length). This maximum spindle torque is to be defined by an appropriate stress analysis or using the equation given below:

$$Q_{sex} = \max(C_{LE0,8}; 0,8C_{TE0,8})C_{spex}F_{ex}$$

where:

C_{spex} : Coefficient to be taken equal to:

$$C_{spex} = C_{sp}C_{fex} = 0,7\left(1 - \left(\frac{4EAR}{Z}\right)^3\right)$$

without being taken less than 0,3

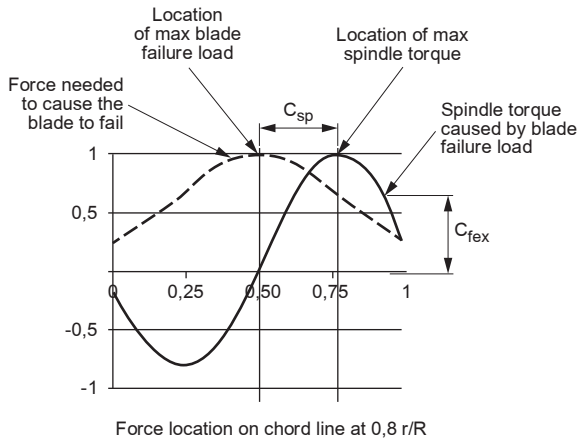
C_{sp} : non-dimensional parameter taking account of the spindle arm

C_{fex} : non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque

$C_{LE0,8}$: Leading edge portion of the chord length at 0,8R

$C_{TE0,8}$: Trailing edge portion of the chord length at 0,8R.

Figure 6 : Blade failure load and related spindle torque along chord line at radius 0,8R



1.5 Propeller blade design

1.5.1 Calculation of blade stresses

The blade stresses are to be calculated for the design loads given in [1.4.2]. Finite element analysis is to be used for stress analysis for final approval for all propellers. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area (r/R < 0,5).

The root area dimensions based on the following formula can be accepted even if the FEM analysis shows greater stresses at the root area:

$$\sigma_{st} = C_1\frac{M_{BL}}{100ct^2}$$

where:

C_1 : Constant equal to:

$$C_1 = \frac{\text{actual stress}}{\text{stress obtained with beam equation}}$$

If the actual value is not available, C_1 is to be taken as 1,6.

M_{BL} : For relative radius r/R < 0,5:

$M_{BL} = (0,75 - r/R)\ R \cdot F$

where F is the maximum of F_b and F_f, whichever has greater absolute value.

1.5.2 Acceptability criterion

The following criterion for calculated blade stresses is to be fulfilled:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1,3$$

where:

σ_{st} : Calculated stress for the design loads.

If FEM analysis is used in estimating the stresses, von Mises stresses are to be used.

1.5.3 Fatigue design of propeller blade

The fatigue design of the propeller blade is based on an estimated load distribution during the service life of the ship and on the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated and the acceptability criterion for fatigue is to be fulfilled as given in [1.5.4]. The equivalent stress is normalised for 10^8 cycles.

For materials with a two-slope SN curve (see Fig 7), fatigue calculations in accordance with this chapter are not required if the following criterion is fulfilled:

$$\sigma_{exp} \geq B_1 \cdot \sigma_{ref2}^{B_2} \cdot \log(N_{ice})^{B_3}$$

where:

B_1, B_2, B_3 : Coefficients for open and ducted propellers:

- for open propellers:
  $B_1 = 0,00328$
  $B_2 = 1,0076$
  $B_3 = 2,101$
- for ducted propellers:
  $B_1 = 0,00223$
  $B_2 = 1,0071$
  $B_3 = 2,471$

For calculation of equivalent stress, two types of S-N curves are available:

- two-slope S-N curve (slopes 4,5 and 10), see Fig 7
- constant-slope S-N curve (the slope can be chosen), see Fig 8.

The type of the S-N curve is to be selected to correspond to the material properties of the blade. If the S-N curve is not known, the two-slope S-N curve is to be used.

a) Equivalent fatigue stress

The equivalent fatigue stress σ_{fat} for 10^8 stress cycles, which produces the same fatigue damage as the load distribution, is given by the following formula:

$$\sigma_{fat} = \rho \, (\sigma_{ice})_{max}$$

where:

$(\sigma_{ice})_{max}$: Mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied and defined by:

$$(\sigma_{ice})_{max} = 0,5 \, [(\sigma_{ice})_{f\,max} - (\sigma_{ice})_{b\,max}]$$

$(\sigma_{ice})_{f\,max}$: Principal stress resulting from forward load

$(\sigma_{ice})_{b\,max}$: Principal stress resulting from backward load.

In calculation of $(\sigma_{ice})_{max}$, case 1 and case 3 (or case 2 and case 4) are considered as a pair for $(\sigma_{ice})_{f\,max}$ and $(\sigma_{ice})_{b\,max}$ calculations. Case 5 is excluded from the fatigue analysis.

b) Calculation of parameter ρ for two-slope S-N curve

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula:

$$\rho = C_1 \cdot (\sigma_{ice})_{max}^{C_2} \cdot \sigma_{fl}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where:

C_1, C_2, C_3, C_4: Coefficients given in Tab 11

$$\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$$

with:

γ_v : Reduction factor for variable amplitude loading

γ_m : Reduction factor for mean stress.

The following values may be used for the reduction factors if the actual values are not available:

$\gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} = 0,67$

$\gamma_v = 0,75$

$\gamma_m = 0,75$

c) Calculation of parameter ρ for constant-slope S-N curve

For materials with a constant-slope S-N curve (see Fig 8), parameter ρ is to be calculated from the following formula:

$$\rho = \left(G \frac{N_{ice}}{N_R}\right)^{\frac{1}{m}} [In(N_{ice})]^{\frac{-1}{k}}$$

where:

k : Shape parameter of the Weibull distribution:

- for ducted propellers: k = 1,0
- for open propellers: k = 0,75

N_{ice} : Value to be taken between $5 \cdot 10^6$ and 10^8

G : Parameter defined in Tab 12. Linear interpolation may be used to calculate the value of G for other m/k ratios than those given in Tab 12.

Table 11 : Coefficients C_1, C_2, C_3 and C_4

	Open propeller	Ducted propeller
C_1	0,000747	0,000534
C_2	0,0645	0,0533
C_3	– 0,0565	– 0,0459
C_4	2,22	2,584

Figure 7 : Two-slope S-N curve

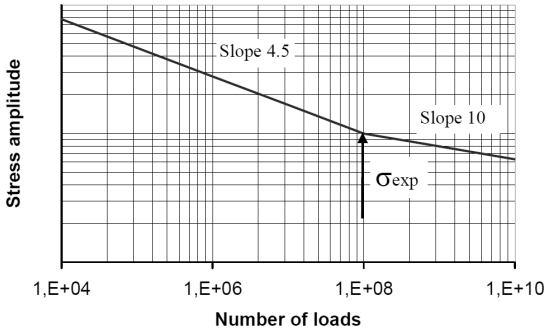


Figure 8 : Constant-slope S-N curve

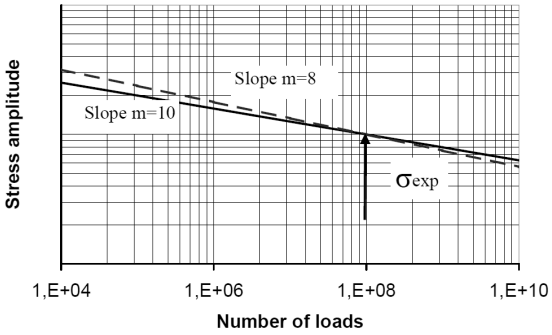


Table 12 : Values for the G parameter for different m/k ratios

m/k	G	m/k	G	m/k	G	m/k	G
3,0	6,0	5,5	287,9	8,0	40320	10,5	$11,899 \cdot 10^6$
3,5	11,6	6,0	720,0	8,5	119292	11	$39,917 \cdot 10^6$
4,0	24,0	6,5	1871	9,0	362880	11,5	$136,843 \cdot 10^6$
4,5	52,3	7,0	5040	9,5	$1,133 \cdot 10^6$	12	$479,002 \cdot 10^6$
5,0	120	7,5	14034	10	$3,629 \cdot 10^6$		

1.5.4 Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on the blade is to fulfill the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geq 1,5$$

where:

σ_{fl} : As defined in [1.5.3], item b).

1.6 Controllable pitch propeller and built-up propeller

1.6.1 Design of blade flange and bolts, propeller hub and controllable pitch mechanism

The blade bolts, the controllable pitch mechanism, the propeller boss and the fitting of the propeller to the propeller shaft are to be designed to withstand the design loads defined in [1.4]. The safety factor against yielding is to be greater than 1,3 and the safety factor against fatigue greater than 1,5. In addition, the safety factor against yielding for loads resulting from loss of the propeller blade through plastic bending as defined in [1.4.5] is to be greater than 1,0.

1.6.2 Blade bolts and flanges

Blade bolts and flanges are to withstand the bending moment M_{bolt}, in kN·m, considered about the bolt pitch circle axis, or another relevant axis for not circular flanges, parallel to the considered root section:

$$M_{bolt} = F_{ex}\left(0,8\frac{D}{2} - r_{bolt}\right)$$

where:

r_{bolt} : Radius from the shaft centreline to the blade bolt plan, in m.

Blade bolt pre-tension is to be sufficient to avoid separation between the mating surfaces, applying the maximum forward and backward ice loads defined in [1.4.2].

The maximum stresses of blade flange, crank carrier and hub due to the load induced by M_{bolt} are to remain below the corresponding yield strengths.

Separate means, e.g. dowel pins, are to be provided between the blade and blade carrier in order to withstand the spindle torque resulting from blade failure (Q_{sex}) or ice interaction (Q_{smax}), whichever is greater.

The rule diameter d_{dp} of the dowel pins, in m, is given by the following formula:

$$d_{dp} = 66\sqrt{\frac{Q_s - Q_{fr}}{PCD \cdot i \cdot \sigma_{0,2}}}$$

where:

PCD : Pitch circle diameter of the dowel pins, in mm

i : Number of pins

Q_s : Spindle torque, in kN·m, equal to:

$Q_s = \max(1,3\ Q_{smax}\ ;\ Q_{sex})$

Q_{fr} : Friction between connected surfaces:

$Q_{fr} = 0,33\ Q_s$

Alternative values of Q_{fr}, according to reaction forces due to F_{ex} or F_f or F_b whichever is relevant, utilising a friction coefficient equal to 0,15 may be used, provided they are approved by the Society.

1.6.3 Components of the pitch control system

Components of controllable pitch mechanisms are to be designed to withstand the blade failure spindle torque Q_{sex} and the maximum blade spindle torque Q_{smax}.

The blade failure spindle torque Q_{sex} is not to lead to any consequential damages.

Fatigue strength is to be considered for the parts transmitting the spindle torque Q_s from the blades to a servo system, considering Q_s acting on one blade.

The maximum spindle torque amplitude Q_{samax} is defined by:

$$Q_{samax} = \frac{Q_{sb} + Q_{sf}}{2}$$

where:

Q_{sb}, Q_{sf} : Spindle torques due, respectively, to ice backward and forward forces.
The formula given in [1.4.2] item g) may be used to determine Q_{sb} and Q_{sf}.

1.6.4 Servo oil pressure

Design pressure for servo oil system is to be taken as the maximum working pressure, taking into account the load caused by Q_{smax} or Q_{sex} when not protected by relief valves, reduced by relevant friction losses in bearings caused by the respective ice loads. Design pressure is, in any case, not to be less than the relief valve set pressure.

1.7 Propulsion line design

1.7.1 Design principle

The strength of the propulsion line is to be designed according to the pyramid strength principle. This means that the loss of the propeller blade is not to cause any significant damage to other propeller shaft line components.

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, are to be designed to withstand the propeller/ice interaction loads as given in [1.4]. The safety factor is to be at least 1,3 against yielding for extreme operational loads, 1,5 for fatigue loads and 1,0 against yielding for the blade failure load.

The ultimate load resulting from total blade failure as defined in [1.4.5] is not to cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be 1,0 for bending and torsional stresses.

1.7.2 Materials

In addition to the requirements of [1.3.1], the shaft material is to comply with Pt C, Ch 1, Sec 7, [2.1.2].

1.7.3 Scantling of propeller, intermediate and thrust shafts

The minimum rule diameter d_{ice}, in mm, of propeller, intermediate and thrust shafts with ice strengthening is equal to:

$$d_{ice} = d \cdot K_{ice\text{-}s}^{\frac{1}{3}}$$

where:

$K_{ice\text{-}s} = Q_{peak} / Q_n \geq 1$

d : Rule shaft diameter, defined in Pt C, Ch 1, Sec 7, [2.2.3].

1.7.4 Scantling of gear shaft

This requirement applies to parts of pinions and wheel shafts between bearings. The other parts of the gear shaft may be considered as intermediate shaft parts.

The minimum rule diameter d_{ice}, in mm, of gear shaft with ice strengthening is equal to:

$$d_{ice} = d \cdot K_{ice\text{-}s}^{\frac{1}{3}}$$

where:

$K_{ice\text{-}s} = Q_{peak} / Q_n \geq 1$

d : Rule shaft diameter, defined in Pt C, Ch 1, Sec 6, [4.4.2].

1.7.5 Calculation of propeller blade failure

The calculation of load due to blade failure is to take into account compression, flexion and torque on shaft induced by the force F_{ex}. The corresponding calculated von Mises stress is to remain below the shaft material yield strength.

The propeller shaft diameter in way of the aft stern tube bearing is to be at least equal to the minimum rule diameter d_{ice} calculated according to [1.7.3], without being less than the rule diameter d_{ex} given by the following formula:

$$d_{ex} = 160\left[\frac{F_{ex}D}{R_e(1-Q^4)}\right]^{\frac{1}{3}}$$

where:

R_e : Yield strength of propeller shaft material, in MPa

Q : Factor equal to d_i / d_o, as defined in Pt C, Ch 1, Sec 7, [2.2.3].

Forward of the aft stern tube bearing, the propeller shaft diameter may be reduced based on direct calculation of the actual bending moments or on the assumption that the bending moment caused by F_{ex} is linearly reduced to 50% at the next bearing, down to zero at the third bearing.

The shaft diameter of the corresponding section is, in any case, not to be less than the minimum rule diameter d_{ice} calculated according to [1.7.3].

1.7.6 Alternative design procedure

Alternative calculation methods to determine design loads of the propulsion components may be considered by the Society. Any alternative calculation method is to include all the relevant loads on the complete dynamic shafting system under all permissible operating conditions. The peak operating torque is therefore to be calculated by means of torsional vibration analysis of the propulsion line, including ice loads and main engine excitations in accordance with the requirements of [1.4.4].

Moreover, an alternative calculation method is to take into account continuous and transient operating loads (dimensioning for fatigue strength) and peak operating loads (dimensioning for yield strength). The ratio of yield strength with respect to corresponding maximum stress is to be at least 1,3 in plain shaft section and 1,0 in stress concentrations sections. The fatigue strength is to be determined with consideration of the dimensions and arrangements of all the shaft connections, and the safety factor is to be at least 1,5.

1.8 Coupling

1.8.1 Flange couplings

The dimensions of coupling flanges are to comply with the requirements of Pt C, Ch 1, Sec 7, [2.5.1].

When the bolts are not fitted, the minimum transmitted torque is equal to the nominal torque Q_n multiplied by the flange coupling ice factor $K_{ice\text{-}cp}$ given by:

$$K_{ice\text{-}cp} = \frac{Q_{peak}}{Q_n} \geq 1$$

where:

Q_{peak} : Maximum peak torque, in kN·m, to be determined from the results of torsional vibration analysis due to ice impact. As an alternative, the following estimation may be used:

- for main propulsion systems powered by diesel engines fitted with slip type or high elasticity couplings, by turbines or by electric motors:

  $Q_{peak} = Q_{emax} + Q_{max} \cdot I / I_t$

- for main propulsion systems powered by diesel engines fitted with couplings other than those mentioned above:

  $Q_{peak} = 1,2\ Q_{emax} + Q_{max} \cdot I / I_t$

In case of fitted bolts, the requirements of Pt C, Ch 1, Sec 7, [2.5.1] apply, using the rule shaft diameter defined in [1.7.3].

The safety factors to be applied are indicated in Pt C, Ch 1, Sec 7, [2.5.1]. With respect to torque transmission, a reduced safety factor of 1,3 may be applied, provided that $1,3\ Q_{peak} > 2,5\ Q_n$.

Moreover, the bolts are to be designed so that the blade failure load in forward or backward directions does not cause yielding.

1.8.2 Shrunk couplings

Non-integral couplings which are shrunk on the shaft by means of the oil pressure injection method or by other means may be accepted, provided that the design complies with Pt C, Ch 1, Sec 7, [2.5.2]. The minimum transmitted torque is the nominal torque multiplied by the ice factor $K_{ice\text{-}cp}$ defined in [1.8.1].

The safety factors to be applied are indicated in Pt C, Ch 1, Sec 7, [2.5.2]. With respect to torque transmission, a reduced safety factor of 1,3 may be applied, provided that $1,3\ Q_{peak} > 2,5\ Q_n$.

1.8.3 Keyed couplings

Keyed couplings are, in general, not to be used in installations with ice class notation.

Keyed couplings may be accepted, provided that the principal mean of torque transmission is ensured by friction in accordance with [1.8.2]. Moreover, the keyway is to comply with the requirements of Pt C, Ch 1, Sec 7, [2.5.5].

1.8.4 Flexible couplings

The flexible couplings are to comply with Pt C, Ch 1, Sec 7, [2.5.4]. In addition, the stiff parts of flexible couplings subjected to torque are to be designed to withstand the loads defined in [1.4.4], item d).

The maximum peak torque Q_{peak} in the flexible components is not to exceed the relevant limits specified by the manufacturer. This is to be verified with a torsional vibration analysis of the propulsion line, including ice loads in accordance with the requirements of [1.4.4].

1.8.5 Clutches

Clutches are to have a static friction torque of at least 1,3 times the peak torque Q_{peak} and a dynamic friction torque of at least 2/3 of the static friction torque.

Emergency operation of clutch after failure of, e.g., operating pressure is to be made possible within a reasonably short time. When arranged with bolts, the coupling is to be on the engine side of the clutch in order to ensure access to any bolt by turning the engine.

1.9 Gear

1.9.1 General

The load capacity of gearings is to comply with the requirements of Pt C, Ch 1, Sec 6, provided that the parameters defined in [1.9.2] to [1.9.4] are used in the detailed method.

1.9.2 Application factor

For the calculation of gearing including ice requirements, the application factor K_A defined in Pt C, Ch 1, Sec 6, Tab 5 is to be replaced by the application factor $K_{A\text{-}ice}$ equal to:

$$K_{A\text{-}ice} = K_A + \frac{Q_{eq} \cdot \frac{I}{I_t}}{Q_n}$$

with:

Q_{eq} : Equivalent ice torque calculated in accordance with ISO 6336 Pt.6 A.3.

The following load spectrum is to be applied to the definition of the ice torque on the propeller Q_{max}, in accordance with the Weibull distribution:

$$Q_{ice}(N) = Q_{max}\left[1 - \frac{\log N}{\log(Z N_{ice})}\right]$$

where:

N : Number of cycles

Q_{max} : Maximum ice torque on the propeller, as defined in [1.4.4]

N_{ice} : Number of ice cycles, as defined in [1.4.2].

The load spectrum is to be divided into 10 load blocks minimum and the effective number of cycles for each load block is calculated with the following formula:

$$n_i = (ZN_{ice})^{\frac{i}{imax}} - \sum_{j=2}^{i} n_{j-1}$$

where:

i : Index of each load block (starting at 1 for the highest load value)

n_i : Number of cycles for the load Q_i defined by:

$Q_i = Q_{ice}(N)\,[1 - (i - 1) / i_{max}]$

with:

i_{max} : Total number of blocks, taken not less than 10.

1.9.3 Inertia ratio

The inertia ratio to be used is I / I_t .

Engine inertia is not to be neglected unless the peak torque Q_{peak} is calculated from the torsional vibration analysis as defined in [1.4.4].

1.9.4 Safety factors

The safety factors S_H and S_F to be applied are those indicated in Pt C, Ch 1, Sec 6, [2.4.14] and Pt C, Ch 1, Sec 6, [2.5.15].

1.10 Chockfast calculation

1.10.1 The calculation of gearbox chockfast is to be carried out taking into consideration the load due to the transmitted torque and using the application factor $K_{A\text{-}Ice}$.

1.11 Azimuthing main propulsors

1.11.1 Design principles

In addition to the above requirements for propeller blade dimensioning, azimuthing thrusters have to be designed for thruster body/ice interaction loads.

Load formulae are given for estimating once in a lifetime extreme loads on the thruster body, based on the estimated ice condition and ship operational parameters. Two main ice load scenarios have been selected for defining the extreme ice loads. Examples of loads are illustrated in Fig 9. In addition, blade order thruster body vibration responses may be estimated for propeller excitation. The following load scenario types are considered:

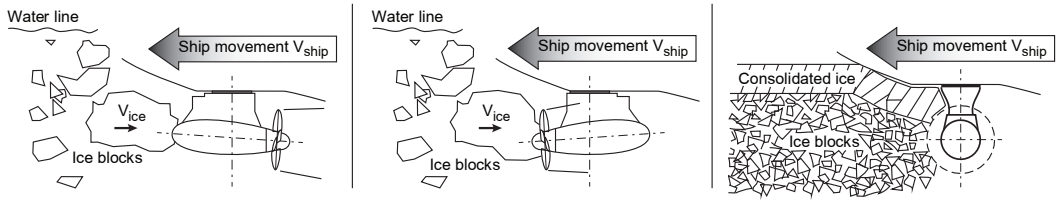
a) Ice block impact to the thruster body or propeller hub

b) Thruster penetration into an ice ridge that has a thick consolidated layer

c) Vibratory response of the thruster at blade order frequency.

The steering mechanism, the fitting of the unit, and the body of the thruster are to be designed to withstand the plastic bending of a blade without damage. The loss of a blade must be taken into account for the propeller blade orientation causing the maximum load on the component being studied. Top-down blade orientation typically places the maximum bending loads on the thruster body.

Figure 9 : Examples of load scenario types



1.11.2 Extreme ice impact loads

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and also on the propeller hub. Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as location of the thruster. The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster has to withstand the loads occurring when the design ice block defined in Tab 2 impacts on the thruster body when the ship is sailing at a typical ice operating speed. Load cases for impact loads are given in Tab 13. The contact geometry is estimated to be hemispherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius has to be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

The ice impact contact load F_{ti}, in kN, is to be calculated as follows:

$$F_{ti} = C_{DMI} 34{,}5 R_C^{0,5} (m_{ice} v_S^2)^{0,333}$$

where:

R_C : Impacting part sphere radius, in m, as shown in Fig 10

m_{ice} : Ice block mass, in kg, as given in Tab 14

C_{DMI} : Dynamic magnification factor for impact loads. If unknown, C_{DMI} may to be taken from Tab 14

v_s : Impact speed, in m/s, as defined in Tab 15 or Tab 16. On a case by case basis, v_s can also be derived from the ship actual design operation speed in ice, subject to the Society agreement.

For impacts on non-hemispherical areas, such as the impact on the nozzle, R_c is to be replaced by the equivalent impact sphere radius R_{ceq}, in m, to be estimated using the equation below:

$$R_{ceq} = \sqrt{\frac{A}{\pi}}$$

where:

A : Contact area, in m^2, as shown in Tab 13.

If the $2 \cdot R_{ceq}$ is greater than the ice block thickness given in Tab 14, the radius is set to half of the ice block thickness.

For impact on the thruster side, the pod body diameter can be used as basis for determining the radius. For impact on the propeller hub, the hub diameter can be used as basis for the radius.

Note 1: The longitudinal impact speed in Tab 15 and Tab 16 refers to the impact in the thruster's main operational direction. For the pulling propeller configuration, the longitudinal impact speed is used for load case T2, impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1, impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

Figure 10 : Dimensions used for R_c

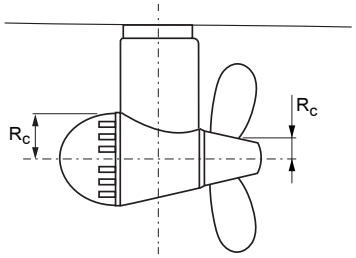
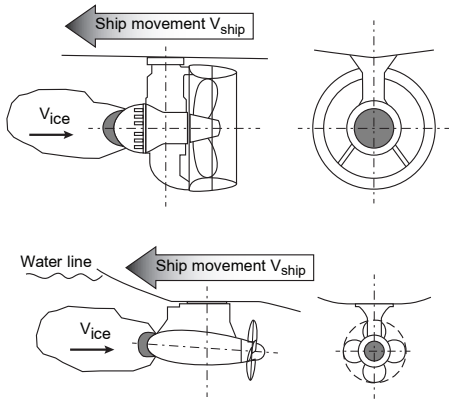
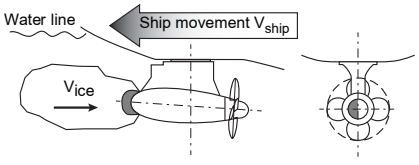


Table 13 : Load cases for azimuthing thruster impact loads

Load Case	Force	Loaded area	
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform pressure applied symmetrically on the impact area	
Load case T1b Non-symmetric longitudinal ice impact on thruster	50% of F_{ti}	Uniform pressure applied on the other half of the impact area	

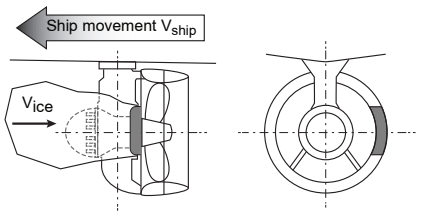
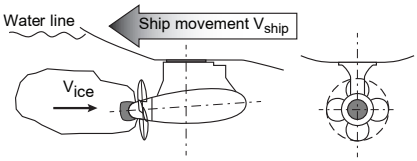
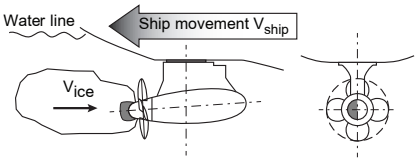
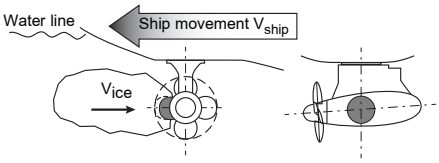
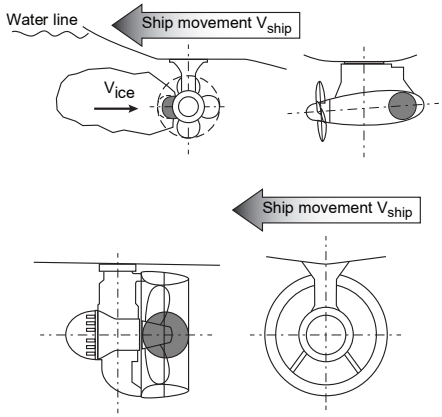
Load Case	Force	Loaded area	
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform pressure applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz})* contact height (H_{ice})	
Load case T2a Symmetric longitudinal ice impact on propeller hub	F_{ti}	Uniform pressure applied symmetrically on the impact area	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	50% of F_{ti}	Uniform pressure applied on the other half of the impact area	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform pressure applied symmetrically on the impact area	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform pressure applied on the other half of the impact area. Nozzle contact radius R to be taken from the nozzle length	
Note 1: For fixed thrusters, only the relevant load cases are to be considered.			

Table 14 : Parameter values for ice dimensions and dynamic magnification

Notation	IA Super	IA	IB	IC
Thickness of the design ice block impacting thruster (2/3 of H_{ice}) (m)	1,17	1,0	0,8	0,67
Extreme ice block mass (m_{ice}) (kg)	8760	5460	2800	1600
C_{DMI} (if not known)	1,3	1,2	1,1	1,0

Table 15 : Impact speeds v_s for aft centerline thruster (m/s)

Notations	IA Super	IA	IB	IC
Longitudinal impact in main operational direction	6	5	5	5
Longitudinal impact in reversing direction (pulling unit propeller hub or pushing unit cover end cap impact)	4	3	3	3
Transversal impact in bow first operation	3	2	2	2
Transversal impact in stern first operation (double acting ship)	4	3	3	3

Table 16 : Impact speeds v_s for aft, wing, bow centerline and bow wing thrusters (m/s)

Notations	IA Super	IA	IB	IC
Longitudinal impact in main operational direction	6	5	5	5
Longitudinal impact in reversing direction (pulling unit propeller hub or pushing unit cover end cap impact)	4	3	3	3
Transversal impact	4	3	3	3

1.11.3 Extreme ice loads on thruster hull when penetrating an ice ridge

In icy conditions, ships typically operate in ice channels. When passing other ships, ships may be subject to loads caused by their thrusters penetrating ice channel walls. There is usually a consolidated layer at the ice surface, below which the ice blocks are loose. In addition, the thruster may penetrate ice ridges when backing. Such a situation is likely in the case of ships having a notation **ICE CLASS IA SUPER** in particular, because they may sail independently in difficult ice conditions. However, the thrusters in ships with lower ice classes may also have to withstand such a situation, but at a remarkably lower ship speed.

In this load scenario, the ship is penetrating a ridge in thruster first mode with an initial speed. This situation occurs when a ship with a thruster at the bow moves forward, or a ship with a thruster astern moves in backing mode. The maximum load during such an event is considered the extreme load. An event of this kind typically lasts several seconds, due to which the dynamic magnification is considered negligible and is not taken into account.

The ridge penetration load F_{tr}, in kN, is to be calculated for the load cases shown in Tab 17, using the formula below:

$$F_{tr} = 32 v_s^{0,66} H_r^{0,9} A_t^{0,74}$$

where:

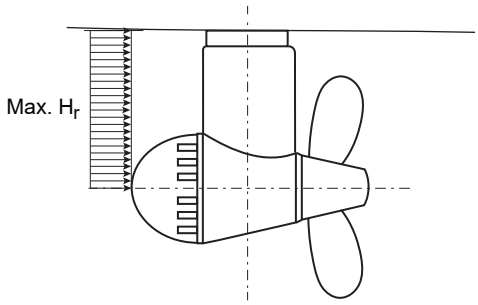
v_s : Ridge penetration speed, in m/s, as given in Tab 18 and Tab 19. On a case by case basis, v_s can also be derived from the ship actual design operation speed in ice, subject to the Society agreement, in m/s

H_r : Total thickness of the design ridge, in m, as given in Tab 18 and Tab 19

A_t : Projected area of the thruster, in m^2, as shown in Tab 17. When calculating the contact area for thruster-ridge interaction, the loaded area in vertical direction is limited to the ice ridge thickness as shown in Fig 11.

The loads must be applied as uniform pressure over the thruster surface.

Figure 11 : Schematic figure showing the reduction of the contact area by the maximum ridge thickness



1.11.4 Acceptability criterion for static loads

The stresses on the thruster have to be calculated for the extreme once in a lifetime loads described in [1.11.1]. The nominal von Mises stresses on the thruster body must have a safety margin of 1,3 against yielding strength of the material. At areas of local stress concentrations, stresses must have a safety margin of 1,0 against yielding.

The slewing bearing, bolt connections and other components must be able to maintain operability without incurring damage that requires repair when subject to loads given in [1.11.2] and [1.11.3] multiplied by safety factor 1,3.

1.11.5 Thruster body global vibration

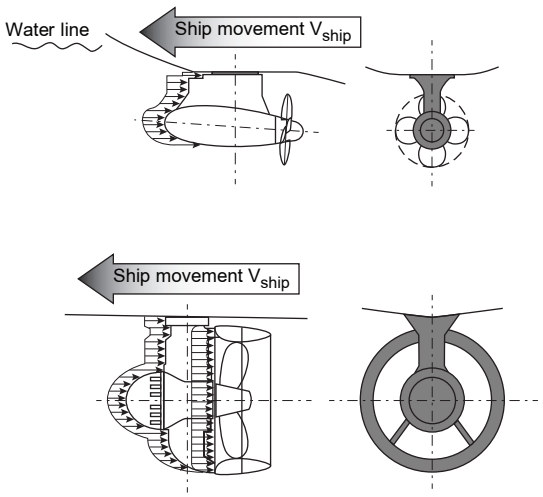
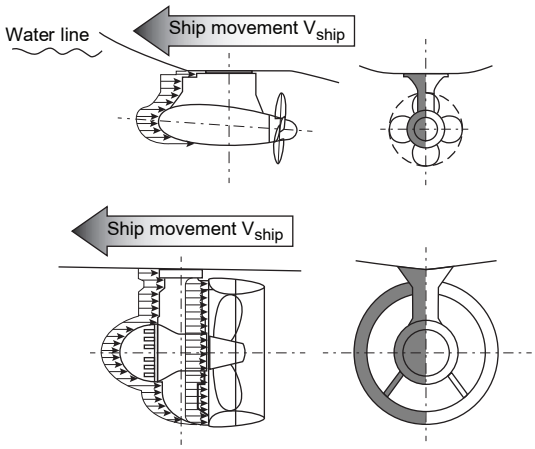
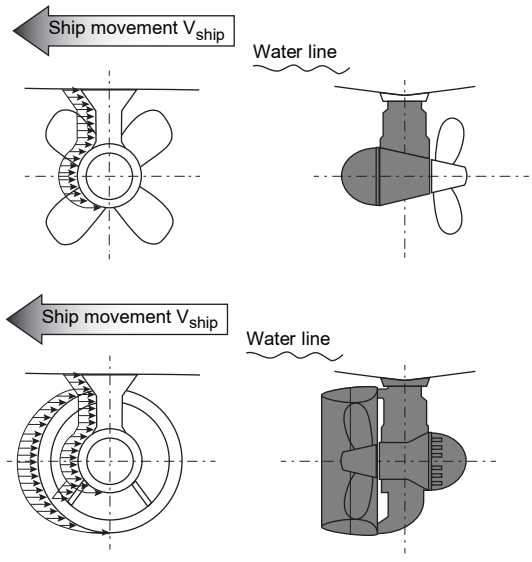
It is to be shown that either:

- the first blade order excitations (above 50% of maximum power) are outside a range of 20% above and 20% below the thruster global modes of vibration
- the structure is designed to comply with the criteria in [1.11.4] when subject to vibratory loads during resonance above 50% of maximum power.

When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water must be taken into account. In addition to this, the effect of ship attachment stiffness is to be modeled.

Vibratory loads may be estimated using a recognized simplified method (i.e. Guidelines for the application of the Finnish-Swedish Ice Class Rules).

Table 17 : Load cases for ridge ice loads

Load Case	Force	Loaded area	
Load case T4a Symmetric longitudinal ridge penetration loads	F_{tr}	Uniform pressure applied symmetrically on the impact area	
Load case T4b Non-symmetric longitudinal ridge penetration loads	50% of F_{tr}	Uniform pressure applied on the other half of the contact area	
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform pressure applied symmetrically on the contact area	

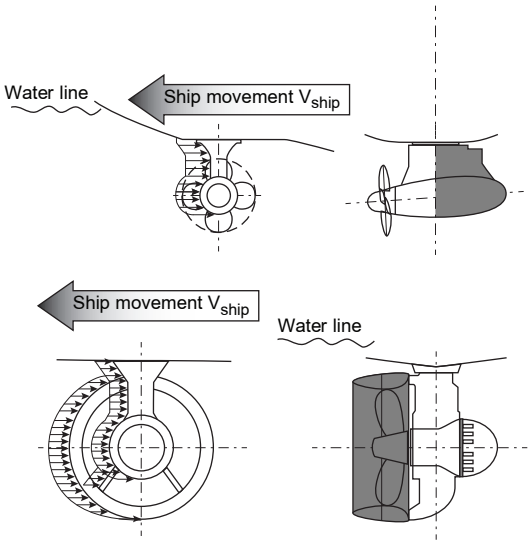
Load Case	Force	Loaded area	
Load case T5b Non-symmetric lateral ridge penetration loads for all azimuthing units	50% of F_{tr}	Uniform pressure applied on the other half of the contact area	
Note 1: For fixed thrusters, only the relevant load cases are to be considered.			

Table 18 : Parameters for calculating maximum loads when thruster penetrates an ice ridge - Aft thrusters, bow first operation

Notations		IA Super	IA	IB	IC
Total thickness of the design ridge (H_r) (m)		8	8	6,5	5
Initial ridge penetration speed (v_s) (m/s)	Longitudinal loads	4	2	2	2
	Transversal loads	2	1	1	1

Table 19 : Parameters for calculating maximum loads when thruster penetrates an ice ridge - Thruster first mode such as double acting ships

Notations		IA Super	IA	IB	IC
Total thickness of the design ridge (H_r) (m)		8	8	6,5	5
Initial ridge penetration speed (v_s)(m/s)	Longitudinal loads	6	4	4	4
	Transversal loads	3	2	2	2

1.11.6 Steering gear design torque in ice

The steering gear design torque in ice T_{steer}, in Nm, is to be obtained from the following formula:

$$T_{steer} = 0,6\frac{Q_{max}}{0,8R}L$$

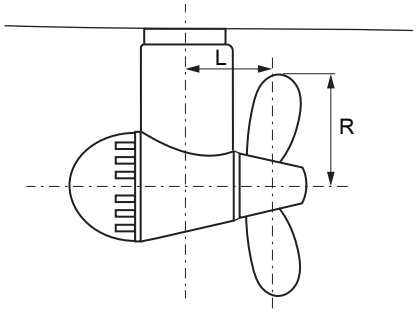
where:

Q_{max} : Maximum torque on the propeller due to ice propeller interaction, in N, as defined in [1.4.4]

R : Propeller radius, in m

L : Distance from the propeller plane to steering axis, in m (see Fig 12).

Figure 12 : Distance from the propeller plane to steering axis



1.11.7 Protection of the steering gear against excessive torque

The steering gear is to be protected by effective means limiting excessive torque resulting from:

a) ice milling torque exceeding design torque and leading to rotation of unit

b) torque caused by plastic bending of one propeller blade in the worse position (related to steering gear) and leading to rotation of the unit.

The steering gear is to be ready for operation after loads defined in item a) or item b) has disappeared.

2 Requirements for propulsion machinery of ICE CLASS ID

2.1 Ice torque

2.1.1 For the scantlings of propellers and shafting, the effect of the impact of the propeller blades against ice is also to be taken into account.

The ensuing torque, hereafter defined as ice torque, is to be taken equal to the value M_G, in N m, calculated by the following formula:

$M_G = m\ D^2$

where:

m : Coefficient equal to 10000

D : Propeller diameter, in m.

2.2 Propellers

2.2.1 Material

The percentage elongation after fracture, measured with a proportional type tensile specimen, of materials used for propellers is to be not less than 15%. Materials other than copper alloys are to be Charpy V-notch impact tested at a temperature of –10°C with a minimum average energy not less than 20 J.

2.2.2 Scantlings

When the notation **ICE CLASS ID** is requested, the width ℓ and the maximum thickness t of the cylindrical sections of the propeller blades are to be such as to satisfy the conditions stated in items a), b) and c) below.

a) Cylindrical sections at the radius of 0,125 D, for fixed pitch propellers:

$$\ell \cdot t^2 \geq \frac{26,5}{R_m \cdot \left[0,65 + \left(\frac{0,7}{\rho}\right)\right]} \cdot \left(\frac{2,85 M_T}{z} + 2,24 M_G\right)$$

b) Cylindrical sections at the radius of 0,175 D, for controllable pitch propellers:

$$\ell \cdot t^2 \geq \frac{21,1}{R_m \cdot \left[0,65 + \left(\frac{0,7}{\rho}\right)\right]} \cdot \left(\frac{2,85 M_T}{z} + 2,35 M_G\right)$$

c) Cylindrical sections at the radius of 0,3 D, for both fixed and controllable pitch propellers:

$$\ell \cdot t^2 \geq \frac{9,3}{R_m \cdot \left[0,65 + \left(\frac{0,7}{\rho}\right)\right]} \cdot \left(\frac{2,85 M_T}{z} + 2,83 M_G\right)$$

where:

ℓ : Width of the expanded cylindrical section of the blade at the radius in question, in cm

t : Corresponding maximum blade thickness, in cm

ρ : D/H

D : Propeller diameter, in m

H : Blade pitch of propeller, in m, to be taken equal to:

- the pitch at the radius considered, for fixed pitch propellers
- 70% of the nominal pitch, for controllable pitch propellers

P : Maximum continuous power of propulsion machinery for which the classification has been requested, in kW

n : Speed of rotation of propeller, in rev/min, corresponding to the power P

M_T : Value, in N·m, of torque corresponding to the above power P and speed n, calculated as follows:

$$M_T = 9550 \cdot \frac{P}{n}$$

z : Number of propeller blades

M_G : Value of the ice torque, in N·m, calculated according to the formula given in [2.1.1].

R_m : Value, in N/mm^2, of the minimum tensile strength of the blade material.

2.2.3 Minimum thickness of blades

When the blade thicknesses, calculated by the formulae given in Pt C, Ch 1, Sec 8, [2.2.1] and Pt C, Ch 1, Sec 8, [2.3.1], are higher than those calculated on the basis of the formulae given in [2.2.2], the higher values are to be taken as rule blade thickness.

2.2.4 Minimum thickness at top of blade

The maximum thickness of the cylindrical blade section at the radius 0,475 D is not to be less than the value t_1, in mm, obtained by the following formula:

$$t_1 = (15 + 2D) \cdot \left(\frac{490}{R_m}\right)^{0,5}$$

In the formulae above, D and R_m have the same meaning as specified in [2.2.2].

2.2.5 Blade thickness at intermediate sections

The thickness of the other sections of the blade is to be determined by means of a smooth curve connecting the points defined by the blade thicknesses calculated by the formulae given in [2.2.2] and [2.2.4].

2.2.6 Thickness of blade edge

The thickness of the whole blade edge, measured at a distance from the edge itself equal to 1,25 t_1 (t_1 being the blade thickness as calculated by the appropriate formula given in [2.2.4]), is to be not less than 0,5 t_1.

For controllable pitch propellers, this requirement is applicable to the leading edge only.

2.3 Shafting

2.3.1 Propeller shafts

a) The diameter of the propeller shaft at its aft bearing is not to be less than the value d_P, in mm, calculated by the following formula:

$$d_P = K_E \cdot \left(\frac{W \cdot R_m}{R_{S,MIN}}\right)^{\frac{1}{3}}$$

where:

K_E :
- K_E = 10,8 for propellers having hub diameter not greater than 0,25 D
- K_E = 11,5 for propellers having hub diameter greater than 0,25 D

W : Value, in cm^3, equal to $\ell \cdot t^2$, proposed for the section at the radius:
- 0,125 D for propellers having the hub diameter not greater than 0,25 D
- 0,175 D for propellers having the hub diameter greater than 0,25 D

R_m : Value, in N/mm^2, of the minimum tensile strength of the blade material

$R_{S,MIN}$: Value, in N/mm^2, of the minimum yield strength (R_{eH}) or 0,2% proof stress ($R_{p\,0,2}$) of the propeller shaft material.

b) Where the diameter of the propeller shaft, as calculated by the formula given in Pt C, Ch 1, Sec 7, [2.2.3], is greater than that calculated according to the formula given in a) above, the former value is to be adopted.

c) Where a cone-shaped length is provided in the propeller shaft, it is to be designed and arranged in accordance with the applicable requirements of Pt C, Ch 1, Sec 7.

d) Propeller shafts are to be of steel having impact strength as specified in NR216 Materials and Welding.

3 Miscellaneous requirements

3.1 Starting arrangements

3.1.1 The capacity of the air receivers is to be sufficient to provide without reloading not less than 12 consecutive starts of the propulsion engine, if this one is to be reversed for going astern, or 6 consecutive starts if the propulsion engine is not to be reversed for going astern.

If the air receivers serve any other purposes than starting the propulsion engine, they are to have additional capacity sufficient for these purposes.

The capacity of the air compressors is to be sufficient for charging the air receivers from atmospheric to full pressure in one hour, except for a ship having the notation **ICE CLASS IA SUPER** and its propulsion engine reserved for going astern, in which case the compressor is to be able to charge the receivers in half an hour.

3.2 Sea inlets, ballast systems and cooling water systems of machinery

3.2.1

a) The cooling water system is to be designed to secure the supply of cooling water also when navigating in ice.

b) For this purpose, for ships with the notations **ICE CLASS IA SUPER**, **ICE CLASS IA**, **ICE CLASS IB**, **ICE CLASS IC** or **ICE CLASS ID**, at least one sea water inlet chest is to be arranged and constructed as indicated hereafter:

1) The sea inlet is to be situated near the centreline of the ship and as aft as possible.

2) As guidance for design, the volume of the chest is to be around one cubic metre for every 750 kW of the aggregate output of the engines installed on board, for both main propulsion and essential auxiliary services.

3) The chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.

4) A pipe for discharging the cooling water, having the same diameter as the main overboard discharge line, is to be connected to the inlet chest.

5) The area of the strum holes is to be not less than 4 times the inlet pipe sectional area.

c) Where there are difficulties in satisfying the requirements of items b) 2) and b) 3) above, alternatively two smaller chests may be accepted, provided that they are located and arranged as stated in the other provisions above.

d) Heating coils may be installed in the upper part of the chests.

e) Arrangements for using ballast water for cooling purposes may be accepted as a reserve in terms of ballast but are not acceptable as a substitute for the sea inlet chests as described above.

f) Where required by Ch 8, Sec 1, [2.2.2], the ballast tanks are to be provided with suitable devices to prevent the water from freezing, which shall be so designed as to avoid any ice formation in the tank which may be detrimental to the tank. For that purpose, the following may be accepted:

- heating systems by heating coils within ballast tanks
- internal circulating/pumping systems
- bubbling systems
- steam injection systems.

Where bubbling systems are applied, following shall be complied with:

- sufficient number of air nozzles is to be distributed along the shell side bottom
- the maximum air pressure induced in the tank is not to exceed the design pressure of tank structure
- exposed vent pipe and vent heads shall be protected from possible blocking by ice
- if the bubbling systems is not supplied by a dedicated compressed air plant, the general service air system may be used for that purpose if justified that its capacity takes into account the air consumption of the bubbling system.

g) Where ballast water exchange at sea is accepted as a process for the treatment of ballast water, ship side ballast discharge valves are to be protected from freezing in accordance with Pt C, Ch 1, Sec 10, [7.3.3], item d). Suitable protection shall be provided also for ballast tanks vent heads, as well as for ballast overflows where existing.

3.3 Steering gear

3.3.1

a) In the case of ships with the notations **ICE CLASS IA SUPER** or **ICE CLASS IA**, due regard is to be paid to the excessive loads caused by the rudder being forced out of the centreline position when backing into an ice ridge.

b) Effective relief valves are to be provided to protect the steering gear against hydraulic overpressure.

c) The scantlings of steering gear components are to be such as to withstand the yield torque of the rudder stock.

d) Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

3.4 Fire pumps

3.4.1 The suction of at least one fire pump is to be connected to a sea inlet protected against icing.

3.5 Transverse thrusters

3.5.1 Tunnels of transverse thrusters are to be fitted with grids for protection against ice impacts.

3.6 Test and certification for propellers

3.6.1 Requirements mentioned in Pt C, Ch 1, Sec 8, [4] are to be referred to. Additionally, material tests mentioned in [1.3] and [2.2.1] are to be undertaken.

Section 4 COLD Notations - Cold Weather Conditions

1 General

1.1 Application

1.1.1 Cold weather conditions

The requirements of this Section apply to ships intended to operate with the following conditions:

- t_{DE} : Design air temperature to be considered for the equipment exposed to low air temperature, which is to be taken 10°C below the lowest mean daily low air temperature
- t_{DH} : Design air temperature to be considered for the hull exposed to low air temperature, which is to be taken equal to the lowest mean daily average air temperature, but not more than 13°C above t_{DE}
- Sea water temperature: not below –2°C
- Wind speed: not greater than 30 knots.

1.1.2 Notations COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

The following additional class notations are assigned, in accordance with Pt A, Ch 1, Sec 2, [6.10.4], to ships intended for service in cold climate environments.

- The additional class notation **COLD DI** is assigned to ships operating in cold climate environments for shorter periods, not necessarily including ice covered waters and fitted with systems and equipment for de-icing complying with the requirements of [2] to [4].
- The additional class notation **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})** are assigned to ships operating in cold weather conditions, as defined in [1.1.1], built and fitted with systems and equipment for de-icing, where t_{DH} and t_{DE} are defined in [1.1.1] for, respectively, hull and equipment exposed to low air temperature:
  - Ships assigned the notation **COLD BASIC (H t_{DH}, E t_{DE})** are to comply with the requirements of [2] to [7].
  - In addition to the requirements listed in [2] to [7], ships assigned the notation **COLD (H t_{DH}, E t_{DE})** are to comply with the requirements for advanced systems and equipment for de-icing defined in [8].

The requirements for the additional class notation **COLD DI** concern mainly the following functions of the ship and its equipment under cold weather conditions:

- decks and superstructures
- propulsion
- machinery installations
- electricity installations
- crew protection
- elimination of ice where necessary for safe access.

The requirements for the additional class notation **COLD BASIC (H t_{DH}, E t_{DE})** and **COLD (H t_{DH}, E t_{DE})** cover also:

- hull
- stability
- navigation
- material.

1.1.3 Notation COLD CARGO

The additional class notation **COLD CARGO** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.10.5], to ships intended to be loaded with liquid cargoes:

- having a cargo temperature below –10°C, in particular when loading is from cold storage tanks (winter conditions), and
- that do not need to be heated in normal operating conditions.

Ships assigned the notation **COLD CARGO** are to comply with the requirements given in [9].

1.2 Documentation to be submitted

1.2.1 Documentation to be submitted for COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

For the additional class notation **COLD DI** the documentation to be submitted to the Society is listed in Tab 1.

For the additional class notation **COLD BASIC (H t_{DH}, E t_{DE})** the documentation to be submitted to the Society is listed in Tab 1 and Tab 2.

For the additional class notation **COLD (H t_{DH}, E t_{DE})** the documentation to be submitted to the Society is listed in Tab 1, Tab 2 and Tab 3.

1.2.2 Documentation to be submitted for COLD CARGO

For the additional class notation **COLD CARGO** the documentation to be submitted to the Society is listed in Tab 4.

1.2.3 Documentation to be kept on board

The Owner is to keep on board the ship the following documentation which is to be made available to the Surveyor:

- when the additional class notation **COLD DI** is assigned:
  - manual for de-icing procedures
- when the additional class notation **COLD BASIC (H t_{DH}, E t_{DE})** or **COLD (H t_{DH}, E t_{DE})** are assigned:
  - manual for de-icing procedures
  - stability manual including loading conditions with ice accretion.

1.3 Testing

1.3.1 Following installation on board, the systems are to be subjected to operational tests to the satisfaction of the Surveyor.

Table 1 : General documentation to be submitted for COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

No.	I/A **(1)**	Plan or document
1	A	De-icing systems including heating systems: • diagrams of the steam, hot water, thermal oil piping or other systems used for de-icing purposes • de-icing arrangements of ballast tanks, sea chests, overboard discharges • de-icing arrangements for air intakes
2	A	De-icing devices distribution board
3	A	Wheelhouse and cargo control room de-icing system arrangement
4	I	De-icing arrangements for gangways, access, working areas, etc.
5	I	List of tools for ice removal
6	I	Electrical load balance, including "de-icing case"
7	I	De-icing system layout
8	I	Procedure for de-icing the sea chests
(1) A: to be submitted for approval ; I to be submitted for information		

Table 2 : Additional documentation to be submitted for COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

No.	I/A **(1)**	Plan or document
1	A	Distribution of steel qualities in structures exposed to low air temperatures
2	A	Trim and stability booklet including the additional loading conditions with ice accretion
3	A	Damage stability calculations when applicable for the loading conditions with ice accretion
4	A	Compartments containing internal combustion engines, auxiliary systems, HVAC systems: • heat balance for ventilation / air supply to engine turbo-blowers • heat balance for sea water / fresh water cooling circuits • minimum temperatures required for ambient air to ensure satisfactory operation of the concerned equipment
5	A	Deck machinery arrangement (windlasses, winches and deck cranes) including their remote control system
6	I	Plan showing the detail of the location of the ice accretion, the detail of the area calculation and the total weight of ice for each area
(1) A: to be submitted for approval ; I to be submitted for information		

Table 3 : Additional documentation to be submitted for COLD (H t_{DH}, E t_{DE})

No.	I/A **(1)**	Plan or document
1	A	De-icing systems including heating systems: • arrangement of the heat tracing systems
2	I	De-icing system layout (for electrical heat tracing)
(1) A: to be submitted for approval ; I to be submitted for information		

Table 4 : Documentation to be submitted for COLD CARGO

No.	I/A **(1)**	Plan or document
1	I	General layout drawing of the cargo and ballast tanks
2	I	Diagram of the ballast piping system, cargo system, steam / thermal oil heating system and steam condensate system with instrumentation
3	A	Details of the heating arrangements (capacity, drawings of the heat exchangers)
4	A	Characteristics of the cargo (thermal conductivity, heat value, density, boiling point, flash point, viscosity vs. temperature)
5	A	Heat transfer calculation note (see [9.3.3])
6	A	Cargo loading and heating procedures
7	I	Risk analysis (see [9.4]).
(1) A: to be submitted for approval ; I to be submitted for information		

2 General requirements for machinery installations for COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

2.1 General

2.1.1 Application

The requirements contained in the present Article cover:

- the ship propulsion system and other essential systems
- the prevention of ice formation which could be detrimental to the safety of the ship or of the passengers and crew.

2.1.2 Thermal barriers are to be considered for all pipe or duct penetrations from exposed decks or bulkheads.

2.2 Principles

2.2.1 Operation of the propulsion system and other essential systems

a) As a general rule, the temperature inside the machinery compartments is to be kept above a minimum value allowing the equipment located in those compartments to operate without restrictions. This applies in particular to the propulsion plant, the electricity generation plant, the emergency generating set, the emergency fire pump and auxiliary systems (such as fuel oil transfer, supply and return piping systems, lubricating oil systems, cooling systems, sewage systems, etc.) and to other essential systems as defined in Pt C, Ch 2, Sec 1.

b) The ventilation capacity can be adjusted so as to limit the heat losses. It should however satisfy the engine needs of combustion air while avoiding excessive vacuum in the compartment.

Note 1: The attention is drawn to any requirements which may impose a minimum number of air changes in the compartment, in particular to avoid flammable oil or gas accumulation.

c) Working liquids (such as fuel oil, lubricating oil, hydraulic oil) are to be maintained in a viscosity range that ensures proper operation of the machinery.

2.2.2 Prevention of ice build-up inside pipes and associated fittings

a) Arrangements are to be made to avoid the build-up of ice inside air pipes (in particular those connected to sea chests, cooling water recirculation tanks and ballast tanks) and inside their automatic closing devices, where fitted.

b) It also applies to:

- sounding pipes and overflow pipes serving cooling water recirculation tanks and water ballast tanks
- piping systems located in exposed areas, including ro-ro spaces, such as compressed air lines, steam lines or steam drain lines when not in use
- spray water lines
- exposed deck scuppers, washing lines and discharge lines.

c) The fire main is to be arranged so that exposed sections can be isolated and means of draining of exposed sections are to be provided. Fire hoses and nozzles need not be connected to the fire main at all times, and may be stored in protected locations near the hydrants.

Note 1: The above mentioned systems are to be drained when not in use.

2.2.3 Prevention of ice build-up in air intakes

Arrangements are to be made to avoid ice accretion on the fresh air intake components (ventilators, louvers, casings, scuppers, etc.), in particular on those serving the machinery spaces, emergency generating set room and HVAC rooms. This may be accomplished by means of closed-circuit ventilation sequences or by electric or steam tracing of the said components.

2.3 Design requirements

2.3.1 Arrangement of pipes subject to ice build-up

a) The pipes subject to ice build-up (see [2.2.2]) are to be placed in unexposed locations, or protected by screening or other suitable arrangement.

b) Where provided, the insulation material is to be protected by a suitable sheath so designed as to withstand possible sea impacts.

2.3.2 Instrumentation

a) Provisions are to be made to ensure a satisfactory operation of the level sensors and remote gauging indicators in ballast tanks.

b) Temperature sensors are to be provided in each ballast tank, giving an alarm in case of low temperature in the tank.

Note 1: The temperature alarms are to be inhibited when the ballast capacities are not used.

c) Temperature and pressure sensors are to be fitted in sea bay, so as to generate an alarm.

d) Ballast pumps are to be fitted with alarm and shutdown, in case of low pressure at the pump suction.

3 General requirements for electrical installations for COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

3.1 General

3.1.1 The permanent electrical de-icing devices are to comply with the rules indicated in Part C, Chapter 2.

3.1.2 Thermal barriers are to be considered for all cables or cable duct penetrations from exposed decks or bulkheads.

3.2 System design

3.2.1 Electrical power for de-icing devices

The electrical power necessary to supply the de-icing devices is to be considered as a permanent load. A specific case of load balance taking into account the load of these de-icing devices is to be submitted to the Society.

4 Other general requirements for COLD DI, COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE}))

4.1 Application

4.1.1 In addition to the requirements of Articles [2] and [3], ships assigned the notation **COLD DI**, **COLD BASIC (H t_{DH}, E t_{DE})** or **COLD (H t_{DH}, E t_{DE})** are to comply with the requirements of this Article.

Ships assigned the notation **COLD BASIC (H t_{DH}, E t_{DE})** or **COLD (H t_{DH}, E t_{DE})** are also to comply with requirements of Articles [5] to [8], as applicable.

4.2 De-icing of deck areas

4.2.1 De-icing tools as per [4.3] is to be provided to allow the de-icing of the ship areas to which the crew may have access during the normal operation of the ship, in particular:

- manoeuvring area
- loading / unloading area
- area around the access to the deckhouses
- passageways, gangways, walkways.

4.2.2 The circulation on exposed decks is to be facilitated by the use of appropriate gratings and stairs (including escapes, access to lifeboats, to winching areas). Where necessary, safety lines are to be provided on the exposed deck.

4.3 De-icing tools

4.3.1 De-icing tools, such as scrapers, lances, showels, etc., are to be provided on board to allow manual de-icing.

They are to be kept in stores of the main deck and at locations protected from ice accretion.

The quantity of equipment is to be sufficient for manual de-icing operation.

4.4 Protection of deck machinery

4.4.1 Specific arrangement for protection of deck machinery (foam monitors, davits, lifeboats, lifejackets lockers, winches, windlasses, cranes), helideck and its access, suppressing the risk of ice formation, such as machinery located in protected spaces, or specific protection arrangement preventing sea water spraying is to be provided.

4.5 Closing appliances and doors

4.5.1 Means are to be provided to remove or prevent ice and snow accretion around hatches and doors (in way of the contact area).

4.5.2 When hatches or doors are hydraulically operated, means are to be provided to prevent freezing or excessive viscosity of liquids.

4.5.3 Watertight and weathertight doors, hatches and closing devices which are not within an habitable environment and require access while at sea are to be designed to be operated by personnel wearing heavy winter clothing including thick mittens.

4.6 HVAC plant

4.6.1 The HVAC plant is to be designed so as to ensure adequate temperature in the accommodation with outside air temperature. Arrangement is made to control humidity.

4.7 Other protections

4.7.1 Specific protection, such as tarpaulins is to be fitted for cargo valves and associated instrumentation.

4.7.2 Firefighter's outfits are to be stored in warm locations on the ship.

5 Additional requirements for hull and stability for COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

5.1 Hull

5.1.1 Grades of steel

The grades of steel for structures exposed to low air temperatures are given in Pt B, Ch 4, Sec 1.

5.1.2 Any fitting or construction lugs in the bow area are to be removed. The bow area is to be of good well fared construction to reduce the possibility of spray production.

The selection and method of fitting of bow anchors with regard to potential spray formation is to be carefully considered. Recessed anchors or anchors in pockets are to be considered.

5.1.3 Shell plating and bow area are to be as smooth as possible to prevent the formation of spray.

5.1.4 Bow anchors are to be recessed as far as possible or in pockets, with provision to ensure that they cannot freeze in place.

5.1.5 Anchors and chain cables are to be of low temperature steel suitable for the conditions defined in [1.1.1].

5.1.6 Material used in external structures above the waterline is to be appropriate for the temperature t_{DH} given in the class notation.

External structure is defined as the plating with stiffening to a distance of 0,6 meter inwards from the shell plating, exposed decks and sides of superstructure and deckhouses.

In general deckhouses and superstructures are of material class I. Deckhouses or superstructures exposed to longitudinal stresses within 0,6 L amidships are of material class II.

5.1.7 When a temperature calculation is required as per Pt D, Ch 9, Sec 4, [5.2], two sets of calculation are required:

- ambient temperature is to be taken as 5°C for air and 0°C for seawater. Other calculation parameters are to be taken as per Pt D, Ch 9, Sec 4, [5.2]. Steel grades are then to be selected in accordance with Pt D, Ch 9, Sec 6, Tab 6.
- ambient temperature is to be taken as t_{DH} for air and –2°C for seawater. Other calculation parameters are to be taken as per Pt D, Ch 9, Sec 4, [5.2]. Steel grades are then to be selected in accordance with Pt B, Ch 4, Sec 1.

5.2 Stability

5.2.1 General

The requirements of Pt B, Ch 3, Sec 2, [2] and Pt B, Ch 3, Sec 2, [3] and the applicable requirements of Part F for ships with the additional class notation **SDS** are to be complied with for the loading conditions described in Pt B, Ch 3, App 2, taking into account the additional weight of ice indicated in [5.2.2].

5.2.2 Weight of ice accretion

The weight distribution of the ice accretion is to be considered on the full length of the ship from the exposed deck and the decks above, including the sides, as follows:

- 30 kg/m^2 for the horizontal exposed areas
- 7,5 kg/m^2 for the vertical or oblique exposed areas.

For the purpose of the calculation the masts are excluded.

6 Additional requirements for machinery installations for notations COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

6.1 Application

6.1.1 In addition to the requirements of Article [2], the requirements contained in the present Article cover the ship propulsion system and other essential systems, which are to remain in operation at the temperature t_{DE}.

6.2 Materials

6.2.1 The materials of pipes and other equipment located on open deck and not insulated are to be suitable for the temperature t_{DE}. The materials of pipes are to comply with recognized standards such as EN10216-4, EN10217-6, etc.

The use of cast iron and other brittle materials are not permitted in areas exposed to low temperature.

Gaskets, jointing materials and seals are to be suitable for the temperature t_{DE}.

6.3 General principles

6.3.1 Operation of the propulsion system and other essential systems

a) Arrangements are to be made to ensure that the machinery can be brought into operation from the dead ship condition assuming an air temperature of t_{DE}.

b) A partial reduction in propulsion capability may be accepted in cold weather conditions provided that the safety of the ship is not impaired.

Note 1: The reduced power is not to be lower than the minimum power required by the ice class notation, where applicable.

6.3.2 Sea inlet and overboard discharge de-icing

Arrangements are to be made to avoid any blockage by ice of:

- the sea inlets
- the overboard discharges situated above the waterline as well as up to 1 m below the ballast waterline.

6.3.3 Ballast tank de-icing

a) Arrangements are to be provided to prevent water ballast freezing in tanks adjacent to the shell and located totally or partly above the ballast waterline.

b) This also applies to other tanks subject to freezing (such as fresh water, fuel oil).

6.3.4 Fire main and air vents heads

At least one of the fire pumps is to be connected to the sea inlet referred to in [6.4.1].

When fixed water-based firefighting systems are located in a space separate from the main fire pumps and use their own independent sea suction, this sea suction is to be also capable of being cleared of ice accumulation (design requirement as specified in [6.4.1], item c)).

Refer also to Pt C, Ch 4, Sec 6, [1.2.1].

Air vents heads are to be fitted with de-icing device.

6.4 Design requirements

6.4.1 Design of the sea inlets

a) The ship is to be provided with at least one sea bay from which pumps supplying cooling water to essential machinery draw.

b) The sea bay is to:
- be supplied with water from at least two sea chests, and
- be connected to the sea chests by pipes, valves and strainers with a cross sectional area equal to the total area of the suctions served by the sea bay.

c) The sea chests are to:
- be fitted on each side of the ship
- be as deeply submerged as possible
- have an open area to the sea of at least five times the total area of the pump suctions served by the sea bay
- be fitted with a strainer plate at the ship's side having perforations approximately 20 mm diameter to prevent ingestion of large ice particles
- be fitted with a steam or compressed air connection for clearing the strainer complying with Pt C, Ch 1, Sec 10, [2.8.4], item e).

d) Diversion valves and piping are to be provided at overboard cooling water discharges to permit warm water to be returned to the sea chests to prevent blockage.

e) Suction pipes are to be connected as low as possible to the sea chest.

Note 1: Other arrangements affording equivalent availability of the cooling water supply can also be considered. Engine cooling systems served by water ballasts may be accepted subject to special consideration.

6.4.2 Prevention of tank over-pressurisation

Provisions are to be made to prevent over-pressurizing the tanks and sea chests when the air or steam injection system is operating. Pressure reduction devices are to be fitted where deemed necessary.

6.4.3 Supporting of pipes

The design and arrangement of the pipe supports and collars are to take into account the weight of ice accretion, which is calculated in accordance with the provisions of [5.2.2].

7 Other additional requirements for COLD BASIC (H t_{DH}, E t_{DE}) and COLD (H t_{DH}, E t_{DE})

7.1 Application

7.1.1 In addition to the requirements of Article [2] to [6], ships assigned the notation **COLD BASIC (H t_{DH}, E t_{DE})** or **COLD (H t_{DH}, E t_{DE})** are to comply with the requirements of this Article.

Ships assigned the notation **COLD (H t_{DH}, E t_{DE})** are also to comply with requirements of Article [8].

7.2 Electrical equipment fitted in open decks

7.2.1 Electrical equipment fitted in open decks are to be suitable for operation at the temperature t_{DE}.

7.3 Cableways supports

7.3.1 Cableways supports are to be designed so as to take into consideration the ice load.

7.4 Navigation and communication equipment

7.4.1 Attention is to be paid ensuring that navigation and communication equipment is suitable for the temperature t_{DE}.

7.5 Fire safety systems

7.5.1 Portable and semi-portable extinguishers are to be located in positions protected from freezing temperatures, as far as practical. Locations subject to freezing are to be provided with extinguishers capable of operation under the temperature t_{DE}.

7.6 Personal protection and evacuation equipment

7.6.1 Personal protection and evacuation equipment are to be suitable for the temperature t_{DE}.

7.6.2 Personal protection for chemical tankers and gas carriers

The protective, safety and emergency equipment for personnel protection (as required by IBC Code, as amended, Chapter 14 or IGC Code, as amended, Chapter 14) is to be suitable for the temperature t_{DE}. The possibility for repeated operation of decontamination showers and an eyewash on deck at the temperature t_{DE} is to be carefully considered.

8 Additional requirements for COLD (H t_{DH}, E t_{DE})

8.1 Application

8.1.1 In addition to the requirements of Article [2] to [7], the requirements contained in the present Article cover the ship systems which are to remain operational at the temperature t_{DE}.

8.2 Machinery installations

8.2.1 Arrangement of pipes subject to ice build-up

a) The pipes subject to ice build-up (see [2.2.2]) are to be protected by screening, heat tracing or other suitable arrangement.

b) Exposed scuppers and discharge pipes are to be arranged with heat tracing.

8.2.2 P/V valves

Specific heating is to be provided for the cargo P/V valves, if any, so as to maintain their proper operation.

8.2.3 Design of heating systems intended for ballast tanks

a) Onboard ships where flammable cargo vapours may enter the ballast tanks in case of structural damage, the temperature of any part of the heating system is not to exceed the maximum temperature allowed for the cargo.

b) The heating lines including the return lines are to be independent from those serving the cargo tanks.

c) Heating coils which are not in use are to be drained.

8.2.4 Ballast tank de-icing

a) Arrangements are to be provided to prevent water ballast freezing in tanks adjacent to the shell and located totally or partly above the ballast waterline.

b) The following systems will be accepted to prevent water ballast freezing:
- heating systems
- internal circulating / pumping systems
- bubbling systems
- steam injection systems.

c) This also applies to other tanks subject to freezing (such as fresh water, fuel oil).

8.2.5 Design of bubbling systems

a) Bubbling systems are to be so designed as to avoid any ice accumulation in the tank which may be detrimental to the tank structure.

b) The bubbling system is to include a sufficient number of air nozzles distributed throughout the tank bottom.

c) The maximum pressure induced in the tank by the air supply system is not to exceed the design pressure of the tank.

d) The bubbling system may be served:
- either by a dedicated compressed air plant, or
- by the general service air system provided its capacity takes into account the air consumption of the bubbling system.

8.3 Electrical system design

8.3.1 Services to be considered for de-icing arrangement

The following services are to be considered for de-icing arrangement:

- heated bridge windows and heated cargo control room windows, including arrangement for heating/isolating the windows washing water system, which avoid formation of ice, or mist reducing the visibility through the windows
- installation of electrical de-icing system for all escape doors and all main doors giving access to the deck area. The system is to be arranged so as to avoid formation of ice, which may block the door
- heating of bunker lines on deck, when electrical heat tracing is provided together with insulation
- heating of scupper lines when electrical heat tracing is provided

- sequence of ventilation in loop in the air inlet compartment so as to avoid ice formation on air intakes for HVAC, machinery room, and emergency generator room
- heating of whistle
- heating of antennas and similar equipment
- a socket outlet is to be provided close to each lifeboat so as to supply the heating system of lifeboat engine.

8.3.2 The electrical services as indicated in [8.3.1] are considered as essential services. They may be activated manually, when the outside temperature alarm is activated.

8.3.3 The heating power capacity for sizing the de-icing system is to be based on a minimum of 10 $|t_{DE}|$ W/m^2, or 300 W/m^2, whichever is the larger.

8.3.4 When the outside temperature is below –10°C during more than 5 hours, an alarm is to be triggered, so as to inform the personnel that the de-icing system is to be put into service.

8.4 Protection of electrical systems

8.4.1 The heating cables or electrical heating system are to be protected against overload and short circuit.

8.4.2 When heating cables are of the self regulated type, the overload protection may be omitted.

8.4.3 The distribution boards dedicated to the de-icing devices are to be arranged with indication of the devices in service.

8.4.4 The distribution boards dedicated to the de-icing devices are to be arranged with insulation monitoring. A specific alarm dedicated to this service is to be provided.

8.4.5 Where electrical heat tracing is provided in dangerous area, the temperature surface of the cable is not to exceed the maximum temperature allowed for the type of cargo, the ship is entitled to carry.

8.5 De-icing of deck areas

8.5.1 A steam, high pressure hot water, or electrical heating system is to be provided on the exposed deck to allow the de-icing of the ship areas to which the crew may have access during the normal operation of the ship as defined in [4.1.1].

Manual de-icing may be accepted as an alternative method to a limited extent, where such a method is found appropriate and practical.

9 Requirements for notation COLD CARGO

9.1 Application

9.1.1 The requirements of this Article apply to ships having one of the service notation **oil tanker**, **FLS tanker** or **chemical tanker** intended to be loaded with liquid cargoes as defined in [1.1.3].

9.2 Arrangement principles

9.2.1 Arrangements are to be made to:

- avoid excessive ice built-up in the ballast tanks located adjacent to the cargo tanks, which may be detrimental to the ship structure
- avoid freezing of the heating fluid in the cargo heaters and in the piping system supplying the heating medium
- maintain the temperature of the heated cargo in all heaters below its boiling point
- maintain the temperature of the cargo in the tanks below its flash point.

9.3 Design and arrangement of the cargo heating means

9.3.1 General

Arrangements are to be made to heat the cargo during loading and after loading, except that:

- products with a flash point below 60°C are not to be directly heated
- products are not to be directly heated by steam or thermal oil having a temperature exceeding the boiling point of the products.

9.3.2 Heating of the cargo tank trunks

Arrangements are to be made to maintain positive temperature in all cargo tank trunks. A sufficient steam capacity is to be made available for that purpose.

The heaters located in the tank trunks are to comply with the following provisions:

- The heaters are to be kept in permanent operation or drained and isolated after each use so that they may not be rendered inoperative due to ice build-up or thermal oil gelation
- The steam / thermal oil pipes supplying the heaters are to be provided with efficient thermal insulation so as to provide the highest heat level at the heater inlet. The condensate lines are to be provided with heat tracing and suitably insulated
- The valves serving the heaters are to be arranged with heating and thermal insulation allowing their operation in the worst expected conditions
- Means are to be provided to monitor the proper operation of the heaters.

9.3.3 Heating of a cargo tank by the adjacent ballast tanks

Where direct heating of the product is not permitted (see [9.3.1]), the adjacent ballast tanks may be accepted as a heating source for the cargo tanks provided that:

- the ice accretion on the ballast tank walls does not exceed 10% of the tank width (lateral tanks) or height (bottom tanks), which is to be justified by heat transfer calculations
- ballast tanks are provided with de-icing arrangements complying with the provisions of [6.3.3]
- as far as practicable with respect to the ship safety (stability and structural integrity), the level in the ballast tanks is kept as close as possible to the ship waterline.

9.3.4 Circulation of the products in cargo tanks

Arrangements are to be made to circulate the liquid cargo in the tanks during cargo heating-up.

9.3.5 Thermometers and temperature sensors

Temperature sensors and thermometers intended for the cargo are to be suitable for temperatures down to –25°C.

9.4 Risk analysis

9.4.1 The risk analysis is to cover at least the following failures:

- overheating of the cargo due to insufficient circulation, cargo pump failure, etc., which could led to the creation of an explosive atmosphere
- freezing of the heating medium due to the low temperature of the cargo
- excessive ice built-up in the ballast tanks.

9.5 Materials

9.5.1 Plating exposed to cold cargo

The selection of the steel grade for the plating of cargo tank boundary exposed to cold cargo is to be based on the following:

- the design minimum cargo temperature
- the steel grade corresponding to the requirements for material class I at low temperatures as defined in Pt B, Ch 4, Sec 1, Tab 11.

The design minimum cargo temperature is to be specified in the loading manual.

9.5.2 Other structural elements

The steel grades of other structural elements are considered by the Society on a case-by-case basis.

CHAPTER 9
ENVIRONMENTAL PROTECTION

Section 1 General Requirements
Section 2 Notations CLEANSHIP and CLEANSHIP SUPER
Section 3 Notations AWT-A, AWT-B and AWT-A/B
Section 4 Notations BWE and BWT
Section 5 Notations GWT, NDO-x days and OWS-x ppm
Section 6 Notations NOX-x% and SOX-x%
Section 7 EGCS-SCRUBBER and SCRUBBER READY
Section 8 Ultra-Low Emission Vessel (ULEV)
Section 9 Exhaust Gas Measurements (EXGEM)
Section 10 Vapour Control System (VCS)
Section 11 Protected FO Tanks (PROTECTED FO TANKS)
Section 12 Fast Oil Recovery System (FORS)
Section 13 BIOFUEL READY
Section 14 OCC-Prepared

Section 1 General Requirements

1 Scope and application

1.1 General

1.1.1 Unless otherwise specified in Tab 1, this Chapter contains the requirements for additional class notations related to environmental protection.

1.1.2 These additional class notations include:

- **CLEANSHIP** and **CLEANSHIP SUPER** notations,
- other notations having a specific scope and listed in Tab 1.

For the assignment of the **CLEANSHIP SUPER** notation, at least three notations among those referred to as "eligible" in Tab 1, column 4, are also to be assigned.

The relevant symbol, scope, reference to the Rules and assignment conditions are given in Tab 1.

Examples of notations are given below:

- **CLEANSHIP**
- **CLEANSHIP**, **BWE**
- **CLEANSHIP SUPER (AWT-A, NOX-80%, SOX-60%)**
- **OWS-5 ppm**
- **AWT-A/B**, **NDO-2 days**

1.1.3 For ships having a measurement, monitoring, recording and transmission equipment for ships emissions and effluents as per the requirements of Ch 9, Sec 2, [2.1.1], the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER** may be completed by **CEMS**.

Table 1 : Additional class notations for environmental protection

Additional class notations	Scope	Reference to the Rules	Eligible for the assignment of **CLEANSHIP SUPER** notation	Assignment conditions
CLEANSHIP	Prevention of sea and air pollution	Ch 9, Sec 2, [2]	N/A	**CLEANSHIP** may be completed by the notation **CEMS**
CLEANSHIP SUPER	Prevention of sea and air pollution	Ch 9, Sec 2, [2] Ch 9, Sec 2, [3]	N/A	At least 3 eligible notations are to be assigned **CLEANSHIP SUPER** may be completed by the notation **CEMS**
AWT-A or **AWT-B** or **AWT-A/B**	Fitting of an advanced wastewater treatment plant	Ch 9, Sec 3	Yes	
BIOFUEL READY	The ship is prepared for a later installation of biofuel propulsion system	Ch 9, Sec 13	No	
BWE	The ship is designed for ballast water exchange in accordance with the technical provisions of BWM Convention (2004), Regulation D-1	Ch 9, Sec 4, [2]	No	
BWT	Fitting of a ballast water treatment plant	Ch 9, Sec 4, [3]	Yes	
EGCS-SCRUBBER	The ship is fitted with an exhaust gas cleaning system using scrubber(s)	Ch 9, Sec 7, [2]	No	
EXGEM	The level of methane and/or methanol and/or formaldehyd emissions of the gas-fuelled or dualfuel internal combustion engines in the relevant fuel operating mode has been measured	Ch 9, Sec 9	No	
Note 1: N/A = not applicable.				

Additional class notations	Scope	Reference to the Rules	Eligible for the assignment of **CLEANSHIP SUPER** notation	Assignment conditions
FORS	The ship is fitted with two (or more) connectors allowing the recovery of the tank contents	Ch 9, Sec 12	No	
GREEN PASSPORT or **GREEN PASSPORT EU**	Hazardous material inventory	NR528	No	
GWT or **GWT-B**	Fitting of a treatment installation for grey waters	Ch 9, Sec 5, [2]	Yes	
NDO-x days	The ship is designed for no discharge operation during x days	Ch 9, Sec 5, [3]	Yes	
NOX-x%	Average NOx emissions of engines not exceeding x% of IMO Tier II limit	Ch 9, Sec 6, [2]	Yes	
OPS( )	Fitting of a shore connection	Ch 14, Sec 5	Yes	
OWS-x ppm	Fitting of an oily water separator producing effluents having a hydrocarbon content not exceeding x ppm (parts per million)	Ch 9, Sec 5, [4]	Yes	
PROTECTED FO TANK	Protection of the fuel oil tanks	Ch 9, Sec 11	No	
SCRUBBER READY	The ship is prepared for a later installation of an exhaust gas cleaning system (EGCS)	Ch 9, Sec 7	No	
SOX-x%	Oil fuels used within and outside SECAs have a sulphur content not exceeding x% of the relevant IMO limit	Ch 9, Sec 6, [3]	Yes	As an alternative, equivalent arrangements (e.g. exhaust gas cleaning systems) may be accepted
ULEV	The ship is fitted with internal combustion engines having the capacity to emit a low level of pollutants	Ch 9, Sec 8	No	
URN	Prevention of underwater radiated noise pollution	NR614	No	
VCS	The ship is fitted with a vapour control system	Ch 9, Sec 10	No	Applies only to tankers
Note 1: N/A = not applicable.				

2 Definitions and abbreviations

2.1 Definitions related to sea pollution

2.1.1 Hazardous wastes

Hazardous wastes are those wastes composed of substances which are identified as marine pollutants in the International Maritime Dangerous Goods Code (IMDG Code).

Hazardous wastes include in particular:

- photo processing chemicals
- dry cleaning waste
- used paints
- solvents
- heavy metals
- expired chemicals and pharmaceuticals
- waste from printers
- hydrocarbons and chlorinated hydrocarbons
- used fluorescent and mercury vapour light bulbs
- batteries.

Note 1: Empty packagings previously used for the carriage of hazardous substances are considered as hazardous substances.

2.1.2 Wastewater

Wastewater includes both sewage and grey water as defined in [2.1.3] and [2.1.5].

2.1.3 Sewage

Sewage means:

- drainage and other wastes from any form of toilets, urinals, and WC scuppers, here designated as black waters
- drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises
- drainage from spaces containing live animals, or
- other waste waters when mixed with the drainages defined above.

2.1.4 Sewage sludge

Sewage sludge means any solid, semi-solid, or liquid residue removed during the treatment of on-board sewage.

2.1.5 Grey water

Grey water includes drainage from dishwashers, showers, sinks, baths and washbasins, laundry and galleys.

2.1.6 Garbage

Garbage means all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically, except those substances which are defined or listed in Annexes I, II, III and IV to MARPOL 73/78.

Garbage includes all kinds of solid wastes like plastics, paper, oily rags, glass, metal, bottles, and incinerator ash. Food wastes are considered as garbage.

2.1.7 Oil residue (sludge)

Oil residue (sludge) means the residual waste oil products generated during the normal operation of a ship such as those resulting from the purification of fuel or lubricating oil for main or auxiliary machinery, separated waste oil from oil filtering equipment, waste oil collected in drip trays, and waste hydraulic and lubricating oils.

2.1.8 Oil residue (sludge) tank

Oil residue (sludge) tank means a tank which holds oil residue (sludge), and from which sludge may be disposed directly through the standard discharge connection or any other approved means of disposal.

2.1.9 Oily bilge water

Oily bilge water means water which may be contaminated by oil resulting from things such as leakage or maintenance work in machinery spaces. Any liquid entering the bilge system including bilge wells, bilge piping, tank top or bilge holding tanks is considered oily bilge water.

2.1.10 Oily bilge water holding tank

Oily bilge water holding tank means a tank collecting oily bilge water prior to its discharge, transfer or disposal.

2.1.11 Oily wastes

Oily wastes means oil residues (sludge) and oily bilge water.

2.1.12 Advanced wastewater treatment (AWT)

AWT means any treatment of wastewater that goes beyond the secondary or biological water treatment stage and may include the removal of nutrients such as phosphorus and nitrogen and a high percentage of suspended solids.

2.1.13 No discharge condition

No discharge condition means a condition without discharge of hazardous wastes, treated and untreated wastewater, oily wastes or garbage into the sea and without incineration carried out.

Note 1: Where the **AWT-A/B** notation is assigned to the ship, the discharge of treated sewage and treated grey water is allowed under the no discharge condition.

Note 2: In the "No discharge condition", no effluents from exhaust gas cleaning systems may be discharged into the sea.

2.2 Definitions related to air pollution

2.2.1 Emission

Emission means any release of substances, subject to control by Annex VI of MARPOL 73/78, from ships into the atmosphere or sea.

2.2.2 Global warming potential (GWP)

GWP means the climatic warming potential of a greenhouse gas relative to that of carbon dioxide (CO_2), calculated in terms of the 100-year warming potential of one kilogram of a greenhouse gas relative to one kilogram of CO_2.

2.2.3 Ozone depleting substances

Ozone-depleting substances means controlled substances defined in paragraph (4) of article 1 of the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, listed in Annexes A, B, C or E to the said protocol in force at the time of application of Annex VI of MARPOL 73/78.

Ozone-depleting substances that may be found on board the ship include, but are not limited to:

- Halon 1211Bromochlorodifluoromethane
- Halon 1301Bromotrifluoromethane
- Halon 2402 1,2-Dibromo-1,1,2,2-tetrafluoroethane (also known as Halon 114B2)
- CFC-11 Trichlorofluoromethane
- CFC-12 Dichlorodifluoromethane
- CFC-113 Trichloro-1,2,2-trifluoroethane
- CFC-114 1,2-Dichloro-1,1,2,2-tetrafluoroethane
- CFC-115 Chloropentafluoroethane.

2.2.4 NOx technical code

NOx Technical Code means the Revised Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines adopted at MEPC 58 on 10 October 2008 with Resolution MEPC.177(58), as amended by Resolution MEPC.317(74).

2.2.5 Permanently sealed equipment

Permanently sealed equipment are equipment where there is no refrigerant charging connections or potentially removable components containing ozone-depleting substances.

2.2.6 Emission control area

Emission control area means an area where the adoption of special mandatory measures for emissions from ships is required to prevent, reduce and control air pollution from NOx or SOx and particulate matter or all three types of emissions and their attendant adverse impacts on human health and the environment. Emission control areas include those listed in, or designated under, regulations 13 and 14 of Annex VI of MARPOL 73/78.

2.2.7 Shipboard incineration

Shipboard incineration means the incineration of wastes or other matter on board a ship, if such wastes or other matter were generated during normal operation of that ship.

2.2.8 Shipboard incinerator

Shipboard incinerator means a shipboard facility designed for the primary purpose of incineration.

2.3 Abbreviations

2.3.1 ECA

ECA means emission control area.

2.3.2 EGC

EGC means exhaust gas cleaning.

2.3.3 OWS

OWS means oily water separator.

Section 2 Notations CLEANSHIP and CLEANSHIP SUPER

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships assigned the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER**.

1.1.2 Ships assigned the additional class notation **CLEANSHIP** are to comply with the provisions of Article [2].
Ships assigned the additional class notation **CLEANSHIP SUPER** are to comply with the provisions of Articles [2] and [3].

1.1.3 It is a prerequisite for the assignment of **CLEANSHIP** or **CLEANSHIP SUPER** that the ship complies with the following regulations:

- adopted Annexes of the MARPOL 73/78 Convention
- International Convention on the control of harmful anti-fouling systems, 2001.

Note 1: Additional requirements may be imposed by the flag and/or Port State Administration (as defined in Pt A, Ch 1, Sec 1, [1.2.1]).

1.1.4 Initial survey tests

After installation on board, the equipment and systems relevant to the requirements of the present Chapter are to be tested in the presence of the Surveyor under operating conditions. The control, monitoring and alarm systems are also to be tested in the presence of the Surveyor or their functioning is to be simulated according to a procedure agreed with the Society.

1.1.5 Periodical tests

Periodical tests and measurements to be done by the Shipowner are given in Article [4].

1.2 Documents to be submitted

1.2.1 Certificates

The certificates to be submitted for the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER** are listed in Tab 1.

1.2.2 Operational procedures

The operational procedures to be submitted for the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER** are listed in Tab 2.

1.2.3 Plans and documents

The plans and documents to be submitted for the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER** are listed in Tab 3.

Table 1 : Required certificates

Certificate	References
IOPP certificate **(1)**	Annex I of MARPOL 73/78, Appendix II
Type approval certificate of: • 15 ppm bilge separator • 15 ppm bilge alarm	IMO Resolution MEPC.107(49) as amended by MEPC.285(70): • Part 1 of the Annex • Part 2 of the Annex
ISPP certificate **(1)**	Annex IV of MARPOL 73/78, Appendix
Type approval certificate of the sewage system	IMO Resolution MEPC.227(64) as amended by IMO Resolution MEPC.284(70)
Type approval certificate of the incinerator **(2)**	• IMO Resolution MEPC.244(66) as amended by IMO Resolution MEPC.368(79) • Annex VI of MARPOL 73/78, Appendix IV
IAPP certificate **(1)**	• Annex VI of MARPOL 73/78, Appendix I • IMO Resolution MEPC.194(61)

(1) Only where required by MARPOL 73/78 Convention, according to the ship's gross tonnage.
(2) Shipboard incinerator is not required. However, when fitted on board, it is to be type-approved.
(3) Only where required by Annex VI of MARPOL 73/78 Convention, according to the engine power and intended use.
(4) The EIAPP certificate may include a NOx-reducing device as a component of the engine. See NOx Technical Code 2008, regulation 2.2.5.
(5) Where such an equivalent arrangement is provided in pursuance of Annex VI of MARPOL 73/78 Convention, regulation 4.
(6) For ships assigned the notations **CLEANSHIP-CEMS** or **CLEANSHIP SUPER( )-CEMS** (see [2.1.1]).

Certificate	References
EIAPP certificates of diesel engines **(3) (4)**	NOx Technical Code 2008, Appendix I
SOx emission compliance certificate Certificate of unit approval for exhaust gas cleaning system **(5)**	IMO Resolution MEPC.340(77)
IAFS certificate or Declaration on Anti-fouling system	International Convention on the control of Harmful and Anti-fouling systems, 2001, Annex 4, Appendices 1 and 2
Type approval certificate of the measurement, monitoring and recording equipment **(6)**	IMO Resolution MEPC.103(49) for NOx emissions IMO Resolution MEPC.340(77) for SO_2 and CO_2 emissions
(1) Only where required by MARPOL 73/78 Convention, according to the ship's gross tonnage. **(2)** Shipboard incinerator is not required. However, when fitted on board, it is to be type-approved. **(3)** Only where required by Annex VI of MARPOL 73/78 Convention, according to the engine power and intended use. **(4)** The EIAPP certificate may include a NOx-reducing device as a component of the engine. See NOx Technical Code 2008, regulation 2.2.5. **(5)** Where such an equivalent arrangement is provided in pursuance of Annex VI of MARPOL 73/78 Convention, regulation 4. **(6)** For ships assigned the notations **CLEANSHIP-CEMS** or **CLEANSHIP SUPER( )-CEMS** (see [2.1.1]).	

Table 2 : Required operational procedures

Operational procedure	Requirements
Shipboard oil pollution emergency plan **(1)**	IMO Resolution MEPC.54(32) as amended by Resolution MEPC.86(44)
Procedure to prepare and maintain an oil record book **(1)**	Annex I of MARPOL 73/78, Appendix III
Procedure to maintain, operate and troubleshoot bilge water treatment systems	IMO Circular MEPC.1/Circ.677
Bunkering procedure	–
Measures to prevent oil pollution and management and disposal of oil leakage and spillage	–
Sewage and grey water management plan and discharge control plan **(1)**	IMO Resolution MEPC.157(55)
Garbage management plan including procedures to prepare and maintain a garbage record book and hazardous waste procedures **(1)**	• IMO Resolution MEPC.220(63) • IMO Circular MEPC/Circ.317 • Annex V of MARPOL 73/78, Appendix • IMO Resolution MEPC.92(45)
Refrigerant management plan: operating procedure to be followed to minimise the risk and the consequences of refrigerant leakage, under normal and emergency conditions, including: • checking of the piping tightness • recharge • detection of leakage • maintenance and repair	–
Procedure to prepare and maintain the ozone-depleting substances record book	–
NOx emission control plan	–
Fuel oil quality management plan	• Annex VI of MARPOL 73/78, Regulation 18 and Appendix VI • IMO Resolution MEPC.182(59)
Where an exhaust gas cleaning (EGC) system is used: • SOx emission compliance plan • Onboard monitoring manual • Procedure to prepare and maintain the EGC record book	IMO Resolution MEPC.340(77)
Biofouling management plan	IMO Resolution MEPC.378(80)
(1) Only where required by MARPOL 73/78 Convention, according to the ship's gross tonnage.	

Table 3 : Required plans and documents

No.	A/I **(1)**	Documents
1		General:
	I	• general arrangement plan with indication of the waste collection and conveying circuits, storage means and treatment installations intended for the prevention of pollution by oil, sewage, grey waters, garbage and hazardous packaged substances
	I	• capacity plan
	A	• program for a waste source reduction, minimization and recycling
2		Prevention of pollution by oil:
	I	• diagram of the oil residue (sludge) system,
	I	• diagram of the independent clean drain system, where provided
	I	• diagram of the oily bilge system (pumping, treatment, discharge including automatic stopping device and recirculation facilities)
	A	• details of the bilge water holding tank
	A	• calculation of the bilge water holding tank capacity
3		Prevention of pollution by wastewater:
	I	• diagram of the grey water system (collection, treatment, discharge)
	I	• diagram of the sewage system (collection, treatment, discharge)
	A	• details of the sewage holding tank and grey water holding tank
	A	• calculation of the sewage holding tank and grey water holding tank capacity
	I	• description of the sewage treatment plant or comminuting/disinfecting system
4		Prevention of pollution by garbage:
	I	• general information on the equipment intended for collecting, storing, processing and disposing of garbage (except where type-approved and type approval certificate submitted)
	A	• calculation of the necessary storing, processing and disposing capacities
	A	• diagram of control and monitoring systems for garbage handling equipment
5		Prevention of pollution by oil spillage and leakage:
	A	• diagram of the fuel oil and lubricating oil overflow systems
	I	• diagram of the fuel oil and lubricating oil filling, transfer and venting systems
	A	• arrangement of the fuel oil and lubricating oil spillage containment systems
	I	• diagram of the control and monitoring system for fuel oil filling, transfer and overflow systems
	A	• diagram of the stern tube lubricating oil system
6		Prevention of oil pollution in case of collision or stranding:
	I	• arrangement of the fuel oil tanks, lubricating oil tanks and sludge tanks with indication of the volume and of the distance between the tank and the ship base line/ship shell side
7		Prevention of pollution by anti-fouling systems:
	A	• specification of antifouling paint
8		Prevention of pollution by refrigerants and fire-fighting media:
	A	• arrangement of retention facilities including material specifications, structural drawings and welding details, as applicable
	A	• means to isolate portions of the plant so as to avoid release of medium

(1) A = to be submitted for approval ; I = to be submitted for informationl

Note 1: Diagrams are to include information about monitoring and recording of parameters.

2 Design requirements for the additional class notation CLEANSHIP

2.1 Waste management and monitoring

2.1.1 Separation of waste streams

Design arrangements and procedures for collecting, sorting, treating, storing and discharging solid and liquid waste and harmful substances are to be such that the discharge or discharge prohibition criteria laid down in annexes I, IV and V of MARPOL 73/78 Convention can be fulfilled.

2.1.2 Continuous emission monitoring system (CEMS)

Ships having the notation **CEMS** are to be fitted with a measurement, monitoring, recording and transmission equipment as following:

a) On-board emission measurement and monitoring equipment

Ships having the notation **CEMS** are to be provided with a type-approved measurement, monitoring and recording equipment, for:

- NOx emissions, in compliance with IMO Resolution MEPC.103(49)
- SO_2 and CO_2 emissions, in compliance with IMO Resolution MEPC.340(77)

Note 1: Note 1: The correspondence between the SO_2/CO_2 ratio and the sulphur content of the fuel oil is detailed in IMO Resolution MEPC.340(77), Table 1 and Appendix II.

b) Remote transmission of the parameters related to waste discharge and air emissions

The following waste discharge and air emission parameters required to be monitored and recorded are to be transmitted on a regular basis (e.g. every day) via a satellite communication system to a shipowner facility ashore:

- NOx, SO_2 and CO_2 emission records in accordance with [2.1.2], item a)
- Oily waste discharge records, in accordance with [2.2.7]
- Wastewater discharge records, in accordance with [2.3.5], or [3.3.4] as applicable for **CLEANSHIP SUPER** notation
- Garbage waste records, in accordance with [2.4.8]
- For units fitted with a exhaust gas cleaning system, the washwater discharge records, in accordance with IMO Resolution MEPC.340(77) Article 10.

Such information is to be made available to the Surveyor of the Society upon request.

2.2 Oily wastes

2.2.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the following requirements of MARPOL 73/78 Convention, Annex I, and with the relevant unified interpretations:

- Reg. 12 for arrangement and capacity of oil residues (sludge) tanks
- Reg. 13 for standard discharge connection
- Reg. 14 for oil filtering equipment
- Reg. 15 for oil discharge criteria
- Reg. 17 for oil record book (machinery space operations).

2.2.2 Bilge water holding tank

All machinery space bilges and spaces containing hydraulic equipment have to be drained into a bilge water holding tank before separation and oil filtration or discharge ashore. This bilge holding tank is to be separate and independent from the sludge tanks.

Sea or freshwater drains not contaminated by oil may be discharged overboard.

For ships operating with heavy fuel oil having a relative density greater than 0,94 at 15°C, the bilge water holding tank is to be fitted with heating facilities, except if the oily water separator capability to efficiently treat the oily water at ambient temperatures (without heating) is justified.

The bilge water holding tank is to be arranged so as to facilitate the separation of any oil (or oil emulsions resulting from the use of bilge cleaning agents) from the bilge water and the removal of accumulated sediments.

The shore discharge piping system from the bilge water holding tank is to be terminated by the standard discharge connection specified in MARPOL 73/78 Convention, Annex I, Reg. 13.

2.2.3 Oil water separating equipment

The following equipment is to be provided on board and is to comply with IMO Resolution MEPC.107(49) as amended by IMO Resolution 285(70):

- 15 ppm bilge separator
- 15 ppm bilge alarm
- automatic stopping device.

The bilge separator, bilge alarm and automatic stopping device are to be type approved and individually certified by the Society. Existing type approval or certification (e.g. Directive 2014/90/EU) may be considered by the Society.

The capacity of the bilge separator is to take into account the route of the vessel, the volume of the bilge water holding tanks and the separating technology.

The 15 ppm bilge separator and the 15 ppm bilge alarm are to be installed in accordance with the provisions of IMO Resolution MEPC.107(49), paragraph 6, as amended by IMO Resolution 285(70).

2.2.4 Oil residue (sludge) tanks

The minimum capacity of the oil residue (sludge) tank is to be calculated according to the criteria specified in MARPOL Annex I, Unified Interpretation 16.

The arrangement of the oil residue (sludge) tank is to comply with MARPOL Annex I, reg. 12 and is to:

- be provided with a designated pump that is capable of taking suction from the oil residue (sludge) tank(s) for disposal of oil residue (sludge). Oil residue (sludge) may be disposed of directly from the oil residue (sludge) tanks through the standard discharge connection referred to in MARPOL 73/78, Annex I, Reg. 13, or any other approved means of disposal
- have no discharge connections to the bilge system, oily bilge water holding tank(s), tank top or oily water separators unless for arrangement authorized in MARPOL Annex I, reg. 12.3 (see also IACS recommendation 121)
- be designed and constructed so as to facilitate their cleaning and the discharge of residues to reception facilities.

2.2.5 Overboard discharges from the bilge pumping system

The overboard discharge valve of any bilge overboard discharge line, unless passing through the 15 ppm bilge separator, is to be kept shut and provided with lead-sealing arrangements.

Note 1: Note 1: Lead-sealing arrangements is not to be understand as a requirement for the valves to be blanked or physically locked. Emergency bilge discharge, and other overboard discharge valves of similar nature, must be available for use at all times in case of an emergency (SOLAS regulation II-1/21). Valve sealing may be accomplished through use of a breakable seal, electronic tracking, or similar method.

2.2.6 Segregation of oil and water ballast

No ballast water is to be carried in any fuel oil or lubricating oil tank.

2.2.7 Discharge records

Provisions are to be made to record the following parameters related to the oily water discharge:

- date and time of the discharge
- ship location
- quantity and oil content of oily water discharged.

2.2.8 Operational procedures

Operational procedures covering oil pollution prevention are to cover the following topics:

- Procedure to maintain, operate and trouble shoot bilge water treatment systems
- Procedure to prepare and maintain an oil record book.

2.3 Wastewaters

2.3.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** are to comply with the following requirements of MARPOL 73/78 Convention, Annex IV, as amended:

- Reg. 9 for sewage systems
- Reg. 10 for standard discharge connection
- Reg. 11 for discharge criteria.

Note 1: Discharge of grey water is not regulated by MARPOL 73/78 Convention.

Note 2: Attention is drawn to the fact that some national regulations prohibit the discharge of sewage (treated or untreated) and grey water while in port or within other designated areas.

2.3.2 Design and arrangement of the sewage system

a) Ships, other than passenger ships sailing in special area, are to be equipped with one of the following sewage systems:
   - a sewage treatment plant, or
   - a sewage comminuting and disinfecting system fitted with facilities for temporary storage of sewage when the ship is less than 3 nautical miles from the nearest land, or
   - a holding tank of the capacity to the satisfaction of the Society (see [2.3.3]).

b) Passenger ships sailing in special area, are to be equipped with one of the following sewage system:

- a sewage treatment plant, or
- a holding tank of the capacity to the satisfaction of the Society (see [2.3.3]).

Note 1: Special area means area covered by MEPC.264(68) International Code for Ships operating in Polar Waters (Polar Code).

In case a sewage treatment plant is installed on board without sewage holding tank, justifications are to be provided for operation in areas, such as port, where outboard discharge of sewage and treated sewage is not permitted.

2.3.3 Holding tanks

The holding tanks are to be protected against corrosion and fitted with a level indicator and a high level alarm. The provisions of Pt C, Ch 1, Sec 10, [8.11.10] are to be complied with.

The holding tank capacity is to be justified in regards on the ship's intended usage, the maximum number of people on board and the sewage treatment systems installed on board. The wastewater quantities to be considered are to be derived from the experience gained on similar types of ships operated in similar conditions. Where no data are available, the figures listed in Tab 4 are to be used.

The sewage discharge pipes connection to reception facilities are to be fitted with standard discharge connection in accordance with MARPOL, Annex IV, Reg. 10.

Sewage, including drainage from medical premises (see also Pt C, Ch 1, Sec 10, [8.11.10], item d), is to be collected separately from grey water, except if a common treatment installation is installed on board.

Note 1: This does not preclude the mixing of effluents after treatment (e.g. treated sewage mixed with grey water).

Note 2: When sea water is mixed with wastewater (e.g. for the purpose of washing the holding tanks), the discharge requirements for the wastewater apply to the resulting mixture.

Note 3: When categories of wastewater having different discharge requirements are mixed together, the most stringent requirements apply to the resulting mixture.

2.3.4 Sewage treatment plants and piping

Sewage treatment plants are to be of a type approved and individually certified by the Society. Existing type approval or certification (e.g. Directive 2014/90/EU) may be considered by the Society. Sewage treatment plants are to comply with the provisions of IMO Resolution MEPC.227(64), as amended by MEPC.284(70).

Provisions are to be made in the design for easy access points for the purpose of obtaining representative influent and effluent samples.

The capacity of the sewage treatment plant is to be enough to accommodate the maximum number of people on board. The wastewater quantities to be considered are to be derived from the experience gained on similar types of ships operated in similar conditions. Where no data are available, the figures listed in Tab 4 are to be used.

Table 4 : Wastewaters generation quantities

No.	Type of wastewater	Unit	Quantities for			
			Cruise ships	Ro-ro passenger ships designed for night voyages	Ro-ro passenger ships designed for day voyages	Cargo ships
1	Black water	litres/person/day	12 for a vacuum system 100 for a conventional flushing system			
2	Grey water (excluding laundry and galley)	litres/person/day	160	150	50	100
3	Laundry	litres/person/day	80	20	20	40
4	Galley	litres/person/day	90	30	30	60
5	Total grey water (2 + 3 + 4)	litres/person/day	330	200	100	200

2.3.5 Discharge records

Provisions are to be made to record the following parameters related to the sewage discharge:

- date and time of discharge
- position of the ship (latitude and longitude)
- quantity of sewage discharged.

2.3.6 Operational procedures

The sewage and grey water management plan and discharge control plan are to cover the following topics:

- Sewage and grey water installation and maintenance;
- Procedures and arrangement to obtain representative influent and effluent samples;
- Discharge control plan and procedure following requirements and prescription of MARPOL Annex IV, reg.11, MEPC.157(55) "Recommendation on Standards for the Rate of Discharge of Untreated Sewage from Ships", and, as relevant, other regulations such as MEPC.264(68), part II-A, Chapter 4.

2.4 Garbage and hazardous wastes

2.4.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the requirements of MARPOL 73/78, Annex V:

- Reg. 3, 4, 5 and 6 for disposal into the sea criteria
- Reg. 9 for placards, garbage management plans and garbage record-keeping.

2.4.2 Storage and disposal

Except otherwise stated in this Article, storage arrangements are to be provided for all kinds of liquid and solid wastes, with a capacity corresponding to one day operation of the ship.

Note 1: Although disposal into the sea and onboard incineration are possible in the conditions specified in MARPOL 73/78 Convention, storage in view of discharge to port reception facilities is to be given first priority. Attention is drawn to the specific requirements that may be made mandatory by certain flag and/or Port State Administrations (as defined in Pt A, Ch 1, Sec 1, [1.2.1]), which may restrict or prohibit waste discharge and/or incineration in the waters under their jurisdiction.

2.4.3 Handling of hazardous waste

Hazardous wastes are to be collected and stored in separate leakproof containers prior to disposal ashore. The storage capacity is to be sufficient for the average production of 30 days. The contents of all containers are to be clearly marked.

Note 1: Waste fluids associated with photo processing, including X-ray development, may be treated to remove silver for recycling. The effluent from the recovery unit may be led to the grey water provided it contains less than 5 parts per million (ppm). The residues from the recovery unit are to be landed ashore for disposal or recycling.

2.4.4 Collection of garbage

Garbage bins are to be placed at suitable places and within a suitable distance in accommodation spaces and open decks.

Hazardous wastes, plastics and food contaminated wastes are to be collected separately from other wastes.

2.4.5 Storage of garbage

The ship is to have sufficient capacity to store all kinds of garbage produced during one day, taking into account the daily waste generation figures given in Tab 5 and the values of density given in Tab 6.

If incineration is permitted in the areas where the ship is intended to operate, the needed capacity for wastes other than glass and tins may be reduced by 40%, without being less than the needed volume corresponding to one day.

2.4.6 Food wastes

Arrangements are to be made to store food wastes prior to discharge to port reception facilities or, where permitted, disposal into the sea.

The onboard storage capacity is to be sufficient for one day food waste production, taking into account the figures given in Tab 5 and the values of density given in Tab 6.

Where food waste disposal into the sea is permitted, precautions are to be taken to ensure that plastics contaminated by food wastes, like plastic food wrappers, are not discharged to sea with other food wastes.

Table 5 : Garbage generation quantities

No.	Type of garbage	Unit	Quantities for			
			Cruise ships	Ro-ro passenger ships designed for night voyages	Ro-ro passenger ships designed for day voyages	Cargo ships
1	Plastics	kg/person/day	0,1	0,1	0,1	0,1
2	Paper and cardboard	kg/person/day	1,0	1,0	1,0	1,0
3	Glass and tins	kg/person/day	1,0	1,0	1,0	1,0
4	Food wastes	kg/person/day	0,7	0,7	0,7	0,7
5	Total garbage (1 + 2 + 3 + 4)	kg/person/day	2,8	2,8	2,8	2,8

Table 6 : Waste density

Type of waste	Density (kg/m³)	
	Compacted waste	Uncompacted waste
Glass, tin	1600	160
Paper, cardboard, plastic	410	40
Food wastes	–	300

2.4.7 Incinerators

Where fitted, incinerators are to be of a type-approved by the Society and individually certified by the Society. Existing type approval or certification (e.g. Directive 2014/90/EU) may be considered by the Society. Incinerators are to be designed and constructed according to the requirements of:

- MEPC.244(66), as amended by IMO Resolution MEPC.368(79)
- MARPOL Annex VI, Appendix IV.

Proper hazardous waste management procedures including segregating hazardous wastes are to be instituted on board each ship to ensure hazardous wastes are not introduced into the incinerator. In particular, batteries are to be removed from any waste that will be incinerated on board.

2.4.8 Discharge records

Provisions are to be made to record the following parameters related to the garbage discharge:

- date and time of discharge
- ship location (latitude and longitude) or location of ashore discharge facilities
- estimated amounts discharged for each category, including incinerator ash (in cubic meters).

2.4.9 Garbage management plan

Procedures for collection, sorting, processing and disposal of garbage are to be available in the garbage management plan required by MARPOL 73/78, Annex V, Reg. 9.

The garbage management plan is to follow MEPC.220(63) "2012 Guidelines for the development of garbage management Plan". Restrictions to the discharge of garbage into the sea are to be clearly indicated and in accordance to MARPOL Annex V (see also MEPC.295(71) "2017 Guidelines for the implementation of MARPOL Annex V, Table 1").

The garbage management plan is to include procedures in order to make sure that the following hazardous wastes are not discharged at sea nor mixed with other waste streams:

- photo processing waste (including X-ray development fluid waste)
- dry cleaning waste, containing in particular tetrachloroethylene or perchloroethylene (PERC)
- printing materials, like inks, except soy based, non chlorinated hydrocarbon based ink products
- laser printer toner cartridges
- unused and outdated pharmaceuticals
- fluorescent / mercury vapour bulbs
- batteries
- used cleaners, solvents, paints and thinners
- products containing metals such as lead, chromium, copper, cadmium and mercury.

2.5 Hull anti-fouling systems

2.5.1 Compliance with IMO AFS Convention

Ships granted with the additional class notation **CLEANSHIP** are to comply with the relevant requirements of IMO Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001, requiring the complete prohibition of organotin compounds which act as biocides and of cybutryne in anti-fouling systems.

2.5.2 Type-approval of anti-fouling systems

Anti-fouling paints are to be of a type approved by the Society, on the basis of the following criteria:

- the product is to be free of organotin tributyltin (TBT).
- small quantities of organotin compounds acting as a chemical catalyst are allowed provided their concentration does not exceed 2500 mg total tin per kg of dry paint.
- average values of cybutryne are not to exceed 200 mg of cybutryne per kg of dry paint.

2.5.3 Biofouling record book

Provisions are to be made to record the biofouling management activities in accordance with the biofouling management plan, including:

- details of repair and maintenance to the anti-fouling system and the marine growth prevention system,
- in-water inspection and inspection report
- cleaning operation and cleaning reports
- details of operations outside the ship's normal operating profile
- details of relevant performance monitoring parameters used to determine inspection intervals
- contingency action.

2.5.4 Biofouling management plan

The biofouling management plan is to be in accordance with IMO resolution MEPC.378(80).

2.6 Prevention of pollution by oil spillage and leakage

2.6.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with MARPOL 73/78 Convention, Annex I, regulation 12A (Oil fuel tank protection).

2.6.2 Overflow systems

All fuel and lubricating oil tanks having a capacity exceeding 10 m^3 are to be fitted with an overflow system and a high level alarm or a flow alarm in the overflow system. The alarm signal is to be given where the person in charge of the bunkering or transfer operation will normally be located.

As an alternative to the overflow system, the Society may accept spill deck containment system in way of the concerned tank, provided it has a capacity:

- of at least that required in [2.6.3], and
- commensurate with the maximum expected filling flow rate of the tank and the time necessary to activate the shutdown of the transfer pump in case of high level in the tank.

The overflow system is to comply with the provisions of Pt C, Ch 1, Sec 10, [9.3].

2.6.3 Containment systems

On the weather and superstructure decks, each fuel or lubricating oil tank vent, overflow and fill pipe connection and each other area where oil spillage may occur is to be fitted with a fixed deck container or enclosed deck area with a capacity of:

- 80 litres if the gross tonnage of the ship is between 300 and 1600
- 160 litres if the gross tonnage of the ship is greater than 1600.

The deck container or area is to be fitted with a closed drainage system.

Note 1: As an alternative arrangement to the closed drainage system, the Society may accept manual draining by gravity or by means of a portable pump, in conjunction with a suitable procedure covering the draining operation, the disposal of the drained oil and the cleaning of the container.

2.6.4 Stern tube leakage

Sealing glands are to be provided with an oil leak prevention air seal or the stern tube oil is to be of a non-toxic and biodegradable quality approved in accordance with recognized standards.

The oil tanks are to be fitted with a level sensor giving an alarm in case of low level. Arrangements are to be made to record the level of those tanks.

All oil filling or topping up operations are to be recorded.

2.6.5 Oily condensates from venting pipes

Vent pipes from engines crankcases are to be led to a venting box provided with a draining pipe connected to a suitable oily drain tank.

In accordance with NR529, [10.3.1.3], this requirement is not applicable to vent pipes from gas and dual-fuel engines crankcases for which a drip tray is to be fitted with suitable draining arrangement. Procedure covering the draining operation, the disposal of the drained oil and the cleaning of the drip tray are to be provided.

2.6.6 Operational procedures

The onboard operational procedure is to cover:

- measures to prevent oil pollution
- oil leakage and spillage management and disposal, and cleaning of the deck containers.

2.7 Refrigeration systems

2.7.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** are to comply with MARPOL 73/78 Convention, Annex VI, regulation 12 (Ozone Depleting Substances).

2.7.2 Application

The following requirements apply to the ship refrigeration and air conditioning (AC) permanent installations with an initial charge of more than 3 kg or more than 5 tonnes of CO2 equivalent of refrigerant.

They do not apply to permanently sealed equipment as defined in Ch 9, Sec 1, [2.2.7].

2.7.3 Acceptable refrigerants

The use of halogenated substances, including hydrochlorofluorocarbons (HCFCs), as refrigerant is prohibited.

2.7.4 Retention facilities

Refrigeration systems are to be fitted with retention facilities having the capability to retain the volume of refrigerant contained in the largest individual refrigeration unit, should the necessity arise to empty any one unit. The retention facilities may be either:

- fully independent from the refrigeration system, i.e. separate tanks, or
- part of the refrigeration system, i.e. redundant condensors: In this case, the combined capacity of the condensors is to be sufficient to store the total volume of refrigerant in the system considering that any one condensor is unavailable e.g. for repair or maintenance reasons.

The retention facilities may be tanks for liquid media and/or bottles for gaseous media. If only tanks for liquid are used as retention facilities, one or more compressors having the combined capacity to discharge completely the medium from the system into the tanks are to be installed.

2.7.5 Prevention of leakage

The following measures are to be taken in order to avoid deliberate emissions of ozone depleting substances:

- Refrigeration systems are to be designed in such a way as to minimise the risk of medium release in the case of maintenance, repair or servicing.
- Arrangements are to be made to isolate those sections which are to be serviced by a system of valves and by-passes, in such a way as not to stop the operation of the plant, while in service, preventing the risk of release of the medium outside of the plant.
- Means are to be provided to avoid the possibility of leak to the atmosphere of the refrigerants or its vapours in any case of failure of the plant.
- A warning instruction plate stating that deliberate emissions of halogenated substances are prohibited, is to be displayed in the vicinity of the vessels and of the releasing devices.

These requirement does not apply to spaces containing only pipes.

2.7.6 Leak detection

Leak detectors are to be installed in spaces where the medium might leak in order to provide continuous leak monitoring.

Provisions for the following verifications are to be made in the onboard operational procedure:

- Checking by the shipowner of the leakage detection system at least once every 12 months to ensure its proper functioning.
- Additional checking of the refrigerants by trained people for leakage at a frequency shown in Tab 7, depending on the initial charge of the system in tonnes of CO_2 equivalent, and corrective actions and repairs in case of leakage detection

Table 7 : Refrigerant leakage - Leak checks minimum frequency

Charge of fluorinated greenhouse gas, in tonnes of equivalent CO_2	Leak checks maximum interval	
	No leakage detection installed	Leakage detection installed
from 5 up to 50	6 months	12 months
above 50 up to 500	3 months	6 months
up to 500	1 month	3 month

2.7.7 Alarm

Any detection of medium leak is to activate an audible and visible alarm in a normally manned location. The alarm is to be activated when the concentration of refrigerant reaches a value agreed with the Society on a case-by-case basis, considering LEL and limit of toxicity of the refrigerant used in the system.

2.7.8 Records

Provisions are to be made to record:

- recharge, full or partial, of equipment containing ozone depleting substances
- repair or maintenance of equipment containing ozone depleting substances, including:
  - checks for leakage
  - checks of leakage detection system
- discharge of ozone depleting substances to the atmosphere and leakage
- discharge of ozone depleting substances to land-based reception facilities
- supply of ozone depleting substances to the ship, storage location and quantities.

2.7.9 Operational procedures

The refrigerant management plan is to include:

- maintenance procedure
- leakage checking frequency and procedure
- leakage detection system checking frequency and procedure
- list and quantity of all refrigerant on board
- qualification and training of personnel.

2.8 Fire-fighting systems

2.8.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with MARPOL 73/78 Convention, Annex VI, regulation 12 (Ozone Depleting Substances).

2.8.2 Acceptable fire-fighting media

The use of halon and halocarbons media in the fixed and portable fire fighting equipment is prohibited.

2.8.3 Design requirements for fire-fighting systems

Provisions are to be made for the safe containment and disposal of fire-fighting media in case of spillage during maintenance or repair.

2.9 Emission of nitrogen oxides (NOx)

2.9.1 Compliance with MARPOL 73/78

Diesel engines fitted to ships granted with the additional class notation **CLEANSHIP** are to comply with the requirements of:

- MARPOL 73/78, Annex VI, Reg. 13
- NOx Technical Code (2008), as amended.

2.9.2 Application

The following requirements apply to all diesel engines, independently of the service, with a rated power of more than 130 kW, installed on the ship, with the exceptions of:

- emergency diesel engines, diesel engines installed in lifeboats and any other diesel engines intended to be used solely in an emergency situation, independently of their rated power
- engines which are subject to alternative measures for limiting NOx emission, under special consideration of the Society.

Note 1: NOx emissions from gas only engines, gas turbines, boilers and incinerators are not subject to these requirements.

2.9.3 NOx certification of engines

Prior to installation onboard the ship, engines have to be NOx-certified in accordance with the relevant provisions of the NOx Technical Code for the intended application. A valid EIAPP certificate (or statement of compliance) is normally to be issued by the Society.

2.9.4 NOx reduction methods

Where NOx reduction methods (such as water injection, fuel oil emulsification, charge air humidification, exhaust gas after-treatment) are used, they are to be approved by the Society and taken into account in the EIAPP certificate of the engine.

The measurement of NOx emission levels, where required for the control of the reduction process (e.g. to adjust the injection rate of the reduction agent for SCR systems), is to be carried out by means of type-approved analysers.

2.9.5 Urea solutions used for SCR systems

The SCR storage tank containing the chemical treatment fluids is to be protected from excessively high or low temperatures applicable to the particular concentration of the solution. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems. The physical conditions recommended by applicable recognized standards (such as ISO 18611-3) are to be taken into account to ensure that the contents of the aqueous urea tank are maintained to avoid any impairment of the urea solution during storage.

2.9.6 Exhaust gas recirculation (EGR) bleed-off water

a) The discharge of the EGR bleed-off water is to be compliant with MEPC.307(73).

b) The holding tank required by MEPC.307(73) to store the residues from the EGR unit is to have a capacity for 30 days of operation of the ship. The residues holding tanks is also to comply with Pt C, Ch 1, Sec 11, [4.9].

2.10 Emission of sulphur oxides (SOx)

2.10.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the relevant requirements of MARPOL 73/78 Convention, Annex VI and related Guidelines:

- Reg. 13 for Sulphur Oxides (SOx) and Particulate Matter
- Reg. 18 and Appendices V and VI for fuel oil quality
- IMO Resolution MEPC.182(59) for the sampling of fuel oil.

2.10.2 Use of low sulphur fuel oils

Where several types of fuel are used in pursuance of [2.10.1], arrangements are to be made to allow the complete flushing of the high sulphur fuel supply system before entering the emission control area (ECA).

Arrangements are to be made to record the following parameters:

- volume of fuel oil in each tank
- date, time and position of the ship when the fuel change-over operation is completed or started (respectively when entering the ECA or leaving the ECA).

2.10.3 Use of exhaust gas cleaning systems

a) Exhaust gas cleaning (EGC) systems, which may be accepted as an arrangement equivalent to the use of low sulphur fuel oils in pursuance of MARPOL 73/78 Convention, Annex VI, Regulation 4.1, are to be approved in accordance with IMO Resolution MEPC.340(77) "2021 Guidelines for exhaust gas cleaning systems".

b) EGC systems are to be fitted with data measuring, recording and processing devices in accordance with IMO Resolution MEPC.340(77).

c) The discharge washwater is to satisfy the criteria given in IMO Resolution MEPC.340(77).

d) A holding tank having a capacity sufficient to store washwater treatment residues generated by the EGC unit during 30 days operation of the ship is to be provided onboard.

Note 1: Washwater treatment residues generated by the EGC are then delivered ashore to adequate reception facilities in order not to be discharged to the sea or incinerated on board.

e) The EGC system's storage tank containing the chemical treatment fluids is to be protected from excessively high or low temperatures applicable to the particular concentration chemical treatment fluids. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems.

3 Additional design requirements for the additional class notation CLEANSHIP SUPER

3.1 Waste minimization and recycling program

3.1.1 Direct waste minimization and recycling programs involving significant reduction of the waste amounts mentioned in Tab 4 are to be implemented. Such programs are to cover the influence of measures such as:

- Use of technical water (e.g. air conditioning condensate) where possible.
- Use of water recovery systems (e.g. filtering and reuse of laundry water - last rinse use for first wash).
- Reclamation and reuse of properly treated and filtered wastewaters as technical water (e.g. in toilet flushing, laundry, open deck washing). Effluents from water treatment plants may be reused or recycled only if they comply with a recognised quality standard for potable water.
- Active water conservation (e.g. use of reduced flow shower heads, vacuum systems for toilets, laundry equipment that utilizes less water).
- Use of reusable packaging and bulk packaging.
- Replacement of plastic packaging by containers built in other material.
- Minimization of the amount of oily bilge water and processing of the oily bilge water and oil residue (sludge) in accordance with the Integrated Bilge Water Treatment System (IBTS) concept (see IMO Circular MEPC.1/Circ.642, as amended).

3.1.2 In addition to the procedures required in [2.4.9], the garbage management plan is to include the procedures for garbage source reduction, minimization and recycling.

3.2 Oily wastes

3.2.1 The bilge water holding tank is to have a capacity that provides to the ship the flexibility of operation in ports, coastal waters and special areas, without the need to discharge de-oiled water overboard.

The minimum capacity of the bilge water holding tank, in m^3, is not to be less than the value calculated from Tab 8. Lower capacities are to be justified.

Table 8 : Minimum capacity of the bilge water holding tank according to main engine rating

Main engine rating P, in kW **(1)**	Capacity (m^3)
up to 1000	4
above 1000 up to 20000	P / 250
above 20000	40 + P / 500
(1) For diesel-electric propulsions, the main engine rating is to be substituted with the aggregate power of the electric power motors.	

3.3 Wastewaters

3.3.1 Design and arrangement of the sewage and grey water systems

The ship is to be fitted with a sewage system and a grey water system designed and arranged as follows:

- an approved sewage treatment plant or sewage comminuting and disinfecting system is to be provided
- a tank is to be provided for the storage of untreated or treated sewage with a capacity complying with [3.3.2]
- a tank is to be provided for the storage of grey waters with a capacity complying with [3.3.2]
- grey waters from galleys are to be collected separately from other grey waters and led through a grease trap prior to additional treatment, storage or discharge.

Note 1: Treated sewage and grey water holding tanks may be combined together.

Note 2: Plastic garbage is to be separated from sewage and/or grey waters before entering the treatment unit.

3.3.2 Holding tanks

Holding tanks for sewage and grey water are to have a capacity sufficient for 24 hours operation of the ship, having regard to the maximum number of persons on board, the daily production of wastewater given in Tab 1 and other relevant factors.

3.3.3 Sewage sludges

Arrangements are to be made for sludge from sewage treatment to be collected and stored in view of being transferred ashore or, where permitted, incinerated on board.

Where provided, incineration devices are to completely burn the sludge to a dry and inert ash and not to discharge fly ash, malodors or toxic substances.

The capacity of the sewage sludge tanks is to be calculated taking into consideration:

- the maximum period of voyage between ports where sludge can be discharged ashore, or
- the incinerator capacity and whether incineration is permitted in the areas where the ship is intended to operate.

In the absence of precise data, a figure of 30 days is to be used.

Arrangements are to be made to dispose of ashes from sludge incineration ashore.

3.3.4 Discharge records

Provisions are to be made to record the following parameters related to the sewage and grey water discharges:

- date and time of discharge
- position of the ship (latitude and longitude)
- quantity of sewage and/or grey water discharged
- quantity of sludges incinerated or discharged ashore.

3.4 Food wastes

3.4.1 Arrangements are to be made to store food wastes and wastes contaminated with food in high integrity sealed packaging and refrigerated to 5°C.

3.5 Prevention of pollution by oil spillage and leakage

3.5.1 Containment systems

A seven-barrel spill kit containing the following is to be available on board, ready to be used during bunkering operation:

- sorbents sufficient to absorb seven barrels of oil
- non-sparking hand scoops, shovels and buckets
- portable containers suitable for holding seven barrels of recovered solid waste and seven barrels of recovered liquid waste
- a minimum of 60 litres of a deck cleaning agent
- appropriate protective clothing to protect personnel from inhalation hazards, eye exposure and skin contact
- non-sparking portable pumps with appropriate hoses.

3.5.2 Oil detection in cooling water circuits

Hydrocarbon detectors are to be provided in sea water and fresh water cooling systems comprising fuel oil or lubricating oil heat exchangers in order to detect any contamination of the water.

3.6 Protection against oil pollution in the event of collision or grounding

3.6.1 All fuel oil and lubricating oil tanks are to be located in protected locations in accordance with the provisions of Pt C, Ch 1, Sec 10, [11.5.3] item b to item e, and the following conditions:

- tanks containing oil residues (sludges) are to be considered as fuel oil tanks
- the requirement is applicable to all tanks and does not depends on tanks' capacities
- this requirement is applicable to all ships regardless of the aggregate capacity of the fuel oil tanks
- the accidental oil fuel outflow performance standard following MARPOL reg.12A-11 is not to be considered as an alternative.

Note 1: This requirement does not apply to engine lubricating oil drain tanks.

3.7 Prevention of air pollution

3.7.1 All refrigerants used onboard are to have:

- a Global Warming Potential (GWP) not exceeding 2000
- an Ozone Depleting Potential (ODP) equal to zero.

3.7.2 Hydrofluorocarbons (HFC) refrigerants with a GWP above 1500 are not to be used onboard.

4 Onboard tests and measurements

4.1 Application

4.1.1 This Article contains additional requirements applying to the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER**.

4.2 Periodical tests and measurements done by the Shipowner

4.2.1 Purpose

The following tests and measurements, done under the responsibility of the Shipowner, are intended to demonstrate the effective implementation of the waste management procedures and the constant level over time kept by the quality of the effluents discharged at sea.

4.2.2 Initial period tests

During the first year of commercial operation, the Shipowner is to proceed with the following measurements and analyses:

- collection of actual shipboard data’s concerning the volume of wastes generation, using the waste streams as defined in Tab 6
- effluent analyses from the sewage treatment plant, on a yearly basis.

4.2.3 Periodical tests after first year of service

The effluents and wastes usually discharged to sea are to be periodically sampled and analysed by a qualified laboratory. The frequency of these tests in a five-year period is specified in Tab 9.

Tab 10 lists the number of occurrences where the pollutant maximum concentration may exceed the limit concentration specified in Tab 11 for the effluent standard for analyses of waters, without exceeding the reject value.

Test results of the measurements are to be recorded in the wastewater and garbage logbooks and made available to the Surveyor during the periodical surveys.

Table 9 : Frequency of analyses of waste streams after the first year of service

Waste stream	Number of analyses in a 5-year period
Sewage treatment plant effluent analyses	2
Machinery bilge water oil content analyses	2

Table 10 : Permissible number of analyses exceeding limit values

Number of analyses in a 5-year period	Maximum number of analyses above limit
2-5	0
20	2

Table 11 : Analyses standard for waters

Water to be tested	Pollutant	Limit concentration	Reject value
Effluent of oil filtering equipment	Oil	15 ppm	–
Effluent of sewage treatment plant	Thermotolerant coliforms (TC)	100 TC/100 ml	–
	Total suspended solids (TSS)	35 mg/l	–
	5-day biochemical oxygen demand (BOD_5) **(1)**	25 mg/l	–
	Chemical oxygen demand (COD)	125 mg/l	–
(1) BOD_5 is the amount, in milligrams per litre, of oxygen used in the biochemical oxidation of organic matter in five days at 20°C.			

Section 3 Notations AWT-A, AWT-B and AWT-A/B

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having one of the additional class notations **AWT-A**, **AWT-B** or **AWT-A/B**.

1.1.2 Periodical tests and measurements to be done by the Shipowner are given in Article [3].

1.2 Documents to be submitted

1.2.1 Certificates

The type approval certificate of the AWT plant according to Annex IV of IMO MARPOL Convention and showing compliance with the requirements of IMO Resolution MEPC.227(64) as amended by MEPC.284(70) and Article [2], as applicable, is to be submitted.

1.2.2 Operational procedures

The wastewater management plan and discharge control plan are to be submitted.

1.2.3 Plans and documents

The plans and documents to be submitted for the aforementioned additional class notations are listed in Tab 1.

Table 1 : Required plans and documents

No.	A/I **(1)**	Documents
1	I	Diagram of the grey water system (collection, treatment, discharge)
2	I	Diagram of the sewage system (collection, treatment, discharge)
3	A	Details of the sewage holding tank and grey water holding tank
4	A	Calculation of the sewage holding tank and grey water holding tank capacity
5	I	Description of the AWT plant and relevant operating principles
(1) I = to be submitted for information; A = to be submitted for approval **Note 1:** Diagrams are to include information about monitoring and recording of parameters.		

2 Additional class notations AWT-A, AWT-B and AWT-A/B

2.1 Scope

2.1.1 The additional class notations **AWT-A**, **AWT-B** and **AWT-A/B** apply to ships fitted with an advanced wastewater treatment (AWT) plant, capable of treating both sewage and grey waters with an effluent quality complying with the relevant provisions of [2.3.2].

Note 1: Effluents from the AWT plant may be reused or recycled only if they comply with a recognised quality standard for potable water.

2.2 Definitions and abbreviations

2.2.1 Thermotolerant coliforms (TC)

Thermotolerant coliforms means the group of coliform bacteria which produce gas from lactose in 48 hours at 44.5°C.

Note 1: Thermotolerant coliforms are sometimes referred to as “fecal coliforms”. The term thermotolerant coliforms is now accepted as more appropriate, since not all of these organisms are of faecal origin.

2.2.2 TRC

TRC means Total Residual Chlorine. TRC is the chlorine remaining in wastewater at the end of a specified contact period as combined or free chlorine.

2.2.3 TSS

TSS is the pollutant parameter total suspended solids.

2.3 Design of the AWT plant

2.3.1 Required capacity

The capacity of the AWT plant is to be sufficient for the maximum number of persons onboard, taking into account the sewage and grey water quantities given in Ch 9, Sec 2, [2.3.4].

2.3.2 Type approval

In general, AWT plants are to be of a type approved in accordance with the effluent standards mentioned in Tab 2. Specific documentation and test reports justifying compliance with the standards given in Tab 3 may also be taken into consideration on a case-by-case basis.

Table 2 : Effluent standards to be applied for the type approval of AWT plants

Notation	Effluent standards to be applied		
	Standards given in IMO Resolution MEPC.227(64), as amended by MEPC.284(70), paragraph 4.1	Standards given in Tab 3	Standards given in Tab 4
AWT-A	X	X	
AWT-B	X		X
AWT-A/B	X	X	X

Table 3 : Additional effluent standards for the type approval of AWT plants - Notation AWT-A

Parameter	Limit	Reference of the standard
Thermotolerant coliform (TC)	14 TC / 100 ml **(1)**	Alaska Department of Environmental Conservation - General permit 2013DB0004, effective August 29, 2014
Total suspended solid (TSS)	30 Q_i/Q_e mg/l **(1) (2)**	
Total residual chlorine (TRC)	7,5 µg/l	

(1) Geometric mean of the samples taken during the test period.

(2) The dilution factor Q_i/Q_e is equal to the ratio of the influent Q_i (sewage, grey water and other liquid streams to be processed by the treatment plant) to the effluent Q_e (treated wastewater produced by the treatment plant).

Table 4 : Additional effluent standards for the type approval of AWT plants - Notation AWT-B

Parameter	Limit	Reference of the standard
Total nitrogen	20 Q_i/Q_e mg/l or at least 70% reduction **(1) (2)**	IMO Resolution MEPC.227(64), as amended by MEPC.284(70), paragraph 4.2
Total phosphorus	1,0 Q_i/Q_e mg/l or at least 80% reduction **(1) (2)**	IMO Resolution MEPC.227(64), as amended by MEPC.284(70), paragraph 4.2

(1) The dilution factor Q_i/Q_e is equal to the ratio of the influent Q_i (sewage, grey water and other liquid streams to be processed by the treatment plant) to the effluent Q_e (treated wastewater produced by the treatment plant).

(2) Reduction in relation to the load of the influent.

3 Onboard tests and measurements

3.1 Periodical tests and measurements done by the Shipowner

3.1.1 Purpose

The following tests and measurements, done under the responsibility of the Shipowner, are intended to demonstrate the effective implementation of the waste management procedures and the constant level over time kept by the quality of the effluents discharged at sea.

3.1.2 Initial period tests

During the first year of commercial operation, the Shipowner is to perform quarterly effluent measurements and analyses for the Advanced Wastewater Treatment plant installed on board.

3.1.3 Periodical tests after first year of service

The frequency of the effluents and wastes usually discharged to the sea and to be tested in a five-year period, and the number of occurrences where the pollutant maximum concentration may exceed the limit concentration, without exceeding the reject value are specified in Tab 5. Limit concentration and reject values are specified in Tab 6.

Test results of the measurements are to be recorded in the wastewater logbooks and made available to the Surveyor during the periodical surveys.

Table 5 : Frequency of analyses of waste streams after the first year of service

Waste stream	Number of analyses in a 5-year period	Maximum number of analyses above limit
Advanced Wastewater Treatment effluent analyses	20	2

Table 6 : Analyses standard for waters

Water to be tested	Pollutant	Limit concentration	Reject value
Effluent of AWT unit	5-day biochemical oxygen demand (BOD_5) **(1)**	25 mg/l	60 mg/l
	Chemical oxygen demand (COD)	125 mg/l	—
	Total residual chlorine **(2)**	7,5 µg/l	100 µg/l
	Thermotolerant coliforms (TC) **(2)**	14 TC/100 ml	40 TC/100 ml
	Total suspended solids (TSS) **(2)**	30 mg/l	150 mg/l
	Total nitrogen **(3)**	20 mg/l	—
	Total phosphorus **(3)**	1,0 mg/l	—

(1) BOD_5 is the amount, in milligrams per litre, of oxygen used in the biochemical oxidation of organic matter in five days at 20°C.
(2) Only for the notations **AWT-A** and **AWT-A/B**
(3) Only for the notations **AWT-B** and **AWT-A/B**

Section 4 Notations BWE and BWT

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having one of the additional class notations **BWE** or **BWT**.

1.2 Documents to be submitted

1.2.1 Certificates

The certificates to be submitted for the aforementioned additional class notations are listed in Tab 1.

1.2.2 Operational procedures

The operational procedures to be submitted for the aforementioned additional class notations are listed in Tab 2.

1.2.3 Plans and documents

The plans and documents to be submitted for the aforementioned additional class notations are listed in Tab 3.

Table 1 : Required certificates

Notation	Certificate	References
BWT	Type approval certificate of the ballast water management system (BWMS)	IMO BWMS Code
		MEPC.169(57), if the BWMS makes use of active substances

Table 2 : Required operational procedures

Notations	Operational procedure	Requirements
BWE	Ballast water management plan, with procedures to prepare and maintain a Ballast Water Record Book	• IMO Resolution MEPC.127(53) as amended by MEPC.306(73) • IMO Resolution MEPC.387(81) Chapter GUIDANCE FOR SHIPS OPERATING IN CWQ (Challenging Water Conditions)
BWT	As above for **BWE** notation	• IMO Resolution MEPC.127(53) as amended by MEPC.306(73) • IMO Circular BWM.2/Circ.20
	Detailed procedures and information for safe application of active substances	

Table 3 : Required plans and documents

Notations	A/I **(1)**	Documents
BWE	A / I	See IMO Resolution MEPC.149(55) and Pt C, Ch 1, Sec 10
BWT	A / I	See Regulation 5.7 of IMO Resolution MEPC.279(70) or Regulation 5.1 of IMO Resolution MEPC.174(58), as appropriate, and Pt C, Ch 1, Sec 13.
(1) A/I = to be submitted for approval or information, in accordance with the relevant Rules.		

2 Additional class notation BWE

2.1 Scope

2.1.1 The additional class notation **BWE** applies to ships intended for ballast water exchange at sea and whose design is in compliance with the technical provisions of BWM convention (2004), Regulation D-1, and with the requirements of this article.

2.2 Design requirements

2.2.1 Design of the pumping and piping systems

The pumping and piping systems involved in the ballast water exchange are to comply with the provisions of Pt C, Ch 1, Sec 10, [7].

2.2.2 Sediment handling

Arrangements are to be made for:

- monitoring the sediment build up
- cleaning the tanks and removing the sediments
- disposing the sediments to reception facilities.

2.2.3 Ballast water exchange operations

The Ballast water management plan is to describe ballast water exchange procedure in accordance with IMO Resolution MEPC.288(71).

2.2.4 Discharge records

Provisions are to be made to get and record the following parameters related to the ballast water discharge:

- date and time of discharge
- ship location (latitude and longitude)
- amounts of water exchanged
- amount of sediments disposed to reception facilities.

3 Additional class notation BWT

3.1 Scope

3.1.1 The additional class notation **BWT** applies to ships complying with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 and to the relevant Guidelines, and fitted with an approved ballast water treatment system.

3.2 Design and installation requirements

3.2.1 General

The ballast water treatment system is to be designed and installed in accordance with the provisions of Pt C, Ch 1, Sec 13.

3.2.2 Ballast water treatment records

Provisions are to be made to get and record the following parameters related to the ballast water discharge/treatment:

- date and time of ballast water discharge and intake (when the treatment is performed at the intake stage)
- ship location (latitude and longitude)
- date, time, duration and conditions of treatment (at intake or discharge stage, or during voyage)
- amounts of water treated.

Section 5 Notations GWT, NDO-x days and OWS-x ppm

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having one of the additional class notations **GWT**, **GWT-B**, **NDO-x days** or **OWS-x ppm**.

1.2 Documents to be submitted

1.2.1 Certificates

The certificates to be submitted for the aforementioned additional class notations are listed in Tab 1.

1.2.2 Operational procedures

The operational procedures to be submitted for the aforementioned additional class notations are listed in Tab 2.

1.2.3 Plans and documents

The plans and documents to be submitted for the aforementioned additional class notations are listed in Tab 3.

Table 1 : Required certificates

Notations	Certificate	Requirements
GWT or **GWT-B**	Type approval certificate of the grey water treatment plant	See Article [2]
OWS-x ppm	Type approval certificate of the oily water separator with indication of "x ppm" performance	See Article [4]

Table 2 : Required operational procedures

Notations	Operational procedure
GWT or **GWT-B**	Grey water management plan and discharge control plan
NDO-x days	Management and storage plan for liquid effluents and solid waste in case of no-discharge operation
OWS-x ppm	Performance monitoring plan for the oily water separator

Table 3 : Required plans and documents

Notation	A/I **(1)**	Documents
GWT or **GWT-B**	I	• diagram of the grey water system (collection, treatment, discharge)
	A	• details of the grey water holding tank
	A	• calculation of the grey water holding tank capacity
	I	• description of the grey water treatment plant and relevant operating principles
NDO-x days	A	Calculation of the storage capacity for solid wastes and liquid effluents
OWS-x ppm	I	Description of the OWS plant and relevant operating principles
(1) I = to be submitted for information ; A = to be submitted for approval **Note 1:** Diagrams are to include information about monitoring and recording of parameters.		

2 Additional class notation GWT and GWT-B

2.1 Scope

2.1.1 The additional class notations **GWT** and **GWT-B** apply to ships fitted with a grey water treatment system, the effluents of which have a quality complying with the relevant provision of [2.2].

Note 1: Effluents from the grey water treatment plant may be reused or recycled only if they comply with a recognised quality standard for potable water.

2.2 Design of the grey water treatment plant

2.2.1 Required capacity

The capacity of the grey water treatment plant is to be sufficient for the maximum number of persons onboard, taking into account the daily production of grey water given in Ch 9, Sec 2, [2.3.4].

2.2.2 Effluent quality

a) For ships granted with the additional class notation **GWT**, the grey water treatment plant is to be so designed that the minimum level of effluent quality complies with the limits given in IMO Resolution MEPC.227(64) section 4.1.

b) For ships granted with the additional class notation **GWT-B**, in addition to the requirements of item a), the grey water treatment plant is to comply with IMO Resolution MEPC.227(64) section 4.2.

2.2.3 Type tests

Grey water treatment plants are to be type-approved in accordance with the relevant requirements of IMO Resolution MEPC.227(64).

3 Additional class notation NDO-x days

3.1 Scope

3.1.1 The additional class notation NDO-x days applies to ships having sufficient onboard storage capacity for solid waste and liquid effluents, allowing the fully loaded ship to operate under the no discharge condition as defined in Ch 9, Sec 1, [2.1.13], during x consecutive days (no discharge period).

3.2 Design requirements

3.2.1 The storage capacity for each of the following solid and liquid wastes is to be sufficient to allow the no discharge operation of the ship during x days:

- plastics
- paper and cardboard
- glass and tins
- food waste
- sewage (see Note 1)
- grey water (see Note 1)
- sewage sludges (where applicable)
- bilge water
- oil residues (sludge)
- hazardous wastes
- washwater treatment residues from EGC units (where applicable).

Note 1: Storage capacity is not required for treated sewage and treated grey water when the notation **AWT-A/B** is assigned to the ship.

3.2.2 Except otherwise stated, the storage capacities are to be based on:

- the maximum number of persons onboard
- the daily production of solid waste and liquid effluents given in Ch 9, Sec 2, [2.3.4] and Ch 9, Sec 2, [2.4.5].

3.2.3 The minimum capacity required for the bilge water holding tank is not to be less than x times the capacity given in Ch 9, Sec 2, Tab 8. Lower capacity may be accepted upon justification (e.g. based on the experience gained on similar ships).

4 Additional class notation OWS-x ppm

4.1 Scope

4.1.1 The additional class notation **OWS-x ppm** applies to ships fitted with an oily water separator (OWS) capable of producing effluents having a hydrocarbon content not exceeding x ppm.

The OWS performance index x is to be ≤ 10.

Note 1: ppm means parts of oil per million parts of water by volume.

4.2 Design requirements

4.2.1 The OWS is to be type approved and individually certified by the Society. For this purpose:

- the OWS is to comply with the provisions of IMO Resolution MEPC.107(49) as amended by IMO Resolution MEPC.285(70), for an effluent quality of x ppm, and
- the bilge alarm and the automatic stopping device are to be efficient for the x ppm limit.

Existing type approval or certification (e.g. Directive 2014/90/EU) may be considered by the Society.

Section 6 Notations NOX-x% and SOX-x%

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having one of the additional class notations **NOX-x%** or **SOX-x%**.

1.2 Documents to be submitted

1.2.1 Certificates

The certificates to be submitted for the aforementioned additional class notations are listed in Tab 1.

1.2.2 Operational procedures

The operational procedures to be submitted for the aforementioned additional class notations are listed in Tab 2.

1.2.3 Plans and documents

The plans and documents to be submitted for the aforementioned additional class notations are listed in Tab 3.

Table 1 : Required certificates

Notations	Certificate	Requirements
NOX-x%	EIAPP certificates of diesel engines **(1)**	See Article [2]
SOX-x%	Type approval certificate of the exhaust gas cleaning system **(2)**	See Article [3]

(1) The EIAPP certificate may include a NOx-reducing device as a component of the engine. See NOx Technical Code 2008, regulation 2.2.5.

(2) Where such an equivalent arrangement is provided in pursuance of Annex VI of MARPOL 73/78 Convention, regulation 4.

Table 2 : Required operational procedures

Notations	Operational procedure
NOX-x%	NOx emissions control plan
SOX-x%	SOx emissions control plan

Table 3 : Required plans and documents

Notation	A/I **(1)**	Documents
NOX-x%	A	Calculation of the weighted average NOx emission level of the ship
	A	Calculation of the weighted average IMO Tier II NOx emission limit of the ship
SOX-x%		Where low sulphur fuel oils are used:
	I	• diagram of the fuel oil supply systems
	I	• change-over procedure
		Where an exhaust gas cleaning system is fitted:
	I	• description of the system and relevant operating principles

(1) I = to be submitted for information; A = to be submitted for approval

Note 1: Diagrams are to include information about monitoring and recording of parameters.

2 Additional class notation NOX-x%

2.1 Scope

2.1.1 The additional class notation **NOX-x%** applies to ships fitted with diesel engines having a weighted average NOx emission level not exceeding x% of the weighted average IMO Tier II limit.

The NOx performance index x is to be ≤ 90.

2.2 Design requirements

2.2.1 General

The diesel engines to be considered are those referred to in Ch 9, Sec 2, [2.9.2].

NOx reducing devices may be considered if they are covered by the EIAPP certificate of the engine.

2.2.2 Calculation of the weighted average NOx emission level of the ship

The weighted average NOx emission level of the ship [NOx]ship , in g/kWh, is to be calculated as follows:

$$[NOx]_{ship} = \frac{\sum_{i=1}^{n} [NOx]_i \cdot P_i}{\sum_{i=1}^{n} P_i}$$

where:

n : Total number of engines installed on the ship

[NOx]i : NOx emission level of each individual engine as per EIAPP certificate, in g/kWh

In case of engines with several fuel operating modes, the fuel operating mode with the lowest NOx emission level is to be taken into account.

P_i : Rated power of each engine, in kW.

2.2.3 Calculation of the weighted average IMO Tier II NOx emission limit of the ship

The weighted average IMO Tier II NOx emission limit of the ship [IMO]ship, in g/kWh, is to be calculated as follows:

$$[IMO]_{ship} = \frac{\sum_{i=1}^{n} [IMO]_i \cdot P_i}{\sum_{i=1}^{n} P_i}$$

where:

n, P_i : As defined in [2.2.2]

[IMO]i : Applicable IMO Tier II NOx emission limit of each individual engine as per MARPOL 73/78, Annex VI, Reg. 13.4, in g/kWh.

2.2.4 Calculation of the NOx performance index x

The NOx performance index x is to be calculated as follows:

$$x = \frac{[NOx]_{ship}}{[IMO]_{ship}}$$

where:

[NOx]ship :Weighted average NOx emissions for the ship, in g/kWh, as calculated in [2.2.2]

[IMO]ship: Weighted average IMO Tier II NOx emission limit for the ship, in g/kWh, as calculated in [2.2.3].

3 Additional class notation SOX-x%

3.1 Scope

3.1.1 The additional class notation **SOX-x%** applies to ships using fuel oils complying with the following criteria:

- the sulphur content of fuel oils used in emission control areas (ECAs) is not is not to exceed x% of the IMO limit given in MARPOL 73/78, Annex VI, regulation 14.4
- the sulphur content of fuel oils used in other areas is not to exceed x% of the IMO limit given in MARPOL 73/78, Annex VI, regulation 14.1.

The SOx performance index x is to be ≤ 90.

Alternative arrangements may be accepted if the resulting SOx emission reduction is deemed equivalent to that corresponding to the use of fuel oils with reduced sulphur content.

3.2 Design requirements

3.2.1 Use of fuel oils with reduced sulphur content

Where fuel oils with reduced sulphur content are used, the requirements in Ch 9, Sec 2, [2.10] are to be complied with.

3.2.2 Use of exhaust gas cleaning systems as alternative arrangement

Where exhaust gas cleaning systems are used, they are to be approved in accordance with IMO Resolution MEPC.340(77), for a SOx emission performance corresponding to the use of a fuel oil having a sulphur content of x% of the IMO sulphur limit applicable to ECAs.

Provisions of Ch 9, Sec 2, [2.10.3] for data measuring and recording are to be complied with.

Section 7 EGCS-SCRUBBER and SCRUBBER READY

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having one of the additional class notations **EGCS-SCRUBBER** or **SCRUBBER READY**.

2 Additional class notation EGCS-SCRUBBER

2.1 Scope

2.1.1 The additional class notation **EGCS-SCRUBBER** applies to new and existing ships fitted with an exhaust gas cleaning system intended to reduce SOx emissions (Scrubber).

2.2 Documents to be submitted

2.2.1 Certificates

The certificates to be submitted for the aforementioned additional class notations are listed in Tab 1.

2.2.2 Operational procedures

The operational procedures to be submitted for the aforementioned additional class notations are listed in Tab 2.

2.2.3 Plans and documents

The plans and documents to be submitted for the aforementioned additional class notations are listed in Tab 3.

Table 1 : Required certificates for the notation EGCS-SCRUBBER

Certificate	Reference
SOx Emission Compliance Certificate (SECC, issued only for units approved on scheme A)	IMO Resolution MEPC.340(77)

Table 2 : Required operational procedures for the notation EGCS-SCRUBBER

Operational procedure	Requirements
• Exhaust gas cleaning unit Technical Manual (ETM) for unit • Onboard Monitoring Manual (OMM) • EGC record book or Electronic Logging system • SOx Emission Compliance Plan (for ship, SECP)	IMO resolution MEPC.340(77)

Table 3 : Required plans and documents for the notation EGCS-SCRUBBER

A/I **(1)**	Document
I	Specifications and operating instructions of EGCS unit
(1) A = to be submitted for approval; I = to be submitted for information	

2.3 Design and installation requirements

2.3.1 General

Approval, survey and certification of EGC systems are to be carried out in accordance with the provisions of IMO Resolution MEPC.340(77).

The EGC system should be capable of achieving Emission Ratio limit value as given in Tab 4, in accordance with MEPC.340(77).

The scrubbers are to be designed and installed in accordance with the provisions of Pt C, Ch 1, Sec 11.

2.3.2 Scrubber installation onboard existing ships

Where scrubbers are installed aboard an existing ship, special attention is to be paid to the ship structure (e.g reinforcement in way of supporting structure), the ship stability, and the prevention of flooding and fire.

Table 4 : Fuel oil sulphur limits in MARPOL Annex VI Regulations 14.1 and 14.4 and corresponding Emission Ratio limits values

Fuel oil sulphur content (% m/m)	Emission ratio (SO2(ppm)/CO_2(% v/v)
0,50	21,7
0,10	4,3
Note 1: The use of the above Emission Ratio limit values is only applicable when using petroleum-derived distillate or residual fuel oils.	

3 Requirements for the additional class notation SCRUBBER-READY

3.1 Scope of this notation

3.1.1 Purpose of additional notation SCRUBBER READY

The purpose of additional class notation **SCRUBBER READY** is to have the ship prepared for a later installation of an Exhaust Gas Cleaning System (EGCS).

3.1.2 Timing for granting of the additional notation SCRUBBER READY

This notation is normally granted during the construction of the ship in accordance with Pt A, Ch 1, Sec 2, [6.8.13]. It can also be granted for existing ships during an overhaul phase, where it is decided that the installation of an EGCS would be postponed to a later opportunity.

3.1.3 Installation of the exhaust gas cleaning system

The installation of the exhaust gas cleaning system in itself is not covered by this notation. This means that this notation does not cover:

- the class approval of the different parts of the EGCS, including, piping systems, tanks, pressure vessels, pumps, control systems. However, it is supposed that above mentioned items will fulfil the Class requirements when they are installed onboard
- the statutory approval of the different parts of the EGCS.

External openings, inlets and discharges involved by the EGCS, especially those located below the water lines are normally included into the scope of this additional notation in order to avoid dry-docking when the rest of the modifications do not require to (e.g. tank installations might require dry-docking).

3.1.4 Selection of an EGCS

a) the type and Manufacturer of the EGCS is to be declared to the Society by the Yard in agreement with the Owner

b) the declared EGCS should be of an approved type

c) the chosen system may be replaced by another system issued by another Manufacturer with similar characteristics when installed. In this case, the Society will give special consideration when discrepancies between the system considered during application of the additional class notation **SCRUBBER READY** and the actually installed EGCS may require adjustments to the design proposed by Yard during the application of the additional class notation **SCRUBBER READY**.

3.1.5 Review of actual modifications during EGCS installations

Modifications undertaken during actual installation of the EGCS is to be reviewed as mentioned in Pt A, Ch 1, Sec 1, [3.3].

3.1.6 When the EGCS is actually installed on-board, the additional class notation **SCRUBBER READY** will be replaced by the additional class notation **EGCS-SCRUBBER**, provided that all the applicable requirements are complied with. See Pt A, Ch 1, Sec 2, [6.8.12].

3.2 Documentation to be submitted

3.2.1 The documentation submitted to the Society in the scope of additional class notation **SCRUBBER READY** will be stamped as “examined” unless drawings are describing items actually installed during construction or maintenance period where the notation is granted.

3.2.2 The documents to be submitted to the Society are listed in Tab 5.

3.3 General arrangement

3.3.1 The initial or modified design of the ship is to take into account the necessary spaces or zones to accommodate the following installations:

- Scrubber process tank(s)
- Pumps
- Ventilation systems
- Scrubber(s) tower(s)
- Treatment system(s), if applicable
- Access arrangements to added/modified compartment.

3.4 Hull items

3.4.1 The documentation listed in Tab 5 is to contain, as a minimum, the information needed to ensure that:

a) the ship design related to internal structure, whenever modified or not, is able to bear the different components of the EGCS, such as the exhaust gas cleaning device in itself, tanks, pumps and other newly installed piece of equipment, in accordance with the classification Rules

b) the existing ship structures are able to bear parts of the EGCS when installed outside the structure (eg: dry scrubber installed on deck), in accordance with the classification Rules

c) the existing ship structures newly assigned to the operation of the EGCS fit to this new function (eg: existing tanks receiving treatment products or used as retention tank might need a specific coating)

d) the scantlings of hull in way of the new hull openings complies with applicable requirements of the classification Rules

e) the elements of the EGCS installation are taken into account in the general arrangement of the vessel in accordance with Rule requirements

f) the ship remains compliant with the rules for anchoring and mooring, taking into account the increased windage area due to modified funnel, if relevant.

Note 1: Regarding the sea water systems, the attention of the shipyards is drawn on the proper dimensioning of those lines serving EGCS installations.

3.5 Machinery items

3.5.1 The documentation listed in Tab 5 is to contain, as a minimum, the information needed to ensure that:

a) the reserved machinery spaces provide sufficient room for the EGCS. If parts of the EGCS need to be installed outside internal compartments, this review is to be extended as necessary to the exposed decks

b) the new piping systems are interconnected to the existing ones in such a way that the working of the already existing installations is not jeopardized and fulfills the Classification Rules. In particular, means for isolation should already be considered: as a principle, piping systems dedicated to the EGCS are normally not to be permanently connected with other piping systems

Note 1: Attention is drawn on the proper dimensioning of the lines of seawater systems serving EGCS installations.

c) the new piping systems are installed in areas fitting to the material used for piping according the Classification Rules (eg: plastic pipes should be carefully selected when installed in hazardous areas)

d) the pressure drop inside the exhaust line, taking into account the installation of the EGCS, would not overpass the allowances established by the engine or boiler Manufacturer. If additional modifications like the installation of other equipment on the exhaust lines (eg economizer, SCR) is planned during the EGCS installation, these elements are also to be taken into account

e) the tanks newly created or re-assigned are fitted with the proper piping systems as described in Pt C, Ch 1, Sec 11

f) the treatment product tanks, if any, are properly arranged (see Pt C, Ch 1, Sec 11)

g) the means to handle products necessary for the EGCS are properly located and designed

h) the production of fresh water on board will be enough to supply the needs of the ship together with the EGCS

i) heat tracing is available for piping systems carrying liquid substances that are likely to solidify on external cool weather conditions, if any

j) for ship navigating in ice, as a minimum, the operation of the ship at the minimum power allowed for ice condition could be possible with EGCS installations connected to ice sea chests

k) the discharge outlets from the EGCS are not located too close from a sea water inlet. A minimum of 4 meters is to be considered unless it can be demonstrated that no water with a pH less than 7 could be pumped through the inlets

l) the design of the discharge outlets from the EGCS is compliant with statutory requirements as mentioned in MEPC.340(77). This should be checked on the basis of the documentation provided with the chosen EGCS design

m) the additional hull openings not used before the installation of the EGCS are fitted with:
- a discharge valve in closed position, not connected to the remote control system
- a blind flange inboard
- a notice mentioning that the valve should not be operated.

3.6 Electricity items

3.6.1 The documentation listed in Tab 5 is to contain, as a minimum, the information needed to ensure that:

a) the electric load balance is taking into account the new installation of the EGCS

b) the emergency lighting fittings, fire detectors, flooding detection and internal communication systems are provided in EGCS Room/area

c) the capacity of main switchboard and local distribution busbars is sufficient when EGCS is taken into account

d) the short circuit calculation is updated taking into account the EGCS

e) the existing automated systems provide the proper interfacing with the EGCS automation system, in particular the EGCS-IAS and EGCS-GNSS interfaces.

3.7 Safety items

3.7.1 The documentation listed in Tab 5 is to contain, as a minimum, the information needed to ensure that:

a) the categorization of compartments according to Pt C, Ch 4, Sec 5 is updated taking into account the installation of the EGCS

b) the fire fighting systems are updated according to Pt C, Ch 4, Sec 6 taking into account the installation of the EGCS

c) the escape routes are updated according to Pt C, Ch 4, Sec 8 taking into account the installation of the EGCS

d) the ventilation systems are updated taking into account the installation of the EGCS.

3.8 Stability items

3.8.1 The documentation listed in Tab 5 is to contain, as a minimum, the information needed to ensure that:

a) the internal bulkheads properties are not changed. Otherwise, re-assessment of the damage stability is to be undertaken, when relevant

b) the stability criteria applicable to the type of ship considered are still fulfilled after the installation of the EGCS. This assessment is to include not only the weight of the equipment installed but also the weight of the liquid contained normally inside the tanks and piping systems when the EGCS is operated

c) the change in lightship parameters requires a new inclining experiment or a weighing test or not. In the affirmative case, it is to be mentioned in the ship certificate that this experiment or test needs to be undertaken after the EGCS installation.

Table 5 : List of documents to be submitted for the notation SCRUBBER READY

No.	Document
GENERAL	
1	Manufacturer and type of system chosen for the application of the notation **SCRUBBER READY**
2	General arrangement of the ship taking into account the installation of the EGCS
3	Characteristics regarding weight and volume for the main equipment and auxiliaries included in the EGCS and not part of the ship list of equipment before modification
4	Electric and fresh water consumption of the EGCS
5	List of the additional treatment products needed for the proper operation of the EGCS, the Material Safety Data Sheet of these products and recommendations of the Manufacturer and the associated risk analysis
6	The operation Manual of the EGCS
7	Risk analysis about availability of essential systems of ship related to failure of EGCS system (see Pt C, Ch 1, Sec 11, [2.3.1])
HULL	
8	Diagram of scrubber installation, fixation diagram, strength calculation for scrubber transverse supports
9	Holes and penetration drawing
10	Funnel transformation drawing, as necessary
11	Casing transformation drawing, as necessary
12	Tank and Capacity Plan taking into account the installation of the EGCS
13	Details of structure modification intended for the EGCS installation
MACHINERY	
14	Modification on boilers fitted with an EGCS if any and the associated piping systems

No.	Document
15	Drawing of the piping systems connected to the EGCS through pipes or tanks, as foreseen after the installation of the EGCS, including existing and new portions of piping.
16	Drawing of new portions of piping systems related to the installation of the EGCS. This drawing should mention hazardous areas where these piping systems might be installed
17	Drawing of the bilge system including portions serving the compartments where elements of the EGCS are located
17	Pressure drop calculation inside the exhaust gas systems after the installation of the EGCS
19	Arrangement drawing of the machinery spaces involved by the installation of the EGCS
20	Arrangement drawing of the replenishment areas for specific products related to the EGCS
21	Fresh water production and consumption balance when the EGCS needs supply of fresh water
22	Heat tracing for EGCS piping systems
23	Details of the discharge outlets for the EGCS
24	Details of the EGCS inlets for ships navigating in the ice, including the way the EGCS will be operated in this case
ELECTRICITY and AUTOMATION	
25	Electrical power balance, taking into account the EGCS installation
26	Short-circuits current calculation taking into account the EGCS installation (where maximum symmetrical short circuit currents in the main switchboard exceed 50 KA)
27	Technical documentation showing the general arrangement of major electrical components (Power and Distribution Panels, Electrical Motors, etc.)
28	Power Supply arrangement, (depicting Stand-by Power Supply for control system)
29	Single Line Diagram of the Control System
30	Bill of materials used in the automation circuits and references (Manufacturer, type, etc.)
31	List of monitored parameters for alarm/monitoring and safety systems (System's Alarm is to be in line with the requirements as per Pt C, Ch 1, Sec 10, Tab 34)
32	List of electrical cables to be installed along with their relevant type approval certificates.
33	Block diagram showing the interfacing between existing systems and the automation system of the EGCS
FIRE SAFETY	
34	Fire control Plan, updated
35	Diagrams of ventilation/extinction/detection installations if modified or in case of creation of new compartments
36	Categorization of spaces according to Pt C, Ch 4, Sec 5 taking into account the installation of the EGCS with the history of the previous space categorization and type approved/Med (if applicable) certification of the new installed pieces of equipment
37	Status of modified fire fighting systems induced by the installation of the EGCS, as necessary
38	Drawing showing escape routes taking into account the installation of the EGCS, as necessary
STABILITY	
39	Damage control Plan, as necessary
40	Damage control Booklet, as necessary
41	Intact stability calculation taking into account the installation of the EGCS
42	Damage stability calculation taking into account the installation of the EGCS, as necessary

Section 8 Ultra-Low Emission Vessel (ULEV)

Symbols

n : Engine speed, in r/min

n_{hi} : Engine high speed, i.e. highest engine speed where 70% of the maximum power occurs

n_{lo} : Engine low speed, i.e. lowest engine speed where 50% of the maximum power occurs

n_{max} : 100% speed for the corresponding test cycle

P : Engine power, in kW

P_{max} : Maximum power in kW as designed by the engine manufacturer.

1 General

1.1 Scope

1.1.1 This Section applies to ships fitted with internal combustion engines having the capacity to emit gaseous pollutants and particular pollutants at a very low level at the time of assignment of **ULEV** additional class notation. The engines may have the capacity to emit a low level of pollutants in a specific operating mode only, hereafter referred to as "ULEV Mode".

The assignment of **ULEV** additional class notation as defined in Pt A, Ch 1, Sec 2, [6.8.15] is based on the information provided for each engine according to the requirements of this Section.

When granting **ULEV** additional class notation, a memorandum is to be endorsed in order to record the list of engines covered, the fuel(s) with which they have been tested and their ULEV mode if any.

1.2 Application

1.2.1 Engines

All internal combustion engines installed on board are to be in compliance with the requirements of this Section, except:

- engines intended to be used only for emergencies, or solely to power any device or equipment intended to be used only for emergencies on the ship on which it is installed, or engines installed in lifeboats intended to be used only for emergency
- engines with a power equal to or less than 19kW, other than:
  - main propulsion engines; and
  - engines driving electric generators including emergency generator.

1.2.2 **ULEV** additional class notation may be assigned to sea-going ships. The requirements of this Section do not apply to vessels dedicated to operations on inland waterways (including estuaries, rivers, estuary and lakes) falling into the scope of EU Regulation 2016/1628.

1.2.3 **ULEV** additional class notation may be assigned to new constructions or to ships in service as long as the engines installed on board, defined in [1.2.1], comply with the requirements of this Section.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted:

- Documents 1 to 8, as applicable, for each engine, including the after-treatment system if installed
- Documents 9 and 10, as applicable, for the whole ship.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Item
1	I	For each engine: Engine particulars, including exhaust after-treatment system particulars (e.g. Data sheet with general engine information, details of parameters, including engine components, settings and fuel specifications, that may influence the emissions of pollutants, Project Guide, Marine Installation Manual or installation recommendations)
2	I	If applicable, diagram of the reagent dosing system and associated control system
3	I	For each engine: Emission monitoring system specification, if applicable
4	I	For each engine or parent engine: Emission test program
5	A	For each engine or parent engine: Emission test report
(1) A : To be submitted for approval; I : To be submitted for information		

No.	I/A **(1)**	Item
6	A	For each engine's test report: If applicable, definition of the engine family and parent engine, and justification for the selection of the parent engine
7	I	For each engine: Accreditation certificate of the testing laboratory or other document showing compliance with [4.2.2]
8	I	For each engine: Engine maintenance manual, including after-treatment system maintenance manual
9	A	List of all engines installed on board including their purpose and serial number
10	I	General arrangement of the engine, exhaust piping and exhaust after-treatment system on the leadership, if applicable, and on the ULEV sistership
(1) A : To be submitted for approval; I : To be submitted for information		

2 Definitions

2.1

2.1.1 "Auxiliary engine" means an engine that does not directly or indirectly provide propulsion.

2.1.2 "Emission control system" means any device, system or element of design that controls or reduces emissions.

2.1.3 "Engine type" means a group of engines which do not differ in essential engine characteristics.

2.1.4 "Engine family" means a manufacturer's grouping of engine types which, through their design, have similar exhaust emission characteristics, and respect the applicable emission limit values.

2.1.5 "Engine operating mode" means a configuration of the engine control system.

2.1.6 "Gaseous pollutants" means the following pollutants in their gaseous state emitted by an engine: carbon monoxide (CO), total hydrocarbons (HC) and oxides of nitrogen (NO_X); NO_X being nitric oxide (NO) and nitrogen dioxide (NO_2), expressed as NO_2 equivalent.

2.1.7 "Internal combustion engine" or "engine" includes, where they have been installed, the emission control system and the communication interface (hardware and messages) between the engine's electronic control unit(s) and any other powertrain or machinery control unit necessary to comply with the requirements of this notation.

2.1.8 "NO_X Control Diagnostic system (NCD)" means a system on board the engine which has the capability of detecting a NO_X Control Malfunction, and identifying its likely cause by means of information stored in computer memory.

2.1.9 "Parent engine" means an engine type selected from an engine family in such a way that its emissions characteristics are representative of that engine family.

2.1.10 "Particle number" or "PN" means the number of solid particles emitted by an engine with a diameter greater than 23 nm.

2.1.11 "Particulate Control Diagnostic system (PCD)" means a system on board the engine which has a capability of detecting a Particulate Control Malfunction and identifying its likely cause by means of information stored in computer memory.

2.1.12 "Particulate matter" or "PM" means the mass of any material in the gas emitted by an engine that is collected on a specified filter medium after diluting the gas with clean filtered air so that the temperature does not exceed 325 K (52°C).

2.1.13 "Particulate pollutants" means any matter emitted by an engine that is measured as PM or PN.

2.1.14 "Propulsion engine" means any engine other than an auxiliary engine.

2.1.15 "ULEV sister ship" means a sister ship as defined in Pt B, Ch 1, Sec 3, [2.5]. Especially, it means that the engines and emission control system types and arrangement on board are identical to that on the leader ship.

3 Requirements for ULEV additional class notation

3.1 Requirements for the engines

3.1.1 Engine testing and design

Compliance with the requirements of [3.2] is to be demonstrated through testing of an engine type as per [4].

Note 1: Engines type-approved in the scope of EU regulation 2016/1628 may be accepted without further testing, provided that satisfactory documentation is submitted to the Society.

3.1.2 Testing on a parent engine may be accepted to demonstrate that the whole engine family complies with the requirements of [3.2]. For this purpose, the parent engine is to be selected by the engine manufacturer, such that the parent engine incorporates those features that will most adversely affect the pollutant emission level. This engine, in general is to have the highest gaseous and particulate pollutant emission level among all of the engines in the engine family.

Parent engine and engine family are to be defined taking into account the emission control system where fitted.

3.1.3

Testing on a reference engine may be accepted to demonstrate that other engines of the same design installed on board comply with the requirements of [3.2] For this purpose, the reference engine is to be selected in order to incorporate those arrangements on board that will most adversely affect the pollutant emission level. This engine, in general is to have the highest gaseous and particulate pollutant emission level among all of the engines of the same design installed on board.

The reference engine is to be defined taking into account the emission control system where fitted.

3.1.4 It may be considered by the Society that satisfactory measurements performed on the leader ship cover the engines installed on an ULEV sister ship, provided the engines, exhaust lines and emission control systems are documented as identical to the types of the ULEV sister ship.

3.2 Emission levels

3.2.1 The emissions of each engine installed on board, parent engine or reference engine, are to be shown to remain below the thresholds given in Tab 2, based on measurements as detailed in [4]:

Table 2 : Maximum emission levels for ULEV additional class notation

Engine power range P (kW)	CO (g/kWh)	HC **(1)** (g/kWh)	NO_X (g/kWh)	PM mass (g/kWh)	PN (g/kWh)
$19 \le P < 75$	5,00	($HC + NO_X \le 4,70$)		0,30	–
$75 \le P < 130$	5,00	($HC + NO_X \le 5,40$)		0,14	–
$130 \le P < 300$	3,50	1,00	2,10	0,10	–
$P \ge 300$	3,50	0,19	1,80	0,015	10^{12}

(1) For gas fuelled engines and dual fuel engines in gas mode, the maximum allowable HC emission level is to be taken as the lower of:

- 6,19 and
- 0,19 + (9 × GER)

Where GER is the average gas energy ratio over the test cycle defined in [4.2.5].

3.3 Emission control monitoring

3.3.1 NO_X control diagnostic

Electronically controlled engines using electronic control either to determine both the quantity and timing of injecting fuel; or to activate, de-activate or modulate the emission control system used to reduce NO_X are to be equipped with a NO_X Control Diagnostic system (NCD) able to identify the NO_X control malfunctions and their likely causes.

The NCD system is to conclude within 60 minutes of engine operation whether a detectable malfunction is present and, in this case, it is to trigger a visual alarm in the engine control room. It is to be possible to identify which malfunction has been detected.

The NCD system is to record each NO_X control malfunction under a specific code and store it in the onboard computer.

Note 1: A NO_X control malfunction is an attempt to tamper with the NO_X control system of an engine or a malfunction affecting that system that might be due to tampering. NO_X control malfunctions include:

- Impeded exhaust gas recirculation (EGR) valve, and
- Failures of the NO_X Control Diagnostic (NCD) system.

3.3.2 NO_X reagent monitoring

When the NO_X control emission includes the use of a reagent, the following parameters are to be monitored:

- level of reagent in the reagent tank
- reagent quality or concentration, or NO_X concentration
- interruption of reagent dosing.

Inadequate values of these parameters are to trigger a distinct visual alarm in the engine control room. Related incidents are to be recorded in the onboard computer.

3.3.3 Particulate control diagnostic

Engines fitted with a particulate after-treatment system are to be equipped with a Particulate Control Diagnostic system (PCD) able to identify the particulate after-treatment system malfunctions.

In cases where the NO_X control system and the particulate control system share the same physical components (e.g. same substrate, same exhaust gas temperature sensor), these components may be monitored by the NO_X Control Diagnostic system only.

The PCD system is to conclude within the periods of engine operation detailed in Tab 3 whether a detectable malfunction is present and, in this case, it is to trigger a visual alarm in the engine control room. It is to be possible to identify which malfunction has been detected.

The PCD system is to record each particulate control malfunction under a specific code and store it in the onboard computer.

Note 1: A Particulate Control Malfunction is an attempt to tamper with the particulate after-treatment system of an engine or a malfunction affecting the particulate after-treatment system that might be due to tampering. Particulate Control Malfunctions include the types detailed in Tab 3.

Table 3 : Particulate after-treatment system malfunction types and corresponding period within which they are to be detected

Malfunction type	Period of engine operation within which the malfunction is to be detected and stored
Removal of the particulate after-treatment system	60 minutes of non-idle engine operation
Loss of function of the particulate after-treatment system	240 minutes of non-idle engine operation
Failures of the PCD system	60 minutes of engine operation

3.4 ULEV Mode

3.4.1 Engines with several operating modes are to comply with the requirements of [3.2] in at least one operating mode. The operating mode complying with the requirements of [3.2] is hereafter referred to as “the ULEV mode”.

3.4.2 The ULEV mode is to be clearly identified in the engine manual and/or shipboard manual and it is to be possible to record when the engine is operating in the ULEV mode or not.

4 Emission measurements

4.1 Pollutants to be measured

4.1.1 The brake specific emissions of the following pollutants, in g/kWh, are to be measured over the test cycle defined in [4.2.5]:

- Oxides of nitrogen, NO_X
- Hydrocarbons, expressed as total hydrocarbons, HC or THC
- Carbon monoxide, CO
- Particulate matter, PM
- Particle number, PN
- Carbon dioxide, CO_2.

Note 1: Carbon dioxide emissions are to be measured for information only.

4.2 Measurements

4.2.1 General

Measurements of the required pollutants are to be carried out according to the requirements of ISO 8178 series include:

- ISO 8178-1:2020
- ISO 8178-2:2021
- ISO 8178-3:2019
- ISO 8178-4:2020
- ISO 8178-5:2021
- ISO 8178-6:2018
- ISO 8178-7:2015
- ISO 8178-8:2015
- ISO 8178-9:2019

or to similar recognized standards or measurement methodologies deemed acceptable by the Society.

4.2.2 Measurements are to be carried out by a testing laboratory holding an accreditation certificate to ISO/IEC 17025:2017 covering testing methods for the measurement of the required pollutants, which is issued by a national accreditation body.

Note 1: Measurements carried out by, or under the responsibility of, an organisation or body designated as a technical service as defined by EU Regulation 2016/1628 may also be accepted.

4.2.3 Measurements may be carried out on board or at a testing facility.

4.2.4 Measurements of each of the required pollutants are to be carried out during the same trial. Each engine subject to measurement is to be tested separately.

4.2.5 Cycle definition

B-Type test cycles as detailed in ISO 8178-4 are to be applied according to the type and operational speed of each engine, as defined in Tab 4.

Table 4 : B-type ISO 8178-4:2020 test cycles to be applied

	Variable speed engine	Constant speed engine
Propulsion engine	E3	E2
Auxiliary engine	C1	D2

4.2.6 As a complement, for electronically controlled engines using electronic control to determine both the quantity and timing of injecting fuel or using electronic control to activate, de- activate or modulate the emission control system used to reduce NO_X, emission measurements are to be carried out at control points chosen randomly within the engine control area detailed in [4.5]. The number of control points is detailed in Tab 5.

The brake specific emissions of NO_X, HC, CO, PM and PN measured at each individual control point are not to exceed the limits given in Tab 2, multiplied by 2.

Table 5 : Number of control points according to the purpose and operation of the engine

	Variable speed engine	Constant speed engine
Propulsion engine	2	1
Auxiliary engine	3	1

4.2.7 Crankcase emissions

All crankcase emissions, including emissions normally routed into the exhaust after-treatment system and emissions normally discharged to the ambient atmosphere, are to be routed into the emissions sampling system for measurement purposes. Alternatively crankcase emissions may be added by calculation.

4.3 Fuel specification

4.3.1 For oil-fuelled engines, emission measurements as per [4.2] are to be carried out with the engine running on a fuel complying with ISO 8217:2024 and with the engine manufacturer's specification.

4.3.2 For engines fuelled with natural gas, emission measurements as per [4.2] are to be carried out with the engine running successively on the reference fuels G_R and G_{20}, without any manual readjustment to the engine fuelling system between the two tests. One adaptation run is permitted after the change of the fuel. The composition of the reference fuels G_R and G_{20} are detailed in Tab 6 and Tab 7.

Note 1: In case where the reference fuels G_R and G_{20} are not available, emission measurements carried out with the engine running on two fuels with a composition different from that of G_R or G_{20} may be accepted provided that:

- The gas fuel compositions comply with the specification of the engine manufacturer, and
- The impact of the composition of the gas fuel is properly documented based on e.g. test reports and engineering analysis, to the satisfaction of the Society.

4.3.3 For engines fuelled with other fuels, emission measurements as per [4.2] are to be carried out with the engine running on fuels complying with the requirements of ISO 8178-5 or of a similar recognized standard deemed acceptable by the Society.

4.3.4 The fuel composition and properties are to be detailed in the test report.

Table 6 : Composition of the reference fuel G_R

Property	Unit	min.	max.
Molar fraction of methane	mol %	84	89
Molar fraction of ethane	mol %	11	15
Molar fraction of other components (N_2, C_2+, other inert components)	mol %	–	1
Mass concentration of sulphur	mg/m^3	–	10

Table 7 : Composition of the reference fuel G_{20}

Property	Unit	min.	max.
Molar fraction of methane	mol %	99	100
Molar fraction of nitrogen	mol %	–	–
Molar fraction of other components (C_2, C_2+, other inert components)	mol %	–	1
Mass concentration of sulphur	mg/m^3	–	10

4.4 Deterioration factors

4.4.1 The values measured according to [4.2] are to be multiplied by the deterioration factors detailed in Tab 8 for the purpose of demonstrating compliance with the emission limits given in [3.2.1].

These deterioration factors need not be applied if the pollutant emission measurements are carried out on engines and after-treatment systems that have already been used for more than 10 000 hours.

Table 8 : Deterioration factors for ULEV additional class notation

Pollutant	CO	HC	NO_X	PM	PN
Deterioration factor	1,3	1,3	1,15	1,05	1,0

4.4.2 Alternatively, case-by-case deterioration factors may be established based on a suitable testing program accounting for ageing of the engine and exhaust after-treatment system during 10 000 hours.

4.5 Control areas

4.5.1 Control area for variable speed auxiliary engines

The control area for variable speed auxiliary engines is delimited by the following curves (See Fig 1):

- upper torque limit:

  engine full load torque curve

- lower torque limit:

  30% of maximum torque

- lower speed limit:

  $n_{lo} + 0,15 \times (n_{hi} - n_{lo})$

- upper speed limit:

  n_{hi}

- points below 30% of maximum net power are excluded from the control area.

In addition, for engines with maximum net power < 300kW and for particulate matter only, the following areas are excluded from the control area:

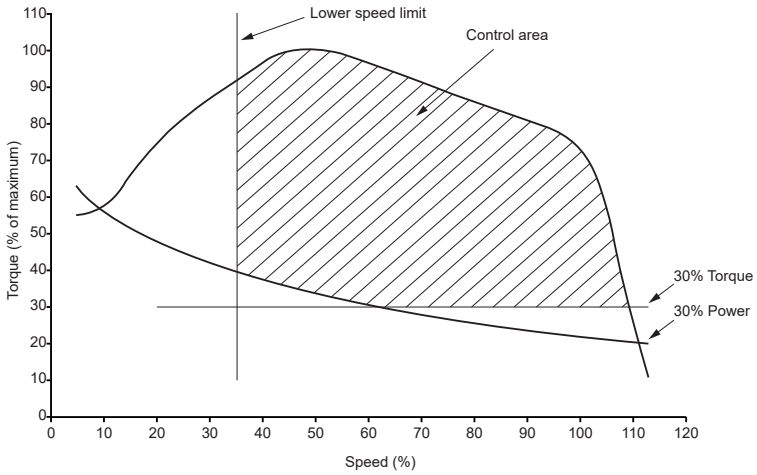
- if $n_C < 2\,400$ r/min, points to the right of or below the line formed by connecting the points of 30% of maximum torque or 30% of maximum net power, whichever is greater, at n_B and 70% of maximum net power at n_{hi}
- if $n_C \geq 2\,400$ r/min, points to the right of the line formed by connecting the points of 30% of maximum torque or 30% of maximum net power, whichever is greater, at n_B, 50% of maximum net power at 2400 r/min, and 70% of maximum net power at n_{hi}

where:

$n_B = n_{lo} + 0,5 \times (n_{hi} - n_{lo})$

$n_C = n_{lo} + 0,75 \times (n_{hi} - n_{lo})$

Figure 1 : Control area for variable speed auxiliary engines



4.5.2 Control area for variable speed propulsion engines

The control area for variable speed propulsion engines is defined as follows (See Fig 2):

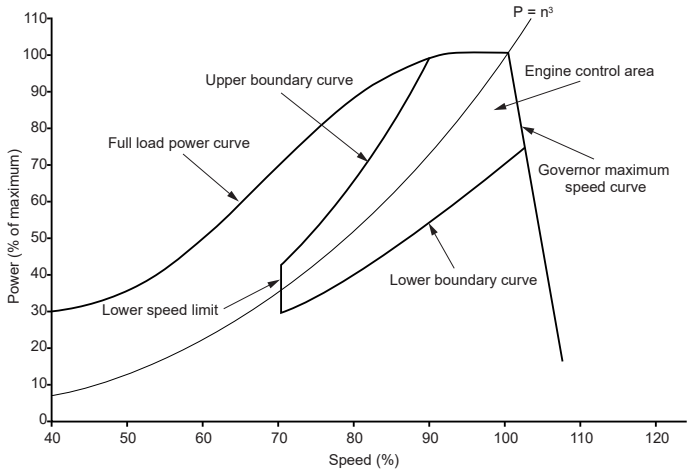
- lower speed limit:
  $0,7 \times n_{max}$
- upper boundary curve:
  $P/P_{max} = 1,45\ (n/n_{max})^{3,5}$
- lower boundary curve:
  $P/P_{max} = 0,7 \times (n/n_{max})^{2,5}$
- upper power limit:
  full load power curve
- upper speed limit:
  maximum speed permitted by governor.

4.5.3 Control area for constant speed propulsion and auxiliary engines

The control area for constant speed engines is defined as:

- speed: 100%
- torque range: between 50% and 100% of the torque corresponding to the engine maximum power.

Figure 2 : Control area for variable speed propulsion engine



5 Onboard surveys

5.1 Initial survey

5.1.1 An onboard survey is to be undertaken by the Surveyor before granting **ULEV** additional class notation in order to check that the general arrangement and engine particulars are consistent with the submitted documents. In particular, the proper operation of the NCD and PCD systems including the associated alarms and the proper operation of recording of the status of engines when operated in the ULEV mode are to be checked in the presence of the Surveyor.

Section 9 Exhaust Gas Measurements (EXGEM)

1 General

1.1 Application

1.1.1 This Section apply to ships fitted with internal combustion engines (including single fuel and/or dual fuel internal combustion engines) for which the level of specific gases emissions are measured according to the methodology described in articles [2] and [3].

The scope of application of this Section includes the following engines:

- Main propulsion engines
- Engines driving electric generator
- Engines driving other auxiliaries when they develop a power of 130kW and above.

The specific gasses emission covered by this Section is, according to the list of gas pollutants mentioned in ISO 8178-1:2020 para. 7.4:

- methane (CH_4)
- methanol (CH_3OH)
- formaldehyde (HCHO).

For the purpose of this Section, “Internal combustion engine” or “engine” includes the emission control system (as defined in [1.3.1]) where installed.

1.2 Additional class notation

1.2.1 In accordance with Pt A, Ch 1, Sec 2 ships complying with the requirements of this Section may be assigned the additional class notation **EXGEM( )** completed between brackets by one or several of the following complementary notation indicating the measured gas pollutants defined in [1.1.1]:

- **CH4** for methane
- **CH3OH** for methanol
- **HCHO** for formaldehyde

The additional class notation **EXGEM** may be completed by:

-AUX, when the level of specified gas emissions has been measured only for auxiliary engines, as identified in IMO NOx Technical Code, section 3.2

-PROP, when the level of specified gas emissions has been measured only for propulsion engines, as identified in IMO NOx Technical Code, section 3.2

-AUX and **-PROP** are not appended to **EXGEM** when the level of specified gas emissions has been measured for single fuel or dual fuel engines installed on board to which these requirements are applicable.

Example:

EXGEM(CH4, CH3OH)

EXGEM(HCHO) -AUX

1.2.2 The assignment of the **EXGEM** additional class notation is based on the information provided for each engine according to the requirements of this Section.

When assigning **EXGEM** additional class notation, a memorandum is to be endorsed in order to record:

a) the list of engines covered, and

b) for each engine:
   - the brake specific emissions of specific gases, in g/kWh and rounded to one decimal place, as defined in [3.5.2]
   - the average level of gas emissions as a mass percentage, in g of gas / g of fuel supplied to the engine and rounded to one decimal place, as defined in [3.5.2]. For this percentage, the mass of pilot fuel shall not be included in the mass of “fuel supplied” considered.

1.3 Definitions

1.3.1 Emission control system

“Emission control system” means any device, system or element of design that controls or reduces emissions.

1.3.2 IMO NOx Technical Code (NTC)

IMO NOx Technical Code or NTC refers to the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines, as amended.

1.4 Documents to be submitted

1.4.1 The Manufacturer is to submit documentation relevant for the gas emission measurement(s) considered:

- If several gas measurements are considered for the same setting of an engine, this is to be clearly mentioned.
- Otherwise, if different settings are considered for the optimisation of specific gas emissions, separate set of documentations are to be delivered to the Society.

1.4.2 In accordance with [1.2.2] and [1.4.1] the documents, listed in Tab 1, are to be submitted for the assignment of the notation **EXGEM**.

- Items 1 to 5: as applicable, for each engine (or parent engine) covered by the requirement of this section (see [2.1]), including the after-treatment system if installed
- Item 6: for the whole ship.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Item
1	I	For each engine: Engine particulars, including emission control system particulars (e.g. Data sheet with general engine information, details of parameters, including engine components, settings and fuel specifications, that may influence the methane emissions, Project Guide, Marine Installation Manual or installation recommendations, Technical file))
2	I	For each engine or parent engine: Emission test program
3	A	For each engine or parent engine: Emission test report
4	A	For each engine's test report: If applicable, definition of the engine family or engine group and parent engine, and justification for the selection of the parent engine
5	I	For each engine: Engine maintenance manual, including after-treatment system maintenance manual if applicable
6	A	For the whole ship: list of all engines installed on board including their purpose and serial number
(1) A: to be submitted for approval ; I: to be submitted for information		

2 Requirements for the EXGEM notation

2.1 Engines

2.1.1 Engine testing and design

The level of gas emissions is to be measured for each engine or parent engine according to [3].

2.1.2 Engine family

Testing on a parent engine may be accepted to assess the level of gas emissions for a whole engine family. For this purpose:

a) The engine family is to be defined as a group of series produced engines which, through their design, are proven to have similar gas emission characteristics, are used as produced and, during installation on board, require no adjustments or modifications which could adversely affect gas emissions. The relevant principles set out in IMO NOx Technical Code, section 4.3 are to be taken into account, focusing on gas emissions instead of NOx emissions.

b) The parent engine is to be selected by the engine manufacturer, on the basis of tests and engineering judgement, such that the parent engine incorporates those features that will most adversely affect the gas emission level. This engine, in general, is to have the highest gas emission level for the applicable test cycle among all of the engines in the engine family or engine group. In case the emissions of several gases are to be measured, justification for the choice of the parent engine is to take into account the expected emission levels of each gas. Testing of several engines or subdivision of the engine family may be needed.

Note 1: The parent engine selected for the purposes of gas emission measurement may be different from the parent engine relevant for NOx measurements provided the parent engine selected for gas emission measurements is already covered by an EIAPP certificate and remains within the setting ranges of the NOx Technical File as defined in the NTC.

c) If engines within the engine family incorporate other variable features which could be considered to affect gases emissions, these features are also to be identified and taken into account in the selection of the parent engine. Where necessary, the engine manufacturer has to test an additional engine, based upon features which indicate that it may have the highest gas emission levels of the engines within that engine family. In case the emissions of several gases are to be measured, justification for the choice of the parent engine is to take into account the expected emission levels of each gas. Testing of several engines or subdivision of the engine family may be needed.

d) The characteristics of the emission control system are to be common among all engines within an engine family.

2.1.3 Engine group

Testing on a parent engine may be accepted to assess the level of gas emissions for a whole engine group. For this purpose:

a) The engine group concept is to be defined as a smaller series of engines produced for similar engine application and which require minor adjustment and modifications during installation or in service on board. The relevant principles set out in IMO NOx Technical Code, section 4.4 are to be taken into account, focusing on gas emissions instead of NOx emissions.

b) The parent engine is to be selected by the engine manufacturer, on the basis of tests and engineering judgement, such that the parent engine incorporates, as far as applicable, those features that will most adversely affect the gas emission level. This engine, in general is to have the highest gas emission level for the applicable test cycle among all of the engines in the engine group.

   The first engine ordered may be registered as the parent engine. If the parent engine is not adjusted to the engine builder defined reference or maximum tolerance operating conditions for the engine group for the test required in [3], the measured gas emission values are to be corrected to the defined reference and maximum tolerance conditions on the basis of emission sensitivity tests on other representative engines.

Note 1: The parent engine selected for the purposes of gas emission measurement may be different from the parent engine relevant for NOx measurements provided the parent engine selected for gas emission measurements is already covered by an EIAPP certificate and remains within the setting ranges of the NOx Technical File as defined in the NTC.

c) If engines within the engine group incorporate other variable features which could be considered to affect gas emissions, these features are also to be identified and taken into account in the selection of the parent engine. Where necessary, the engine manufacturer has to test an additional engine, based upon features which indicate that it may have the highest gas emission levels of the engines within that engine group.

d) The characteristics of the emission control system are to be common among all engines within an engine group.

3 Emission measurements

3.1 Values to be measured

3.1.1 The concentration of gases in the exhaust gases is to be measured at each step of the test cycle defined in IMO NOx Technical Code, section 3.2.

3.1.2 When found relevant by the Manufacturer, all crankcase emissions, including emissions normally routed into the exhaust after-treatment system and emissions normally discharged to the ambient atmosphere, are to be routed into the emissions sampling system for measurement purposes. Alternatively crankcase emissions may be added by calculation.

3.2 Measurement methodology

3.2.1 Measurements are to be carried out on a test bed according to the procedure set out in IMO NOx Technical Code Ch.5. Where provided, the emission control system is to be in use for the test and its functioning parameters are to be recorded. The Society may accept on-board measurement as long as the measurement devices available show the same reliability and accuracy as on a test bed.

3.2.2 Measurements are to be witnessed by a Society's surveyor.

3.2.3 The concentration of gases in the exhaust gases is to be measured and recorded in terms of, or equivalent to, ppm to at least the nearest whole number.

3.2.4 Gas analyser

The gases analysers are to have a measuring range appropriate for the accuracy required to measure the concentration of gases in the exhaust gas, as defined in IMO NOx Technical Code Appendix 3, section 1.6.

The gases analyser and gases measurement set-up are to comply with ISO 8178-1:2020 for gases measurement.

3.3 Test fuel

3.3.1 Emission measurements as per [3.2] are to be carried out with the engine running on a fuel complying with the specification of the engine manufacturer.

3.3.2 A fuel sample is to be collected during the test. The gas fuel is to be analysed to give fuel composition. The gas fuel composition and properties are to be detailed in the test report.

3.3.3 The fuel temperature is to be measured and recorded together with the measurement point position.

3.3.4 Dual fuel engines are to be tested in the mode where the gas emissions needed to be quantified are relevant.

3.4 Data evaluation for gases emissions

3.4.1 For the evaluation of the gaseous emissions, the data recorded for at least the last 60 seconds of each mode is to be averaged, and the concentration of gases during each mode is to be determined from the averaged recorded data and the corresponding zero and span check data. The averaged results are to be given in terms of ppm to at least the nearest whole number.

3.5 Calculation of the gases emissions

3.5.1 The following gases emission values are to be determined according to the methodology given in IMO NOx Technical Code, section 5.12, and rounded to one decimal place:

- brake specific emissions of gases, in g/kWh
- average level of gas emissions as a mass percentage, in g of gas / g of fuel supplied to the engine.

3.5.2 Both the brake specific emissions of gases, in g/kWh, and the average level of gases emissions as a mass percentage, in g of gases per g of fuel supplied to the engine, are to be computed based on measurements on the reference test cycle.

3.5.3 For the purpose of gases emissions calculation values, the ratio between the density of the considered gas and the density of exhaust gas is to be taken as provided in ISO 8178-4:2020 table 6. Duly justified alternative values might be proposed by the manufacturer with the agreement of the Society.

4 Initial survey

4.1 Onboard survey

4.1.1 An onboard survey is to be undertaken by the Surveyor before assigning **EXGEM** additional class notation in order to check that the general arrangement and engine particulars are consistent with the submitted documents.

Section 10 Vapour Control System (VCS)

1 General

1.1 Application

1.1.1 The additional class notation **VCS** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.8.17], to ships fitted with systems for control of vapour emission from cargo tanks complying with the requirements of this Section.

The notation **TRANSFER** is added to the notation **VCS** for ships fitted with systems for control of vapour emission from cargo tanks to another ship and vice versa. Additional requirements for the additional notation **TRANSFER** are given in Article [6].

1.1.2 As a rule, this notation is applicable to ships which are assigned one or more of the following class notations:

- **oil tanker**
- **chemical tanker**
- **FLS tanker**
- **liquefied gas carrier**
- **combination carrier/OOC**
- **combination carrier/OBO**.

1.2 Definitions

1.2.1 Diluted

A flammable gas or mixture is defined as diluted when its concentration in air is less than 50% of its lower explosive limit.

1.2.2 Flammable cargoes

Flammable cargoes are crude oils, petroleum products and chemicals having a flashpoint not exceeding 60 °C (closed cup test) and other substances having equivalent fire risk.

1.2.3 Inerted

Inerted is the condition in which the oxygen content in a flammable gas/air mixture is 8% or less by volume.

1.2.4 Independent

Two electrical systems are considered independent when any one system may continue to operate with a failure of any part of the other system, except the power source and electrical feeder panels.

1.2.5 Lightering operation

Lightering operation is the operation of transferring liquid cargo from one ship to one service ship.

1.2.6 Maximum allowable transfer rate

Maximum allowable transfer rate is the maximum volumetric rate at which a ship may receive cargo or ballast.

1.2.7 Service ship

Service ship is a ship which receives and transports liquid cargoes between a facility and another ship and vice versa.

1.2.8 Ship vapour connection

The ship vapour connection is the point of interface between the ship's fixed vapour collection system and the collection system of a facility or another ship. Hoses or loading arms on board, carried for the purpose of these Rules, are considered part of the vapour control system of the ship.

1.2.9 Terminal vapour connection

The terminal vapour connection is that point at which the terminal vapour collection system is connected to a vapour collection hose or arm.

1.2.10 Topping-off operation

Topping-off is the operation of transfer of liquid cargo from a service ship to another ship in order to load the receiving ship at a deeper draft.

1.2.11 Vapour balancing

Vapour balancing is the transfer of vapour displaced by incoming cargo from the tank of a ship receiving cargo into a tank of a facility delivering cargo via a vapour collection system.

1.2.12 Vapour collection system

The vapour collection system is an arrangement of piping and hoses used to collect vapour emitted from a ship's cargo tank and to transport the vapour to a vapour processing unit.

1.2.13 Vapour processing unit

Vapour processing unit is that component of a vapour control system that recovers or destroys vapour collected from a ship.

1.3 Documentation to be submitted

1.3.1 Tab 1 lists the documents which are to be submitted.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Document
1	A	Diagrammatic plan of the vapour piping system including: • material specifications • dimensions, scantlings and sizes • ratings (temperature/pressure) • joining details • fittings and standards used
2	A	Diagrammatic drawing of the gauging system and overfill protection including: • Manufacturer and type of the instruments • plan of hazardous area locations • location of electrical equipment in gas-dangerous spaces and safe certificates of the electrical instruments intended to be used in hazardous locations • electrical schemes concerning the alarm system supply • electrical schemes concerning the intrinsically safe circuits
3	A	Diagrammatic drawings of the venting system, including necessary data for verifying the venting capacity of the pressure/vacuum valves
4	I	Pressure drop calculations comparing cargo transfer rates versus pressure drops from the farthest tanks to the vapour connection, including any possible hoses
5	I	Calculations showing the time available between alarm setting and overfill at maximum loading rate for each tank
6	A	Instruction manual
7	I	Information on the anti-detonation devices, including Manufacturer and type of the device employed as well as documentation on any acceptance tests carried out, only for ships for which the notation **TRANSFER** is requested
(1) A : to be submitted for approval ; I : to be submitted for information.		

2 Vapour system

2.1 General

2.1.1 Installation of vapour collection system

a) Each ship is to have vapour collection piping permanently installed, with the tanker vapour connection located as close as practical to the loading manifolds.

b) In lieu of permanent piping, chemical tankers may have vapour connections located in the vicinity of each cargo tank in order to preserve segregation of the cargo systems.

2.1.2 Incompatible cargoes

If a tanker simultaneously collects vapour from incompatible cargoes, it is to keep these incompatible vapours separate throughout the entire vapour collection system.

2.1.3 Liquid condensate disposal

Means are to be provided to eliminate liquid condensate which may collect in the system.

2.1.4 Electrical bonding

Vapour collection piping is to be electrically bonded to the hull and is to be electrically continuous.

2.1.5 Inert gas supply isolation

When inert gas distribution piping is used for vapour collection piping, means to isolate the inert gas supply from the vapour collection system are to be provided. The inert gas main isolating valve required in Pt C, Ch 4, Sec 15, [13.4.2] may be used to satisfy this requirement.

2.1.6 Prevention of interference between vapour collection and inert gas systems

The vapour collection system is not to interfere with the proper operation of the cargo tank venting system. However, vapour collection piping may be partly common with the vent piping and/or the inert gas system piping.

2.1.7 Flanges

a) Bolt hole arrangement of vapour connection flanges to the terminal is to be in accordance with Tab 2.

b) Each vapour connection flange is to have permanently attached 12,7 mm diameter studs protruding out of the flange face for at least 25,4 mm.

c) The studs are to be located at the top of the flange, midway between bolt holes and in line with bolt hole patterns.

Table 2 : Bolting arrangement of connecting flanges

Pipe nominal diameter (mm)	Outside diameter of flange (mm)	Bolt circle diameter (mm)	Bolt hole diameter (mm)	Bolt diameter (mm)	Number of bolts
≤ 12,70	88,90	60,45	15,75	12,70	4
≤ 19,05	98,55	69,85	15,75	12,70	4
≤ 25,40	107,95	79,25	15,75	12,70	4
≤ 31,75	117,35	88,90	15,75	12,70	4
≤ 38,10	127,00	98,55	15,75	12,70	4
≤ 50,80	152,40	120,65	19,05	15,87	4
≤ 63,50	177,80	139,70	19,05	15,87	4
≤ 76,20	190,50	152,40	19,05	15,87	4
≤ 88,90	215,90	177,80	19,05	15,87	8
≤ 101,60	228,60	190,50	19,05	15,87	8
≤ 127,00	254,00	215,90	22,35	19,05	8
≤ 152,40	279,40	241,30	22,35	19,05	8
≤ 203,20	342,90	298,45	22,35	19,05	8
≤ 254,00	406,40	361,95	25,40	22,22	12
≤ 304,80	482,60	431,80	25,40	22,22	12
≤ 355,60	533,40	476,25	28,45	25,40	12
≤ 406,40	596,90	539,75	28,45	25,40	16
≤ 457,20	635,00	577,85	31,75	28,54	16
≤ 508,00	698,50	635,00	31,75	28,57	20
≤ 609,60	749,30	749,30	35,05	31,75	20

2.2 Vapour manifold

2.2.1 Isolation valve

a) An isolation valve capable of manual operation is to be provided at the ship vapour connection.

b) The valve is to have an indictor to show clearly whether the valve is in the open or closed position, unless the valve position can be readily determined from the valve handle or valve stem.

2.2.2 Labelling

The vapour manifold is to be:

- for the last 1 m painted red/yellow/red, with the red bands 0,1 m wide and the yellow band 0,8 m wide
- labelled “VAPOUR” in black letters at least 50 mm high.

2.3 Vapour hoses

2.3.1 Hoses

Each hose used for transferring vapour is to have:

- a design burst pressure of at least 0,175 MPa
- a maximum working pressure of at least 0,035 MPa
- the capability of withstanding at least 0,014 MPa vacuum without collapsing or constricting

- electrical continuity with a maximum resistance of 10000 Ω
- resistance to abrasion and kinking
- the last 1 m of each end of the hose marked in accordance with [2.2.2].

For hose flanges see [2.1.7].

2.3.2 Handling equipment

Vapour hose handling equipment is to be provided with hose saddles which provide adequate support to prevent kinking or collapse of hoses.

2.4 Vapour overpressure and vacuum protection

2.4.1 General

The cargo tank venting system is:

a) to be capable of discharging cargo vapour at 1,25 times the maximum transfer rate in such a way that the pressure in the vapour space of each tank connected to the vapour collection system does not exceed:

   1) the maximum working pressure of the tank

   2) the operating pressure of a safety valve or rupture disk, if fitted

b) not to relieve at a pressure corresponding to a pressure in the cargo tank vapour space of less than 0,007 MPa

c) to prevent a vacuum in the cargo tank vapour space that exceeds the maximum design vacuum for any tank which is connected to the vapour collection system, when the tank is discharged at the maximum rate

d) not to relieve at a vacuum corresponding to a vacuum in the cargo tank vapour space less than 0,0035 MPa below the atmospheric pressure.

2.4.2 Pressure/vacuum safety valves

a) Pressure/vacuum safety valves are to be fitted with means to check that the device operates freely and does not remain in the open position.

b) Pressure relief valves are to be fitted with a flame screen at their outlets, unless the valves are designed in such a way as to ensure a vapour discharge velocity of not less than 30 m/second.

3 Instrumentation

3.1 Cargo tank gauging equipment

3.1.1 Each cargo tank that is connected to a vapour collection system is to be equipped with a cargo gauging device which:

- provides a closed gauging arrangement which does not require opening the tank to the atmosphere during cargo transfer
- allows the operator to determine the liquid level in the tank for the full range of liquid levels in the tank
- indicates the liquid level in the tank, at the position where cargo transfer is located
- if portable, is installed on tank during the entire transfer operation.

3.2 Cargo tank high level alarms

3.2.1 General

a) Each cargo tank that is connected to a vapour collection system is to be equipped with an intrinsically safe high level alarm system which alarms before the tank overfill alarm, but not lower than 95% of the tank capacity.

b) The high level alarm is to be identified with the legend “HIGH LEVEL ALARM” and have audible and visible alarm indications that can be seen and heard where the cargo transfer is controlled.

3.2.2 Alarm characteristics

The high level alarm is:

- to be independent of the overfill alarm
- to alarm in the event of loss of power to the alarm system or failure of the electric circuits to the tank level sensors
- to be able to be checked at the tank for proper operation prior to each transfer or contain an electronic self-testing feature which monitors the condition of the alarm circuits and sensors.

3.3 Cargo tank overfill alarms

3.3.1 General

a) Each cargo tank that is connected to a vapour collection system is to be equipped with an intrinsically safe overfill alarm which alarms early enough to allow the person in charge of transfer operation to stop such operation before the cargo tank overflows.

b) The overfill alarm is to be identified with the legend "OVERFILL ALARM" and have audible and visible alarm indications that can be seen and heard where the cargo transfer is controlled and in the deck cargo area.

3.3.2 Alarm characteristics

The overfill alarm is:

- to be independent of both the high level alarm (see [3.2.1]) and the cargo gauging system (see [3.1])
- to alarm in the event of loss of power to the alarm system or failure of the electric circuits to the tank level sensors
- to be able to be checked at the tank for proper operation prior to each transfer or contain an electronic self-testing feature which monitors the condition of the alarm circuits and sensors.

3.4 High and low vapour pressure alarms

3.4.1 Pressure alarms

Each vapour collection system is to be fitted with one or more pressure sensing devices that sense the pressure in the main collection line, and which:

- have a pressure indicator located where the cargo transfer is controlled
- alarm the high pressure at not more than 90% of the lowest relief valve setting in the tank venting system
- alarm at a low pressure of not less than 100 mm WG for an inerted tank, or the lowest vacuum relief valve setting in the cargo venting system for a non-inerted tank.

3.4.2 Equivalence

Pressure sensors fitted in each cargo tank are acceptable as equivalent to pressure sensors fitted in each main vapour collection line.

4 Instruction manual

4.1 General

4.1.1

a) Each ship utilizing a vapour emission control system is to be provided with written operational instructions covering the specific system installed on the ship.

b) Instructions are to encompass the purpose and principles of operation of the vapour emission control system and provide an understanding of the equipment involved and associated hazards. In addition, the instructions are to provide an understanding of the operating procedures, piping connection sequence, start-up procedures, normal operations and emergency procedures.

4.2 Content

4.2.1 The instructions are to contain:

a) a line diagram of the tanker's vapour collection piping including the location of all valves, control devices, pressure-vacuum safety valves, pressure indicators, flame arresters and detonation arresters, if fitted

b) the maximum allowable transfer rate for each group of cargo tanks having the same venting line, determined as the lowest of the following:

   1) 80% of the total venting capacity of the pressure relief valves in the cargo tank venting system

   2) the total vacuum relieving capacity of the vacuum relief valves in the cargo tank venting system

   3) the rate based on pressure drop calculations at which, for a given pressure at the facility vapour connection, or, if lightering, at the vapour connection of the service ship, the pressure in any cargo tank connected to the vapour collection system exceeds 80% of the setting of any pressure relief valve in the cargo tank venting system

c) the initial loading rate for each cargo tank, to be determined in such a way as to minimise the development of a static electrical charge, when applicable

d) tables or graphs of transfer rates (and corresponding vapour collection system pressure drops through the vapour hoses, if foreseen) determined from the most remote cargo tanks to the ship vapour connection as follows:

   1) for each cargo handled by the vapour collection system at the maximum and the lowest transfer rates

   2) based on 50% cargo vapour and air mixture, and a vapour growth rate appropriate for the cargo being loaded

e) the safety valve setting at each pressure-vacuum safety valve.

5 Testing and trials

5.1

5.1.1 General

Machinery and equipment which are part of the vapour collection system are to be tested in compliance with the applicable requirements of the various Sections of the Rules.

5.1.2 Hydrostatic tests

Pressure parts are to be subjected to hydrostatic tests in accordance with the applicable requirements.

5.1.3 Pressure/vacuum valves

Pressure/vacuum valves are to be tested for venting capacity. The test is to be carried out with the flame screen installed if contemplated in accordance with [2.4.2].

5.2 Shipboard trials

5.2.1 Upon completion of construction, in addition to conventional sea trials, specific tests may be required at the Society's discretion in relation to the characteristics of the plant fitted on board.

6 Additional requirements for notation "TRANSFER"

6.1 Application

6.1.1 These requirements are applicable to service ships.

6.2 Equipment

6.2.1 Ships with inerted cargo tanks

If the cargo tanks on a ship discharging cargo and a ship receiving cargo are inerted, the service ship is to have means to inert the vapour transfer hose prior to transferring cargo vapour and an oxygen analyzer with a sensor or sampling connection fitted within 3 m of the ship vapour connection which:

- activates an audible and visual alarm at a location on the service ship where cargo transfer is controlled when the oxygen content in the vapour collection system exceeds 8% by volume
- has an oxygen concentration indicator located on the service ship where the cargo transfer is controlled
- has a connection for injecting a span gas of known concentration for calibration and testing of the oxygen analyser.

6.2.2 Ships with cargo tanks not inerted

If the cargo tanks on a ship discharging cargo are not inerted, the vapour collection line on the service ship is to be fitted with a detonation arrester located within 3 m of the ship vapour connection.

6.2.3 Electrical insulating flange

An electrical insulating flange or one length of non-electrically conductive hose is to be provided between the ship vapour connection on the service ship and the vapour connection on the ship being lightered.

Section 11 Protected FO Tanks (PROTECTED FO TANKS)

1 General

1.1 Application

1.1.1 The provisions of the present Section apply only to ships with an aggregate oil fuel capacity of less than 600 m^3.

Note 1: For ships with an aggregate oil fuel capacity of 600 m^3 and above, the provisions of Pt C, Ch 1, Sec 10, [11.5.3] apply.

1.1.2 The provisions of this Section apply to all oil fuel tanks except small oil fuel tanks, as defined in [1.2.5].

1.2 Definitions

1.2.1 "Oil fuel" means any oil used as fuel oil in connection with the propulsion and auxiliary machinery of the ship in which such oil is carried.

1.2.2 "Length (L)" means 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel the waterline on which this length is measured shall be parallel to the designed waterline. The length (L) shall be measured in metres.

1.2.3 "Breadth (B)" means the maximum breadth of the ship, in metres, measured amidships to the moulded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material.

1.2.4 "Oil fuel tank" means a tank in which oil fuel is carried, but excludes those tanks which would not contain oil fuel in normal operation, such as overflow tanks.

1.2.5 "Small oil fuel tank" is an oil fuel tank with a maximum individual capacity not greater than 30 m^3.

1.2.6 "C" is the ship's total volume of oil fuel, including that of the small oil fuel tanks, in m^3, at 98% tank filling.

1.2.7 "Oil fuel capacity" means the volume of a tank in m^3, at 98% filling.

2 Design requirements

2.1 Distance from the bottom shell plating

2.1.1 Oil fuel tanks are to be located above the moulded line of the bottom shell plating nowhere less than the distance h as specified below:

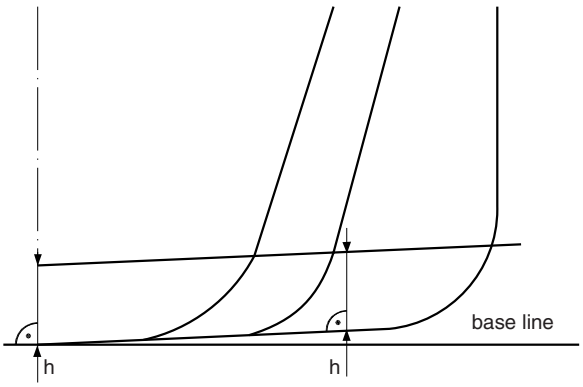
h = B / 20 m or

h = 2,0 m, whichever is the lesser.

The minimum value of h is 0,76 m.

2.1.2 In the turn of the bilge area and at locations without a clearly defined turn of the bilge, the oil fuel tank boundary line shall run parallel to the line of the midship flat bottom as shown in Fig 1.

Figure 1 : Oil fuel boundary lines relating to bottom shell



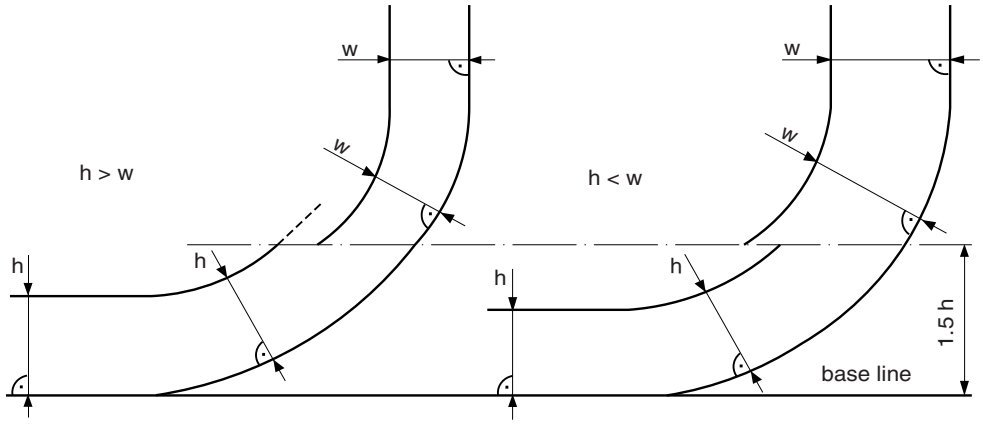
2.2 Distance from the side shell plating

2.2.1 Oil fuel tanks shall be located inboard of the moulded line of the side shell plating, nowhere less than the distance w which, as shown in Fig 2, is measured at any cross-section at right angles to the side shell, as specified below:

w = 0,4 + 2,4 C / 20000 m

The minimum value of w is 0,76 m.

Figure 2 : Oil fuel boundary lines relating to side shell



2.3 Oil fuel piping lines

2.3.1 Lines of oil fuel piping located at a distance from the ship's bottom of less than h, as defined in [2.1], or from the ship's side less than w, as defined in paragraph [2.2] are to be fitted with valves or similar closing devices within or immediately adjacent to the oil fuel tank. These valves are to be capable of being brought into operation from a readily accessible enclosed space the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. The valves are to close in case of remote control system failure (fail in a closed position) and are to be kept closed at sea at any time when the tank contains oil fuel except that they may be opened during oil fuel transfer operations.

2.3.2 The valves or similar closing devices referred to in [2.3.1] above may be located in the double bottom provided they are arranged at a distance from the ship's bottom of not less than 0,5 h.

2.3.3 Air pipes and overflow pipes from oil fuel tanks are not considered as part of the lines of fuel oil piping referred to in [2.3.1] above and may therefore be located at a distance from the ship side of less than w.

2.4 Suction wells

2.4.1 Suctions wells in oil fuel tanks may protrude into the double bottom below the boundary line defined by the distance h provided that such wells are as small as practicable and the distance between the well bottom and the bottom shell plating is not less than 0,5 h.

Section 12 Fast Oil Recovery System (FORS)

1 General

1.1

1.1.1 The additional class notation **FORS** may be assigned to ships with oil fuel tanks and cargo tanks, as applicable, fitted with two (or more) connectors allowing the recovery of the tank contents as follows:

- by injecting sea water through one connector, the tank contents being recovered through the other one, or
- by introducing a submersible pump into the tank through one of the connectors.

1.1.2 The additional class notation **FORS** may be completed by the notation **-NS** when the connectors are intended to be used during the normal service of the ship and, for that purpose, comply with the additional requirements given in Article [3].

1.1.3 For ships not assigned with the notation **-NS**, the connectors may be used only to facilitate the recovery of the tank contents when the ship is damaged or wrecked.

1.2 Documents to be submitted

1.2.1 The plans and documents to be submitted are listed in Tab 1.

1.2.2 The procedures for installation, use and maintenance of the connectors are to be submitted for information.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Exhaustive list of cargo tanks and oil fuel tanks, mentioning their capacity and whether they are fitted with connectors or, alternatively, capacity plan with same information
2	I	Ship layout drawing showing the location and the type of the connectors
3	A	Drawing of each type of connector with indication of wall thickness, material and coating
4	A	Calculation of the maximum allowable flow rate, when the additional notation **-NS** is assigned to the ship
(1) A: to be submitted for approval ; I: to be submitted for information		

1.3 Definitions

1.3.1 Oil fuel

"Oil fuel" means any oil used as fuel oil in connection with the propulsion and auxiliary machinery of the ship in which such oil is carried. For the purpose of this definition, oil residues (sludge) and oily bilge water are not to be considered as oil fuel.

1.3.2 Oil fuel tank

"Oil fuel tank" means a tank in which oil fuel is carried, but excludes those tanks which do not contain oil fuel in normal operation, such as overflow tanks.

1.3.3 Cargo

"Cargo" means a liquid cargo carried in bulk in an oil tanker as defined in SOLAS 74 (as amended), Regulation 2.12, or in a chemical tanker as defined in SOLAS 74 (as amended), Regulation 3.19.

1.3.4 Cargo tank

"Cargo tank" means a tank in which cargo as defined in [1.3.2] above is carried. It includes slop tanks.

1.3.5 Tank

For the purpose of the **FORS** notation, a tank means either an oil fuel tank or a cargo tank.

1.3.6 Connector

A connector means a pipe section fitted with a flange sealed by a blind flange. It may be:

- a "Tee" pipe section inserted in a piping system connected to the tank top and which cannot be isolated from the tank,
- a dedicated pipe section directly connected to the tank, which may extend or not below the tank top plating.

1.3.7 Fast oil recovery system

The fast oil recovery system is a set of connectors designed and arranged in compliance with the requirements below.

2 Requirements for the design and installation of the connectors

2.1 General

2.1.1 The following tanks are to be fitted with connectors:

- all cargo tanks, irrespective of their capacity,
- oil fuel tanks having a capacity of more than:
  - 30 m^3 when the aggregate oil fuel capacity of the ship is less than 600 m^3
  - 5% of the aggregate oil fuel capacity when that capacity is of 600 m^3 or more

2.1.2 Unless otherwise specified, the design and installation of the connectors are to comply with the applicable provisions of the Rules.

2.1.3 The installation of the connectors is not to affect the safe operation of the piping systems connected to the tank nor to result in an increase of the pressure or vacuum in the tank during the normal pumping operations, likely to exceed its design pressure.

2.2 Number of connectors

2.2.1 The number of connectors is to be in accordance with the recommendations of the fast oil recovery system's designer.

2.2.2 Where tanks are required to be fitted with connectors in pursuance of [2.1.1], at least two connectors are to be provided.

Note 1: Where tanks are interconnected (e.g. through an overflow piping system) common connectors may be used.

2.3 Design of the connectors

2.3.1 Materials

Materials used for the connectors and gaskets are to comply with the relevant provisions of Pt C, Ch 1, Sec 10 and are to be suitable for the characteristics of the concerned fluids.

2.3.2 Thickness

The thickness of the connectors is not to be less than:

- the minimum value indicated in Pt C, Ch 1, Sec 10, Tab 6, column 2, if the connector is fitted to the tank
- that of the adjacent pipe if the connector is fitted to a pipe.

2.3.3 Flanges

The connector flange and blind counter-flange intended for the hose connection are to have a nominal diameter of 200 mm and to be designed in accordance with a recognised standard.

2.4 Installation and access

2.4.1 Fitting of the connectors to a piping system

The following piping systems may be used for the installation of the connectors:

- venting pipe
- sounding pipe
- overflow pipe
- drop line
- pressure / vacuum valve header
- sampling pipe.

2.4.2 Fitting of the connectors to the tank top

Connectors fitted to the tank top are to be welded:

- to the tank plating, or
- to an access cover (such as man hole cover, tank cleaning hatch cover, etc.).

2.4.3 Inclination angle and height of the connectors

The connectors may be installed vertically, horizontally or in inclined position.

The height of the connector flange above the deck is not to be less than 200 mm.

2.4.4 Free passage area

The installation of a connector is not to reduce the free passage area of the concerned pipe line.

2.4.5 Bending radius

Where the connectors are intended for the introduction of a submersible pump into the tank, the bending radius of the concerned pipe line is not to be less than 1 meter.

2.4.6 Prevention of progressive flooding

Connector pipes are to satisfy the criteria for the prevention of progressive flooding given in Pt C, Ch 1, Sec 10, [5.5]

2.4.7 Supporting of the connectors

Where necessary, brackets or alternative means of support are to be provided. Refer to Pt C, Ch 1, Sec 10, [9.1.9].

2.4.8 Name plates and warning plates

Each connector is to be fitted with:

a) a name plate giving the following information:

1) identification of the tank

2) nature of the tank content (oil fuel or cargo)

3) volume of the tank

4) purpose of the connector (water injection, oil recovery, introduction of a submersible pump, as applicable)

5) distance between the connector flange and the lowest allowable position of the submersible pump, where applicable

b) a warning plate indicating that the connector is not to be used during the normal operation of the ship, except if the notation **-NS** is assigned to the ship.

2.4.9 Access

A free zone is to be arranged in way of each connector to ensure easy access. This zone is to include at least the volume defined as follows:

- 200 mm from the flange circumference
- between 100 and 2500 mm from the connector flange plane.

3 Additional requirements for -NS notation

3.1 General

3.1.1 The provisions of this Article apply to the ships assigned the additional notation **-NS**, i.e. where the connectors are intended to be used during the normal service of the ship.

3.2 Requirements

3.2.1 Principle

The use of the connectors may not under any circumstances cause:

- an excessive vacuum or pressure in the tank likely to affect the tank structure
- a damage of any component of the piping systems connected to the tank, in particular the air pipe automatic closing devices.

3.2.2 Maximum allowable flow rate

The maximum allowable flow rate is to be indicated and justified for each connector, taking into account:

- the pressure losses in the air pipe
- the design static head of the tank
- the characteristics of the air pipe automatic closing device, if any.

Note 1: The air pipe automatic closing devices are to be of a type approved by BV for the worst expected conditions. Refer to Pt C, Ch 1, Sec 10, [9.1.6] and Pt C, Ch 1, Sec 10, [20.3].

3.2.3 Name plate

The name plate referred to in [2.4.8], item a) above is also to include the value of the maximum flow rate allowed for the connector.

Section 13 BIOFUEL READY

1 General

1.1 Scope

1.1.1 The additional class notation **BIOFUEL READY** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.8.20], to new or existing ships for which the use of biofuel has been technically analysed and, if applicable, tested.

When granting the additional class notation **BIOFUEL READY**, a memorandum is to be endorsed in order to record:

- the specification of the biofuel(s) intended to be used, the blend ratio(s) and the type(s) of blend(s) (including fossil fuel specification)
- the list of engines covered and their main destination (auxiliary or propulsion).

1.2 Application

1.2.1 Engines

The following internal combustion engines are to comply with the requirements of this Section:

- main propulsion engines
- engines driving electric generators
- engines driving other auxiliaries essential for safety and navigation and cargo pumps in tankers, when they develop a power of 110 kW and over.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

1.4 Definitions and abbreviations

1.4.1 IMO NOx Technical Code or NTC refers to the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines, as amended.

1.4.2 Biofuel means fuel oil which is derived from biomass and hence includes, but is not limited to, processed used cooking oils, fatty-acid-methyl-esters (FAME) or fatty-acid-ethyl-esters (FAEE), straight vegetable oils (SVO), hydrotreated vegetable oils (HVO), glycerol or other biomass to liquid (BTL) type products.

1.4.3 Biofuel blend means a blend of biofuel and fossil fuel oil.

1.4.4 Blend ratio means the mass percentage of biofuel in a biofuel blend.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents
1	I	Analysis of the technical consequences of using biofuel on engine(s) performance and ship safety
2	I	For each engine: NOx emission test report, NOx measurement device type approval certificate and operating manual, if applicable as per [2.1.5]
3	I	Type and specification of the biofuel(s) or biofuel blend(s)
4	I	Fuel change-over procedure
5	A	Biofuel or biofuel blend storage tanks, piping and handling system
6	I	For each engine: Engine manufacturer statement whether the considered biofuel or biofuel blend may be used and under which conditions **(2)**
7	I	Test protocol for the NOx measurements, if applicable as per [2.1.5]

(1) A : to be submitted for approval ; I : to be submitted for information

(2) The engine manufacturer statement may apply to an engine type or series of engines and does not need to be specific to the considered engine and ship.

2 Requirements for the BIOFUEL READY notation

2.1 Technical analysis

2.1.1 Principle

A technical analysis is to be carried out in order to identify and assess any possible consequences of the use of the specified biofuel or biofuel blend on:

- the engine or boiler performance and actually available power
- the engine NOx emissions, if applicable as per [2.1.5]
- the safety of the ship taking into account fuel properties (viscosity, corrosivity, toxicity etc..).

The following cases are to be taken into account in the assessment:

- Fuel change-over, including tank cleaning if needed, and foreseeable fuel compatibility issues
- Onboard fuel transfer
- Clogging issues
- Material compatibility issues
- Onboard fuel storage, including fuel ageing, (oxidation, microbial growth), and possible need for heating
- Operation of engines, boilers and other equipment (e.g. oil discharge monitoring equipment)
- Functioning of safety systems, including fire-extinguishing systems.

Any change of engine setting or onboard equipment is to be identified and documented.

2.1.2 Ship safety

Specific attention is to be paid to the intended biofuel or biofuel blend possible toxicity and relevant mitigating measures are to be implemented in order to avoid any impact on persons on board. Relevant mitigating measures may include increased ventilation rates, location of exhausts of tank vents, suitable personal protective equipment.

2.1.3 Engine performance

It is to be demonstrated that the engine is able to deliver the minimum propulsion power to maintain the manoeuvrability of the ship in adverse conditions when running on the intended biofuel or biofuel blend. For ships which are required to maintain minimum propulsion power as per MARPOL Annex VI regulation 21.5, the minimum propulsion power may be assessed according to MEPC.1/Circ.850 rev.3.

2.1.4 In the case of a ship assigned the additional service feature **SRTP**, the minimum level of fuel to be kept available is to be assessed taking into account the actual consumption of the engines when running on the intended biofuel or biofuel blend.

2.1.5 NOx emissions

NOx emission measurements according to [2.4] may be required in consideration of the requirements of MARPOL Annex VI Regulation 18.3, as interpreted by IMO Circular MEPC.1/Circ.795/Rev.6.

2.2 Onboard arrangement

2.2.1 Where provided, storage tanks, piping and handling systems dedicated to biofuel or biofuel blend are to comply with the requirements of Part C, Chapter 1.

2.2.2 Where storage or use of several types of fuels is foreseen, dedicated storage tanks are to be provided for each type of fuel.

2.2.3 Storage tanks, piping and handling systems, including gaskets, intended to be used with biofuel or biofuel blend, are to be made of materials compatible with the intended biofuel or biofuel blend.

2.3 Biofuel specification

2.3.1 The biofuel or biofuel blend intended to be used as fuel is to be specified, i.e. the relevant fuel characteristics according to ISO 8217:2024 are to be established and submitted to the Society for information. When existing, the biofuel standard is to be detailed, e.g. EN14214 for FAME or EN15940 for paraffinic diesel fuel from synthesis or hydrotreatment.

2.3.2 The biofuel or biofuel blend specification is to comply with the requirements of the engine manufacturer.

2.3.3 The flashpoint (determined using the closed cup test according to ISO 2719:2016) of the biofuel or biofuel blend is to be not less than 60°C.

2.3.4 The sulphur content of the biofuel or biofuel blend is not to exceed the applicable sulphur content set forth in MARPOL Annex VI Regulation 14.

2.3.5 The biofuel or biofuel blend is not to contain any inorganic acid.

2.4 Engine testing

2.4.1 Where applicable, as per [2.1.5], the level of NOx emissions is to be measured for each engine intended to run on biofuel according to one of the following methods of IMO NOx Technical Code:

- Test bed testing in accordance with IMO NOx Technical Code Ch 5. Such test may be performed on a reference engine or parent engine according to IMO NOx Technical Code Ch 3
- Onboard testing in accordance with IMO NOx Technical Code Ch 5
- Onboard simplified measurement method in accordance with IMO NOx Technical Code §6.3
- Onboard direct measurement and monitoring in accordance with IMO NOx Technical Code §6.4.

2.4.2 The composition of the fuel used for the test is to be representative of the biofuel or biofuel blend intended to be used on board. The maximum intended blend ratio is to be used for the test.

Section 14 OCC-Prepared

1 General

1.1 Application

1.1.1 The additional class notation **OCC-PREPARED** may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.8.14], to new ships designed with specific arrangements intended to accommodate an onboard carbon capture and storage (CCS) system at a later stage. It may also be assigned to existing ships when the installation of a CCS system is considered during a future retrofit.

1.1.2 The additional class notation **OCC-PREPARED** aims at limiting the impact of the future installation of a CCS system on the ship arrangement and systems by considering the technical design features of the considered CCS system and the applicable Society's Rules when assigning the notation **OCC-PREPARED**.

1.1.3 The additional class notation **OCC-PREPARED** provides requirements for CCS systems using an amine-based solvent for the absorption of CO_2.

CCS systems using a different technology than amine-based solvent will be considered by the Society on a case-by-case basis.

1.1.4 After the installation of the system on board in accordance with Pt C, Ch 1, Sec 12, the ship may be assigned the additional service feature **OCC** as defined in Pt A, Ch 1, Sec 2, [4.16.17] in replacement of the additional class notation **OCC-PREPARED**.

1.2 Definitions and abbreviations

1.2.1 Definitions and abbreviations specific to CCS system are given in Pt C, Ch 1, Sec 12, [1.3].

1.3 Documentations to be submitted

1.3.1 The documentation to be submitted for the notation **OCC-PREPARED** is listed in Tab 1.

Table 1 : Documentation to be submitted

N°	I/A **(1)**	Documentation
1	I	General description of the foreseen CCS equipment and its installation, including: • details of the solvent system, separation system and CO_2 system as in defined in Pt C, Ch 1, Sec 12, [1.3] • details regarding weight and volume of the different pieces of equipment • schematic diagram of the systems • MSDS of the chemicals • specification with operating parameters (temperatures, pressures) • operating manual • storage and bunkering of the MEA / chemical products • storage and discharge of the captured CO_2
2	I	General arrangement drawing of the ship showing: • the future CCS system installed on board • arrangement of the storage tanks (MEA, CO_2, etc.) indicating modification and / or creation of new capacities if any.
3	I	Hazardous area plan of the ship where applicable
4	A	Machinery spaces general arrangement with CCS equipment
5	A	Preliminary loading conditions accounting for the future installation of the CCS system and associated weight distribution
6	I	Preliminary electrical load analysis
7	I	List of monitored parameters for alarm/monitoring and safety systems
8	I	Preliminary block diagram showing the interfacing between existing systems and the automation system of the CCS system
9	A	Preliminary steam balance
10	A	Dimensioning analysis (see [1.3.2]) and preliminary structural modification
11	A	Feasibility and impact analysis (see [1.3.3])
12	I	General risk analysis made by the CCS manufacturer on the CCS system itself
(1) I = to be submitted for information; A= to be submitted for approval.		

1.3.2 Dimensioning analysis

The dimensioning analysis:

- specifies the main dimensions and characteristics of the components of the different systems of the CCS installation, such as:
  - solvent system: bunkering, tanks, pumps, heat exchanger, etc.
  - separation system: exhaust gas cooler, exhaust gas blower, absorber and desorption unit (regenerator or stripper), etc.
  - CO_2 system: compression and liquefaction of the CO_2, transfer and storage, offloading, etc.
- specifies and explains the spaces and volumes needed for the installation of the future systems to be taken into account in the initial design of the ship.
- specifies the elements for the strength assessment of the decks supporting the equipment such as the design loads considered on the decks and bulkheads where equipment will be installed at installation stage including the solvent, together with their expected location and the minimum surface bearing the loads on deck.

1.3.3 Feasibility and impact analysis

The feasibility and impact analysis describes the next steps preparing the installation of the CCS system on board. This document is to contain the following information:

- list of the main equipment to be installed
- for each equipment:
  - the design specification and any restriction to be considered for the installation
  - ship's compartments or areas where the equipment will be installed.
- overall diagram of the CCS system installation detailing the interconnection and interfaces between the CCS system and other installations and systems of the ship
- basic design drawings showing the foreseen routing of the piping and cables
- the procedure for future installation, considering the practical impact on the ship, detailing foreseen necessary conversion work (such as, for instance, dismantling ceilings or hull opening)
- identification of limitations which may appear at the time of the installation of the CCS system in the existing systems of the ship, such as:
  - availability of electrical power and electrical components of the ship (bus bars, cables, etc.) and the selection of the protections (short circuit current)
  - cooling capacity
  - compressed air system capacity
  - exhaust gas system in regards of the maximum pressure drop admissible by the engines and boilers
  - impact on any other system depending on the ship's specifics
  - heating capacity for the desorption unit recovering the CO_2 from the solvent

  The modifications that may be necessary to accommodate the installation of the CCS system are to be detailed in order to demonstrate the feasibility.
- impact on the mooring and anchoring equipment, see [2.3.1] item f)
- impact on the bilge system, see [2.3.1] item i)
- identification of the ship's safety systems and arrangement modifications which may be necessary at the time of the CCS system installation:
  - space categorization
  - fire-fighting and fixed fire alarm and fire detection systems
  - ventilation system
  - escape routes.

  The feasibility and impact analysis will provide a basis for the review of the relevant documentation at the time of actual installation on board, in view of assigning the additional service feature **OCC**.

2 Requirements for OCC-PREPARED

2.1 General

2.1.1 The general ship design requirements given in [2.2] are to be complied with prior the assignment of the additional class notation **OCC-PREPARED**.

2.1.2 The detail design requirements given in [2.3] are to be complied with:

- either prior the assignment of the additional class notation **OCC-PREPARED**, or
- at CCS installation stage. In this case the necessary modifications are to be documented in the feasibility and impact analysis.

2.2 General ship design

2.2.1 Available spaces

Spaces are to be allocated for the equipment of the foreseen CCS system. The volumes of these spaces are to be specified based on the current design of the CCS system. The calculation and explanation of the volume needed are to be detailed in the feasibility and impact study.

2.2.2 General arrangement

a) Location of tanks intended for the storage of chemicals or CO_2 are to comply with:

- the requirements of Pt B, Ch 2, Sec 2
- the requirements of Pt C, Ch 1, Sec 12, [2.4.4] for solvent tank
- the requirements of Pt C, Ch 1, Sec 12, [4.1.1] for CO_2 tank.

b) The elements of the CCS system installation are to be considered in the general arrangement of the vessel in accordance with the applicable requirements. In particular, chemicals and process involved, flammability and toxicity of the solvent, toxicity and asphyxiating effect of CO_2 are to be considered for the location of the components of the CCS systems in regards of hazardous area, service and accommodation spaces and cargo area.

2.2.3 Longitudinal strength and stability

a) Preliminary loading conditions accounting for the future installation and operation of the CCS system (modification of the lightship distribution and weights of liquids and other consumables) are to be submitted. The applicable longitudinal strength and stability criteria are to be complied with.

b) For ships assigned the additional class notation **SDS**, a preliminary assessment of the damage stability is to be provided where the internal watertight bulkheads arrangements are changed.

c) Where the CCS system is to be installed on board an existing ship, the change in lightship parameters is to be assessed and the feasibility and impact analysis is to indicate whether or not a new inclining experiment or a weighting test is to be carried out.

2.3 Detailed design

2.3.1 General arrangement and local strength

a) Strength of tanks which will be reassigned to the storage of fluids, such as solvent, is to be assessed according to Part B, Chapter 7

b) Solvent tanks are to be coated with an anti-corrosion coating

c) Strength of decks and bulkheads that will support the weights of the CCS system is to be assessed according to Part B, Chapter 7

d) Tanks intended for the storage of chemicals or CO_2 are to comply with the following requirements:

- Pt C, Ch 1, Sec 12, [2.4] for solvent tank
- Pt C, Ch 1, Sec 12, [4.1] for CO_2 tank.

e) For existing ships, new openings in the ship's structure necessary for cables and pipes passage, or any other purpose, for the installation of the CCS system are to comply with the following requirements:

- Pt B, Ch 4, Sec 5, [6.2] for openings in stiffeners
- Pt B, Ch 4, Sec 5, [6.3] for openings in primary supporting members
- Pt B, Ch 4, Sec 5, [6.4] for openings in strength decks
- Pt B, Ch 4, Sec 5, [6.6] for openings in shell plating

Particular attention is to be paid in areas where openings already exist.

Additional checks may be required depending on the locations of the new openings and the service notation assigned to the ship.

f) In case of modification of the funnel, the requirements for anchoring and mooring defined in Pt B, Ch 12, Sec 4 are to be verified considering the possible increase of the windage area.

2.3.2 Machinery

a) The available machinery spaces are to provide sufficient room for the CCS system. If parts of the CCS system need to be installed outside machinery space, space available on deck is also to be sufficient for normal operation and maintenance of the equipment to be installed.

b) Piping systems are to comply with the following requirements, as far as applicable depending on the fluids, pressure temperature and location:
   - Pt C, Ch 1, Sec 10 for general piping system (cooling, compressed air, …)
   - Pt C, Ch 1, Sec 11 for piping system of Direct Contact Cooling (DCC) exchanger (see item h))
   - Pt C, Ch 1, Sec 12, [2] to Pt C, Ch 1, Sec 12, [4] as applicable for CCS piping system (solvent, CO_2, etc.).

c) The pressure drop inside the exhaust line, taking into account the installation of the CCS system, is not to exceed the recommendations given by the engine or boiler manufacturers (See Pt C, Ch 1, Sec 12, [2.1.4]).

d) The tanks newly created or re-assigned are to be fitted with piping systems as described in Pt C, Ch 1, Sec 12.

   Solvent tanks air vents are to comply with Pt C, Ch 1, Sec 12, [3.1.1].

   CO_2 tank venting is to comply with Pt C, Ch 1, Sec 12, [4.1.2].

e) Where steam is used as a heating medium of the solvent to separate the CO_2, an estimated steam balance is to be provided. Modifications to the steam system for the future installation on board of the CCS system are to be documented.

f) The impact on the cooling water systems (sea water and fresh water) is to be assessed. Sea water inlet, pumps capacity, piping, production of fresh water on board are to be designed for the needs of the ship including the CCS system and are to comply with Pt C, Ch 1, Sec 10.

g) The capacity of the control and service air receiver is to be compliant with Pt C, Ch 1, Sec 10, [17.4] including the consumption of the CCS system. Any modification to the compressed air system is to be assessed.

h) Where the exhaust gases are to be cooled prior the CO_2 absorption process, the exhaust gas cooling and treatment system is to be in accordance with Pt C, Ch 1, Sec 12, [2.5].

i) The impact of the installation of the CCS system on the bilge system and the scuppers is to be assessed. The bilge system and the scuppers as foreseen after installation of the CCS system are to comply with Pt C, Ch 1, Sec 12, [3.4].

2.3.3 Electricity and automation

a) The preliminary electric load balance is to take into account the foreseen CCS system.

b) The impact of the installation of the CCS system on the emergency lighting fittings, fire detectors, flooding detection and internal communication systems is to be assessed. They will have to be provided as foreseen after installation of the CCS system in the spaces or areas where the CCS system is planned to be installed.

c) The capacity of the main switchboard and local distribution busbars is to be sufficient for the CCS system. Any modification in the electrical installation is to be assessed in the Feasibility and Impact analysis.

d) The impact on the existing automated systems for the proper interfacing with the CCS automation system is to be assessed. Modifications on the automation systems are to comply with Part C, Chapter 3.

2.3.4 Safety

a) The impact of the installation of the CCS system on fire insulation requirements is to be assessed. Space categorization and fire insulation as foreseen after installation of the CCS system are to comply with Pt C, Ch 4, Sec 5.

b) The impact of the installation of the CCS system on fixed fire-fighting systems and on fixed fire alarm and fire detection systems is to be assessed. These systems as foreseen after installation of the CCS system are to comply with the requirements of Pt C, Ch 4, Sec 3, Pt C, Ch 4, Sec 6 and Pt C, Ch 4, Sec 15.

c) The impact of the installation of the CCS system on escape routes is to be assessed. Escape routes as foreseen after installation of the CCS system are to comply with Pt C, Ch 4, Sec 8.

d) The impact of the installation of the CCS system on ventilation systems is to be assessed. Ventilation systems as foreseen after the installation of the CCS system are to comply with the requirements of Pt C, Ch 1, Sec 12, [3.5] and of Pt C, Ch 4, Sec 5, [6].

CHAPTER 10
CBRN AND BIORISK

Section 1 CBRN Notations - General Requirements
Section 2 CBRN Notations - Ship Arrangement
Section 3 CBRN Notations - CBRN Protection
Section 4 CBRN Notations - Piping and Electrical Equipment
Section 5 CBRN Notations - Pre-Wetting and Washdown System
Section 6 Biological Risk Management (BIORISK)

Section 1 CBRN Notations - General Requirements

1 General

1.1 Scope

1.1.1 The present Section details requirements for the protection of personnel onboard civilian ships intended for operation in atmospheres contaminated by chemical, biological, radiological or nuclear hazardous material (CBRN) for rescue or damage control purposes.

However, these requirements do not cover:

- operation in explosive atmosphere
- resistance to the mechanical effects of explosions leading to CBRN contamination, except the resistance of the collective protection system to for ships to be assigned the additional class notation **CBRN- AIR BLAST RESISTANCE**. In particular, this chapter does not cover the resistance of structure to and thermal effects of nuclear or non-nuclear explosions.

1.2 Application

1.2.1 The following additional class notations may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.14.1], to ships equipped in order to permit safe operation in CBRN conditions and complying with the requirements of the present note, as detailed below:

- The additional class notation **CBRN** is assigned to ships where a citadel with a collective protection system can be established, in order to effectively protect people inside from contamination.

  Ships assigned the additional class notation **CBRN** are to comply with the requirements of:

  - Ch 10, Sec 2 for ship arrangement
  - Ch 10, Sec 3 for CBRN protection
  - Ch 10, Sec 4 for piping and electrical equipment
  - Article [2], except [2.5], for inspection and construction testing.
- The additional class notation **CBRN** may be completed by **-WASH DOWN** for ships which, in addition to the above features, are provided with a wash-down system, in order to give increased protection during CBRN operations and allow immediate primary decontamination of the superstructures.

  Ships for which the additional class notation **CBRN** is completed by **-WASHDOWN** are to comply with the requirements of:

  - the above mentioned Ch 10, Sec 2 to Ch 10, Sec 4
  - Ch 10, Sec 5 for pre-wetting and washdown systems
  - Article [2] for inspection and construction testing
- The additional class notation **CBRN** may be completed by **- AIR BLAST RESISTANCE** for ships having a collective protection system designed to withstand according to the requirements of Ch 10, Sec 3, [2].

1.3 Documents to be submitted

1.3.1 Documents to be submitted are listed in Tab 1.

1.3.2 CBRN operation specification

It is the responsibility of the Owner to detail the range of CBRN threats to be covered in order to enable efficient protection. The following information is to be clearly stated as a basis for design and in-service follow-up:

- CBRN agents to be considered (especially the list of chemical or bacteriological agents to be considered).
- Particulars of the required detection system(s), especially whether biological detection is required and whether a portable detection system is acceptable.
- Nature of operations to be carried out in the polluted area (mere crossing of the polluted area or e.g. personnel rescue, pollution control / cleanup, coordination etc.). Specific spaces and systems related to these operations that need to be operable in CBRN mode are to be listed.
- Maximum duration for such operations.
- Number of persons on board during operation (intervention personnel and rescued people).
- List of spaces required to be included in the citadel, as well as functionalities that may be available to a limited extent under CBRN mode (e.g. cooking and food supply) as referred to in Section 2 [1.1.2]
- Specific overpressure values and associated tolerances, especially if different from the reference values mentioned in this Chapter.
- Required arrangement of cleansing stations

Table 1 : Documentation to be submitted

No	I / A **(1)**	Documents to be submitted
1	I	CBRN operation manual
2	I	Citadel and shelter general arrangement
3	A	Citadel, airlock and cleansing station ventilation drawing, system details and sizing calculation
4	A	Arrangement of the CBRN protection plant, including, for ships for which the additional class notation **CBRN** is to be completed by **-AIR BLAST RESISTANCE**, details of the airblast protective device
5	A	For ships for which the additional class notation **CBRN** is to be completed by **-WASH DOWN**: • Pre-wetting and wash-down system drawing, system details and sizing calculation.
6	A	Details of ventilation opening controls and monitoring
7	I	Engine room general arrangement
8	A	Details of engine air supply and engine casing
9	A	Details of door arrangement, control and monitoring
10	A	CBRN detection system drawing and details
11	A	Electrical equipment certificates for environmental protection, in line with Ch 10, Sec 4, [2.1.1]
12	A	Diagram of the scupper and sanitary discharge system
13	I	Calculation of required airflows, pressure and CO_2 levels during the collective protection ventilation test, unless this test is carried out with the specified maximum number of people on board, see [2.3.3]
14	A	Fire control plan showing: • Citadel, sub-citadels and/or shelter • Storage location of personal protective equipment • CBRN detection system • Pre-wetting and washdown system and associated control valves.
15	I	Procedures in case of fire during CBRN operation
(1) A: To be submitted for approval, I: To be submitted for information		

1.3.3 The CBRN operation manual is to include:

- The CBRN operation specification.
- A plan showing the citadel, space for rescued people, shelter, airlock and cleansing station arrangement.
- A plan showing all liquid and gastight closing appliances that need to be closed prior to CBRN operation, together with a detailed description of this system.
- A detailed description of the detection system required in Sec 3, [1] with relevant drawings, operating instructions and alarm codes for the CBRN detection system.
- A detailed description and drawings of the citadel ventilation system. Parts of the system to be used solely for CBRN operation are to be outlined.
- Detailed procedure for switching to CBRN mode including:
  - closure of all openings
  - modifications of the ventilation system if relevant
  - CBRN filter activation.
- Measures to be taken in case of alarm related to the CBRN system (e.g. loss of overpressure).
- Measures to be taken in case of fire during CBRN operation.
- Measures to be taken for the replacement of the filters and for their disposal after contamination.

1.3.4 The following information is to be clearly shown on the fire control plan:

- Citadel and/or shelter
- Storage location of personal protective equipment
- CBRN detection system
- Pre-wetting and wash down system and associated control valves for ships for which the additional class notation **CBRN** is completed by **-WASHDOWN**.

1.4 Definitions and abbreviations

1.4.1 CBRN

Chemical, Biological, Radiological and Nuclear.

1.4.2 CBRN mode

Activation of the CBRN mode provides a contamination-free area in the whole citadel.

CBRN mode needs to be defined for the following systems:

- monitoring, control and alarm systems, including management of the airlocks and cleansing station
- CBRN detection system
- collective protection system
- pre-wetting and washdown system on ships for which the additional class notation **CBRN** is completed by **-WASH DOWN**.

1.4.3 CBRN operation

Ship operation in an environment where CBRN hazard is expected. During CBRN operation, the citadel and the collective protection system are switched to CBRN mode.

1.4.4 Citadel

Space or group of spaces surrounded by liquid and gastight boundaries and protected by overpressure and filtrated air ventilation system, in view of allowing personnel inside the citadel to keep their operational capability without wearing PPE in case of external CBRN contamination.

1.4.5 Collective protection system

The collective protection system is the ventilation system that provides a contamination-free environment in the citadel by:

- keeping the citadel at an overpressure with respect to the outside atmosphere and,
- providing clean air inside the citadel.

1.4.6 Shelter

Space or group of spaces that can be made liquid and gastight

2 Construction testing and inspection

2.1 General

2.1.1 This article details acceptance tests to be carried out during ship commissioning. They may be carried out at yard or during sea trials.

2.1.2 The provisions of [2.2] to [2.4] are applicable to ships with the additional class notation **CBRN** or **CBRN-WASH DOWN**. The provisions of [2.5] are applicable only to ships with the additional class notation **CBRN-WASH DOWN**.

2.2 Closure test

2.2.1 Remote closing of all openings in the citadel and shelter boundaries is to be tested, including doors, valves and ventilation openings.

2.3 Collective protection ventilation test

2.3.1 The collective protection ventilation system is to be tested upon building completion in order to demonstrate that the required overpressure can be maintained, and that the CO_2 level remains acceptable.

2.3.2 Once the pressure has been stabilized in the citadel, the overpressure is to be maintained for a duration corresponding to the minimum between:

- 1h, and
- the maximum duration for CBRN operation according to the CBRN operation specification.

This test is to be carried out with the ventilation system fed from the main power source. In addition, it is to be checked that the ventilation system functions properly when fed from the emergency power source.

2.3.3 The required airflows, pressure and CO_2 levels may be assessed by the Shipyard based on calculation according to a standard acceptable to the Society. Alternatively, the test may be carried out with a number of people inside the citadel equal to the maximum number of people on board during CBRN operation according to the CBRN operation specification and it is to be checked that CO_2 levels in all spaces, including machinery spaces, remain acceptable during the whole test. In this case, the test duration may need to be adapted to ensure stabilization of the CO_2 level.

2.3.4 The citadel overpressure is to remain within the required range during the whole test. This includes:

- differential pressure between the citadel and the outside atmosphere
- differential pressure between the citadel, cleansing station, airlocks and outside atmosphere
- differential pressure between machinery spaces included in the citadel and the rest of the citadel, if applicable
- differential pressure between engine enclosure and machinery spaces, if applicable.

2.3.5 A functioning test of the airlocks and cleansing stations is to be carried out with the collective protection ventilation system working.

2.4 CBRN detection test

2.4.1 A functioning test of the CBRN detection system is to be carried out. However, no actual contamination is to be used for the purpose of this test.

2.4.2 Each line is to be tested from the level of the detector, with means defined by the system supplier, in order to verify that detector activation will trigger the required alarms.

2.5 Pre-wetting and washdown test

2.5.1 A functioning test of each section of the pre-wetting and washdown system is to be carried out.

2.5.2 It is to be checked that all external surfaces are actually covered by a film of water while the system is activated.

2.5.3 Proper drainage of the water is to be checked, i.e. that there is no water accumulation on deck.

2.5.4 Remote operation of each section valve is to be tested.

Section 2 CBRN Notations - Ship Arrangement

1 Citadel

1.1 Spaces to be included in the citadel

1.1.1 The ship is to be provided with a citadel covering all enclosed spaces that may need to be accessed during CBRN operation, as defined in the CBRN operation specification. The ventilation of the citadel is to comply with the requirements of Ch 10, Sec 3, [2].

1.1.2 The citadel is to include at least all accommodation spaces and normally manned control stations, galleys and pantries, any space dedicated to the storage of food, and normally manned machinery spaces.

However, where specified in the CBRN operation specification, some of these spaces may be excluded from the citadel provided that the required functionalities are available in the citadel.

Note 1: See Article [7] for machinery space arrangement, especially engine room.

1.2 Spaces where explosive atmosphere may occur

1.2.1 If spaces where an explosive atmosphere may occur, such as ro-ro or vehicle spaces, paint store, battery room or other spaces as relevant, need to be covered by the collective protection system, they are to be provided with a dedicated, gastight exhaust duct and their ventilation system is to comply with the requirements of Ch 10, Sec 3, [2.2].

1.3 Boundaries of the citadel

1.3.1 All boundaries of the citadel are to be liquid and gastight.

1.3.2 All openings in the citadel boundaries, except air supply ducts directly led to engines enclosed in a gastight enclosure, are to be able to be made liquid and gastight:

- either automatically, or
- by manual operation, both locally and from the CBRN control station.

Doors and hatches that are required to be closed during CBRN operation need not be remotely controlled from the CBRM control station.

1.3.3

Doors in citadel boundaries are generally to open towards the inside of the citadel or the compartment with the highest overpressure level. Where this is not feasible due to e.g. means of escape design constraints, means of latching are to be provided so as to ensure that the door in closed position will withstand the pressure differential expected when the citadel is pressurized.

1.3.4

Hold-back hooks not subject to release from the CBRM control station are prohibited on doors in citadel boundaries.

1.3.5

Indication is to be provided in the damage control station as to whether each opening in the citadel boundary is open or closed.

1.3.6

Windows in the citadel boundary are to be liquid and gastight and of the non-opening type.

1.3.7

Cable and duct penetrations in citadel boundaries are to be reduced to a minimum and, where needed, are to be designed so as to reconstitute the tightness of the penetrated deck or bulkhead.

1.4 Means of access to the citadel

1.4.1 As a minimum, access to and egress from the citadel is to be possible through:

- One cleansing station complying with the requirements of Article [6] for access and/or egress during CBRN operation.
- One airlock - which may be combined with the airlock included in the cleansing station - complying with the requirements of Article [5] for egress during CBRN operations.

1.4.2 As far as practicable, the airlocks and cleansing stations provided for access to and egress from the citadel are also to be the main and secondary escape routes from the citadel.

2 CBRN Control station

2.1 Function

2.1.1 All monitoring and control functions relevant for CBRN operation are to be available at the CBRN control station. Tab 1 lists monitoring and control functions required at the CBRN control station.

2.2 Location

2.2.1 The CBRN control station may be included in the navigation bridge or operation control room or located in a dedicated room.

Table 1 : Summary of monitoring and control requirements for CBRN systems (during CBRN operation)

System	Indication	Alarm	Control	References
CBRN detection system				
• CBRN contamination detection outside	• CBRN control station • Navigation bridge	Audible and visual alarm: • Navigation bridge • CBRN control station	CBRN control station	Ch 10, Sec 3, [1.2]
• CBRN contamination detection in the citadel	• CBRN control station • Navigation bridge	Audible and visual alarm: • Navigation bridge • CBRN control station • Throughout the citadel	CBRN control station	Ch 10, Sec 3, [1.2]
CBRN collective protection ventilation system				
• Differential pressure between citadel and outside atmosphere	CBRN control station	• CBRN control station • Navigation bridge	–	Ch 10, Sec 3, [2.1.3]
• Differential pressure between machinery space and other spaces in the citadel	CBRN control station	• CBRN control station • Navigation bridge	–	Ch 10, Sec 3, [2.2.3]
• Differential pressure between enclosed engine casing and machinery space	CBRN control station	• CBRN control station • Navigation bridge	–	Ch 10, Sec 3, [2.2.3]
• Position of liquid and gastight closing appliances in the citadel and shelter boundaries	CBRN control station	–	Local and remote at the CBRN Control station	[1.3] and [4]
• Doors and hatches in citadel or shelter boundaries	CBRN control station	–	CBRN control station **(1)**	[1.3] and [4]
• Airlock and cleansing station doors	CBRN control station	Alarm at the CBRN control station in case more than one door is open	–	[5] and [6.2]
• Isolation valves in piping system	CBRN control station	–	Local and remote, inside the citadel	Ch 10, Sec 4, [1.1]
• Differential pressure between machinery space and outside atmosphere	CBRN control station	CBRN control station	–	–
Pre-wetting and washdown system				
• Pump	• CBRN control station • Navigation bridge	–	Local and remote at the CBRN control station	Ch 10, Sec 5, [2.2.2]
• Section valves	• CBRN control station • Navigation bridge	–	Local and remote at the CBRN control station	Ch 10, Sec 5, [2.2.2]
(1) Remote control is not required for doors and hatches that are required to be closed during CBRN operation.				

3 Space for rescued people

3.1 Accommodation for rescued people

3.1.1 When rescuing of people is part of the ship's CBRN operation specification, a dedicated space is to be available as accommodation for rescued people. This space is to be included in the citadel and provided with suitable ventilation, lighting and sanitary facilities.

3.1.2 Spaces for rescued people may be used for other purposes when the ship is not in CBRN rescuing operation. However, rescued people are not to be accommodated in the radio room, the wheelhouse or the CBRN control station and main access passageways which are to be kept clear.

3.2 Means of escape

3.2.1 Spaces for rescued people are to be provided with means of escape in line with the applicable requirements of Pt C, Ch 4, Sec 8.

4 Shelter

4.1 Sheltered spaces

4.1.1 As far as practicable, any enclosed space that is not part of the citadel – i.e. not protected by overpressure ventilation – is to be capable of being made liquid and gastight for the whole duration of the CBRN operation.

4.1.2 Sheltered spaces are to be provided with suitable means of cooling in order to maintain a temperature allowing proper functioning of the equipment installed therein during CBRN operation.

4.2 Openings in shelter boundary

4.2.1 Any opening in the boundaries of such shelter is to comply with the requirements of [1.3] for openings in the boundaries of the citadel.

5 Airlock

5.1 Arrangement

5.1.1 Airlocks are to have a simple rectangular shape with two doors not less than 1 m apart.

5.1.2 Airlocks are to be enclosed by gastight walls and doors.

5.2 Doors

5.2.1 Airlock doors are to be provided with sills at least 300mm high.

5.2.2 Airlock doors are to be self-closing doors.

5.2.3 Airlock doors are to be wide enough to allow the passage of personnel wearing Personal Protective Equipment (PPE).

5.2.4 Means are to be provided to ensure that only one door may be opened at a time during CBRN operation. An alarm is to be provided at the CBRN control station in case more than one of the doors is not fully closed.

5.3 Purging

5.3.1 The doors of airlocks are to be provided with suitable interlocks to ensure airlock purging immediately after the door leading to the open deck or to the cleansing station has been opened. The other door leading to the citadel is to remain closed during purging.

5.3.2 Airlock purging is to consist of at least 5 air changes. Attention is to be paid to possible air pockets and toxic gases accumulation, considering actual airflow.

6 Cleansing station

6.1 Arrangement

6.1.1 A shower is to be arranged immediately outside the cleansing station for initial decontamination before entering the cleansing station.

6.1.2 Cleansing stations are to be so arranged as to allow total undressing of potentially contaminated personnel and undressing of PPE, decontamination of personnel and containment and cleaning of contaminated PPE or clothing.

6.1.3 Cleansing stations are to have a simple rectangular shape

6.1.4 Access from the cleansing station to the citadel is to be through an airlock complying with the requirements of Article [5].

6.1.5 The cleansing station and its associated airlock are to be sized to allow the entry and decontamination of personnel carrying a stretcher with a casualty and relevant medical equipment.

6.2 Doors and boundaries

6.2.1 Cleansing stations are to be enclosed by gastight boundaries and doors.

6.2.2 Cleansing station doors are to be self-closing doors without any fixing device.

6.2.3 Cleansing station doors, except the door leading to the open deck, are to be provided with viewing ports.

6.2.4 Means are to be provided to ensure that only one door can be opened at a time during CBRN operation. An alarm is to be provided at the CBRN control station in case more than one of the doors is not closed.

7 Machinery space arrangement

7.1 Allowable arrangements for engine room and internal combustion machinery spaces

7.1.1 The requirements of [7.1.2] to [7.1.5] are applicable to engine rooms and to all machinery spaces containing internal combustion machinery that is required to remain operational during CBRN operation. For ease of reading, such machinery spaces are called “engine room” in the following requirements.

7.1.2 Depending on the ship operating range and CBRN operation philosophy, the engine room may be:

- included in the citadel, i.e. ventilated with decontaminated air and maintained in overpressure with respect to the atmosphere, or
- sheltered, i.e. able to be closed gastight, or
- unprotected.

7.1.3 If the engine room is included in the citadel, the requirements of [7.2] are to be applied, together with all requirements applicable to spaces in the citadel.

7.1.4 If the engine room is sheltered:

- The ship is to have the additional class notation **AUT-UMS** as defined in Pt A, Ch 1, Sec 2, [6.4.2] and Ch 3, Sec 1, and
- The requirements of [7.3] are to be applied.

7.1.5 Unprotected engine room may be acceptable considering the specified CBRN operation scope and provided:

- The ship has the additional class notation **AUT-UMS** as defined in Pt A, Ch 1, Sec 2, [6.4.2] and Ch 3, Sec 1, and
- All accesses and means of escape are sized so as to allow for easy passage of personnel wearing PPE, and
- Relevant measures are taken to limit contamination and ease cleaning after CBRN operation, see especially [8.1], and
- The requirements of [7.4] are complied with.

7.2 Machinery space included in the citadel

7.2.1 Access

Access from a machinery space included in the citadel to other spaces in the citadel and reverse is to be through an airlock complying with the requirements of Article [5].

7.2.2 Air supply

Internal combustion machinery required to remain operational may be:

- either enclosed in a gastight enclosure and provided with a dedicated ducted air supply. Then the requirements of [7.2.3] are to be applied.
- or directly supplied by air from the engine room. Then the requirements of [7.2.4] are to be applied.

7.2.3 Engine with dedicated air supply

a) The engine is to be enclosed in a gastight enclosure and provided with a dedicated air supply duct.

b) Engine supply and exhaust air ducts are to be gastight.

c) Engines with gastight design may be accepted as an alternative to gastight enclosure around the engine.

d) The engine enclosure is to be maintained at a pressure below ambient pressure in the engine room. The differential pressure between the engine room and the enclosure is to be at least 0,5 mbar.

7.2.4 Engine supplied by air from the engine room

In case no dedicated air inlet duct is provided for the engine:

- air supply for the engine is to be taken into account in the sizing of the ventilation system serving the engine room during CBRN operation, and
- the engine exhaust air duct is to be gastight.

7.3 Sheltered machinery space

7.3.1 Sheltered machinery spaces are to comply with the provisions of Article [4].

7.3.2 Access from a sheltered machinery space to the citadel is to be through an airlock complying with the requirements of Article [5].

7.3.3 The engine is to be gastight or enclosed in a gastight enclosure and provided with a dedicated ducted air supply, in line with the requirements of [7.2.3], items a) to c).

7.4 Unprotected machinery space

7.4.1 Access from an unprotected machinery space to the citadel or to any sheltered space is to be through a cleansing station and associated airlock, complying with the requirements of Article [6].

7.4.2 In addition, access from the citadel or from a sheltered space to an unprotected machinery space may be provided through an airlock complying with the requirements of Article [5].

7.4.3 All accesses, stairways and passageways in unprotected machinery spaces are to be sized so as to allow the passage of personnel wearing PPE.

7.5 Fire protection

7.5.1 Machinery spaces which are not permanently manned during CBRN operation are to be provided with a fixed fire detection and alarm system complying with the requirements of Pt C, Ch 4, Sec 15, [8].

7.5.2 Machinery spaces located out of the citadel are to be provided with a fixed fire extinguishing system complying with the relevant requirements of Pt C, Ch 4, Sec 15.

7.5.3 In case the engine is enclosed in a gastight enclosure, the enclosure is to be provided with a fixed fire detection and alarm system and with a fixed fire extinguishing system suitable for category A machinery spaces and complying with the relevant requirements of Pt C, Ch 4, Sec 15.

7.6 Engine room cooling

7.6.1 Adequate cooling is to be provided in the engine room in order to keep the temperature at an acceptable level for personnel and to maintain safe equipment operation during CBRN operation.

8 Superstructure design

8.1 Precautions for decontamination

8.1.1 The shape of external decks and superstructures is to be such as to avoid local accumulation of water.

8.1.2 Surfaces that may be exposed to CBRN agents are to be made of easily decontaminable materials. This includes exposed interior surfaces in airlocks and cleansing stations and unprotected spaces, as well as external surfaces. Alternatively, removable means of protection of interior surfaces of airlocks and cleansing stations may be provided for installation before CBRN operations, if mentioned in the CBRN operation specification.

9 Marking

9.1 Openings

9.1.1 All openings in the citadel and shelter boundaries are to be prominently marked. The marking is to indicate clearly (e.g. with a color code) in which situation the concerned opening may or may not be open.

9.2 Equipment

9.2.1 Equipment the setting of which needs to be modified for entering CBRN mode is to be prominently marked. The marking is to indicate clearly the relevant setting for each situation (CBRN operation or standard operation).

Section 3 CBRN Notations - CBRN Protection

1 Detection system

1.1 Detection

1.1.1 The ship is to be provided with a fixed CBRN detection system, consisting of detectors, cables, data treatment unit and control panel, adapted to the CBRN agents to be considered as per the CBRN operation specification.

A portable CBRN detection system may however be accepted when specified in the CBRN operation specification.

1.1.2 For fixed CBRN detection systems, detectors are to be provided as detailed in Tab 1.

Where portable CBRN detection system is provided, the number of portable detectors is to be in line with the requirements stated in the CBRN operation specification.

1.1.3 Detectors are to be of a type approved by the Society, complying with the requirements of Part C, Chapter 3.

1.1.4 Radioactivity detectors are to remain accessible for maintenance purposes.

Table 1 : Minimum number and location of CBRN detectors

		Location				
		In the citadel	Filtering station **(1)**	Cleansing station **(2)**	Open air	Sea water below the waterline
Hazard	Radioactivity	As a minimum, one detector in the citadel and one detector at the navigation bridge	1	1	2	1
	Chemical agents	–	–	–	1 **(4) (5)**	–
	Biological agents **(3)**	To be agreed depending on concerned biological agent				

(1) The detector is to be located immediately downstream of the filters

(2) One detector per cleansing station is to be provided. The detector may be installed either in the cleansing station, or in the citadel close to the access to the cleansing station

(3) Biological agent detection is required only if and as specified in the CBRN operation specification

(4) Outside chemical detectors are to be located away from:

- ventilation and engine exhaust openings
- superstructures and physical obstacles

(5) Additional outside chemical detectors may be required by the Owner depending on the ship type and configuration.

1.2 Alarm and monitoring

1.2.1 An audible and visual alarm is to be provided at the navigation bridge and at the CBRN control station in case CBRN contamination is detected. The alarms are to be distinct depending on the detected hazard. The location where contamination is detected is to be indicated.

In addition, an alarm is to be provided locally in case contamination values above thresholds are measured at any one detector.

1.2.2 For each hazard covered by the CBRN detection system, the detected agent or agent family and measured value at the location where contamination has been detected is to be displayed at the damage control station.

1.2.3 An alarm is to be provided throughout the citadel in case CBRN contamination is detected inside the citadel. The criterion for triggering an alarm in the whole citadel may be higher than that for triggering an alarm at the navigation bridge and CBRN control station, e.g. higher measured value, time delay or number of detectors impacted, to the satisfaction of the Society.

2 Collective Protection system

2.1 Citadel ventilation

2.1.1 The citadel is to be provided with a dedicated ventilation system, which does not serve any other space not included in the citadel.

2.1.2 The citadel ventilation system is to be capable of maintaining an overpressure of 5 mbar relative to atmospheric pressure in all spaces within the citadel, except as specified in [2.2.1].

2.1.3 Means of monitoring the overpressure in the citadel are to be provided and an alarm is to be provided at the CBRN control station in case the overpressure drops below the required minimum level.

2.1.4 The ventilation system is to be sized so as to provide breathable air in the whole citadel during the expected duration of CBRN operation. The maximum number of people on board is to be taken into account for this purpose as well as the air consumption of any equipment located in the citadel and which may need to be used during CBRN operation. Especially, in case a machinery space included in the citadel contains a non-enclosed internal combustion machinery, air supply for this equipment is to be taken into account as required by Ch 10, Sec 2, [7.2.4].

Note 1: Expected leakages through citadel boundaries, including sealed openings, are to be considered.

2.1.5 The sizing of the ventilation system is to be documented in a detailed calculation supported by a drawing showing air flowrates and pressure levels in each part of the citadel.

2.1.6 Ventilation fans are to be located downstream of the CBRN filters.

2.1.7 Exhaust air from the citadel may be used for the ventilation of:

- Other spaces in the citadel, including machinery spaces included in the citadel, or
- Airlocks, or
- Cleansing stations.

2.1.8 As a rule, suitable non-return devices are to be fitted on ventilation ducts in order to maintain the required overpressure in the protected spaces and to prevent air flow from outside or decontamination spaces towards protected spaces or from machinery spaces towards other spaces.

2.1.9 Parts of the ventilation system not fully complying with the requirements of Pt C, Ch 4, Sec 5, [6] may be accepted provided that:

- They are used solely during CBRN operation, and suitably marked to this end, and
- They are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and
- The ventilation system in use during normal operation is fully compliant with the requirements of Pt C, Ch 4, Sec 5, [6]
- Suitable arrangements are provided to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

2.1.10 Ventilation inlets for the citadel are to be widely separated from any ventilation outlets.

2.2 Ventilation of machinery spaces or hazardous spaces included in the citadel

2.2.1 This sub-article applies to machinery spaces or spaces where an explosive atmosphere may occur, when such spaces are included in the citadel. These spaces are referred to as machinery or hazardous spaces included in the citadel.

2.2.2 The ventilation system for machinery or hazardous spaces included in the citadel is to be capable of maintaining an overpressure of at least 200 Pa with respect to the atmospheric pressure. Machinery or hazardous spaces included in the citadel are to remain at an under pressure of at least 100 Pa with respect to other spaces included in the citadel.

2.2.3 During CBRN operation, machinery or hazardous spaces included in the citadel may be ventilated with exhaust air from other spaces in the citadel, subject to the provisions of [2.1.9] and provided that:

- the levels of CO_2 and oxygen remain acceptable for personnel to work in the space without breathing apparatus, and
- non-return valves are fitted in the ventilation ducts in order to maintain the differential pressure between machinery or hazardous spaces and other spaces included in the citadel.

2.3 CBRN Protection plant

2.3.1 The CBRN protection plant is to include gas and particulate filters capable of efficiently removing all CBRN agents listed in the CBRN operation specification:

- The CBRN gas filters are to be activated carbon filters capable of eliminating chemical agents and other gases.
- The CBRN particulate filters are to be high efficiency particulate air (HEPA) filters realizing a collection efficiency H13 according to EN 1822-1 or a collection efficiency of 99.97% of particles of 0,3 µm or greater.

2.3.2 The air inlet for the protection plant is to be provided with suitable devices to prevent water, moisture, particulate and corrosive marine salts from entering the CBRN filtration system. In addition, suitable pre-filters are to be provided so that the quality and humidity content of the air blown on the CBRN filter is in line with manufacturer's specification.

2.3.3 Filters are to be easy to change.

2.3.4 A damper is to be installed downstream of the CBRN filters. This damper is to be interlocked with the inlet fan and open only when the inlet fan is working and blowing air towards the citadel.

2.4 Airlocks and cleansing stations

2.4.1 Airlocks and cleansing stations are to be provided with a mechanical ventilation capable of providing at least 30 air changes per hour.

2.4.2 Airlocks and cleansing stations are to be supplied with decontaminated air. Exhaust air from the citadel may be used for this purpose, provided suitable non-return devices are installed as relevant.

2.4.3 Exhaust air from an airlock may be used as supply for the associated cleansing station, provided suitable non-return devices are installed as relevant.

2.4.4 Ventilation exhausts from airlocks are to be led to the associated cleansing station or to the open deck. Ventilation exhausts from cleansing stations are to be led to the open deck and provided with suitable non-return devices as necessary to avoid airflow from the outside towards inside the airlock.

3 Airblast Resistance

3.1 Application

3.1.1 The requirements of this article apply to ships for which the additional class notation **CBRN** is to be completed by **- AIRBLAST RESISTANCE**.

3.2 Protection of ventilation openings

3.2.1 The ventilation openings of spaces included in the citadel are to be capable of withstanding a blast overpressure of 70 mbar.

3.2.2 Ventilation openings that need to remain open during CBRN operation are to be provided with means of closing controllable from the CBRN control station.

3.3 Protection of collective protection system air inlet

3.3.1 The air inlet for the CBRN protection plant is to be provided with an protective device able to withstand 0,3 bar overpressure. The protective device is to be installed upstream of the filters.

4 Personal protective equipment (PPE)

4.1 General

4.1.1 A sufficient number of complete sets of protective equipment is to be carried on board, according to the scope defined in the CBRN operation specification.

4.1.2 A set of protective equipment is to consist of:

- CBRN suit
- CBRN gloves and shoes
- Self-contained breathing apparatus with adequate CBRN mask.

In addition, prophylactic kits adapted to the risks expected according to the CBRN operation specification are to be provided as relevant.

4.2 Self-contained breathing apparatus

4.2.1 The ship is to be equipped with at least a high pressure air compressor complete with all fittings necessary for refilling the bottles of air breathing apparatuses.

4.2.2 The capacity of the air compressor is to be sufficient to allow the refilling of all the bottles of air breathing apparatuses in no more than 30 min.

4.2.3 It is to be possible to supply the air compressor with clean air from the citadel.

4.2.4 In case the main air intake for the compressor is located outside of the citadel, suitable interlock with the CBRN detection system is to be provided to avoid contamination of the breathable air system.

4.2.5 Air supply for the air compressor is to be taken into account for the sizing of the citadel ventilation system.

Section 4 CBRN Notations - Piping and Electrical Equipment

1 Piping systems

1.1 General

1.1.1 Piping systems not serving the citadel are not to pass through the citadel.

1.1.2 In general, separate piping systems are to be provided to serve:

- the citadel
- shelters, if any
- airlocks and cleansing stations
- other unprotected spaces.

On case by case basis, the Society may accept other arrangements if needed for operational reasons, provided suitable isolation valves are fitted. These valves are to be operable locally and remotely from inside the citadel. Indication of their position is to be provided at the CBRN control station, and they are to be marked in line with the requirements of Ch 10, Sec 2, [9].

1.1.3 Sea suctions serving the fire main, decontamination showers, cooling systems, and pre-wetting and wash down system where provided, are to be located as low as possible.

1.2 Scupper and bilge systems

1.2.1 Separate scupper and bilge systems are to be provided for:

- The citadel
- Shelters, if any
- Airlocks and cleansing stations
- Other unprotected spaces.

1.2.2 Scupper and bilge systems are to be sized taking into account decontamination systems, i.e. decontamination shower in cleansing stations and wash down system on ships assigned with the additional class notation **CBRN-WASH DOWN**.

1.2.3 Drainage from the cleansing stations and external decontamination shower are to be led directly overboard.

1.2.4 Scuppers from spaces within the citadel or the shelter, and from airlocks and cleansing stations are to be fitted with adequate devices, such as water traps, that will preserve the required overpressure in the protected spaces and prevent the ingress of external air.

1.2.5 Separate scupper and bilge systems are to be provided for spaces that are maintained at different overpressure during CBRN operation.

1.3 Air, sounding and overflow pipes

1.3.1 The potable water tank venting is to be led inside the citadel.

1.3.2 Vent pipes and filling connections of service tanks are to be arranged so that hazardous material cannot enter the tanks during CBRN operation.

2 Electrical equipment

2.1 Environmental protection

2.1.1 Electrical equipment located in the citadel or shelter is to have environmental category (EC) at least EC 31 C or EC 33 C as applicable. Environmental categories are defined in Pt C, Ch 2, Sec 1, [3.10].

2.1.2 If the local temperature around the equipment may be expected to rise above 55°C, specific testing may be required.

2.2 Emergency source of power

2.2.1 The following systems are to be supplied by the emergency source of power:

- CBRN detection system
- Control and monitoring of openings in citadel boundaries.

Section 5 CBRN Notations - Pre-Wetting and Washdown System

1 General

1.1 Application

1.1.1 This section applies to ships assigned with the additional class notation **CBRN-WASH DOWN**.

1.2 Ventilation openings

1.2.1 The ventilation openings are to be arranged so as to prevent water ingress in the ventilating ducts when the pre-wetting and wash down system is in use

2 Pre-wetting and washdown system

2.1 System arrangement

2.1.1 The ship is to be provided with a pre-wetting and wash down system capable of providing continuous and complete coverage of all external horizontal and vertical surfaces of superstructures and weather decks.

Any equipment installed on open deck is to be covered by this system.

2.1.2 The capacity of the pre-wetting and wash down system is to be not less than 3 L/min for each square meter of protected area.

2.1.3 Nozzles are to be so arranged that all parts of the protected surfaces can be covered by a moving film of water.

2.1.4 The pre-wetting and wash-down system may be divided into sections capable of being operated independently.

2.2 System equipment

2.2.1 The pre-wetting and wash down system may share pumps and/or piping with other systems, including fire-fighting systems. In this case, the pump capacity is to be sufficient to supply either the pre-wetting and wash down system or the other system(s).

2.2.2 The pump and section valves are to be capable of local and remote operation from the CBRN control station. Indication of each section valve open or close position is also to be provided at this location.

2.2.3 Pipes, valves and nozzles are to be protected against corrosion and are to comply with the relevant requirements of Pt C, Ch 1, Sec 10.

2.2.4 Means are to be provided to flush the system with fresh water and drainage cocks are to be installed. Precautions are to be taken in order to prevent clogging of the nozzles by impurities contained in pipes, nozzles, valves and pumps.

Section 6 Biological Risk Management (BIORISK)

1 General

1.1 Application

1.1.1 This Section applies to ships where measures intended to prevent and manage infectious disease outbreaks on board have been implemented.

Ships complying with the requirements of this Section may be granted one of the following additional class notations:

- **BIORISK MANAGED** when an outbreak management plan has been established and implemented on board the ship, as described in [2].
- **BIORISK SECURED** when, in addition to the requirements applicable for **BIORISK MANAGED**, permanent systems, arrangements and fixed or portable equipment, retained as risk control measures, as required by [3] are provided on board.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
Documents to be submitted for the additional class notation **BIORISK MANAGED**		
1	I	Outbreak Management Plan, including the associated set of procedures, protocols and instructions
2	I	Risk assessment report
3	I	Specification of the type, quantity and storage locations of PPEs
4	I	Signs, posters and marking specification, describing the type and foreseen location of these items
Supplementary documents to be submitted for the additional class notation **BIORISK SECURED**		
5	I	General arrangement plan showing the location, extent and arrangement of the quarantine area
6	A	Details of the means of monitoring the accesses of the quarantine area required in [3.2.3]
7	A	Details of the means of communication required in [3.2.5]
8	A	Diagram of the natural and mechanical ventilation systems, showing: • the location of the inlets and outlets to the quarantine area, other accommodation spaces and normally manned control stations • means for air filtration or disinfection, where provided
9	A	Details of the means for air filtration or disinfection, where provided, including testing and approval references. For filters using active technologies, details of the associated safety measures (see [3.3.3]) are to be provided.
10	A	Specification of the means to monitor body temperature required in [3.4.2]

(1) A: To be submitted for approval
I: To be submitted for information

2 BIORISK MANAGED

2.1 Biological risk assessment

2.1.1 A biological risk assessment is to be carried out in order to identify the risks to the crew and passengers with regards to reasonably foreseeable infectious diseases that may occur on board the ship. The risk assessment is to involve medical experts and is to be carried out according to a method from recognized standards accepted by the Society (e.g. ISO 31010:2009), involving a risk identification process as well as the definition of relevant risk control measures covering possible failures at each step of the chain of events (avoid embarking contaminated goods or persons, detection of suspect cases, prevention of further contamination, evacuation or treatment of confirmed cases). The risk assessment is to cover the operations under normal conditions as well as the case of an outbreak developing on board. When relevant the risk control measures are to be commensurate with the current epidemic situation onshore.

2.1.2 The risk assessment report is to list the guidance documents used to prepare the risk assessment.

Note 1: Guidance documents may include NI 673 "Guidelines for Management of COVID-19 and Infectious Diseases" issued by the Society. Other recognized guidelines may be considered.

2.1.3 The adopted risk control measures and provisions are to be described in appropriate documents and implemented on board.

2.2 Outbreak Management Plan

2.2.1 An Outbreak Management Plan describing the measures and procedures applied to prevent and to respond to an outbreak developing on board, is to be established based on the risk assessment required in [2.1]. The documents used as references to define the Plan are to be listed in the Outbreak Management Plan.

2.2.2 The Outbreak Management Plan and the corresponding procedures are to be permanently available on board.

2.2.3 In general, at least the following items are expected to be covered in the Outbreak Management Plan, as appropriate and commensurate to the concerned ship:

- description of responsibilities to manage the Outbreak Management Plan
- resources and personnel needed
- means of information and communication, including relevant signage for circulation and crowd management
- conditions for embarkation and disembarkation of crew passengers and other persons
- physical distancing
- personal hygiene, hand washing
- cleaning and disinfection of facilities
- food and other essential supply, storage and distribution
- water supply
- onboard services and supplies
- personal protective equipment
- heating, ventilation and air conditioning systems
- health screening on board
- waste management
- Medical supplies and equipment, including oxygen supplies and storage location
- Areas dedicated to the storage of relevant supplies
- Areas to be dedicated to specific outbreak management operations (e.g. suspected cases isolation, health screening etc.) when such operations are to be carried out.

2.2.4 The Outbreak Management Plan and the corresponding set of procedures and instructions are to be reviewed and updated by the Owner on a regular basis, as necessary.

2.2.5 Where risk control measures include specific supplies or non-permanent equipment to be made available on board, their type and description, quantities, availability, locations, as well as provisions for user's training, user's instructions and storage conditions are to be included in the Outbreak Management Plan and documents. They are to be stored on board in properly identified locations.

2.3 Personal Protective Equipment (PPE)

2.3.1 Personal Protective Equipment are to be available on board, including:

- face mask covering the mouth and nose
- surgical masks
- plastic apron or impermeable gown
- standard, non-sterile gloves, as well as cleaning gloves. Both types are to be available in various sizes.
- goggles or visors.

2.3.2 The type and quantity of PPEs is to result from the risk assessment and is to be available on board as defined in the Outbreak Management Plan.

2.4 Signs and marking

2.4.1 The following equipment is to be available on board, as defined in the Outbreak Management Plan:

- posters with hygiene and physical distancing recommendations
- circulation and crowd management signage.

The type, quantity and location of those signs and markings are to be as defined in the Outbreak Management Plan.

3 Additional requirements for BIORISK SECURED

3.1 General

3.1.1 The additional class notation **BIORISK SECURED** may be assigned to ships complying with the requirements of this article in addition to those defined for the additional class notation **BIORISK MANAGED**.

3.1.2 Compliance with the requirements of this article may be achieved through a specific configuration of doors, ventilation systems, or other systems, provided this configuration complies with the requirements of Part C, Chapter 4, especially regarding means of escape (Pt C, Ch 4, Sec 8) and ventilation (Pt C, Ch 4, Sec 5, [6]), as applicable.

3.2 Quarantine area

3.2.1 A quarantine area is to be arranged, or ready to be arranged, on board, consisting of a number of cabins where infected persons or persons suspected to be infected may be isolated. The size of the quarantine area is to be coherent with the ship operational profile and the procedures set out in the Outbreak Management Plan.

In case the quarantine area is not a permanently arranged area, the Outbreak Management Plan is to include provisions for making the quarantine area available in case of an outbreak.

3.2.2 Ventilation

a) A mechanical ventilation system of the extraction type, capable of providing at least 10 air changes per hour in each cabin, is to be provided in the quarantine area.

b) The required air flow may be achieved through air recirculation within a given cabin provided:

- air recirculation is done through a filter with a particulate matter efficiency ePM1 of at least 50% according to ISO EN 16890-1 or at least 50% over the 0.3µm - 1µm range; and
- at least 2 fresh air changes per hour are ensured.

c) Exhaust ducts serving spaces in the quarantine area are not to serve any other space outside of the quarantine area.

d) Each space in the quarantine area is to be provided with a dedicated exhaust duct not serving any other space, unless the air is filtrated through a high efficiency particulate air (HEPA) filter realizing a collection efficiency H13 according to EN 1822-1 or a collection efficiency of 99.97% of particles of 0,3 µm or greater.

Alternatively exhaust ducts may serve several spaces in the quarantine area provided the operation of the exhaust fan is monitored and, in the event of failure of the exhaust fan, an audible and visual alarm is given at a continuously manned location. In addition temporary measures such as using certified medical face masks are to be implemented until the system functionality has been restored.

e) Enthalpy wheels may be fitted on such exhaust ducts from the quarantine area provided that:

- the enthalpy wheel is capable of being stopped when the area is used as a quarantine area; and
- it is demonstrated that no air leakage will occur between the supply and the exhaust in this configuration.

f) Exhaust air from the cabins of the quarantine area is to be led directly outside to a location at least 6 m away from areas normally accessible to passengers or crew. This distance is to be measured from the centre of the exhaust outlet. This distance may not be applied provided the air outlet is equipped with a HEPA filter realizing a collection efficiency H13, according to EN 1822-1, or a collection efficiency of 99,97% of particles of 0,3 µm or greater, or with an alternative disinfection system. Documentation supporting the efficiency of the alternative disinfection system is to be submitted to the Society.

3.2.3 Access

a) Washing stations are to be provided at each access to the quarantine area with means to wash hands and sufficient room for the storage of clean and soiled materials and for doning medical gowns.

A hydro-alcoholic gel dispenser or a basin with water and soap may be accepted as means to wash hands.

b) Direct access to an open deck or to a side shell door is to be provided from the quarantine area, so that an infected person can be evacuated without entering other parts of the ship.

The corridor serving any cabin in the quarantine area and access therefrom to the open deck or to the side shell door is to have a sufficient width to permit the passage of the enclosed stretcher and totally enclosed wheelchair required by [3.4.3].

c) Means of monitoring access to the quarantine area are to be provided. An alarm, a CCTV system, or other alternative system covering all accesses to the quarantine area may be accepted for this purpose.

3.2.4 Cabin arrangement

a) Each cabin in the quarantine area is to be provided with an individual sanitary unit including at least toilets, a handwash basin and a shower or bathtube.

b) Each cabin in the quarantine area is to have a self-closing door.

3.2.5 Means of communication

a) A means for the quarantined person to contact assistance is to be available in each cabin of the quarantine area. Fixed internal telephone, portable devices or other alternative means, may be accepted for this purpose.

b) Means are to be available in each cabin of the quarantine area for the crew or medical staff to check the condition of each quarantined person without entering the cabin. Video monitoring, telephone communication or other alternative means may be considered for this purpose.

3.3 Ventilation of accommodation spaces and normally manned control stations

3.3.1 Supply air for accommodation spaces and normally manned control stations is to be either:

a) Directly taken from the outside, possibly through enthalpy wheels; or

b) Filtrated with a particulate matter efficiency ePM1 of at least 50% according to ISO EN 16890-1 or at least 50% over the 0,3 µm – 1 µm range; or

c) Otherwise disinfected, e.g. through Ultraviolet Germicidal Irradiation (UVGI) or other alternative disinfection system. Documentation supporting the efficiency of the alternative disinfection system is to be submitted to the Society.

3.3.2 When UVGI system is used, installation in the upper part of the room is not allowed. UVGI lamps may be either incorporated into room air-recirculation units or part of a duct irradiation system. In both cases, the functioning parameters of the system are to be adjusted, taking into account the air flow, in order to provide UV-C rays at the relevant wavelength for the targeted pathogen and sufficient irradiation time to inactivate it.

3.3.3 The use and arrangement of filters using active technologies, such as oxydation, ionization, ozone, etc, and associated safety measures is to be given special consideration by the Society.

3.3.4 Air inlets for accommodation spaces and normally manned control stations are to be located at least 3 m away from air outlets from these spaces or from similar spaces and at least 10 m away from air outlets from the quarantine area.

These distances are to be measured from the center of the concerned air inlet or outlet.

These distances may not be applied when the concerned air inlet or outlet is equipped with filters or alternative disinfection system according to [3.3.1] item b) or c).

3.3.5 In public spaces designed to accommodate more than 50 persons, a mechanical ventilation system capable of providing at least 6 air changes per hour is to be provided. The required air flow may be partially achieved through air recirculation inside the space in accordance with [3.3.1] item b) or item c). Alternatively, a ventilation system capable of providing 4.5 fresh air changes per hour may be accepted.

The ventilation system may be fitted with an air flow regulation system allowing to operate it with a lower rate of air changes when found acceptable according to the Outbreak Management Plan.

3.4 Other equipment

3.4.1 Internal communication

A means allowing to organize crew meetings through videoconference is to be available on board. It is to be possible to connect to this system from:

a) the wheelhouse; and

b) the engine control room; and

c) at least one crew public space.

3.4.2 Means to monitor body temperature

Means to monitor the body temperature of the crew and passengers on a regular basis are to be available on board. Either fixed or portable equipment may be accepted for this purpose.

3.4.3 At least one totally enclosed stretcher and one totally enclosed wheelchair are to be available on board.

4 Onboard testing

4.1 Initial survey

4.1.1 An initial survey is to be carried out on board prior to granting the additional class notation **BIORISK MANAGED** or **BIORISK SECURED**.

4.1.2 The initial survey is to include:

a) Verification that the Outbreak Management Plan and associated documents are available on board.

b) Verification that the PPEs, signs, marking and medical supplies required by the Outbreak Management Plan are available on board.

4.1.3 In addition to the requirements of [4.1.2], the initial survey for the additional class notation **BIORISK SECURED** is to include:

a) Functional testing of the ventilation arrangements for the quarantine area, as required by [3.2.2], and for the accommodation spaces and normally manned control stations, as required by [3.3]. It is to be checked that the ventilation system is functioning properly with the air filtration or alternative air disinfection system working.

b) Functional testing of the means of monitoring the access to the quarantine area.

c) Verification of availability of the means of communication for the quarantine area.

d) Functional testing of the means of monitoring body temperature.

e) Verification of availability of totally enclosed stretcher and totally enclosed wheelchair.

CHAPTER 11
MANOEUVRING, MOORING, ANCHORING AND POSITION KEEPING

Section 1 Ship Manoeuvrability (MANOVR)

Section 2 Heading Control in Adverse Conditions

Section 3 Single Point Mooring (SPM)

Section 4 Unsheltered Anchoring

Section 5 Dynamic Positioning (DYNAPOS)

Section 1 Ship Manoeuvrability (MANOVR)

1 General

1.1 Application

1.1.1 The additional class notation **MANOVR** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.15.1], to ships whose manoeuvring capability standards comply with the requirements of this Section.

1.1.2 The requirements of this Section reproduce the provisions of IMO Resolution A751(18) "Interim Standards for Ship Manoeuvrability".

Note 1: According to Resolution MSC.137(76), these provisions are to be applied to ships of all rudder and propulsion types, of 100 m in length and over, and to chemical tankers and gas carriers regardless of the length, which were constructed on or after January 2004.

1.2 Manoeuvre evaluation

1.2.1 Conventional trials

The requirements in this Section are based on the understanding that the manoeuvrability of ships can be evaluated from the characteristics of conventional trial manoeuvres.

1.2.2 Compliance with the requirements

The following two methods can be used to demonstrate compliance with these requirements:

a) Scale model tests and/or predictions using computer programs with mathematical models can be performed to predict compliance at the design stage.

   Results of the models test and/or computer simulations will be confirmed by full scale trials, as necessary.

b) Compliance can be demonstrated based on the results of full scale trials conducted in accordance with these requirements.

2 Definitions

2.1 Geometry of the ship

2.1.1 Length (L)

Length (L) is the length measured between the aft and forward perpendiculars.

2.1.2 Midship point

Midship point is the point on the centreline of a ship midway between the aft and forward perpendiculars.

2.1.3 Draught T_A

The draught T_A is the draught at the aft perpendicular.

2.1.4 Draught T_F

The draught T_F is the draught at the forward perpendicular.

2.1.5 Mean draught T_M

The mean draught T_M is defined as $T_M = (T_A + T_F)/2$.

2.2 Standard manoeuvres and associated terminology

2.2.1 Test speed

The test speed (V) used in the requirements is a speed of at least 90% of the ship's speed corresponding to 85% of the maximum engine output.

2.2.2 Turning circle manoeuvre

The turning circle manoeuvre is the manoeuvre to be performed to both starboard and port with 35° rudder angle or the maximum rudder angle permissible at the test speed, following a steady approach with zero yaw rate.

2.2.3 Advance

Advance is the distance travelled in the direction of the original course by the midship point of a ship from the position at which the rudder order is given to the position at which the heading has changed 90° from the original course.

2.2.4 Tactical diameter

Tactical diameter is the distance travelled by the midship point of a ship from the position at which the rudder order is given to the position at which the heading has changed 180° from the original course. It is measured in a direction perpendicular to the original heading of the ship.

2.2.5 Zig-zag test

Zig-zag test is the manoeuvre where a known amount of helm is applied alternately to either side when a known heading deviation from the original heading is reached.

2.2.6 10°/10° zig-zag test

10°/10° zig-zag test is performed by turning the rudder alternately by 10° either side following a heading deviation of 10° from the original heading in accordance with the following procedure.

a) after a steady approach with zero yaw rate, the rudder is put over 10° to starboard/port (first run)

b) when the heading has changed to 10° off the original heading, the rudder is reversed to 10° to port/starboard (second run)

c) after the rudder has been turned to port/starboard, the ship will continue turning in the original direction with decreasing turning rate. In response to the rudder, the ship is then to turn to port/starboard. When the ship has reached a heading of 10° to port/starboard off the original course, the rudder is again reversed to 10° to starboard/port (third run).

2.2.7 First overshoot angle

The first overshoot angle is the additional heading deviation experienced in the zig-zag test following the second run.

2.2.8 Second overshoot angle

The second overshoot angle is the additional heading deviation experienced in the zig-zag test following the third run.

2.2.9 20°/20° zig-zag test

20°/20° zig-zag test is performed using the same procedure given in [2.2.6] above using 20° rudder angle and 20° change of heading, instead of 10° rudder angle and 10° change of heading, respectively.

2.2.10 Full astern stopping test

Full astern stopping test determines the track reach of ship from the time an order for full astern is given until the ship stops in water.

2.2.11 Track reach

Track reach is the distance along the path described by the midship point of a ship measured from the position at which an order for full astern is given to the position at which the ship stops in the water.

3 Requirements

3.1 Foreword

3.1.1 The standard manoeuvres are to be performed without the use of any manoeuvring aids which are not continuously and readily available in normal operations.

3.2 Conditions in which the requirements apply

3.2.1 In order to evaluate the performance of a ship, manoeuvring trials are to be conducted to both port and starboard and in the conditions specified below:

- deep, unrestricted water
- calm environment
- full load, even keel condition
- steady approach at test speed.

3.3 Criteria for manoeuvrability evaluation

3.3.1 Turning ability

The advance is not to exceed 4,5 ship lengths (L) and the tactical diameter is not to exceed 5 ship lengths in the turning circle manoeuvre.

3.3.2 Initial turning ability

With the application of 10° rudder angle to port/starboard, the ship is not to have travelled more than 2,5 ship lengths by the time the heading has changed by 10° from the original heading.

3.3.3 Yaw checking and course keeping ability

a) The value of the first overshoot angle in the 10°/10° zig-zag test is not to exceed:
   1) 10°, if L/V is less than 10 seconds,
   2) 20°, if L/V is 30 seconds or more, and
   3) (5 + 1/2 (L/V)) degrees, if L/V is 10 seconds or more, but less than 30seconds,

   where L and V are expressed in m and m/second, respectively.

b) The value of the second overshoot angle in the 10°/10° zig-zag test is not to exceed the above criterion values for the first overshoot by more than 15°.

c) The value of the first overshoot angle in the 20°/20° zig-zag test is not to exceed 25°.

3.3.4 Stopping ability

The track reach in the full astern stopping test is not to exceed 15 ship lengths. However, this value may be increased at the discretion of the Society for large ships.

4 Additional considerations

4.1 Trials in different conditions

4.1.1 Where the standard trials are conducted in conditions different from those specified in [3.2.1]c, the corrections deemed necessary by the Society are to be made in each case.

4.2 Dynamic instability

4.2.1 Where standard manoeuvres indicate dynamic instability, the Society may require additional tests to be conducted to define the degree of instability, such as spiral tests or the pull out manoeuvre.

Section 2 Heading Control in Adverse Conditions

1 General

1.1 Application

1.1.1 The additional class notations **HEADING CONTROL-DS** and **HEADING CONTROL-IS** may be assigned in accordance with Pt A, Ch 1, Sec 2, [6.15.2], to ships arranged with redundant propulsion and steering systems complying with this Section.

1.1.2 The purpose of the additional class notations **HEADING CONTROL-DS** and **HEADING CONTROL-IS** is to attest that the ship has redundant propulsion/steering systems in order to maintain its heading to the waves in adverse weather conditions in order to avoid large transversal acceleration taking into account the windage of the deck cargo if any.

1.1.3 The additional class notation **HEADING CONTROL-DS** is assigned to ships with duplicated propulsion and steering systems able to maintain their heading to the waves in case of single failure on the propulsion or steering system and compliant with the present Section with the exclusion of Article [4].

1.1.4 The additional class notation **HEADING CONTROL-IS** is assigned to ships with independent propulsion and steering systems complying with the provisions relevant to the notation **HEADING CONTROL-DS** and, in addition, the requirements set in [4] covering the event of fire or flooding casualty in machinery space.

1.1.5 Machinery, electrical installation and automation are to comply with the relevant provisions of Part C.

1.2 Definitions

1.2.1 Heading to the waves

A ship heading to the waves means that the ship axis remain within +/– 30° with respect to the waves direction.

1.2.2 Propulsion system

A propulsion system is a system that provides thrust to the ship. It includes:

- the prime mover, including the integral equipment, driven pumps, etc.
- the equipment intended to transmit the torque
- the propulsion electric motor, where applicable
- the equipment intended to convert the torque into thrust
- the auxiliary systems necessary for operation
- the control, monitoring and safety systems.

1.2.3 Steering system

A steering system is a system that controls the heading of the ship. It includes

- the power actuating system
- the equipment intended to transmit the torque to the steering device
- the steering device (e.g. rudder, rotatable thruster, waterjet steering deflector, etc.).

1.2.4 Propulsion auxiliary systems

Propulsion auxiliary systems include all the systems that are necessary for the normal operation of a propulsion system. It includes or may include:

- the fuel oil supply system from and including the service tanks, and the parts of the filling, transfer and purifying systems located in machinery spaces
- the lubricating oil systems serving the engines, the gearbox, the shaftline bearings, the stern tube, etc., and the parts of the lubricating oil filling, transfer and purifying systems located in machinery spaces
- the hydraulic oil systems for operating clutches, controllable pitch propellers, waterjet reverse deflectors, starting systems, etc.
- the fresh water cooling systems serving any component of the propulsion system or used for cooling the fuel oil circuits, the lubricating oil circuits, the hydraulic oil circuits, etc
- the sea water cooling systems used for cooling any component of the propulsion system or any of the afore-mentioned systems
- the heating systems (using electricity, steam or thermal fluids)
- the starting systems (air, electrical, hydraulic)

- the control air systems
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems
- the ventilation installation where necessary (e.g. to supply combustion air or cooling air to the primer movers).

1.2.5 Steering auxiliary systems

Steering auxiliary systems include all the systems that are necessary for the normal operation of a steering system. It includes or may include:

- the fresh water cooling systems
- the sea water cooling systems
- the control air systems
- the power supply (air, electrical, hydraulic)
- the control, monitoring and safety systems.

1.2.6 Safety systems

Safety systems include all the systems that are necessary for the safety of the ship operation. They include:

- fire fighting systems
- bilge system
- communication systems
- navigation lights
- life-saving appliances
- machinery safety systems which prevent of any situation leading to fire or catastrophic damage.

1.2.7 System failure

A system failure means any failure of an active component of a propulsion system, steering system or power generation plant, including their auxiliary systems.

Only single failure needs to be considered.

1.2.8 Active components

An active component means any component of the main propulsion system or auxiliary propulsion system that transmits mechanical effort (e.g. gear), converts or transfers energy (e.g. heater) or generates electric signals for any purpose (e.g. control system).

Pipes, manually controlled valves and tanks are not to be considered as active components.

1.2.9 Separate compartments

Separate compartments mean compartments which are separated by a fire and watertight bulkhead.

1.3 Documents to be submitted

1.3.1 HEADING CONTROL-DS

The documents listed in Tab 1 are to be submitted for ships assigned with the additional class notation **HEADING CONTROL-DS**.

1.3.2 HEADING CONTROL-IS

In addition to the documents listed in Tab 1, for ships assigned with the additional class notation **HEADING CONTROL-IS**, the documents listed in Tab 2 are to be submitted.

Table 1 : Documents to be submitted for HEADING CONTROL-DS

No.	I/A **(1)**	Document
1	I	Electrical load balance, including one of the propulsion system out of service
2	I	Machinery spaces general arrangement of duplicated propulsion system, steering systems and main electrical components
3	A	Diagram of fuel oil system, lubricating system, hydraulic oil systems, sea water and fresh cooling systems, heating systems, starting air system, control air system, steering system
4	A	Single line diagrams of main electrical distribution system

(1) A : to be submitted for approval
I : to be submitted for information

(2) The risk analysis may be in the form of a Failure Mode and Effect Analysis (FMEA). Ch 2, App 1 describes an acceptable procedure for carrying out the FMEA.

No.	I/A **(1)**	Document
5	A	Description of the duplicated propulsion system
6	A	Description of the duplicated steering system
7	A	A risk analysis demonstrating the availability of the heading control capability in case of a system failure as defined in [1.2.7] **(2)**
8	I	An operating manual with the description of the operations necessary to recover the propulsion, steering and safety systems in case of a single failure (see [2.1.1])
9	I	Heading control analysis as described in [2]
10	A	Description of the thrusters system when considered in the heading control analysis
11	A	Failure and casualty scenarios as defined in [3.2]

(1) A : to be submitted for approval
I : to be submitted for information

(2) The risk analysis may be in the form of a Failure Mode and Effect Analysis (FMEA). Ch 2, App 1 describes an acceptable procedure for carrying out the FMEA.

Table 2 : Additional documents to be submitted fro HEADING CONTROL-IS

No.	I/A **(1)**	Document
1	I	Description of the independent propulsion system
2	I	Description of the independent steering system
3	A	Bulkhead arrangement of separate machinery spaces

(1) A : to be submitted for approval
I : to be submitted for information

2 Heading control analysis

2.1 General

2.1.1 A heading control analysis justifying the ship ability to be steered and maintained head to the wave, from any incoming wave direction and in adverse conditions, is to be submitted to the Society.

2.1.2 The heading control analysis is to be based on the assumptions defined in [2.2] and [2.3].

2.1.3 Compliance with the performance criteria set in [2.4] is to be demonstrated.

2.2 Environmental adverse conditions

2.2.1 Adverse conditions mean sea conditions with the following parameters:

- significant wave height H_s = 5,5 m
- peak wave period T_P = 7,0 to 15,0 sec
- mean wind speed V_w = 19,0 m/s

Wind and waves are assumed to be coming from the same direction.

2.3 Loading conditions

2.3.1 Typical loading conditions from the approved trim and stability booklet are to be considered including maximum windage area due to the cargo and the ship superstructure.

2.3.2 The windage area of the ship including its cargo on deck, when relevant, is to be described for each wind direction considered relative to the ship longitudinal axis.

2.4 Performance criteria

2.4.1 General

The ship ability to maintain its heading to the waves in the conditions defined in [2.2] and [2.3] is to be justified by compliance with the following criteria:

$$\frac{M_{steer}}{M_{wind} + M_{drift}} \geq 1,15$$

Where:

M_{wind} : Horizontal (yaw) moment due to the wind (see [2.4.2])

M_{drift} : Horizontal (yaw) moment due to the wave drift (see [2.4.3])

M_{steer} : Horizontal (yaw) moment due to the steering forces counteracting the above moments (see [2.4.4]).

The above moments are to be assessed for several headings to the wave and wind, typically from 0° to 180° with steps of 15°.

2.4.2 Assessment of horizontal wind moment

The horizontal moment due to the wind is to be assessed based on one of the following method:

- Calculations based on wind coefficients as per NR445, Rules for Offshore units, Part B, Chapter 1, or
- Wind tunnel testing, or
- Computational Fluid Dynamic.

The windage forces are to be assessed based on the windage area with respect to the heading.

The assessment of the positions of the centre of wind resistance and centre of resistance of the immersed hull, in a plane perpendicular to the wind direction, are to be documented.

2.4.3 Assessment of horizontal wave drift moment

The horizontal moment due to the wave drift is to be assessed based on one of the following method:

- Hydrodynamic analysis using a sea-keeping software based on potential flow theory
- Computational Fluid Dynamic
- Model tank test

Full set of numerical results are to be provided.

The software used is to be documented.

When deemed necessary, the Society may require a validation report of the software used.

The positions of the centre of wave drift forces and centre of resistance of the immersed hull, in a plane perpendicular to the wave direction, are to be documented.

2.4.4 Assessment of horizontal steering moment

The assessment of the horizontal steering moment is to be based on a method accepted by the Society.

Intermediate results are to be provided: minimum vessel speed, rudder forces, thruster forces (if any), and position of centre of hull resistance.

The contribution of the rudder(s) and auxiliary thruster(s), if any, for every failure and casualty scenarios defined in [3.2], is to be taken into account considering the possible loss of propulsion power or steering equipment.

3 Requirements for duplicated propulsion and steering systems

3.1 Principles

3.1.1 Ships assigned the additional class notation **HEADING CONTROL-DS** are to be fitted with:

- at least two steering systems, as defined in [3.3], so designed and arranged that, in case of any failure as defined in [1.2.7] affecting such systems or their auxiliary services, there remain sufficient heading control capability to head the ship to the waves, as defined in [1.2.1]
- at least two main propulsion systems, as defined in [3.3.3] are to be fitted

Note 1: This requirement may be waived when others means than main propulsion system are used for heading control, e.g. azimuth thrusters (see [3.3.1]).

- duplicated propulsion auxiliary systems and steering auxiliary systems as defined in [3.4] and [3.5]
- electrical installations and automation system, as defined in [3.6] and [3.7], so designed that in case of any failure as defined in [1.2.7] there remains enough electrical power to maintain simultaneously:
  - sufficient heading control capability to head the ship to the waves, as defined in [1.2.1]
  - the availability of safety systems.

3.1.2 The loss of one compartment due to fire or flooding is not to be considered as a failure for assignment of the additional class notation **HEADING CONTROL-DS**. Accordingly, the propulsion systems and/or their auxiliary systems or components thereof may be installed in the same compartment. This also applies to the steering systems and the electrical power plant.

3.1.3 Compliance with requirements [3.1.1] above is to be demonstrated by a risk analysis.

3.2 Failure and casualty scenarios

3.2.1 The description of the failure and casualty scenarios based on the results of the risk analysis are to be submitted.

The description is to include the loss of one propulsion system, one rudder system, one electrical generator, one thruster system and a calculation of the remaining power and thrust force in order to assess the steering moment as defined in [2.4.4].

3.3 Propulsion and steering systems

3.3.1 The propulsion and steering machinery is to consist of at least two mechanically independent propulsion and at least two mechanically independent steering systems so arranged that, in case one propulsion or steering system becomes inoperative due to a system failure, the ship will remain able to keep its heading to the waves, as defined in [1.2.1], with the following assumptions:

- adverse weather conditions as defined in [2.2]
- loading conditions as defined in [2.3].

When fitted, an azimuthal thruster may replace one of the propulsion systems and one of the steering systems required above.

3.3.2 The auxiliary systems serving the propulsion may have common components, be arranged for possible interconnection or serve other systems on board the ship provided that in case of any single failure affecting those systems, not more than one propulsion or steering system is disabled. This is to be substantiated by the risk analysis.

3.3.3 In case a propulsion system becomes inoperative due to a failure as indicated in [1.2.7], the following conditions are to be satisfied:

- other propulsion/steering systems that were in operation before the failure are not to be affected by the failure. In particular there should be no significant modification of the power or rotational speed of the concerned prime mover
- other propulsion/steering systems that were not in operation before the failure are to be maintained available (heating and prelubrication) and able to be started within 45 seconds after the failure
- safety precaution for the failed propulsion system are to be taken, such as shaft blocking.

This is to be demonstrated during the sea trials.

3.3.4 The steering systems are to be so designed and arranged that in case of any failure, as defined in [1.2.7], in the systems or in the associated auxiliary systems (cooling systems, electrical power supply, control system, etc.) not more than one steering system is disabled, thus allowing the steering capability to be continuously maintained. This is to be substantiated by the risk analysis.

3.4 Propulsion auxiliary systems

3.4.1 Oil fuel storage and transfer systems

At least two storage tanks for each type of fuel used by the propulsion engines and the generating sets are to be provided. Means and procedures are to be provided to periodically equalize the content on each storage tank and on each service tank during the consumption of the fuel.

3.5 Steering systems

3.5.1 Synchronising system

The steering capability of the ship is to be maintained in case of failure of the synchronising system required by the Rules, Pt C, Ch 1, Sec 14, [3.2], without stopping.

3.6 Electrical installations

3.6.1 Single failure leading to the loss of more than one generating set at one time may be accepted, provided the FMEA demonstrates that, after the failure, enough power still remains available to operate the ship under the conditions stated in [3.3.1].

The recourse to the capacity of emergency source is not to be considered.

3.6.2 The main switchboard is to be automatically separable in two sections.The switchboard is to be arranged with all circuits properly distributed between these sections.

Where a failure occurs on one section of the main switchboard, the remaining section is to be able to supply the services defined in [1.2.2] to [1.2.6].

3.7 Automation

3.7.1 The automation system is to be arranged in such a way that a single failure of the control system may lead to the loss of one steering system only.

4 Requirements for independent propulsion and steering systems

4.1 General design requirements

4.1.1 In addition to the requirements set in [3], ships assigned with the notation **HEADING CONTROL-IS** are to comply with this Article.

4.1.2 In the event of fire or flooding casualty in a machinery space, the propulsion, steering and power generation capabilities are to remain sufficient to maintain the heading control of the ship head to the wave as defined in [1.2.1].

4.1.3 Fire and flooding casualties are to be considered in machinery spaces or any space containing a component of a propulsion system, auxiliary propulsion system, steering system and auxiliary steering systems, as defined in requirements [1.2.2] to [1.2.5].

Fire and flooding casualties are to be limited to a single space.

4.1.4 Compliance with requirements above is to be demonstrated by a risk analysis.

4.2 Propulsion and steering systems

4.2.1 Where a propulsion or steering system becomes inoperative due to a fire or flooding casualty, other propulsion and steering systems are not to be affected by the casualty.

4.2.2 The two independent propulsion and steering systems required in [3.3] are to be located in separate compartments.

4.2.3 The auxiliary systems serving the propulsion or steering systems may have common components, be arranged for possible interconnection or serve other systems on board the ship provided that in case of any single failure or fire or flooding casualty affecting those systems, not more than one propulsion or steering system is disabled. This is to be substantiated by the risk analysis.

4.3 Electrical installations

4.3.1 Electrical power plant, including main distribution system is to be arranged in separate compartments, so that in case of fire or flooding casualty, the electrical power necessary to supply the systems defined in [1.2.2] to [1.2.6] remain available.

4.3.2 Single failure and fire and flooding casualties leading to the loss of more than one generating set at one time may be accepted, provided the FMEA demonstrates that, after the failure, enough power still remains available to operate the ship under the conditions stated in [3.3.1] and [3.3.2].

The recourse to the capacity of emergency source is not to be considered.

4.3.3 The main switchboard is to be automatically separable in two sections distributed in independent spaces separated by watertight and A60 fire resistant bulkheads. The switchboard is to be arranged with all circuits properly distributed between these sections.

Where a failure occurs on one section of the main switchboard, the remaining section is to be able to supply the services indicated in [1.2.2] to [1.2.6].

4.4 Automation

4.4.1 The automation system is to be arranged in such a way that a single failure of the control system, including fire and flooding casualty, may lead to the loss of one steering system only.

4.4.2 Control stations of propulsion and steering system are to be arranged so that, in case of fire or flooding casualty, the control is still available.

4.5 Compartment arrangement

4.5.1 Separation bulkhead between machinery compartments is to be A60.

4.5.2 The separation bulkhead between two compartments are to be designed so as to withstand the maximum water level expected after flooding.

4.5.3 The machinery control room is to be separated from all machinery spaces by A60 bulkhead.

4.5.4 The main switchboard is not to be located in the control room.

4.6 Propulsion auxiliary systems

4.6.1 Oil fuel service tanks and supply lines

Oil fuel service tanks are to be located in separate spaces and means and procedures are to be provided to periodically equalize their content during the consumption of the fuel.

Oil fuel supply from each service tank to the propulsion machinery and to the electrical power plant is to be ensured by two separate lines.

4.6.2 Oil fuel units

Oil fuel units serving the propulsion machinery and the electric power plant are to be distributed in two separate spaces so that in case of fire in one of those spaces, the heading capability criteria set in [2.4].

4.6.3 Oil fuel purifying system

Where duplicated oil purifiers are required by the rules, they are to be distributed in two separate spaces.

4.7 Ventilation system

4.7.1 The ventilation system is to be so designed and arranged that in case of fire in one machinery space accompanied with ventilation stopping, the ventilation is to remain operative in other spaces, so that the availability criteria set out in [4.1.2] are satisfied.

5 Tests on board

5.1 Operating tests

5.1.1 Each propulsion systems, steering system as well as the power generation plant are to be subjected to the tests required by the Rules.

5.2 Sea trials

5.2.1 The propulsion machinery, steering machinery and the power generation plant are to undergo the following tests during the sea trials:

- tests required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures
- the values of the power and speed developed by the propulsion prime movers under test are to be recorded, as well as the electrical consumption
- the starting of the stand-by propulsion system after a failure as defined in [3.3.3]
- Tests with steering system out of service.

Section 3 Single Point Mooring (SPM)

1 General

1.1 Application

1.1.1 The additional class notation **SPM** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.15.3] to ships fitted forward with equipment for mooring at single point mooring or single buoy mooring terminals, using standardised equipment complying with the recommendations of the Oil Companies International Marine Forum (OCIMF), according to the requirements of this Section.

1.1.2 These requirements comply with and supplement the Guidelines for Offshore Tanker Operations (1st edition - 2018).

Note 1: Subject to Owner's agreement, applications for certification in compliance with the following previous editions of the OCIMF recommendations are examined by the Society on a case-by-case basis:

- 1st edition (1978): Standards for Equipment Employed in the Mooring of Ships at Single Points Moorings
- 2nd edition (1988): Recommendations for Equipment Employed in the Mooring of Ships at Single Point Moorings
- 3rd edition (1993): Recommendations for Equipment Employed in the Mooring of Ships at Single Point Moorings
- 4th edition (2007): Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings.

Note 2: The edition considered is specified in the certificate relating to the **SPM** notation.

1.1.3 Some components of the equipment used for mooring at single point moorings may be common with the bow emergency towing arrangements specified in Pt B, Ch 12, Sec 4, [3], provided that the requirements of this Section and of Pt B, Ch 12, Sec 4, [3] are complied with.

1.1.4 The relevant requirements of this Section may also be applied to ships fitted afterward with equipment for mooring at single point mooring or single buoy mooring terminals. In such a case, the additional class notation **SPM** is assigned by the Society on a case by case basis.

2 Documentation

2.1 Documentation for approval

2.1.1 In addition to the documents in Pt B, Ch 1, Sec 4, the following are to be submitted to the Society for approval:

- general layout of the forecastle arrangements and associated equipment
- constructional drawing of the bow chain stoppers, bow fairleads and pedestal roller fairleads, together with material specifications and relevant calculations
- drawings of the local ship structures supporting the loads applied to chain stoppers, fairleads, roller pedestals and winches or capstans.

2.2 Documentation for information

2.2.1 In addition to the documents required in Pt B, Ch 1, Sec 4, the following documentation is to be submitted to the Society for information:

- specifications of winches or capstans giving the continuous duty pull and brake holding force
- DWT, in t, of the ship at summer load line defined in Pt B, Ch 1, Sec 3, [2.1.12].

3 General arrangement

3.1 General provision

3.1.1 For mooring at SPM terminals ships are to be provided forward with equipment to allow for heaving on board a standardised chafing chain of 76 mm in diameter by means of a pick-up rope and to allow the chafing chain to be secured to a strongpoint.

3.1.2 The strongpoint is to be a chain cable stopper.

3.2 Typical layout

3.2.1 Fig 1, Fig 2 and Fig 3 show the forecastle schematic layout of the ship which may be used as reference.

3.3 Equipment

3.3.1 The components of the ship's equipment required for mooring at single point moorings are the following:

- bow chain stopper, according to [5.1]
- bow fairlead, according to [5.2]
- pedestal roller fairlead, according to [5.3]
- winch or capstan, according to [5.4].

Figure 1 : Typical forecastle schematic layout

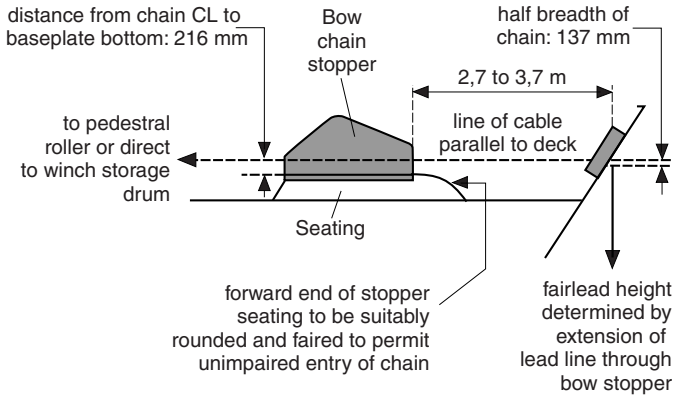
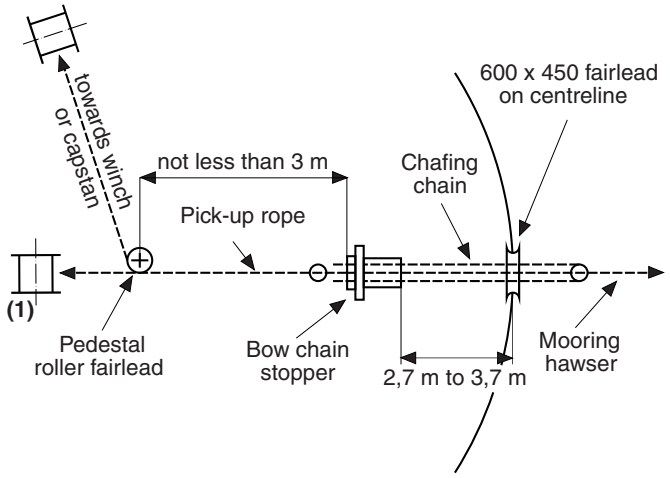
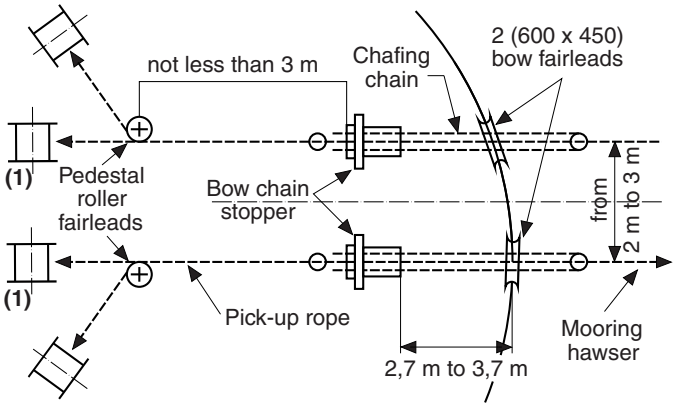


Figure 2 : Forecastle schematic layout for DWT ≤ 150000 t



(1) Winch storage drum without pedestal roller

Figure 3 : Forecastle schematic layout for DWT > 150000 t



(1) Winch storage drum without pedestal roller

4 Number and safe working load of chain stoppers

4.1 General

4.1.1 The number of chain stoppers and their safe working load (SWL), in kN, depending on the DWT of the ship, are defined in Tab 1.

Table 1 : Number and SWL of chain stoppers

Deadweight, in t	Chain stoppers	
	Number	Safe working load (SWL), in kN
DWT ≤ 100000	1	2000
100000 < DWT ≤ 150000	1	2500
DWT > 150000	2	3500

4.1.2 Although the required safe working load (SWL) is generally agreed by the SPM terminal operators, Owners and shipyards are advised that increased safe working load may be requested by terminal operators to take account of local environmental conditions.

In such case the Society is to be duly informed of the special safe working load to be considered.

5 Mooring components

5.1 Bow chain stopper

5.1.1 The ship is to be equipped with bow chain cable stoppers complying with the requirements in Tab 1 and designed to accept standard chafing chain of 76 mm in diameter.

Note 1: The chafing chains are made of:

- grade Q3 steel for ships of less than 350000 t DWT
- grade Q4 steel for ships of equal to or greater than 350000 t DWT.

However, chafing chains are supplied by the SPM terminal operators and are not required to be part of the ship's equipment.

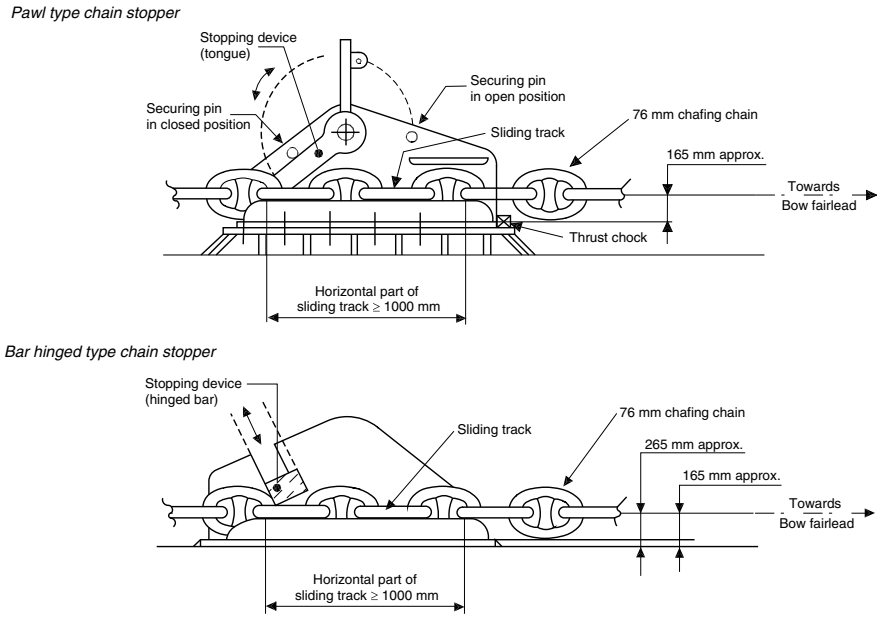
5.1.2 The stoppers are to be capable of securing the 76 mm common stud links of the chain cable when the stopping device (chain engaging pawl or bar) is in the closed position and freely passing the chain cable and its associated fittings when the stopping device is in the open position.

5.1.3 Bow chain stoppers may be of the hinged bar or pawl (tongue) type or other equivalent design. Hydraulic bow chain stoppers with interlocks and emergency shut-down systems integral to the bow loading system are to be considered by the Society on a case-by case basis.

Smit type towing bracket fittings are not to be used as bow chain stoppers.

Typical arrangements of bow chain stoppers are shown in Fig 4.

Figure 4 : Typical bow chain stoppers



5.1.4 The stopping device (chain engaging pawl or bar) of the chain stopper is to be arranged, when in the closed position, to prevent it from gradually working to the open position, which would release the chafing chain and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

5.1.5 Chain stoppers are to be located between 2,7 m and 3,7 m inboard from the bow fairleads (see Fig 1, Fig 2 and Fig 3).

When positioning, due consideration is to be given to the correct alignment of the stopper relative to the direct lead between bow fairlead and pedestal roller fairlead.

5.1.6 Bow chain stoppers are to be capable of withstanding a load equivalent to their safe working load (SWL) and, in such condition, meeting the strength criteria specified in Article [7].

5.1.7 Stopper support structures are to be trimmed to compensate for any camber and/or sheer of the deck. The leading edge of the stopper base plate is to be faired to allow for the unimpeded entry of the chafing chain into the stopper.

5.1.8 Where the chain stopper is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by efficient thrust chocks capable of withstanding a horizontal force equal to the required working strength and, in such condition, meeting the strength criteria specified in Article [7].

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1 (Grade 10.9 is recommended).

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

5.1.9 The chain stopper is to be made of fabricated steel (see NR216 Materials and Welding, Chapter 3) or other ductile material such as steel forging or steel casting complying with the requirements of NR216 Materials and Welding, Chapter 5 and NR216 Materials and Welding, Chapter 6, respectively.

5.1.10 Use of spheroidal graphite (SG) iron casting (see NR216 Materials and Welding, Chapter 7) may be accepted for the main framing of the chain stopper provided that:

- the part concerned is not intended to be a component part of a welded assembly
- the SG iron casting is of ferritic structure with an elongation not less than 12%
- the yield stress at 0,2% is measured and certified
- the internal structure of the component is inspected by means of non-destructive examinations.

5.1.11 The material used for the stopping device (pawl or hinged bar) of chain stoppers is to have mechanical properties similar to grade Q3 chain cable defined in NR216 Materials and Welding, Ch 10, Sec 2.

5.2 Bow fairleads

5.2.1 One bow fairlead is to be fitted for each bow chain stopper.

5.2.2 For ships of more than 150000 t DWT, where two bow fairleads are required, the fairleads are to be spaced 2,0 m centre to centre apart, if practicable, and in no case more than 3,0 m apart.

For ships of 150000 t DWT or less, for which only one bow fairlead is required (see Tab 1), it is generally to be fitted on the centreline.

5.2.3 Bow fairleads are to be capable of withstanding a load equivalent to the safe working load (SWL) of the bow chain stopper that they serve (see [4.1]) and, in such condition, meeting the strength criteria specified in [7]. The load position is to be based on hawser angles as follows:

- in the horizontal plane, up to 90° from the ship's centreline, both starboard and portside
- in the vertical plane, up to 30° above and below horizontal.

5.2.4 Fairleads are normally of a closed type (such as Panama chocks) and are to have an opening large enough to pass the largest portion of the chafing gear, pick-up rope and associated fittings.

For this purpose, the inner dimensions of the bow fairlead opening are to be at least 600 mm in width and 450 mm in height.

5.2.5 Fairleads are to be oval or round in shape.

The lips of the fairleads are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when heaving inboard.

The bending ratio (bearing surface diameter of the fairlead to chafing chain diameter) is to be not less than 7 to 1.

5.2.6 The fairleads are to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the chain stopper and the fairlead.

5.2.7 Fairleads are to be made of fabricated steel plates (see NR216 Materials and Welding, Chapter 3) or other ductile material such as weldable steel forging or steel casting complying with the requirements of NR216 Materials and Welding, Chapter 5 and NR216 Materials and Welding, Chapter 6, respectively.

5.3 Pedestal roller fairleads

5.3.1 Pedestal roller fairleads are to be used only when the mooring arrangement design is not permitting direct straight leads to a winch storage drum. The number of pedestal roller fairleads for each bow chain stopper is not to exceed two, and the angle of change of direction of the pick-up rope is to be kept as low as possible.

The pedestal roller fairleads are to be fitted not less than 3 m behind the bow chain stopper.

Typical arrangements using pedestal roller fairleads are shown in Fig 1, Fig 2 and Fig 3.

5.3.2 The pedestal roller fairleads are to be capable of withstanding a horizontal force equal to the greater of the values:

- 225 kN
- the resultant force due to an assumed pull of 225 kN in the pick-up rope.

Stresses generated by this horizontal force are to comply with the strength criteria indicated in [7].

5.3.3 It is recommended that the fairlead roller should have a diameter not less than 7 times the diameter of the pick-up rope. Where the diameter of the pick-up rope is unknown it is recommended that the roller diameter should be at least 400 mm.

5.4 Winches or capstans

5.4.1 Winches or capstans used to handle the mooring gear are to be capable of heaving inboard a load of at least 15 t. For this purpose winches or capstans are to be capable of exerting a continuous duty pull of not less than 150 kN and withstanding a braking pull of not less than 225 kN.

5.4.2 If a winch storage drum is used to stow the pick-up rope, it is to be of sufficient size to accommodate 150 m of rope of 80 mm diameter.

6 Supporting hull structures

6.1 General

6.1.1 The bulwark plating and stays as well as the deck structure are to be reinforced in the region of the fairleads to withstand the force defined in [5.2.3]and meet the strength criteria specified in Article [7].

6.1.2 Deck structures in way of bow chain stoppers, including deck seatings and deck connections, are to be suitably reinforced to resist a horizontal load equal to the required working strength and, in such condition, to meet the strength criteria specified in [7].

For deck bolted chain stoppers, reinforcements are to comply with [5.1.8].

6.1.3 The deck structures in way of the pedestal roller fairleads and in way of winches or capstans as well as the deck connections are to be reinforced to withstand, respectively, the horizontal force defined in [5.3.2] or the braking pull defined in [5.4.1] and to meet the strength criteria specified in Article [7].

6.1.4 Main welds of the bow chain stoppers with the hull structure are to be 100% inspected by means of non-destructive examinations.

7 Strength criteria

7.1 General

7.1.1 The equivalent stress σ_{VM} induced by the loads in the equipment components (see [3.3]) is to be in compliance with the following formula:

$\sigma_{VM} \leq \sigma_a$

where:

σ_a : Permissible stress, to be taken, in N/mm², as the lower of 0,5 R_{eH} and 0,3 R_m

R_{eH} : Minimum yield stress, in N/mm², of the component material

R_m : Tensile strength, in N/mm², of the component material.

Section 4 Unsheltered Anchoring

1 General

1.1 Application

1.1.1 The additional class notation **UNSHELTERED ANCHORING** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.15.4], to ships fitted with anchoring equipment in deep and unsheltered water complying with the requirements of this Section, in addition to the requirements from Pt B, Ch 12, Sec 4, as applicable to equipment.

1.1.2 The requirements of this Section apply to ships with an equipment length L_E, as defined in Pt B, Ch 12, Sec 4, [1.2.2], greater than 135 m and intended to anchor in deep and unsheltered water with:

- depth of water up to 120 m
- current speed up to 3 knots (1,54 m/s)
- wind speed up to 27 knots (14 m/s)
- waves with significant height up to 3 m.

The scope of chain cable, being the ratio between the length of chain paid out and water depth, is assumed to be to the maximum possible and not less than 3.

2 Anchoring equipment

2.1 Equipment number for deep and unsheltered water

2.1.1 The equipment number for deep and unsheltered water EN_1 is to be obtained from the following formula:

$$EN_1 = 0,628\left[a\left(\frac{EN}{0,628}\right)^{\frac{1}{2,3}} + b(1-a)\right]^{2,3}$$

where:

$$a = 1,83 \cdot 10^{-9} \cdot L_E^{\,3} + 2,09 \cdot 10^{-6} \cdot L_E^{\,2} - 6,21 \cdot 10^{-4} \cdot L_E + 0,0866$$

$$b = 0,156 \cdot L_E + 8,372$$

EN : Equipment Number as defined in Pt B, Ch 12, Sec 4, [1.2.2]

L_E : Equipment length L_E of the ship as defined in Pt B, Ch 12, Sec 4, [1.2.2].

2.1.2 Anchors and chain cables are to be in accordance with Tab 1 and based on the Equipment Number for deep and unsheltered water EN_1.

2.2 Anchors

2.2.1 In addition to the provisions of Pt B, Ch 12, Sec 4, [2.1]:

- Anchors are to be of the stockless High Holding Power (HHP) type
- The mass of the head of stockless anchor, including pins and fittings, is not to be less than 60% of the total mass of the anchor
- The mass of individual anchors may differ by ± 7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

2.3 Chain cables for bower anchors

2.3.1 In addition to the provisions of Pt B, Ch 12, Sec 4, [2.2], bower anchors are to be associated with stud link chain cables of grade Q2 or Q3 as given in Tab 1. The total length of chain cable is to be divided in approximately equal parts between the two anchors ready for use.

2.4 Anchor windlass and chain stopper

2.4.1 Anchor windlass, chain stopper and supporting structure of anchor windlass and chain stopper are to comply with Pt B, Ch 12, Sec 4, [2.5] and Pt B, Ch 12, Sec 4, [2.6], unless otherwise specified.

2.4.2 Notwithstanding the requirements of [2.4.1], the windlass unit prime mover is to be able to supply for at least 30 minutes a continuous duty pull Z_{cont}, in N, given by:

$$Z_{cont} = 35d^2 + 13,4\ m_A$$

where:

d : Chain diameter, in mm, as per Tab 1

m_A : HHP anchor mass, in kg, as per Tab 1.

2.4.3 In addition to [2.4.1], for testing purpose, the speed of the chain cable during hoisting of the anchor and cable is to be measured over 37,5 m of chain cable and initially with at least 120 m of chain and the anchor submerged and hanging free. The mean speed of the chain cable during hoisting of the anchor from the depth of 120 m to the depth of 82,5 m is to be at least 4,5 m/min.

Where the available water depth is insufficient, an equivalent test method, compensating the missing hanging chain weight, is to be submitted for special examination by the Society. In case the test method is not considered equivalent, the maximum water depth associated to the additional class notation **UNSHELTERED ANCHORING** is to be limited to the tested depth and specified in a memorandum.

Table 1 : Anchoring equipment for ships in unsheltered water with depth up to 120m

Equipment number EN_1 $A \le EN_1 < B$		High Holding Power (HHP) stockless bower anchors		Stud link chain cables for bower anchors		
		Number of anchors	Mass per anchor (m_a), in kg	Total length, in m	Diameter (d), in mm	
A	B				Q2	Q3
–	1790	2	14150	1017,5	105	84
1790	1930	2	14400	990	105	84
1930	2080	2	14800	990	105	84
2080	2230	2	15200	990	105	84
2230	2380	2	15600	990	105	84
2380	2530	2	16000	990	105	84
2530	2700	2	16300	990	105	84
2700	2870	2	16700	990	105	84
2870	3040	2	17000	990	105	84
3040	3210	2	17600	990	105	84
3210	3400	2	18000	990	105	84
3400	3600	2	18300	990	106	84
3600	3800	2	19000	990	107	85
3800	4000	2	19700	962,5	108	87
4000	4200	2	20300	962,5	111	90
4200	4400	2	21100	962,5	114	92
4400	4600	2	22000	962,5	117	95
4600	4800	2	22900	962,5	119	97
4800	5000	2	23500	962,5	122	99
5000	5200	2	24000	935	125	102
5200	5500	2	24500	907,5	130	105
5500	5800	2	25000	907,5	133	107
5800	6100	2	25500	880	137	111
6100	6500	2	25700	880	140	113
6500	6900	2	26000	852,5	143	115
6900	7400	2	26500	852,5	147	118
7400	7900	2	27000	825	152	121
7900	8400	2	27500	825	154	123
8400	8900	2	28000	797,5	158	127
8900	9400	2	28900	770	162	132
9400	10000	2	29400	770	–	135
10000	10700	2	29900	770	–	139
10700	11500	2	30600	770	–	143
11500	12400	2	31500	770	–	147
12400	13400	2	33200	770	–	152
13400	14600	2	35000	770	–	157
14600	–	2	38000	770	–	162

Section 5 Dynamic Positioning (DYNAPOS)

1 General

1.1 Application

1.1.1 The additional class notation **DYNAPOS** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.15.5], to ships fitted with dynamic positioning system complying with the requirements of this Section.

This notation is completed by additional symbols defined in [1.4], according to the operational mode of the system.

1.1.2 These requirements are additional to those applicable to the classification of the corresponding ships or mobile offshore units. Attention is drawn to the fact that dynamic positioning systems may be required to comply with existing national regulations.

1.1.3 With reference to the Rules for the Classification of Ships, the following requirements apply:

- Pt C, Ch 1, Sec 2 when the thruster is driven by an internal combustion engine
- Pt C, Ch 1, Sec 15 for azimuthal and transverse thrusters
- Part F, Chapter 3 depending on the automation system installed.

1.2 Definitions

1.2.1 Alarm devices

Visual and audible signals enabling the operator to immediately identify any active single failure which is relevant to the requirements of the applicable notation described in this Section.

1.2.2 Bus-tie breaker

A device connecting or disconnecting switchboards and/or switchboard parts which are normally divided. “Closed bus-tie(s)” means connected switchboards or switchboard parts.

1.2.3 Computer system

A system consisting of one or more computers and associated hardware, software and their interfaces.

1.2.4 Dynamic positioning operator station (DP operator station)

A workstation designated for DP operations, where necessary information sources, such as indicators, displays, alarm panels, control panels and internal communication systems are installed. This includes but is not limited to: DP joystick and independent joystick control operator stations, required position DP system reference systems’ Human Machine Interface (HMI), manual thruster levers, thruster emergency stops, mode change systems, thruster emergency stops, internal communications.

1.2.5 Dynamic positioning operation (DP operation)

Using the DP system to control surge, sway and yaw automatically.

1.2.6 Dynamic positioning operator (DPO)

A member of the crew engaged in operating a Dynamic Positioning (DP) system as the primary watch keeper at the DP control desk. DPO monitors the DP system and logistic operations around the vessel.

1.2.7 Dynamically positioned vessel (DP vessel)

A unit or a vessel which automatically maintains its position and/or heading (fixed location, relative location or predetermined track) by means of thrust force.

1.2.8 Environment

Environmental conditions include wind, current and waves. Ice loads are not taken into account.

1.2.9 Failure

An occurrence in a component or system that causes one or both of the following effects:

- loss of component or system function; and/or
- deterioration of functional capability to such an extent that the safety of the vessel, personnel or environmental protection is significantly reduced.

1.2.10 Failure modes and effects analysis (FMEA)

A systematic analysis of systems and sub-systems to a level of detail that identifies all potential failure modes, down to the appropriate sub-system level, and their consequences. However, if it can be shown that at a certain level between overall system level and component level there is no further effect on the overall system if a failure occurs, then it is not necessary to continue to the next level down.

1.2.11 FMEA proving trials

The test program for verifying the FMEA. FMEA proving trials are required at the new built stage of the vessel, and will need to be repeated if the vessel undergoes a major upgrade and/or conversion.

1.2.12 Hidden failure

A failure that is not immediately evident to operations or maintenance personnel and has the potential for failure of equipment to perform an on-demand function, such as protective functions in power plants and switchboards, standby equipment, backup power supplies or lack of capacity or performance.

1.2.13 Joystick system

A system with centralised manual position control and manual and/or automatic heading control.

1.2.14 Junk data

Junk data is confused data of no recognised format to the recipient. It contains data types and/or formatting which are not recognised by the receiving nodes on the network. Junk Data is data with no particular structure or protocol as viewed by the recipient. This type of “garbage” data can be thought of as similar to radio static, and at high levels can saturate the transmission capacity of a network, blocking the transmission of all valid communication. Junk data primarily acts as a bandwidth “thief”.

1.2.15 Loss of position and/or heading

The vessel's position and/or heading is outside the limits set for carrying out the DP activity in progress.

1.2.16 Network

A digital communication link to allow the communication of information between network nodes. Examples of communication standards include Ethernet, CAN bus, RS232, RS485, Modbus, Profibus and others.

1.2.17 (Network) Node

Any addressable device (for example a device with a MAC address) on a network with the capability to send/receive data.

1.2.18 Position keeping

Maintaining a desired position and/or heading or track within the normal excursions of the control system and the defined environmental conditions (e.g. wind, waves, current).

1.2.19 Power management system

A system that ensures continuity of electrical supply to DP equipment under all operating conditions.

1.2.20 Recognized data

Recognised data is that which is used for normal network operations and conforms to formats and protocols that are normally processed by the network components. It may contain valid handshaking and security information that permits free flow of data across the network. Recognised data is of a format that is expected by the devices connected to the network. The presence of recognised data therefore prompts network devices to attempt to process the data. Recognised data will pass the network interface card of a node and will put load on the CPU of a node.

1.2.21 Redundancy

The ability of a component or system to maintain or restore its function when a single failure has occurred. Redundancy can be achieved, for instance, by the installation of multiple components, systems or alternative means of performing a function.

1.2.22 Test

A procedure intended to establish the quality, performance, or reliability of DP system component(s).

1.2.23 Time to safely terminate (operations)

The amount of time required in an emergency to safely cease operations of the DP vessel.

1.2.24 Trials

A test of the performance, qualities, or suitability of the DP system. A trial can consist of one or more tests, and proves that the Worst Case Failure (WCF) is not exceeded.

1.2.25 Worst-case failure design intent (WCFDI)

The specified minimum DP system capabilities to be maintained following the worst-case failure. The worst-case failure design intent is used as the basis of the design. This usually relates to the number of thrusters, generators and/or switchboards that can simultaneously fail.

1.2.26 Worst-Case Failure (WCF)

The identified single fault in the DP system resulting in the maximum detrimental effect on DP capability as determined through the FMEA.

1.3 Dynamic positioning sub-systems

1.3.1 The installation necessary for dynamically positioning a vessel comprises, but is not limited to, the following sub-systems:

- power generation and distribution system, i.e. all components and systems necessary to supply the DP system with power
- thruster system, i.e. all components and systems necessary to supply the DP system with thrust force and direction
- DP control system, i.e. all control components and systems, hardware and software necessary to dynamically position the vessel.

1.3.2 Power generation and distribution system means all components and systems necessary to supply the DP system with power. The power system includes but is not limited to:

- prime movers with necessary auxiliary systems including piping, fuel, cooling, pre-lubrication and lubrication, hydraulic, pre-heating, and pneumatic systems
- generators
- switchboards
- power supplies, including uninterruptible power supplies (UPS), and
- power management system(s) (as appropriate)
- heating, ventilation and air-conditioning systems
- associated cabling and cable routing.

1.3.3 Thruster system means all components and systems necessary to supply the DP system with thrust force and direction. The thruster system includes:

- thrusters with drive units and necessary auxiliary systems including piping, cooling, hydraulic, and lubrication systems, etc.
- main propellers and rudders if these are under the control of the DP system
- automatic thruster control system(s)
- manual thruster controls, and
- associated cabling and cable routing.

1.3.4 Dynamic Positioning control system (DP control system) means all control components and systems, hardware and software necessary to dynamically position the vessel. The DP control system consists of the following:

- computer system/joystick system
- operator stations and display system (operator panels)
- position reference system(s)
- environmental sensors
- associated cabling and cable routing, and
- networks.

1.4 Additional and optional class notation

1.4.1 The notation **DYNAPOS** is completed by one of the following additional notations according to the operational mode of the installation:

- **SAM** (semi-automatic mode): The operator's manual intervention is necessary for position keeping:
  - the control system of installations receiving the notation **SAM** is to achieve synthetic control of all the thrusters thanks to a simple single device (for instance, a joystick)
  - the control system is to indicate the position and heading of the unit to the operator. Control settings are to be displayed
  - the control device handle is to have a well-defined neutral position (no thrust)
  - any dynamic positioning installation provided with an automatic control is to be additionally fitted with a manual manoeuvring control complying with the requirements of the **SAM** notation.
- **AM** (automatic mode): position keeping is automatically achieved.
- **AT** (automatic tracking): the unit is maintained along a predetermined path, at a preset speed and with a preset heading which can be completely different from the course.
- **AM/AT**: the installation combines the **AM** and **AT** capabilities.

Note 1: When the notation **AM/AT** is used in the rest of this Section, the corresponding requirements are applicable to notations **AM** or **AT** or **AM/AT**.

The notation **SAM** may be completed by **-HWIL** when the control system has been verified according to the requirements of NR632 Hardware-in-the-loop Testing..

The notation **AM**, **AT** or **AM/AT** may be completed as applicable by:

- One of the notation **R** or **RS**:
  - the notation **R**, when the dynamic positioning system is provided with redundancy achieved by using two or more systems or alternative means of performing a function, as defined in [1.2.21].
  - the notation **RS**, when in addition to symbol **R**, the redundancy is achieved by using two systems or alternative means of performing a function physically separated as defined in [4.1.2].

Note 2: **R** and **RS** cannot be assigned together.

- The environmental station keeping index **ESKI(x;x)** indicating the station keeping capability of the vessel (as a percentage of time) under given environmental conditions defined in Article [9].
- The notation **-HWIL** when the control system has been verified according to the requirements of NR632 Hardware-in-the-loop Testing.

The notation **R** or **RS** may be completed by **-DDPS** and/or **-EI**:

- The notation **-DDPS** is assigned when the ship is fitted with a system which enables the vessel to undertake digital surveys in compliance with the requirements of Article [11].
- The notation **-EI** is assigned when the ship is fitted with an enhanced dynamic positioning control system in compliance with the requirements of Article [10].

Example:

DYNAPOS SAM -HWIL

DYNAPOS AM R ESKI(99;95) -HWIL -DDPS -EI

DYNAPOS AT ESKI(99;95)

DYNAPOS AM/AT RS -DDPS

1.4.2 Installations intended to be assigned the notation **DYNAPOS AM/AT** are to be provided with a calculation unit including, in addition to the computer, a reference clock and peripheral equipment for visualisation and printing.

The computer type and features are to comply with the requirements regarding performance in environmental conditions to the satisfaction of the Society.

Calculation cycle fulfilment is to be automatically monitored. Any failure of the computer is to activate a visual and audible alarm.

1.4.3 For the **DYNAPOS AM/AT** notation, the ship is to be fitted with an automatic control and a standby manual control, the latter being equivalent to the control system required for the **SAM** notation.

1.4.4 Association of DP system with position mooring system

These Rules do not cover the association of the dynamic system with a position mooring system; in such case a special examination of the installations is to be carried out by the Society. Technical considerations concerning this type of installation are given in [4.1.6] for information.

1.4.5 The practical choice of the dynamic positioning classification notation is governed by the following guidelines:

The notation **DYNAPOS SAM** is not granted to the following types of units:

- diving support vessel
- cable and pipe laying ship
- lifting units

1.5 Installation survey during construction

1.5.1 Installations built under special survey are subject to:

- examination of documents with consideration of those specified in [1.6]
- surveys during fabrication and component testing carried out at the supplier's works and at the yard
- dock and sea trials with a Surveyor from the Society in attendance.

1.6 List of documents to be submitted

1.6.1 In addition to the drawings and specifications required by the Rules for the Classification of Ships, the documents listed in Tab 1 are required.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents to be submitted
1	A	Documentation on the environment conditions long term distribution (see [9.4.1])
2	I	Owner performance request, if any
3	A	Diagram of the environmental limit conditions (also called capability plot) for the conditions defined in the specification and at least with all thrusters running and selected in DP, and the worst case failure.
4	A	Functional block diagram of the sensor and reference systems (position/environmental conditions)
5	A	Functional block diagram of the control unit
6	A	Single line diagram and specification of the cables between the different equipment units (power, control, display)
7	A	Electrical power balance
8	A	List of the equipment units with, for each one, Manufacturer's identification, type and model
9	A	Type test reports for the sensors of the measurement systems, or equivalent
10	A **(3)**	Type test report or case-by-case approval certificate for the DP control system
11	A	For approval of propulsion, based on rotary azimuth thrusters: - layout drawings of thrust units, thrust shafts and blocks - arrangement of hull passages - thrust curves of each propulsion unit
12	A	Electrical power management layout drawings and specification if provided on board
13	A	Internal communication system description
14	A	Description of the operator stations (layout on board, descriptive diagrams of the display consoles)
15	A	Alarm list and parameter values displayed on the consoles
16	A	Program of FMEA Proving tests alongside quay and at sea
17	A **(2)**	Analysis of consequences of single failures in accordance with rule requirements in the form of a failure mode and effect analysis (FMEA) (see [2.4].
18	A **(2)**	Study of possible interaction between thrusters
19	I	Technical specification of the positioning system
20	I	Operating manual of the positioning system including: - description of the equipment - maintenance guide - emergency procedures.
21	I	Vessel-specific DP-operation manuals (see [7.1])
22	A	Program of FMEA Annual tests alongside quay and at sea

(1) A : To be submitted for approval; I : To be submitted for information.
(2) For symbols **R** and **RS** only.
(3) Tests to be in accordance with Pt C, Ch 3, Sec 6

2 Performance analysis

2.1 General

2.1.1 A performance analysis of the DP system is required in order to justify design options and limit allowable environmental conditions. This capability analysis is to consider the main features of the DP system:

- DP controller models
- installed power
- sizing, location and dynamic behaviour of thrusters

with regard to the required station keeping ability and accuracy in the specified environmental conditions.

2.2 Condition of analysis

2.2.1 The environmental conditions to be considered in the analysis are normally defined by the Owner for the intended service of the unit. However, for symbol **R** and **RS** assignment, the following situations are to be considered:

- normal environmental conditions: those environmental conditions in which nominal position holding performances are attained, while the unit is in the normal working situation
- safety environmental conditions: environmental conditions such that any single failure of a thruster or generator unit occurring in service does not impair position keeping or operational safety

- limiting environmental conditions: those environmental conditions in which position keeping is possible with all thrusters running, only installations essential for safety being in service.

When symbol **R** and **RS** assignment is not required, the analysis may be limited to normal environmental conditions, in any event considering single failure of a generating set. The required analysis may be performed either:

- by a mathematical model of the behaviour of the unit, possibly associated with tank test results, or
- on the basis of previous operational experience gained on similar installations.

2.3 Modelling and simulations

2.3.1 Capability plots, being a simulated balance of the unit's power generation, thrust and environmental forces and moments, is required for symbol **R** and **RS** assignment.

2.3.2 The simulation required in [2.3.1] is notably to include suitable modelling of the following:

- environmental forces (e.g. wind, currents)
- hydrodynamic behaviour of the unit
- aerodynamic behaviour of the unit
- dynamic action of thrusters
- control loop.

2.3.3 Simulation results are to include a power and thrust determination for each case under consideration and are to be presented as follows:

- Plots should be produced in polar form, with a wind speed scale between 0 and 50 m/s (15 mm = 10 m/s)
- Wind, waves and currents should be assumed coincident in direction. The current speed should be invariant with depth
- The limiting wind speed should be plotted at least once every 15° around the vessel. Linear interpolation between points is acceptable.

2.3.4 At least a minimum of two plots is required, under the same weather conditions. Plot 1 is to be with all systems fully functional, that is all thrusters able to develop the maximum thrust as required. Plot 2 is to be produced on the same scale as Plot 1 and represent the worst case failure mode, or an amalgamation of the worst cases.

Note 1: The simulation is to take account of the response of the unit to oscillating forces of positive average (waves, wind, possible external links) likely to have a resonant action upon the dynamic system composed of the unit together with its DP system.

2.4 Failure mode and effects analysis

2.4.1 For installation intended to be assigned the notation **DYNAPOS AM/AT R** and **DYNAPOS AM/AT RS** an FMEA is to be carried out. This is a systematic analysis of systems and subsystems to the level of detail required to demonstrate that no single failure as defined in [3.2] will cause a loss of position and/or heading and is to establish worst-case failure design intent.

2.4.2 The FMEA is to provide general vessel information and specify the overall acceptance criteria, i.e. notation(s), to allow the Society to understand how the (sub) systems work at a level that allows them to correctly assess their failure modes. The systems can be organised as per Tab 2.

Table 2 : Major DP equipment

No.	System	Subsystem
1	DP Control	Computers and consoles, networks, hardware architecture, position reference systems, environmental systems, etc.
2	Power Generation	Generators, voltage regulators, governors, protection systems
3	Power Distribution	High and low voltage AC distribution systems, emergency systems configuration and distribution, UPS systems configuration and distribution, low voltage DC distribution systems and control power supplies, bus tiebreakers and breaker interlocks, protection systems
4	Propulsion System	Main propellers and/or thrusters and their drives, hydraulic systems, lubrication systems, emergency stops, steering gear, gearboxes, cooling system, control loops, manual levers, joystick, DP interfaces
5	Control System	Integrated control system, thruster control systems, vessel management system, power management system (including load sharing, load shedding, load reduction, and black out recovery), data networks, hardware architecture, etc.
6	Machinery System	Prime movers, fuel system, freshwater and seawater cooling systems, lubrication systems, compressed air systems, remote controlled valve systems, heating, ventilation, and air conditioning (HVAC), etc.
7	Safety system	Emergency shutdown system, quick closing valves, etc.

2.4.3 Each system should be considered in a bottom-up approach, starting from the system's functional output, and failure is to be assumed by one possible cause at a time. Since a failure mode may have more than one cause, all potential independent causes for each failure mode are to be identified.

2.4.4 The analysis within the FMEA is to show the level of redundancy of each sub-system as well as the conse-quences of possible common mode failures. Therefore, each physically and functionally independent sub-system and the associated failure modes with their failure causes related to normal operational modes of the sub-system are to be described.

2.4.5 Where cross connections between redundant groups exist, fault tolerance, fault resistance and the potential for fault propagation are to be analysed by the FMEA and proven during the initial sea trials. The FMEA study in general only analyses failure effects based on a single failure in the system and, therefore, a failure detection means, such as visual or audible warning devices, automatic sensing devices, sensing instrumentation or other unique indications, is to be identified. Where applicable, mitigating factors need to be stated.

For each system defined in Tab 2, the conclusion on the cross connections is to be provided in the corresponding part of FMEA. If there are no cross connections, it is to be stated explicitly. If the cross connections exist, each is to be listed with the protective arrangements described, including, but not limited to, by discriminative studies, simulation and test reports.

2.4.6 Where the system element failure is non-detectable (i.e. a hidden fault or any failure which does not give any visual or audible indication to the operator) and the system can continue with its specific operation, the analysis is to be extended to determine the effects of a second failure, which in combination with the first undetectable failure may result in a more severe failure effect, e.g. hazardous or catastrophic effect. For installations intended to be assigned the symbol **RS**, the FMEA is to state the separation design intent and give descriptions of the installation of redundant sub-systems in fire and flooding protected compartments and zones. The method of separating the different zones is to be identified. The design is to be analysed and is to contain a conclusion on whether the separation design intent is met.

2.4.7 A test program specifying tests to verify assumptions and conclusions within the FMEA is to be drawn up and submitted to the Society for approval.

2.4.8 The FMEA is to summarise and conclude as a minimum the following:

- for each sub-system analysed, the conclusions are to be stated
- for the total DP system, an overall conclusion is to be stated identifying the most critical sub-system
- a compliance statement referring to the acceptance criterion and with reference to the capability polar plots as defined in [2.3.3].

2.4.9 The FMEA is to be kept updated and is to be available on board for inspection by the Society.

3 Equipment class

3.1 General

3.1.1 The DP-vessel is to be operated in such a way that the worst-case failure, as determined in [2.4.1], can occur at any time without causing a breach of acceptable excursion criteria set for loss of position and/or heading for **DYNAPOS AM/AT R** or **DYNAPOS AM/AT RS**.

3.1.2 When a DP-vessel is assigned an equipment class, this means that the DP-vessel is suitable for all types of DP-operations within the assigned and lower equipment classes.

3.2 Equipment class according to single failure

3.2.1 **DYNAPOS AM/AT**, is equivalent to IMO equipment class 1. A loss of position and/or heading may occur in the event of a single failure.

3.2.2 **DYNAPOS AM/AT R**, is equivalent to IMO equipment class 2. A loss of position and/or heading is not to occur in the event of a single failure in any active component or system. Common static components may be accepted in systems which will not immediately affect position keeping capabilities upon failure (e.g. ventilation and seawater systems not directly cooling running machinery). Normally such static components will not be considered to fail under reserve that they are built and installed in accordance with the rules of classification of the ship. Single failure criteria include, but are not limited to:

- any active component or system (generators, thrusters, switchboards, communication networks, remote-controlled valves, etc.); and
- any normally static component (cables, pipes, manual valves, etc.) that may immediately affect position keeping capabilities upon failure and is not properly documented with respect to protection.

3.2.3 **DYNAPOS AM/AT RS**, is equivalent to IMO equipment class 3. A loss of position and/or heading is not to occur in the event of a single failure in any active component or system, as specified for symbol **R** (see [3.2.2]).For symbol **RS** a single failure however includes:

- items listed in [3.2.2], and any normally static component is assumed to fail
- all components in any one watertight compartment, from fire or flooding
- all components in any one fire subdivision, from fire or flooding. For cables, see [6.1.2].

3.2.4 For symbol **R** and **RS**, a single inadvertent act is to be considered as a single failure if such an act is reasonably probable.

4 Functional requirements

4.1 General

4.1.1 All components in a DP system are to comply with the relevant Rules for the Classification of Ships.

4.1.2 In order to meet the single failure criteria given in [3.2], redundancy of components will normally be necessary as follows:

- for symbol **R**, redundancy of all active components
- for symbol **RS**, redundancy of all components and A-60 physical separation of the components, or equivalents.

For symbol **RS**, full redundancy of the control system may not always be possible (e.g., there may be a need for a single change-over system from the main computer system to the backup computer system). Non-redundant connections between otherwise redundant and separated systems may be accepted provided that these are operated so that they do not represent a possible failure propagation path during DP operations. Such connections are to be kept to the absolute minimum and made to fail to the safest condition. Failure in one system is in no case to be transferred to the other redundant system.

4.1.3 Redundant components and systems are to be immediately available without needing manual intervention from the operators and with such capacity that the DP operation can be continued for such a period that the work in progress can be terminated safely. The transfer of control is to be smooth and within acceptable limitations of the DP operation(s) for which the vessel is designed.

4.1.4 If external forces from mission-related systems (cable lay, pipe lay, mooring, etc.) have a direct impact on DP performance, the influence of these systems are to be considered and factored into the DP system design. Where available from the DP system or equipment manufacturer, such data inputs are to be provided automatically to the DP control system. Additionally, provisions are to be made to provide such data inputs into the DP control system manually. These systems and the associated automatic inputs are to be subject to analysis, as specified in [2.4], and surveys and testing specified in [8.2].

4.1.5 The analysis of the consequences of anchor line breaks or thruster failure is to be carried out according to the operational situation. For symbol **R** or **RS** assignment, hidden failure monitoring or regular maintenance is to be provided on all devices where the FMEA shows that a hidden failure will result in a loss of redundancy.

4.1.6 When associated with position mooring equipment and used to assist the main dynamic positioning in special circumstances of operation, for instance in the vicinity of an offshore platform, this system is to be designed in such a way as to remote control the length and tension of individual anchor lines.

The analysis of the consequences of anchor line breaks or thruster failure is to be carried out according to the operational situation.

4.2 Power system

4.2.1 The electrical installations are to comply with the applicable requirements of the Rules for the Classification of Ships, in particular for the following items:

- general conditions
- power supply systems
- rotating electrical machinery
- transformers
- switchboards
- electrical cables
- electrical batteries
- rectifiers
- electronic equipment
- electromagnetic clutches and brakes, with special consideration for the Rules applicable to the electric propulsion system, see Pt C, Ch 2, Sec 14.

4.2.2 System configuration requirements for main power supply and propulsion systems is detailed in Tab 3.

4.2.3 The power system is to have an adequate response time to power demand changes.

Table 3 : System configuration for main power supply and propulsion systems

Equipment class	–	1	2	3
Additional class notation **DYNAPOS**	**SAM**	**AM/AT**	**AM/AT R**	**AM/AT RS**
Distribution system	According to SOLAS and the present Rules		redundant	redundant in separate rooms
Electric generators			redundant	redundant in separate rooms
Main switchboard			One with bus tie circuit breaker(s) Two or more circuits equally distributed	Two or more switchboards, with bus tie circuit-breakers normally open, located in separate rooms
Thrusters and associated control systems			redundant	redundant in separate rooms
Power management system components			redundant	redundant in separate rooms
Note 1: Redundant is to be understood as defined in [1.2.17].				

4.2.4 For **DYNAPOS AM/AT**, the power system need not be redundant.

4.2.5 For **DYNAPOS AM/AT R**, the power system (generators, main busbars, etc.) is to be divisible into two or more systems so that, in the event of failure of one sub-system, at least one other system will remain in operation. The power system(s) may be run as one system during operation, but is to be arranged with bus tie breaker(s) to separate the systems automatically upon failures, to prevent the transfer of failure of one system to the other, including, but not limited to, overloading and short circuits.

4.2.6 For **DYNAPOS AM/AT RS**, the power system (generators, main busbars, etc.) is to be divisible into two or more systems such that in the event of failure of one system, at least one other system will remain in operation. The divided power system is to be located in different spaces separated by A-60 class divisions, or equivalent. Where the power systems are located below the operational waterline, the separation is also to be watertight. Bus tie breakers are to be open during equipment class 3 operations unless equivalent integrity of power operation can be accepted according to [4.1.2].

4.2.7 A dedicated UPS is to be provided, a minimum of one UPS for **AM/AT**, two UPSs for **AM/AT R** and three UPSs for **AM/AT RS** with one being located in a separate room, to ensure that any power failure will not affect more than one DP control system and its associated components. The reference systems and sensors are to be distributed on the UPSs in the same manner as the control systems they serve, so that any power failure will not cause loss of position keeping ability. An alarm is to be initiated in case of loss of charge power. UPS battery capacity is to provide a minimum of 30 minutes operation following a main supply failure. For symbol **R** and **RS**, the charge power for the UPSs supplying the main control system is to originate from different power systems. The bypass supply may originate from a common power source.

4.2.8 Alternative energy storage (e.g. batteries and fly-wheels), as per Part F, Chapter 14, may be used as sources of power to thrusters as long as all relevant redundancy, independence and separation requirements for the relevant notation are complied with. For symbol **R** and/or **RS**, the available energy from such sources may be included in the consequence analysis function, required in [4.9.4], when reliable energy measurements can be provided. The energy measurements then need to calculate the remaining time the vessel can hold position and/or heading if the position and/or heading keeping is dependent on the batteries. Alarms are to be generated based on available energy, levels of which may depend on the vessel's operation. However, when the available energy level falls be-low the calculated time of 30 minutes a continuous alarm is to be generated.

4.2.9 Sudden load changes resulting from single faults or equipment failures is not to create a blackout.

4.3 Monitoring and management of the electricity production and propulsion

4.3.1 As a general rule, the monitoring level of electric generators, their prime movers and power supply equipment, main propulsion diesel engines and electric propulsion are to be in accordance at least with the requirements of the additional classification notation **AUT CCS**. For installations assigned the symbol **RS**, the requirements of **AUT UMS** or **AUT IMS** may be considered.

4.3.2 For symbol **R** and **RS**, the power available for position keeping is to be sufficient to maintain the vessel in position after the worst case failure as per [3.2.2] and/or [3.2.3].

4.3.3 For symbol **R** and **RS** an automatic power management system is required and is to be capable of, but not limited to:

- enabling quick supply and/or sharing of active and/or reactive power to consumers in all operating conditions including generator failure, change of thruster configuration or operation of mission equipment
- monitoring power sources and informing the operator about desirable configuration changes such as starting or stopping of generators
- providing automatic change-over of a generating set in case of detected failure; this required capability mainly applies to normal operating conditions.
- providing synchronization of generators to a live switchboard and/or between live switchboards
- providing black-out prevention function by:
  - limitation of absorbed power. Proportional cutbacks may be adequately implemented: static rectifier tripping, thrust command limits, etc. Any automatic limitation is to activate warning devices.
  - implementation of suitable delays in connecting heavy consumers
  - standby starting of additional power sources (generators or alternative power sources)
  - assessment of priority criteria and automatic load shedding of non-essential services
- assisting with restarting the power distribution in case of a (partial) blackout.

4.3.4 Adequate redundancy of the power management system is to be provided as per Tab 3. For symbol **RS** one power management controller and operator station are to be located in a separate room.

4.4 Thruster system

4.4.1 The thruster design and construction are to comply with the applicable requirements of the Rules for the Classification of Steel Ships.

4.4.2 The provisions of this Section apply to fixed axis or orientable thrusters using fixed or orientable pitch propellers installed below the hull and tunnel thrusters. The use of other thruster types (for example cycloidal propellers) is subject to a special examination.

4.4.3 Electric propulsion installations are to comply with the requirements of Pt C, Ch 2, Sec 14.

4.4.4 For symbol **R** and **RS** assignment, attention is drawn to the requirements stated in [3.2.2] and [3.2.3].

4.4.5 The thruster system is to provide adequate thrust in longitudinal and lateral directions, and provide yawing moment for heading control.

4.4.6 The values of thruster force used in the consequence analysis required in [4.9.4] are to be corrected for interference between thrusters and other effects which would reduce the effective force.

4.5 Thruster control

4.5.1 Closed loop command of thruster pitch, azimuth and RPM is to be provided from the controller. Feedback signals are to be provided by independent sensors connected to the controlled device.

4.5.2 Controllers are to incorporate features for avoiding commands likely to overload mechanical gearing or prime movers. Control is preferably to be performed using active power measurements.

4.5.3 Thrusters are to be capable of being easily stopped.

4.5.4 Each thruster on a DP system is to be capable of being remote-controlled individually, independently of the DP control system at the DP operator's area.

4.6 Thruster monitoring and protection

4.6.1 Thruster monitoring is to be provided by the controller unit. Thruster monitoring is to enable:

- detection of equipment failures
- monitoring of the correlation between set and achieved values of control parameters.

The following parameters are to be monitored:

- status of thrusters (on-line/off-line)
- pitch, RPM, azimuth
- thruster load level
- electric motor stator winding temperature
- temperature of main bearings (except roller type)
- lube oil and hydraulic fluid pressure and temperature.

4.6.2 The parameters monitored in [4.6.1] are to be displayed at the DP operator station and/or independent joystick system display. The parameters are also to be continuously visible at displays/indicators separate from the DP operator station and independent joystick system display. At least, display of pitch, rpm and azimuth (alternatively thrust and thrust direction), for each propulsion unit, shall be readable from the normal position of the DP operator.

4.6.3 Failure of a thruster, azimuth or speed command is to trigger an alarm, and is not to cause an increase in thrust magnitude and/or change in thrust direction. A change in thrust direction is only allowed if the thruster fails to zero thrust or zero pitch thereby not producing any thrust in an uncontrolled direction.

4.6.4 Failure of a thruster pitch, azimuth or speed feedback is to trigger an alarm, and is not to cause an uncontrolled increase in thrust magnitude or uncontrolled change in thrust direction.

4.6.5 A single failure in the thruster control system or in its communication lines are not to lead to failure of more than one thruster.

4.6.6 Provision for automatic stop of a thruster is to be restricted to circumstances liable to bring about immediate plant damage and is to be submitted for approval.

4.6.7 The individual thruster emergency stop systems are to be protected against accidental activation. For symbol **R** and **RS**, the thruster emergency stop systems are to have loop monitoring for both open loop and short-circuit failures in the emergency stop circuit. Failures in the emergency stop loop monitoring are not to cause the stop of a thruster. For symbol **RS**, the effects of fire and flooding are to be considered.

4.6.8 When the main propulsion propellers are under DP control, they are to be considered as thrusters, and all relevant requirements of these rules will apply. When rudders are not included under DP control a rudder out of zero alarm is to be given at the DP control centre in case the rudder is not in zero when the vessel is under control by the DP-control system.

4.7 DP operator station

4.7.1 The DP operator station is to be located where the operator has a good view of the vessel's exterior limits and the surrounding area. The DP operator station is to display information from the power system, thruster system and DP control system to ensure that these systems are functioning correctly. Information necessary to safely operate the vessel under DP control is to be visible at all times. Other information is to be available at the request of the operator.

4.7.2 The DP operator station is:

- to be based on sound ergonomic principles which promotes proper operation of the system.
- to be arranged for easy selection of the control mode, i.e. manual joystick, or automatic DP control of thrusters, propellers and rudders.

To clearly display the active mode:

- to have segregation of redundant equipment to reduce the possibility of common mode failure occurrence
- to have ease of access for maintenance purposes
- to have protection against adverse effects from environment and from electrical and electromagnetic disturbances.

4.7.3 For equipment classes 2 and 3, operator controls are to be designed so that no single inadvertent act on the DP operator's station can lead to a critical condition loss of position and/or heading.

4.7.4 Where several operator stations are provided, control is only to be possible from one operator station at a time, adequate interlocking devices are to be fitted and indication of the operator station in control is to be displayed at each operator station.

4.7.5 Alarm and control systems concerning the same function are to be grouped together (position reference system, propulsion selection, power generation).

4.7.6 Equipment that should be located at the DP operator station includes, but is not limited to:

- DP control and independent Joystick operator station(s)
- manual thruster levers
- mode change systems
- thruster emergency stops
- internal communications, and
- position reference systems' HMI, when considered necessary.

4.7.7 A two-way voice communication facility, independent of the unit’s general system, is to be provided between the main operator station and the following spaces: navigation bridge, engine room, engine control room, responsible officer's accommodation, other control locations specific to the task of the unit. The two means for communication are to be fed by independent power supplies.

4.8 DP control system

4.8.1 In general, the DP control system is to be installed in a room with sufficient climate and temperature control.

4.8.2 Alarms and warnings for failures in all systems interfaced to and/or controlled by the DP control system are to be audible and visual. A record of their occurrence and of status changes is to be provided together with any necessary explanations. The alarm list is given for information in Tab 4.

4.8.3 The DP control system is to prevent failures being transferred from one system to another. The redundant components are to be so arranged that any failed component or components can be easily isolated, so that the other component(s) can take over smoothly with no loss of position and/or heading.

4.8.4 It is to be possible to control the thrusters manually, by individual levers and by an independent joystick, in the event of failure of the main DP control system. If an independent joystick is provided with sensor inputs, failure of the main DP control system is not to affect the integrity of the inputs to the independent joystick. This requirement may be omitted for installation intended to be assigned the notation **DYNAPOS SAM**.

4.8.5 The software is to be produced in accordance with an appropriate international quality standard recognised by the Society.

Table 4 : Alarm and warning system

No.	Parameters and equipment	Alarms or group of alarms **(1)**			Signalling		
		DP operator	VMS	Thruster control	DP operator	VMS	Thruster control
1	Ship coordinates and desired position				X		
2	Actual position				X		
3	Warning deviation setting				X		
4	Maximum deviation required				X		
5	Deviation from the desired operating area outside the a.m. limits	X					
6	Thruster availability ready for operation				X	X	X
7	Thruster in operation				X	X	X
8	Thruster failure (this includes thruster controllers and pumps)	X		X			
9	Thruster command and feedback failures	X		X			
10	Thruster emergency stop functionality				X		X
11	Thruster emergency stop failures	X	X	X			
12	Vectorial thrust output outside limit	X					
13	Total output of all thrusters				X	X	X
14	Thrust limitation by available power	X	X				
15	Power supply failure	X	X **(4)**				
16	Power management failure for each component critical to position and/or heading keeping		X				
17	Desired heading				X		
18	Actual heading				X		
19	Deviation from desired heading outside limit	X					
20	Status of each heading reference system connected or not				X		
21	Failure of each heading reference system	X					
22	Automatic switching to standby heading reference system	X					
23	Failure of the vertical reference sensor measuring the pitch, roll and heave of the vessel	X					
24	Status of each vertical reference sensor connected or not				X		
25	Automatic switching to vertical standby reference sensor	X					
26	Indication of wind speed and direction				X		
27	Operational status of each wind sensors, both speed and direction				X		

No.	Parameters and equipment	Alarms or group of alarms **(1)**			Signalling		
		DP operator	VMS	Thruster control	DP operator	VMS	Thruster control
28	Failure of each wind sensor, both speed and direction	X					
29	Automatic switching of wind sensor	X					
30	Computer/Controller failures	X	X				
31	Automatic switching to standby computer/ controller	X	X				
32	Abnormal input signals to the a computer, controller, PLC, I/O station, etc	X	X	X			
33	Failure of analogue input signals to a computer, controller, PLC, I/O station, etc.	X	X	X			
34	Failure of communication between DP computers/controllers	X					
35	Number of generators available				X	X	
36	Failure of each position reference system connected or not	X					
37	Status of each position reference system connected or not				X		
38	Automatic start of standby DGs					X	
39	Functionality of the DP joystick				X		
40	Operational status of each network				X	X	
41	Network failure	X	X	X			
42	Operator station functionality for each operator station				X		
43	Operator station failures for each operator station	X					
44	Command transfer functionality between operator stations				X		
45	Functionality of the independent joystick				X **(5)**		
46	Unavailability of the independent joystick	X **(5)**					
47	UPS/Battery system failures	X	X				
48	UPS bypass switch closed	X	X				
49	Diesel generator load sharing functionality					X	
50	Diesel generator load sharing failures		X				
51	Diesel generator auxiliary equipment failures		X				
52	Sea water cooling circuit failures		X				
53	Fresh water cooling circuit failures		X				
54	Compressed air failures		X				
55	HVAC failures in rooms critical to position and/or heading keeping		X				
56	Power management functionality					X	
57	Power management failures		X				
58	ESD controller and circuits failures **(3)**		X				
59	Mission related equipment sensors connected or not				X		
60	Mission-related equipment failures **(3)**	X	X				

(1) Where there are two or three X marks in any row, alarms or group of alarms can be on the DP operator station, VMS and the thruster control system, or any combination of these, or on only one of the three pieces of equipment. If there is only one X mark in a row, the alarm or group of alarms requires to be alarmed on that specific.

(2) Applicable if the ESD has an impact on the DP system.

(3) Only applicable if the mission-related equipment is connected to or has an impact on the DP system.

(4) For symbol **R** and **RS**

(5) Alarm and signalling on the Independent Joystick System only.

Note 1: Depending on the DP classification notation required, the above-mentioned list may be simplified.

Note 2: Instead of an individual alarm, when it is possible to discriminate the cause of the alarm, an alarm group may be displayed.

4.9 Computers

4.9.1 For symbol **SAM** or **AM/AT**, the DP control system need not be redundant.

4.9.2 For symbol **R**, the DP control system is to consist of at least two computer systems. Common facilities such as self-checking routines, alignment facilities, data transfer arrangements and plant interfaces are not to be capable of causing the failure of more than one computer system. An alarm is to be initiated if any computer fails or is not ready to take control.

4.9.3 For symbol **RS**, the DP control system is to consist of at least two computer systems with self-checking facilities. Common facilities such as self-checking routines, alignment facilities, data transfer arrangements and plant interfaces are not to be capable of causing failure of more than one computer system. In addition, one backup DP control system should be arranged. An alarm is to be initiated if any computer fails or is not ready to take control.

4.9.4 For symbol **R** and symbol **RS**, the DP control system is to include a software function, normally known as "consequence analysis", which continuously verifies that the vessel will remain in position even if the worst-case failure occurs. This analysis is to verify that the thrusters, propellers and rudders (if included under DP control) that remain in operation after the worst-case failure can generate the same resultant thruster force and moment as required before the failure. The consequence analysis is to provide an alarm if the occurrence of a worst-case failure would lead to a loss of position and/or heading due to insufficient thrust for the prevailing environmental conditions (e.g. wind, waves, current, etc.). For operations which will take a long time to safely terminate, the consequence analysis is to include a function which simulates the remaining thrust and power after the worst-case failure, based on input of the environmental conditions.

Note 1: Manual input of weather trend or forecast might be possible, in order to integrate relevant meteorological data in the system, if available.

4.9.5 Redundant computer systems are to be arranged with automatic transfer of control after a detected failure in one of the computer systems. The automatic transfer of control from one computer system to another is to be smooth with no loss of position and/or heading.

4.9.6 For equipment class 3 (symbol **RS**), the backup DP control system is to be in a room, separated by an A-60 class division or equivalent from the main DP control station. During DP operation, this backup control system is to be continuously updated by input from at least one of the required sets of sensors, position reference system, thruster feedback, etc., and to be ready to take over control. The switchover of control to the backup system is to be manual, situated on the backup operator system, and is not to be affected by a failure of the main DP control system. Main and backup DP control systems are to be so arranged that at least one system will be able to perform automatic position keeping after any single failure.

4.9.7 Each DP computer system is to be isolated from other onboard computer systems and communications systems to ensure the integrity of the DP system and command interfaces. This isolation may be effected via hardware and/or software systems and physical separation of cabling and communication lines. Robustness of the isolation is to be verified by analysis and proven by testing. Specific safeguards are to be implemented to ensure the integrity of the DP computer system and prevent the connection of unauthorised or unapproved devices or systems.

4.9.8 For DP control systems based on a computer system, it is to be demonstrated that the control systems work properly in the environmental conditions prevailing on board ships and units. To this end, the DP control systems are to be submitted to the environmental tests defined in Pt C, Ch 3, Sec 6, with special consideration for electromagnetic interference).

4.10 Networks

4.10.1 For symbol **R** and **RS** networks are to be redundant including, but not limited to, cables, routers, etc. A failure of one network should not prevent any individual system from performing its functions.

4.10.2 The topology of networks are to be based on "active" redundancy and not only be dependent on the "passive" redundancy provided by protective functions.

4.10.3 Networks are to be monitored in operation for abnormal levels of data transmission and computational activity. Monitoring could include:

- Network utilisation: Bandwidth consumption of traffic streams on relevant network segments
- Component utilisation levels (especially processor and memory utilisation)
- Component health (internal and external)
- Number of lost connections and/or dropped packets over time.

4.10.4 Network failures, including but not limited to network storms caused by either recognized or junk data, are to be contained preventing the failure and/or its effects from propagating. These failures are to initiate an alarm.

4.10.5 Network components should be arranged with an automatic change-over to a continuously available stand-by power supply in case of loss of the normal power source.

4.11 Independent joystick system

4.11.1 A joystick system independent of the main DP control system is to be arranged.

4.11.2 The power supply for the independent joystick system (IJS) is to be independent of the DP control system UPSs.

4.11.3 The independent joystick system is to have automatic heading control.

4.11.4 An alarm is to be initiated upon failure of the IJS.

5 Position reference systems and environmental sensors

5.1 General

5.1.1 As a general rule, a DP control system is to include at least two independent reference systems:

- for **SAM** notation assignment, only one reference system is required
- for the notation **AM/AT**, at least two independent position reference systems are to be installed and simultaneously available to the DP control system during operation
- for symbol **R** and symbol **RS**, at least three independent position reference systems are to be installed and simultaneously available to the DP control system during operation
- for symbol **R** and **RS**, when two or more position reference systems are required, they are not all to be of the same type, but based on different principles and suitable for the operating conditions, in order to avoid external common cause failure modes.

5.1.2 As a general rule, the system is to allow for smoothing and mutual adjustment of the inputs originating from various position reference systems and transfer between reference is to be bumpless. Other arrangements are subject to special examination by the Society. Change-over is preferably to take place automatically in the event of failure of the reference system in use.

5.2 Arrangement and performance of reference systems

5.2.1 The position reference systems are to produce data with adequate accuracy and repeatability for the intended DP-operation.

5.2.2 Visual and audible alarms are to be activated when the unit deviates from the set heading or from the working area determined by the operator. The performance of position reference systems is to be monitored and warnings provided when the signals from the position reference systems are either incorrect or substantially degraded.

5.2.3 Indication of the reference system in operation is to be given to the operator.

5.2.4 For symbol **RS**, at least one of the position reference systems is to be connected directly to the backup control system.

5.3 Type of position reference system

5.3.1 Position reference systems are to be selected with due consideration to operational requirements, both with regard to restrictions caused by the manner of deployment and expected performance in the working situation.

5.3.2 When a satellite based position reference system (GNSS) is used, interested parties are reminded that this equipment is to be designed in accordance with IMO Resolutions A 694 (17), A 813 (19) and MSC 112(73). Such equipment is to be approved, at least by a competent national authority, and the relevant certificate is to be submitted to the Society. For other reference systems the same procedure is to be applied as when the system is covered by an IMO resolution and this document is to be considered. In use, the effects of masking of the satellite receivers or interference need to be considered when operating the vessel near offshore installations.

5.3.3 When an acoustical reference system is used, a hydrophone is to be chosen to minimise the influence of mechanical and acoustical disturbance on the transmission channels, such as propeller noise, spurious reflection on the hull, interference of riser, bubble or mud cluster on the acoustic path.

The directivity of transponders and hydrophones is to be compatible with the availability of the transmission channels in all foreseeable operational conditions. It is to be possible to select the frequency range and the rate of interrogation according to prevailing acoustical conditions, including other acoustical systems possibly in service in the area.

5.3.4 When a laser or radar based positioning system is used, the effects of masking have to be taken into account either caused by Interference by line of sight due to temporary physical obstructions (for instance crane loads), permanent physical obstructions caused by the structure of the vessel itself (for instance legs on Jack-Up vessels) or obstructions on the target vessel or unit during vessel position changes. In case of permanent physical obstructions on the vessel itself, the blind sectors created by these obstructions are to be determined during the initial sea trials and recorded in the FMEA and the vessel-specific DP-operation manual (VSDPOM).

5.3.5 When a taut wire system is used, materials used for wire rope, tensioning and auxiliary equipment are to be appropriate for marine service. The anchor weight is to be designed to avoid dragging on the sea floor and is not to induce, on recovery, a wire tension exceeding 60% of its breaking strength. The capacity of the tensioner is to be adapted to the expected movement amplitude of the unit.

5.3.6 When the signals from the position reference system are likely to be altered by the movement of the unit (rolling, pitching), a correction of the position is to be made. For this purpose, a vertical reference unit or motion reference unit of appropriate characteristics with regard to the expected accuracy of position measurement is to be provided. The VRU/MRU is to be multiplied in number for assignment of notations **R** and **RS**, as per Tab 5.

Table 5 : Configuration for reference systems, vessel sensors and computers

Equipment class	–	1	2	3
DYNAPOS class notations	**SAM**	**AM/AT**	**AM/AT R (1)**	**AM/AT RS (1)**
Number of control computers	1	1	2	3, one of them connected to the backup control station
Manual control: joystick, with automatic heading	may be fitted	Yes	Yes	Yes
One man operating the DP system	Yes	Yes	Yes	Yes
Position reference system	1	2 **(2)**	3 **(2)**	3, one of them connected to the backup control station **(2)**
Vertical reference system	1	1	3	3, one of them connected to the backup control station
Wind sensor	1	1	3	3, one of them connected to the backup control station
Gyro	1	2	3	3, one of them connected to the backup control station

(1) When the **DYNAPOS** notation is supplemented by **-EI**, reference is made to Tab 8.
(2) When two or more position reference systems are required, they are not all to be of the same type, but based on different principles and suitable for the operating conditions.

5.4 Other reference systems

5.4.1 Other reference systems such as short to medium range radio positioning systems and global positioning systems may be used. Whatever the chosen principle (for example, hyperbolic or polar determination), the accuracy of the position measurement is to be satisfactory in the whole operational area.

5.5 Environmental sensors

5.5.1 Environmental sensors are to measure at least vessel heading, vessel motion, wind speed and direction.

5.5.2 Arrangement of sensors and monitoring

Sensors are to be as far as possible provided with failure monitors (overheating, power loss):

- inputs from sensors are to be monitored in order to detect possible faults, notably relative to temporal evolution of the signal. As regards the analogue sensors, an alarm is to be triggered in the event of connecting line wire break, short-circuit or low insulation
- inputs from sensors simultaneously in use are to be compared in order to detect significant discrepancy between them
- any failure of automatic change-over, if applicable, between sensors is to activate visual and audible alarms at the DP operator station
- sensors for symbol **R** and **RS** and sensors used for the same purpose connected to redundant systems are to be arranged independently so that failure of one will not affect the others.

5.5.3 For symbol **RS**, one of each type of sensor is to be connected directly to the backup control system and is to be separated where possible by an A-60 class division, or equivalent, from the other sensors. If the data from these sensors is passed to the main DP control system for their use, this system is to be arranged so that a failure in the main DP control system cannot affect the integrity of the signals to the backup DP control system.

5.5.4 When for symbols **R** and **RS**, DP control system is fully dependent on correct signals from vessel sensors, then these signals are to be based on three systems serving the same purpose (i.e., this will result in at least three heading reference sensors being installed).

5.5.5 Heading

Heading is to be measured by suitably chosen gyrocompasses, quantities of which depend on the notation of the vessel (see Tab 5 and/or Tab 8).

5.5.6 Wind speed and direction are to be measured by suitably located wind sensors, due consideration being given to superstructure influence.

6 Installation requirements

6.1 Cables and piping systems

6.1.1 For symbol **R**, the piping systems for fuel, lubrication, hydraulic oil, cooling water and pneumatic circuits and the cabling of the electric circuits essential for the correct functioning of the DP system are to be located with due regard to fire hazards and mechanical damage.

6.1.2 For symbol **RS**:

- Redundant piping systems (i.e., piping for fuel, cooling water, lubrication oil, hydraulic oil and pneumatic circuits etc.) are not to be routed together through the same compartments. Where this is unavoidable, such pipes may run together in ducts of A-60 class or quivalent, the termination of the ducts included, which are effectively protected from all fire hazards except that represented by the pipes themselves.
- Cables for redundant equipment or systems are not to be routed together through the same compartments. Where this is unavoidable, such cables may run together in cable ducts of A-60 class or equivalent, the termination of the ducts included, which are effectively protected from all fire hazards except that represented by the cables themselves. Cable connection boxes are not allowed within such ducts.

6.1.3 For symbol **R** and **RS**, systems not directly part of the DP system but which, in the event of failure, could cause failure of the DP system (common fire suppression systems, engine ventilation systems, heating, ventilation and air conditioning (HVAC) systems, emergency shutdown systems (ESD), etc.) are also to comply with the relevant requirements of these Rules.

6.2 Thruster location

6.2.1 The thruster location and operational modes are to be chosen so as to minimise interference between thrusters as well as disturbance caused to the proper operation of sensor systems or specific equipment the unit is provided with.

6.2.2 Thruster intake depth is to be sufficient to reduce the probability of ingesting floating debris and of vortex formation.

6.2.3 The integrity of the hull is not to be adversely affected by thruster installation, particularly where retractable or tunnel thrusters are provided.

6.2.4 The thruster system is to provide adequate thrust in longitudinal and lateral directions and provide yawing moment for heading control.

6.2.5 Transverse fixed axis thrusters, if used, are to be capable, for notation **AM/AT**, of providing sufficient thrust in the contemplated range of speed of the unit.

6.2.6 The values of the thruster forces used in the consequence analysis (see [4.9.4]) are to be corrected for interference between thrusters and other effects which will reduce the effective force.

6.2.7 For symbol **R** and **RS**, the thruster system is to be connected to the power system in such way that the requirement in [6.2.4] can be complied with, even after failure of one of the constituent power systems and one of the thrusters connected to that system.

7 Operational requirements

7.1 General

7.1.1 The operating instructions available onboard are to require that the following operational conditions are fulfilled:

- Before every DP operation, the DP system is to be checked according to an applicable vessel specific “location” checklist(s) and other decision support tools, in order to make sure that the DP system is functioning correctly and that it has been set up for the appropriate mode of operation.
- During DP-operations, the system should be checked at regular intervals according to the applicable vessel-specific watch-keeping checklist.
- DP-operations necessitating symbol **R** or **RS** should be terminated when the environmental conditions (e.g. wind, waves, current, etc.) are such that the DP-vessel will no longer be able to keep position if the single failure criterion applicable to the notation should occur. In this context, deterioration of environmental conditions and the necessary time to safely terminate the operation are also to be taken into consideration. This should be checked by way of environmental envelopes if operating in **AM/AT** and by way of an automatic means (e.g. consequence analysis) if operating in symbol **R** or **RS**.

7.1.2 The following checklists, test procedures, trials, instructions and documents are to be available onboard:

- an electronic or physical copy of the valid Approved FMEA
- an electronic or physical copy of the valid Approved FMEA Proving Trials, Trials procedures and the Records/Report
- records of any modifications or equivalents including any relevant software updates and records of any associated tests
- the Vessel Specific Dynamic Positioning Operations Manual (VSDPOM) including:
  - organisation and responsibility during DP operations
  - DP operating instructions
  - a description of all the systems associated with the dynamic positioning of the vessel, including backup systems and communication systems
  - a description of the different operational modes and transition between operational modes
  - blackout recovery procedure
  - list of critical components.

8 Tests and trials

8.1 Inspection at works

8.1.1 Inspections at the works of items subject to classification are to be carried out to the attending Surveyor's satisfaction, in accordance with a previously agreed program.

8.1.2 Thruster and electrical installation tests are to be conducted in accordance with the requirements for electric propulsion in Pt C, Ch 2, Sec 14.

8.2 Trials

8.2.1 Before a new installation is put into service and after modification of an existing installation and at periodic intervals, port and sea trials are to be carried out to check the proper functioning and performances of the DP system.

8.2.2 A test program of these trials is to be submitted in advance to the Society.

8.2.3 The initial survey is to include a complete test of all systems and components and the ability to keep position and heading after single failures associated with the assigned equipment class. For symbol **R** and **RS**, the findings of the FMEA analysis required in [2.4] are to be confirmed by the initial survey.

8.2.4 The periodical survey is to include a sample test of all systems and components and the ability to keep position and heading after single failures associated with the assigned equipment class. For symbol R and RS, the findings of the FMEA analysis required in [2.4] are to be verified by the periodical survey.

8.2.5 Any sea trials are to be of sufficient duration to confirm satisfactory operation.

8.2.6 The final test reports of dock and sea trials are to be submitted to the Society.

9 Environmental station keeping index ESKI

9.1 Definition

9.1.1 An environmental station keeping index (ESKI) may be associated with each of the class notations **DYNAPOS AM**, **DYNAPOS AT** or **DYNAPOS AM/AT** as defined in [1.4.1].

9.1.2 The ESKI indicates the station keeping capability of the vessel (as a percentage of time) under given environmental conditions.

9.2 Environmental conditions

9.2.1 The ESKI is based on environmental conditions consistent with the geographical area of vessel operation. It is a two numbers vector (xx ; xx).

9.2.2 For unlimited service, a set of standard North Sea Environmental Conditions is to be used (see Tab 6).

9.2.3 For restricted service, a long-term distribution of environmental conditions prevailing where the vessel is in operation is to be considered.

Table 6 : ESKI / Mean wind speed

Significant wave height, in m	Corresponding mean wind speed (kts)	Annual frequency, in %	ESKI, in %
0 - 1	0 - 4,8	25,2	25
1 - 2	4,8 - 11,6	32,2	57
2 - 3	11,6 - 17,5	20,9	78
3 - 4	17,5 - 24,3	11,1	89
4 - 5	24,3 - 29,1	5,4	95
5 - 6	29,1 - 34,0	2,5	97
6 - 7	34,0 - 37,9	1,2	98
7 - 8	37,9 - 41,8	0,6	99
8 - 9	41,8 - 46,3	0,3	99
9 and more	More than 46,3	0,3	99
Note 1: For the calculations, a constant current of 1.5 kts is assumed, in the same direction as the wind and the waves (to sum up all the environmental forces effects).			

9.3 Condition of ESKI estimation

9.3.1 The ESKI indicates the allowable environmental conditions for two system configurations:

- with all thrusters operating
- with the most critical single failure.

Note 1: The most critical failure of any component in the ship is to be considered, which sometimes can lead to the loss of several thrusters at the same time. Taking into account only the failure of the most efficient thrusters would be in some particular cases not relevant.

9.3.2 The ESKI reflects the capability to maintain position with the most unfavourable heading.

9.3.3 Environmental forces (wind, wave drift and current loads) and thrust are to be evaluated through calculations, model tests or other method, in agreement with the Society.

9.4 Documentation to be submitted and example

9.4.1 The ESKI calculation is to be documented in order to justify the results. Generally the relevant documents are as follows:

- capability plots for two considered configurations for the calculation: all thrusters alive, most critical single failure
- documentation on the environment conditions long term distribution (any area for restrictive service, North Sea (see Tab 6 for unlimited service)
- owner performance request, if any.

9.4.2 For unlimited service, North Sea area conditions are to be considered. The wind and wave statistics are indicated in Tab 6.

9.4.3 Example of calculation

According to [9.2], the ESKI can be calculated with various environmental data, depending on the service area of the ship. As an example, the calculation for unlimited service (North Sea conditions being the reference) is given hereafter.

For this example, the following results are extracted from the capability plots (see Tab 7). The ESKI is directly read in Tab 6.

- 41,0 kts corresponds to an ESKI of 99
- 25,8 kts correspond to an ESKI of 95

For this vessel, the ESKI number is (99 ; 95).

Note 1: Attention is drawn on the fact that the ESKI should always be read together with the associated capability plots.

Table 7 : Example

Plot	Condition of operation	Maximum allowable **(1)** wind speed (kt)
1	All thrusters available	41,0
2	Most critical single failure	25,8
(1) On most ships this corresponding incident angle is directly abeam.		

10 Enhanced DP system

10.1 General

10.1.1 The requirements of the present Article apply to ships fitted with an enhanced dynamic positioning control system, such system improving the reliability, availability and operability of a DP vessel. When compliance with the present Article, the notation **-EI** may be granted as per [1.4.1].

10.2 DP Control system

10.2.1 The DP control system is to consist of at least a main control system and an alternative control system capable to maintain without disruption the position holding capabilities of the unit in case of complicated failure of the main control system. For symbol **R** and **RS**, the Independent Joystick System required in [4.11] can be considered as the alternative control system. For symbol **RS**, the backup control system required in [4.9.3] can be considered as the alternative control system.

10.2.2 The main DP control system is to consist of two independent and redundant computer systems as specified in [4.9.2] and [4.9.3]. The alternative DP control system is to consist at least of a single and independent computer system ready to take over control of DP operations at any given times in case of failure of the main DP control system. The switch-over of control of the alternative DP control system is to be manual.

10.2.3 The alternative DP control system is to perform self-checking routines. An audible and visual alarm is to be initiated in case of failure or unavailability of the alternative DP control system.

10.2.4 For symbol **R**, the main and alternative DP control systems may be located in the same DP control station.

10.2.5 The main and alternative DP control systems are to be powered by independent power supplies and each one by its own uninterruptible power supply (UPS) capable to provide a minimum of 30 minutes operation following main supply outage failure.

10.2.6 In order to allow post incident analysis, a data logger with a storage capacity of 7 days is to be provided to collect automatically and continuously time-stamped events from the DP control systems. The recorded data are to be easily accessible to the operators and are to be available for upload to an offline storage media.

10.2.7 The following data of the main and alternative DP control system are to be recorded by the data logger:

- Operational status
- All manual inputs
- All automatic inputs and outputs.

10.2.8 The main DP control system is to provide online capability plots and online simulation of the position holding capabilities for the most relevant failure modes. These functionalities are to be verified as far as feasible by full scale testing during sea trials.

10.3 Position reference system

10.3.1 At least four independent position reference systems are required (see Tab 8). They are to be designed and so arranged as to ensure that three of them are to be continuously available during DP operations.

10.3.2 The position reference systems are to be based on two different principles and a minimum of two Global Navigation Satellite Systems (GNSS) are required. At least one of the GNSS is to be equipped to receive two distinct signal frequencies.

Table 8 : Configuration for reference systems, vessel sensors and computers for enhance reliability DP system

Equipment class	2	3
DYNAPOS class notations	**AM/AT R -EI**	**AM/AT RS -EI**
Number of control computers	3	3
Manual control: joystick, with automatic heading	Yes **(1)**	Yes
One man operating the DP system	Yes	Yes
Position reference system	4 **(2)**	4 **(3)**
Vertical reference system	4 **(2)**	4 **(3)**
Wind sensor	4 **(2)**	4 **(3)**
Gyro	4 **(2)**	4 **(3)**
(1) May be omitted if the alternative DP control system includes also all of the requirements of the independent joystick system **(2)** One of them is to be connected to the alternative DP control system **(3)** One of them is to be connected to the backup DP control system (see (5.2.4) and Table 3)		

10.3.3 Position reference systems are to be independent of each other and supplied from UPSs. Their power supply and interface with DP control systems are to be in accordance with the redundancy requirements.

10.3.4 Position reference systems can be interfaced to both DP control systems provided that the failure of a position reference system does not jeopardize the independence requirement between the main and alternative DP control systems.

10.4 Other vessel sensors

10.4.1 At least four vertical reference systems and four gyrocompasses are required (see Tab 8). Two of them are to be based on two different measurement principles.

10.4.2 At least four wind sensors are required (see Tab 8). Two of them are to be based on two different measurement principles.

10.4.3 Sensors are to be supplied from UPSs. Their power supply and interface with DP control systems are to be in accordance with the redundancy requirements but at least one sensor of each type is to be directly interfaced to the alternative DP control system (DP Class 2) or backup DP control system (DP class 3).

10.4.4 Sensors can be interfaced to both DP control systems provided that the failure of a sensor does not jeopardize the independence requirement between the main and alternative DP control systems.

11 Digital DP survey

11.1 General

11.1.1 The requirements of the present Article apply to ships fitted with a system which independently collects data from the DP system as described within this Article and makes the data available in a readable format in order for the correct functionality of the DP system to be validated and verified by the Society digitally from an onshore location during Class surveys.

11.1.2 Prior to using the system for digital verification, according to figure 2, the system as described in [11.1.1] is to be validated, according to figure 1, ensuring that evidence produced by the system likely corresponds accurately to the real behavior of the DP system.

11.1.3 Ships fitted with a system in compliance with [11.1.1] and [11.1.2], may be granted the notation **DDPS** as per [1.4.1].

11.2 Definitions

11.2.1 Assessment

Assessment means the action or an instance of making a judgment about something.

11.2.2 Data

Data means the facts and statistics collected together for reference or analysis.

11.2.3 Data completeness

Data completeness means, referring to ISO 8000-2, having all the data that existed in the possession of the sender at the time the data message was created. It also means the extent to which the relevant data sets, the expected records of a data set, and data elements, attributes and values in a data set are provided and reflect the scope and the real world.

11.2.4 Data quality

Data quality means the degree of quality that data is fit for its intended uses in operations, decision making and planning.

11.2.5 Digital Information Management System

Digital Information Management System (DIMS) means a software function that helps organize and analyze data. The purpose of an information system is to turn raw data, generated by tests typically performed by crew guided by a class approved programme, into useful information that can be used for verification and validation of survey tests by the Society.

11.2.6 Digital Survey System

Digital Survey System (DSS) means a system enabling data from the DP system to be collected, treated and visualized, for the purpose of digitally validating and verifying the correct functionality of the DP system. Typically the DSS consists of the DIMS, fitted on the vessel, and the Digital Survey Visualization Application (DSVA), which can be used on the vessel as well as onshore.

11.2.7 Digital Survey Visualization Application

Digital Survey Visualization Application (DSVA) means a software application which visualizes recorded parameters and functionalities of the DP system. The DSVA is to have a facility for the owner to request verification from the society and for the society to provide the result of the verification to the owner.

11.2.8 Equipment Under Test (EUT)

Equipment Under Test (EUT) means a manufactured product undergoing testing, either at first manufacture or later during its life cycle as part of ongoing functional testing and calibration checks.

11.2.9 Evidence

Evidence means the available body of facts or information indicating whether test results are true or valid.

11.2.10 Evidence quality

Evidence quality reflects the extent to which confidence is put in the evidence supporting test results.

11.2.11 Raw data

Raw data means data collected as time series that can be linked to related tests, creating a relationship between collected data and the timeframe during which a particular test has been carried out.

11.2.12 Remote access

Remote access is the ability to access a computer or a network remotely through a network connection. Remote access enables users to access the systems they need when they are not physically able to connect directly; in other words, users access systems remotely by using a telecommunications or internet connection.

11.2.13 Test session

Test session means a time period defined by a start and end time during which a test on a system or single piece of equipment is conducted.

11.2.14 Time stamped

Time stamped means to mark something with a printed or digital record of when something happened or was done.

11.3 Documentation and test attendance

11.3.1 In addition to the drawings and specifications required by the documents listed in Tab 1, the additional documents listed in Tab 9 are required.

11.3.2 The tests to be performed and witnessed for the acceptance of the DSS are listed in Pt C, Ch 3, Sec 3, Tab 5, and are to be in accordance with requirements for Cat II/III systems.

Table 9 : Documents to be submitted

No	I/A **(1)**	Documents to be submitted
1	A	Functional description of the DSS
2	A	List of DSS units/components (Original Equipment Manufacturer (OEM), type, etc.)
3	A	Single line diagram of the supply and monitoring of DIMS
4	A	Description of the internal and external communication protocols
5	I	Risk analysis demonstrating that failures of DIMS have no effect on the DP control system, including the network storm protection of DIMS
6	I	Data access procedures
7	A	Data storage procedures
8	A	Data treatment procedures
9	A	Programme of the vessel's DP tests including associated data points for data validation
10	A	Programme of the vessel's DP tests including associated data points for data verification
11	A	Test programme of the DSS for integration
12	I	Data transfer procedures
13	A	List of standards used for data communication links
14	A	Diagrams/Description of DSVA, if not included in the functional description of DSS (Item 1)
15	A	Specification of cables between the vessel's DP system equipment and the DIMS
16	I	Operating manual of the DSS
17	A	Specification of the data manipulation prevention measures
18	A	Specification of alarm list filters if utilised
19	A	Specification of signal segregation in case signals cross redundancy zones **(2)**
20	A	Procedures detailing how failures are simulated or signals are failed for each test, including how the system is restored after a failure (if not detailed in data treatment procedures in Item 8)
(1) A: To be submitted for approval ; I: To be submitted for information **(2)** For symbol RS only		

11.4 Recorded parameters

11.4.1 The data gathered and used as evidence is to be in the form of system generated data, i.e. trending (time series) of system parameters (see Tab 10) and functionalities (see Tab 11), which are recorded as individual test sessions which include as a minimum a start and end time for each session. In addition, it may be accepted that some data cannot be automatically gathered by the DIMS requiring the evidence for that particular test session to be based on screen captures, pictures and/or videos.

11.4.2 When evidence is based on screen captures, pictures and/or videos, these is to be delivered as digital files, date and time stamped, whereby the date and time corresponds to the date and time that the test session, for which this evidence is submitted, is conducted. Vessel owner is to also have procedures in place, approved by the Society, to guarantee that evidence of this kind is genuine.

11.4.3 The parameters to be recorded by the DIMS are detailed in Tab 10. This list is the minimum required list of parameters necessary to enable digital surveys to be conducted.

11.4.4 The functionality as described in Tab 11 is to be able to be recorded.

11.5 Data Communication and Management

11.5.1 Data storage

The DIMS is to record all the parameters and functionality as per Tab 10 and Tab 11 while the system is in an active state, and store this data for at least a period covering four Annual surveys and a Class Renewal survey.

Table 10 : Parameters to be recorded

Item	Parameters to be recorded	Alarms or group alarms	Indication/ Measured values
1	Ship coordinates and desired position		X
2	Actual position		X
3	Deviation from the desired operating area outside the a.m. limits		X
4	DP setup including: **(3)** • power distribution overview for main power and standby power • operational status of all environmental reference sensors • operational status of all position reference sensors • engine configuration • thruster configuration • pump configurations on all fuel oil systems associated with the DP system • pump configuration on all lubrication oil systems associated with the DP system • pump configuration on all cooling water systems associated with the DP system • pump configuration on all hydraulic systems associated with the DP system • DP Class as set in the DP system		X
5	Thruster availability ready for operation		X
6	Thruster in operation		X
7	Thruster failure (this includes thruster controllers and pumps)	X	
8	Thruster command and feedback failures	X	X
9	Thruster emergency stop functionality	X	X
10	Thruster emergency stop failures	X	
11	Vectorial thrust output outside limit	X	X
12	Total output of all thrusters		X
13	Thrust limitation by available power	X	X
14	Power supply failure	X	
15	Power management failure	X	
16	Desired heading		X
17	Actual heading		X
18	Deviation from desired heading	X	X

Note 1: Depending on the DP classification notation required, the above-mentioned list may be simplified.

(1) Only if applicable, as ESD functionality might not be installed on every DP vessel.

(2) Applicable only if the mission-related equipment is connected or has an impact on the DP system.

(3) This can take the form of a clear GUI showing the status of the specified equipment during each test session.

Item	Parameters to be recorded	Alarms or group alarms	Indication/ Measured values
19	Failure of any heading reference system	X	X
20	Automatic switching to standby heading reference system		X
21	Failure of the vertical reference sensor measuring the pitching and rolling of the unit	X	X
22	Automatic switching to vertical standby reference sensor		X
23	Indication of wind speed and direction sensor	X	X
24	Wind sensor failure, speed and direction	X	X
24	Automatic switching of wind speed and direction sensor		X
26	Computer/Controller failures	X	X
27	Automatic switching to standby computer/controller	X	X
28	Abnormal input signals to the computer/controller, analogue input failures	X	
29	Position reference system failure	X	X
30	Position reference system indication		X
31	Automatic start/switch on of a standby power generation device		X
32	Functionality of the DP joystick		X
33	Operational status of each network		X
34	Network failure	X	X
35	Operator station functionality for each operator station		X
36	Operator station failures for each operator station	X	X
37	Command transfer functionality between operator stations		X
38	Functionality of the independent joystick		X
39	Unavailability of the independent joystick	X	X
40	Two-way voice functionality between key DP equipment rooms		X
41	UPS/Battery system failures	X	X
42	Automatic switching to battery power on loss of main power for each UPS/Battery system		X
43	30 minutes of battery power on loss of main supply for each UPS/Battery system	X	X
44	Power generation device load sharing functionality		X
45	Power generation device load sharing failures	X	X
46	Power generation auxiliary equipment failures	X	X
47	Sea water cooling circuit failures	X	X
48	Fresh water cooling circuit failures	X	X
49	Compressed air failures	X	X
49	Power management input failure	X	
49	ESD controller and circuits failures **(1)**	X	
50	Mission-related equipment **(2)** failures	X	

Note 1: Depending on the DP classification notation required, the above-mentioned list may be simplified.

(1) Only if applicable, as ESD functionality might not be installed on every DP vessel.

(2) Applicable only if the mission-related equipment is connected or has an impact on the DP system.

(3) This can take the form of a clear GUI showing the status of the specified equipment during each test session.

Table 11 : Functionality to be recorded

Item	Functionality	Alarms or group alarms	Indication/ Measured values
1	Consequence analysis as per [4.9.4]	X	X
2	Mathematical model as per [2.2.1]	X	X
3	Load rejection as per [4.2.9]		X
4	Load acceptance as per [4.2.9]		X
5	Power demand as per [4.2.7]		X

11.5.2 Data quality assurance is the process of data profiling to discover inconsistencies and other anomalies in the data. The vessel owner is to have physical and logical security measures in place to prevent unauthorized or unintentional modification of software, whether undertaken at the physical system or remotely.

11.5.3 Access to the DSVA is to be password protected and all operators, crew members conducting tests, surveyors reviewing tests, etc., are to be identified, as a minimum with name and position, when logged in. Each test is to be digitally signed when completed by an onboard authorized signature. Each test is to be digitally signed when verified by class, by the class surveyor.

11.5.4 It is to be possible to run DSS both in connected (to e.g. application provider and/or the Society) and in offline mode. When verification data is collected in offline mode the results are to be uploaded automatically when the system becomes connected again.

11.5.5 If the DSVA is used on a device on the vessel, which communicates wirelessly with the DIMS on the vessel, the system is to comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements. Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

11.5.6 For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not self-fail as a result of electromagnetic interference during expected operating conditions.

11.5.7 A clear warning is to be displayed when important boxes, such as the name box for the test operator or boxes for completion of a test step, are not filled upon ending a test session.

11.5.8 The data link between the DIMS and the monitored equipment is to be self-checking, detecting failures on the link itself and data communication failures on nodes connected to the link. Detected failures are to initiate an alarm.

11.5.9 The logical map of networks is to be provided as per Pt C, Ch 3, Sec 3, [8.3].

11.5.10 Logical inventories

List of IP address ranges with, for each one:

- the list of switches concerned
- the functional description of the IP range
- the list of Dynamic Host Configuration Protocol (DHCP) servers, relevant IP address management plan and IP history recording policy
- the list of equipment MAC address
- interconnections with other ranges
- flow matrix with source, destination, IP, ports, service, motivation, roles, volume estimation and time windows if any.

List of non-IP networks with, for each network:

- the list of MAC addresses or addresses specific to the industrial protocols on the network
- the list of switches concerned
- functional description of the network
- devices connected to other networks (connectors).

List of non-Ethernet access points with, for each one:

- the list of access ports
- addressing, if there is a special protocol
- the list of connected devices.

List of logical servers and desktops with, for each one, if applicable:

- IP addressing (network, mask, gateway)
- operating system version
- underlying physical server
- applications and their versions
- services and versions.

List of connectors and communicating field devices (remote I/O, sensors, actuators, etc.) with, for each one:

- IP addressing (network, mask, gateway), the associated MAC addressing and network or the specific addressing, if appropriate
- applications
- unit of measurement
- type of data.

11.6 Hardware requirements

11.6.1 The DIMS on the vessel is to be continuously powered and is to have an automatic change-over to a stand-by power supply in the case of loss of normal power, so that tests on the vessel's power supply do not adversely affect the recording of data.

11.6.2 All cabling between the DIMS and the various components of the DP system are to be in compliance with I [6.1].

11.6.3 The data network architecture is to be capable of performing according to the required availability level. Hardware installed onboard is to be able to perform according to applicable conditions where it is installed, and any applicable limitations are to be documented.

11.6.4 Hardware connecting devices are to be chosen, when possible, in accordance with international standards.

11.6.5 Any coupling devices are to be designed, as far as practicable, so that in the event of a single fault, they do not alter the network function. When a failure occurs, an alarm is to be activated. Addition of coupling devices is not to alter the network function.

11.7 Cyber security

11.7.1 A DSS accepted according to this Article is to also comply with the cyber security requirements, including remote access, as per NR659.

11.7.2 The remote access method is to be approved by the Society on a case-by-case basis.

11.7.3 Prior to installation, all artefacts, software code, executables and the physical medium used for installation on the vessel are to be scanned for viruses and/or malicious software. Results of the scan are to be documented and kept with the planned maintenance system (PMS), in a software registry or equivalent. Barriers, either hardware or software, are to be implemented to ensure the integrity of the DIMS, and the systems it is connected to, and prevent the connection of unauthorised or unapproved devices or systems until such devices are scanned for viruses and/or malicious software.

11.8 Validation

11.8.1 Validation can be performed as part of the FMEA proving trials (see [1.2.11]), and serves to prove that recorded parameters (see Tab 10) and functionalities (see Tab 11), and the presentation (see Tab 12), correspond to the real life behavior of the DP system. Validation of the recorded parameters is therefore always to be performed and witnessed on the vessel by the Society.

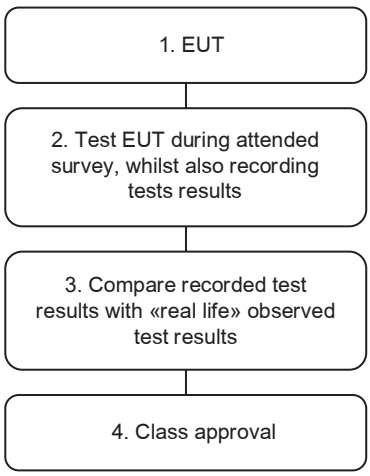
11.8.2 The validation program, detailing all tests and monitored data points is to be submitted to the Society prior to the onboard tests and is to be approved.

11.8.3 The validation process is detailed in Fig 1.

11.8.4 During the validation process, evidence is to be delivered in such a way that the Society can assess that the test(s) has been executed in the right manner and that the evidence is complete and genuine. This includes ensuring that the test is applied in the right manner to the equipment/system, when in the correct mode, and the ability to validate that the recorded result likely corresponds accurately to the real world.

11.8.5 The DSS integration tests, as specified and conducted by the OEM, and the validation tests, as specified in the program of the vessel's DP tests including associated data points for data validation, is to be witnessed by the Society.

Figure 1 : Validation process



11.9 Verification

11.9.1 For any digital verification method to be accepted the method must be able to provide relevant, genuine and trustworthy results to the Society in order for the Society to be able to objectively assess whether the DP system meets the single failure criteria for its corresponding class notation. This includes ensuring that the test is applied in the right manner to the equipment/system, and in the correct mode.

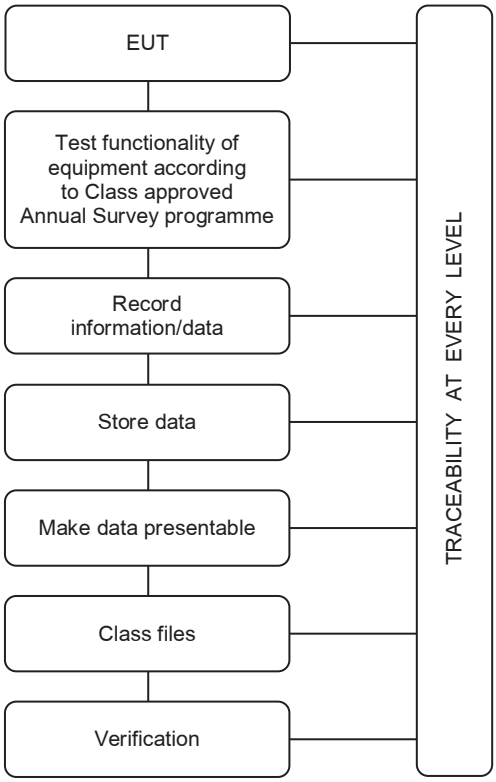
11.9.2 Evidence generated by a digital verification method complying with the requirements within this notation, can upon request, be accepted as additional to, or replacing evidence generated from the attended survey activities as required by the applicable class notation rules.

11.9.3 In case the digital verification method will not be able to fully generate evidence regarding the status of the system, the digital verification method may be used in combination with an attended survey in order to provide sufficient verification coverage.

11.9.4 Approval that the new digital verification method complies with the requirements within this Article, is to be on a case-by-case basis.

11.9.5 The verification process, to establish whether the DP system meets regulatory or technical standards, is detailed in Fig 2.

Figure 2 : Verification process



11.9.6 Each test session (see [11.4.1]) is to generate a class file containing all activity and results - such as operator inputs as control commands, equipment disconnected or disabled, simulated failures, system direct response as alarms and feedbacks, and system indirect response as a loss of position and heading - during the time stamped session, which is to be submitted to the Society. As a minimum, the items as specified in Tab 12 are to be displayed via the DSVA.

11.9.7 All test sessions are to be concluded and witnessed by the society, either on board or remotely, within the window of the survey scheme applicable to the vessel.

11.9.8 The DSVA is to have functionality for:

- Identifying which class files have been submitted to the Society and keep record of which results are accepted or not. The format, scope and frequency used for delivering the class files to the Society, is to be agreed upon and approved by the Society.
- Displaying at a minimum the parameters and configurations as defined in Tab 12, for each test session.
- Playback of each test session, with allowance for play, pause, wind and rewind, whereby it is possible to observe the system response from normal system operation to a failed state and vice versa.

Table 12 : Parameters and configurations to be displayed

Parameters and configurations	Static	Dynamic
Date and time when the test session is conducted	X	
Graphical representation of the vessel and position		X
DP set up (including DP Class setting, Power Distribution setup, pump setup, etc.)	X	X
Status for all position reference sensors **(1)**		X
Status for all environmental sensors **(1)**	X	X
Heading data		X
Power generation parameter data		X
Thruster representation (including rotation, percentage thrust and order/feedback)		X
Wind speed and direction **(2)**	X	X
Calculated sea current speed and direction **(2)**	X	X
Alarms - text and colour **(1)**		X
Name box for crew member conducting the test **(3)**	X	
Name box for class surveyor	X	
Comment box or other facility for the test operator to leave an explanation, as to why, in case a test is aborted, unsuccessful or for any other reason not completed in the intended manner, linked to the unsuccessful attempt	X	

Note 1: Depending on the DP classification notation required and the complexity of the vessel, the above-mentioned list may be simplified

(1) Status is to indicated Normal, Warning and Alert states

(2) Speed and direction of the wind and sea current may either be dynamically or statically displayed

(3) This could be connected to the login when accessing the DSVA to record a test.

11.9.9 The Society is to also have access to the raw data produced from each test session, i.e. the original test data from the vessel.

11.9.10 Independent of the class files send to the Society, the vessel owner is to keep, and make accessible to the Society, updated records of the verification status of the complete DP system, i.e. for each item to be verified, information on what, how and when verification has been performed and the corresponding status/results.

11.9.11 The DIMS, DSVA and vessel DP FMEA is to be kept up to date in order to reflect any changes made to the DP system or DP system technical operating modes. Therefore a system is to be in place for change management related to software versions and changes in system parameters. This change management procedure also applies to any changes made to the functionality or the firmware of DIMS and/or the DSVA.

11.9.12 It is accepted that the vessel will undergo DP tests involving activities which are outside the scope of class. Based on owner's request and specific agreements the Society may assist in assessment also of this scope.

11.10 Qualification

11.10.1 All verification activities requiring manual operations to perform the test(s), i.e. crew performing the test rather than the system collecting data automatically such as in the case of generator temperature readings, is to be executed by qualified personnel on the vessel.

11.10.2 An Owner's attestation, confirming that the Dynamic Positioning Officer (DPO), Chief Engineer (CE) and/or Electro Technical Officer (ETO) are duly qualified to carry out the tests in the Annual Survey program is to be made available to the Society.

11.10.3 Where the test results as tested by the Dynamic Positioning Officer (DPO), Chief Engineer (CE) and/or Electro Technical Officer (ETO) do not correspond to the findings of the attending Surveyor, or in case of doubt on the results, the Society may request the Owner to withdraw the qualification attestation of the person carrying out the test(s) until further training and re-assessment of his/her qualification.

CHAPTER 12
CARGO OPERATION, SECURING AND SAFETY

Section 1	SINGLEPASSLOADING
Section 2	Bow and Stern Loading / Unloading Systems
Section 3	Supply at Sea (SAS)
Section 4	Centralised Cargo and Ballast Water Handling Installations (CARGOCONTROL)
Section 5	Container Lashing Equipment
Section 6	OPEN-HATCH
Section 7	Efficient Washing of Cargo Tanks (EWCT)
Section 8	Increased Admissible Cargo Tank Pressure (IATP)
Section 9	Electric Vehicle Onboard Charging (EVOC)
Appendix 1	Definition of Specific Route Conditions for the Notation LASHING-RSSA

Section 1 SINGLEPASSLOADING

1 General

1.1 Application

1.1.1 The additional class notation **SINGLEPASSLOADING** may be assigned to ships having the service notation **ore carrier** which are specially designed for single pass loading. This additional class notation may be completed by the design loading rate in tons per hour, for example: **SINGLEPASSLOADING [16000 t/h]**.

1.1.2 The additional class notation **SINGLEPASSLOADING** only covers the loading sequences provided to the Society, as referred to in [2.2.1].

1.2 Definitions

1.2.1 Loading sequence

The loading sequence is the step-by-step description of the loading process of the ship starting from empty condition (no cargo in holds) and ending at the fully loaded condition. The loading sequence is to include the description of the necessary de-ballasting operations.

1.2.2 Loading step

A loading step is one step of the loading sequence. The step begins when the considered empty cargo hold starts to be filled up and ends when this cargo hold reaches its final filling. In case of multiple loaders acting simultaneously the loading step begins when the considered empty cargo holds start to be loaded and ends when these holds reach their final filling.

1.2.3 Loading rate

The loading rate is defined as the total mass of cargo divided by the time needed for the ship to be entirely loaded during active filling operations, and is expressed in t/h (tons per hour).

1.2.4 Design loading rate

The design loading rate is the maximum loading rate, in t/h, for which the ship is designed.

1.2.5 Single pass loading

The ship can be loaded from empty (ballast) condition up to the fully loaded condition by filling each cargo hold to the maximum permissible cargo mass in a single pour.

1.2.6 Mistiming the loading of cargo may result in cargo overloading, also called overshooting.

This phenomenon is prevented through means of control and monitoring, as required in [4.3] and [5.3].

In case an additional margin is requested by the designer or the owner, the requirements in [4.2.5] are to be complied with.

2 Documentation to be submitted

2.1 Design loading rate

2.1.1 The design loading rate is to be defined by the designer and submitted to the Society. Its value is to be indicated in the loading manual. Unless otherwise specified, the design loading rate is to be taken as 16000 t/h.

2.2 Loading sequences

2.2.1 Applicable loading sequences are to be submitted by the designer to the Society for review. These loading sequences are to describe every loading step from empty (ballast) condition up to the ship's final loading condition. If multiple loaders are used, the corresponding information is to be detailed. Typical final loading conditions to be considered include homogeneous loading conditions, alternate loading conditions and part loading conditions, as applicable.

2.2.2 For any considered loading sequence, the following information is to be provided at the initial stage (empty condition) and at the end of each loading step:

- cargo hold mass of each cargo hold
- ballast tanks filling levels
- longitudinal distribution of still water bending moment and shear force. The corresponding values are to be given at least at the transverse cargo bulkheads and at mid-hold positions
- trim and draught of the ship (mean, aft and fore)
- metacentric height, corrected for free surface effects.

2.3 Hold mass curves

2.3.1 Hold mass curves for each single cargo hold are to be provided in the loading manual. The curves are to show the maximum allowable and minimum required mass of cargo and double bottom contents (e.g. ballast water) of each cargo hold as a function of the draught at mid-hold position (for determination of the permissible mass in a single cargo hold, refer to Pt D, Ch 4, App 2).

2.3.2 Hold mass curves for any two adjacent cargo holds are to be provided in the loading manual. They are to show the maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent cargo holds as a function of the mean draught in way of these cargo holds. This mean draught may be obtained averaging the draughts at both mid-hold positions (for determination of permissible mass in two adjacent cargo holds, refer to Pt D, Ch 4, App 2).

Note 1: In the context of single pass loading all loading steps are to be related to the hold mass curves in harbour condition, while only the initial (ballast) and final (fully loaded) step are to be related to the hold mass curves in seagoing condition.

3 Loading instrument and alternative loading

3.1 Loading instrument

3.1.1 The ship loading instrument is to ascertain that:

- the mass of cargo and double bottom contents remains within the limits defined by the hold mass curves
- the resulting still water bending moment and still water shear force remain within the permissible values, as applicable in port conditions.

3.2 Alternative loading

3.2.1 If any deviation from the approved loading sequence is deemed necessary by the Master, it is to be carried out in compliance with the relevant requirements of SOLAS Ch VI Reg.7.3. To this end a new loading plan is to be agreed with the loading terminal.

4 Hull requirements

4.1 General

4.1.1 The Master is to ensure that the ship's manoeuvring capability upon arrival in the loading port in (light) ballast condition is adequate for berthing at the designated loading terminal, taking into consideration the environmental conditions (e.g. wind, waves and current) and the port lay-out (e.g. available space for turning and air draught).

4.1.2 During each loading step, the de-ballasting operations are to be completed within the same time as the cargo loading operations.

4.2 Hull structure

4.2.1 The hull girder strength and local strength are to comply with the relevant requirements of Part B during each loading step of the applicable loading sequences, as defined in [2.2.1]. Intermediate stages of loading and de-ballasting are to be taken into consideration to ensure that the most severe situation during the loading step is covered.

4.2.2 The ship structure is to withstand the design loading rate, as defined in [2.1].

4.2.3 During each loading step, the filling level in each cargo hold is to remain within the permissible limits of the applicable hold mass curves as defined in [2.3].

4.2.4 The inner bottom is to comply with the requirements for the additional class notation **GRABLOADING**, as defined in Ch 15, Sec 2.

4.2.5 In case an extra margin is requested by the designer or the owner to cover for overshooting, the following is to be complied with:

- An extra amount of cargo, in t, taken equal to the product of the design loading rate, in t/h, and the maximum overshooting time, in h, as specified by the designer is to be considered in one cargo hold at a time for the following assessments, in both sea-going and harbour conditions:
  - local scantling of cargo hold bulkheads (plating and stiffeners)
  - partial cargo hold FE analysis.
- In addition, the corresponding loading conditions are to be provided in the loading manual and shall prove that the related still water hull girder loads remain within the allowable values.

4.3 Control and monitoring

4.3.1 An automatic draught reading system, feeding draught and trim data to the loading computer, is to be provided. Readings are also to be provided in the cargo loading station.

5 System requirements

5.1 General

5.1.1 The ship is to be fitted with a de-ballasting system and a separate stripping system having a capacity consistent with the design loading rate.

5.1.2 Arrangements are to be made for synchronizing the de-ballasting rate with the loading rate, as well as in time starting of the stripping operations.

5.1.3 Where provided, the ballast water treatment system is to be designed for the maximum expected de-ballasting rate.

5.2 Ballast piping

5.2.1 Ballast main and branch lines are to have sufficient diameter so that the sea water velocity in those lines does not exceed the limits stated in Pt C, Ch 1, Sec 10, [5.8.3], in all de-ballasting configurations (depending on the number of ballast pumps in operation and number of ballast tanks served simultaneously).

5.3 Control and monitoring

5.3.1 Ballast pumps and all valves necessary for the de-ballasting and stripping operations are to be capable of being controlled from the cargo loading station and / or ballast control station.

5.3.2 Ballast tanks are to be fitted with level sensors feeding tank sounding levels to the loading computer and providing a remote indication in the cargo loading station.

5.3.3 Fuel oil tanks for storage of bunkers are to be fitted with level sensors feeding tank sounding levels to the loading computer and providing a remote indication in the cargo loading station.

Section 2 Bow and Stern Loading / Unloading Systems

1 General

1.1 Application

1.1.1 The requirements of the present Section are applicable for oil tankers fitted with bow or stern loading/unloading systems and intended to be granted class notations defined in [1.2].

1.1.2 The requirements of the present Section are to be considered in addition to the applicable requirements of Part D, Chapter 7.

1.2 Class notations

1.2.1 Additional class notation BLUS

Oil tankers equipped with bow loading/unloading systems and complying with the requirements of the present Section may be granted the additional class notation **BLUS**.

1.2.2 Additional class notation SLUS

Oil tankers equipped with stern loading/unloading systems and complying with the requirements of the present Section may be granted the additional class notation **SLUS**.

1.3 Scope of classification

1.3.1 Additional class notations **BLUS** and **SLUS**, as defined in [1.2] cover classification requirements relating to the following equipment and items:

- general arrangement of bow or stern loading/unloading systems
- cargo transfer piping for bow or stern loading/unloading systems
- relevant mooring arrangements
- traction winches and storage reel
- bow and stern control stations
- fire protection of areas relating to bow or stern loading/unloading systems
- ventilation of spaces in relevant bow or stern areas.
- electrical equipment for bow or stern loading/unloading systems
- instrumentation and automation for bow or stern loading/unloading systems.

1.3.2 All equipment covered by additional class notations **BLUS** and **SLUS** is to be function tested.

1.4 Definitions

1.4.1 Oil tanker

For the purpose of the present Note, oil tanker means a ship with service notation **oil tanker**, as defined in Pt A, Ch 1, Sec 2, [4].

1.4.2 Hazardous areas

Hazardous areas are areas where flammable or explosive gases are normally present or likely to be present. Hazardous areas are categorized as Zone 0, Zone 1 and Zone 2, as defined in Pt C, Ch 2, Sec 1, [3.13].

Detailed definitions of hazardous areas are given as follows in Pt D, Ch 7, Sec 5.

1.4.3 Cargo area

The cargo area is that part of the ship that contains cargo tanks as well as slop tanks, cargo pump rooms including pump rooms, cofferdams, ballast or void spaces adjacent to cargo tanks or slop tanks as well as deck areas throughout the entire length and breadth of the part of the ship above these spaces.

When independent tanks are installed in hold spaces, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space are excluded from the cargo area.

1.5 Documents to be submitted

1.5.1 General

In addition to the documentation requested by the Ship Rules, the following documents are to be submitted:

- general arrangement of bow or stern loading/unloading systems and mooring arrangements, including loading/unloading manifold, traction winch, storage reel, fairleads and chain stoppers, relevant control stations
- hazardous area plan and electrical equipment data
- plans showing fire protection and fire extinguishing arrangements for the bow or stern loading/unloading areas
- ventilation of spaces in bow or stern areas
- spill containment arrangements
- details of cargo piping from the cargo area to loading/unloading manifold, including standard construction details
- operating manual.

1.6 Operating Manual

1.6.1 An Operating Manual is to be submitted to the Society, for approval, as requested in [1.5.1].

1.6.2 The Operating Manual is to provide, at least, the following information relating to ship operation:

- mooring procedure including specific operation of mooring related equipment
- connection / disconnection of hose coupling
- emergency disconnection procedure
- cargo transfer
- specific loading conditions including cargo load distribution
- cleaning and gas-freeing
- provisions for avoiding overfilling of cargo tanks.

1.6.3 The Operating Manual is to provide references to drawings relating to relevant arrangements, equipment, safety installations, emergency escape routes.

2 Materials

2.1 General

2.1.1 Material for construction are to comply with the requirements of NR 216 Material and Welding.

2.1.2 Unless otherwise specified, materials for cargo piping are to comply with the requirements of Pt C, Ch 1, Sec 10 applicable to piping systems of class III.

The requirements of Pt D, Ch 7, Sec 4, [3.3.2] are also to be taken into account.

3 General design

3.1 Mooring system

3.1.1 Mooring equipment are to be designed in accordance with relevant requirements given in Pt B, Ch 12, Sec 4 and Pt B, Ch 12, App 2.

3.1.2 Mooring system is to be provided with a device indicating continuously the tension in lines during loading/unloading operations.

3.1.3 The requirement of [3.1.2] may be waived for ships fitted with a dynamic positioning system for operations and intended to be assigned the additional class notation **DYNAPOS**, as defined in Pt A, Ch 1, Sec 2, [6].

3.1.4 Mooring system instrumentation is to include chain stopper control and mooring lines control.

3.2 Cargo piping system

3.2.1 Cargo piping outside cargo area is to be fitted with a shut-off valve at its connection with the piping system within the cargo area and separating means such as blank flanges or removable spool pieces are to be provided when the piping is not in use, irrespective of the number and type of valves in the line.

3.2.2 Connection with shore or offshore unit is to be fitted with a shut-off valve and a blank flange. The blank flange may be omitted when a patent hose coupling is fitted.

3.2.3 Cargo lines outside the cargo area are to be installed outside accommodation spaces, service spaces, machinery spaces and control stations.

3.2.4 Pipe connections outside the cargo area are to be of welded type only, except for connections with manifold or loading/ unloading equipment.

3.2.5 Spray shields are to be provided at the connection station, except where the loading/unloading manifold is located outboard. Spill containment arrangements with sufficient capacity are to be provided under the loading/ unloading manifold.

3.2.6 Cargo lines outside cargo area are to be provided with arrangements for easy draining to the cargo area, in a cargo tank.

3.2.7 Loading/unloading lines are to be fitted with means to be purged by inert gas after use and maintained gas free when not in use. Due consideration is to be given to isolation between cargo and the inert gas system.

3.3 Ventilation

3.3.1 Air inlets, entrances and openings to machinery spaces, service spaces and control stations are to be located at least 10 m from the coupling and are not to be located facing the cargo hose connection.

3.3.2 For ships intended to be assigned the additional notation **SLUS**, due consideration is to be given to the location of ventilation inlets and outlets of machinery spaces and openings of deckhouses and superstructure boundaries.

3.4 Hazardous areas and electrical installations

3.4.1 Spaces used for housing loading/unloading hoses, cargo lines and loading/unloading manifold are to be considered as hazardous area Zone 1.

3.4.2 Spaces within 3 m from the boundary of spill containment arrangements are to be considered as hazardous, Zone 1.

3.4.3 Electrical equipment and cables located in hazardous areas are to be of a certified safe-type and are to comply with the requirements of Pt D, Ch 7, Sec 5.

3.5 Positioning

3.5.1 Ship positioning and manoeuvring during loading/unloading operations is to be ensured by:

- controllable pitch propeller
- side thrusters of adequate power.

3.5.2 For ships fitted with dynamic positioning system, the requirements given under the scope of additional class notation **DYNAPOS** are to be complied with.

3.6 Emergency Disconnection System (EDS)

3.6.1 Bow or stern loading/unloading systems are to be provided with an automatic EDS and a back-up EDS.

3.6.2 Functions of automatic EDS are to be performed in sequence and are to include:

- tripping of transfer pumps
- emergency closing of valves
- coupler disconnection
- mooring system release.

3.6.3 The back-up EDS is to be manually operated, allowing the individual operation of coupler and mooring system.

3.7 Control station

3.7.1 A control station from which are performed all operations relating to ship positioning and monitoring of mooring and loading/unloading parameters is to be arranged in the relevant bow or stern area or on the navigation bridge.

3.7.2 Boundaries of the control station, including windows and side scuttles, are to be of A-60 insulated.

3.7.3 Adequate emergency escape routes are to be provided for the control station.

3.8 Communications

3.8.1 Means of communication, such as telephones, two-way portable radios, etc, are to be provided onboard between the control station and shore or offshore unit. Means of emergency communication are also to be provided.

3.8.2 Means of communication are to be such that the communication can be maintained in the eventuality of any equipment failure or incidents during loading/unloading operations.

3.8.3 Means of communication in hazardous areas are to be of a certified safe-type.

3.8.4 A communication sequence is to be established for all phases of loading/unloading operation.

3.9 Safety features

3.9.1 The layout of bow or stern loading/unloading system is to be based on the principle of the minimization of risk and consequences of relevant fire and explosion events relating to bow or stern areas.

3.9.2 The following additional safety equipment is to be provided, as a minimum:

- protection of mooring elements against shocks and contact with hull elements
- protection of hose coupling against shocks and contact with hull elements
- additional water jets and foam monitors for bow or stern area, at the satisfaction of the Society
- a fixed foam fire extinguishing system, at the satisfaction of the Society, covering loading/unloading areas
- a fixed water-spray system covering the area of mooring elements, hose couplings and control station area.

3.9.3 Bow or stern loading/unloading system is not to interfere with the safe launching of survival craft. Provisions are to be made to protect launching stations from sprays in case of hose and pipe bursting.

Section 3 Supply at Sea (SAS)

1 General

1.1 Application

1.1.1 The additional class notation **SAS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.16.4], to ships having the service notation **supply** fitted with installations for underway ship-to-ship supply at sea of liquid and solid supplies, complying with the requirements of this Section.

Specific operation may be added if relevant (e.g. **SAS** - seismic support).

1.1.2 The requirements of this Section apply in addition to the requirements of Part E, Chapter 3.

1.1.3 Application to other types of ship may be considered on a case-by-case basis.

1.2 Documents to be submitted

1.2.1 The plans and documents to be submitted to the Society are listed in Tab 1.

1.3 Definitions

1.3.1 Supply At Sea (SAS)

SAS means refuelling at sea or underway provisioning at sea of solid and liquid supplies.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documents to be submitted
1	I	Description and operation manuals of the ship's SAS systems and equipment, including limiting conditions for SAS operations
2	A	Plans showing each proposed combination of equipment, fully rigged
3	I	Details of solid cargo to be transferred: maximum weight and dimensions
4	A	Details of liquid cargo to be transferred and diagram of the fluid transfer system
5	I	Details of maximum sea state and environmental conditions under which SAS operations are permitted
6	I	General arrangement showing: • relative disposition of SAS stations and associated clearances • location of SAS control stations • arrangement of solid cargo transfer routes
7	A	Lifting appliances: plans and construction drawings of all lifting appliances, masts, derricks, rigs
8	I	Mooring plan, including details and SWL of lines, bitts, fairleads and winches to be used
9	A	Details of equipment identified for SAS operations. Design and installation loads on the equipment together with details of securing and holding down arrangements. Details of the access required for maintenance and to operate the equipment
10	I	Description of safety devices (emergency breakaway, antislack devices, alarms, limit switches…)
11	A	Drawings of the foundations of lifting appliances and winches, including footprint and reaction forces
12	I	National or international regulations, standards or specifications used for type testing of equipment requiring type testing according to Tab 3
13	I	SWL of all components of SAS installation
14	A	Test and inspection programme for the test onboard: static load test, checking verifications, dynamic overload tests
15	A	Details of structural reinforcement under SAS stations dump areas
16	A	Diagram of internal ship communication system
17	I	Diagram of ship to ship communication system
18	I	Arrangement plan of low intensity lightning of SAS stations and transfer routes

(1) I : To be submitted for information.
A : To be submitted for approval.

1.3.2 SAS station

SAS station is the deck area fitted with SAS equipment providing the capability to carry out underway provisioning of liquid and/or solid cargo.

1.3.3 SAS control station

SAS control station is a station from which it is possible to operate SAS equipment and observe the SAS operations performed at SAS station(s).

2 Design and construction

2.1 SAS equipment

2.1.1 Typical arrangement

Solid supply installations are generally made of:

- support line and inhaul line with their necessary associated items (hooks, derricks, mast...) to run the traveller block manually or by means of winches between delivery ship and receiving ship, or
- on-board cranes.

Liquids supply installations are generally made of:

- hose lengths secured by saddles to the support line with their necessary associated items (hooks, derricks, mast...) and run between both ships by means of winches, or
- floating hoses running between both ships (stern transfer).

Other types of SAS installations may be used and are to be submitted to the Society for special examination.

2.1.2 General

SAS pieces of equipment onboard supply vessels are to comply with the following requirements:

- they are to be type approved according to [4.1]
- certificates of inspection of materials and equipment are to be provided as indicated in [4.2]
- fitting onboard of the SAS equipment is to be witnessed by a Surveyor of the Society and the relevant certificate is to be issued
- demonstration of the strength, structural integrity and good working of SAS equipment is to be effected for each ship through shipboard testing as mentioned in [4.4] and this is to be reported in the above certificate.

2.1.3 Emergency breakaway

All SAS equipment and facilities are to be designed to permit the application of emergency breakaway procedures that are normally to be complete within one minute of the commencement of initiation. Use may be made of quick release couplings and/or breakable couplings. Attention is to be given to the attachment of wires and ropes to winch drums and the selection of emergency breakaway equipment (wire cutters, axes, etc.).

2.1.4 Prevention measures

Fenders are to be provided to protect the ship from ship-to-ship contact during SAS operations.

Measurements are to be taken to prevent electrostatic hazards during liquids transfer operation.

2.1.5 Survey of elements within the scope of ship classification

The fixed parts of the SAS equipment and connections to ship structure (masts, crane pedestals, winches and equipment foundations, local reinforcements under the dump area and transfer lanes) are to be surveyed at the yard by a Surveyor of the Society within the scope of the ship classification.

2.1.6 Safe Working Load (SWL) of SAS equipment

The safe working load of SAS components is to be sufficient to withstand the maximum load to which such component may be subjected during the SAS operation. The safe working load is to be indicated by the designer.

For tensioned spanwire, the SWL of the rigging components is the maximum design tension of the spanwire given by the designer.

As a rule, the SWL of the components which are not part of the tensioned line (i.e. riding and retrieving lines) is not to be less than 35 kN.

2.1.7 Winches

Winches are to incorporate safety features that permit safe SAS operations and cater for the unique loading conditions that may arise during SAS operations. The following functions are to be fulfilled:

a) Quick and efficient engagement and disengagement of the service brake by both automatic and manual means

b) Long term locking of the winch drum having manual engagement and disengagement

c) For spanwire and retrieving winches:
- an overload protection preventing the wire/rope being overstressed during SAS operations (e.g. when ships move or roll apart)
- slack rope prevention that maintains tension in the wire when the winch is operating under no load

d) Proper spooling of the wire onto the drum

e) Winches are to be fed by an alternative power supply.

Combined stress resulting from application in the most unfavourable conditions of a tension in the cable equal the breaking load of this cable is not to be higher than 80% of the comparison elastic limit of the material of which strength elements such as frame, drum, drum axles, assembly welds, etc. are made.

Minimum braking force of service brakes is not to be less than 1,5 times the safe working force on the brake.

2.1.8 Steel wire ropes

Steel wire ropes used for SAS operations are to be in compliance with requirements of NR216 Materials and Welding, Ch 10, Sec 5.

The ratio of the specified breaking load of the cable to its SWL is not to be taken less than 3,5.

2.1.9 Hoses and fittings

Hoses for transferring liquids are to be in accordance with standards applicable to the intended application.

2.1.10 Masts

Masts, cranes, derricks and rigs used for SAS operations and fenders positioning are to comply with the relevant requirements of NR526 Rules for Lifting Appliances, considering the most unfavourable combination of all safe working loads applied to the mast.

2.1.11 Shipboard fittings and supporting hull structures associated with mooring

Mooring lines are only to be led through class approved closed fairleads.

Additional lines are to be readily available to supplement moorings if necessary or in the event of a line failure.

It is recommended to use all available fairleads and bitts to avoid concentration of loads.

The requirements of Pt B, Ch 12, Sec 4 and Pt B, Ch 12, App 2 are applicable.

2.2 Steering capability

2.2.1 General

The steering gear system is to fulfil the requirements defined in Pt C, Ch 1, Sec 11.

2.2.2 Electrical power supply

An alternative power supply either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment is to be provided, sufficient at least to supply the steering gear power unit such that the latter is able to perform the duties of auxiliary steering gear.

This power source is to be activated automatically, within 45 seconds, in the event of failure of the main source(s) of electrical power.

The independent source is to be used only for this purpose.

The alternative power source is also to supply the steering gear control system, the remote control of the power unit and the rudder angle indicator.

2.2.3 Steering control systems

Any single failure in the steering control system including its interfaces to the navigation system is not to impair the steering capability which is to be continuously maintained.

Such single failure may affect any active component as defined in Ch 2, Sec 1, [1.2.6] from interfaces to the navigation system to interfaces to the mechanical steering actuators.

Compliance with the above is to be demonstrated by a risk analysis performed in compliance with Ch 2, App 1, Procedures for Failure Modes and Effect Analysis.

A dynamic positioning system, with **DYNAPOS AM/AT R** notation, could be considered as an alternative regarding the availability of the steering system.

3 Arrangement and installation

3.1 General

3.1.1 SAS systems are to be designed and installed such that degradation or failure of any SAS system will not render another ship system inoperable.

3.2 Arrangement of SAS stations

3.2.1 Location of SAS stations

The distance separating two alongside SAS stations, if any, is recommended not to be less than 20 m and not to exceed 40 m.

As far as practicable, one side SAS station is to be located amidships to maximise crew protection during SAS operations in heavy weather conditions.

3.2.2 Clearance requirements

A clearance of at least 30° aft and forward of each side SAS station is to be provided.

For the stern station, if any, sufficient clearance is to be provided for safe deployment of refuelling equipment with regard to deck and stern equipment.

3.2.3 Protection of personnel

a) Bulwarks, guard rails or other equivalent arrangement are to be provided in exposed upper deck positions with regard to personnel protection, in accordance with Pt B, Ch 12, Sec 2.

b) In general, SAS operations are to be carried out with guard rails in position. Where, for operational reasons, this is not practicable, alternative equivalent arrangements are to be provided.

c) Slip-free surfaces are to be provided in the areas where SAS operations are conducted, and tripping hazards are to be minimized.

d) A minimum distance of at least 3 m between any SAS station superstructure and the edge of the weather deck is to be provided.

In case this distance is practically not achievable, specific measures are to be described in order to provide protection to personnel (individual protection, maximum size of solid loads transferred, marks on SAS area, procedures used, limitation of operations according to weather conditions ...)

e) Authorised personnel only is allowed at the SAS station. During liquid transfer operation, authorised personnel is to be equipped with protective clothing

3.2.4 Access

The rigging securing points are to be arranged so that safe access is provided to authorised personnel, including ladders and walkways on the masts.

3.2.5 SAS equipment stores

SAS equipment and fittings are to be stored in dedicated stores, readily accessible from authorised personnel SAS station. The stores are to have direct access to the weather deck.

3.2.6 Sources of high intensity noise

SAS stations are to be arranged so that exposure to high intensity noise (above 85 dB) is as low as practicable during SAS operations.

3.3 SAS control station arrangement

3.3.1 General

a) A SAS control station is to be provided for control and monitoring of all equipment involved in SAS operations as requested in [3.4] and [3.5].

b) The controls for SAS equipment are to be situated at one control position or grouped in as few positions as possible, to the satisfaction of the Society.

c) For liquid transfer, the SAS control station is to be located at a safe distance from the filling connection.

d) The SAS control station is to be located so that it provides a clear view of all SAS stations and associated equipment.

3.4 Communication

3.4.1 Bridge conning position

A conning position for the officer in charge of the SAS operations is to be provided on the navigation bridge with a duplicated position on both bridge wings.

From this conning position, it is to be possible to observe the ship heading and relative motion of the ships conducting SAS operations. In addition, a gyro compass readout and rudder angle indicator are to be readily visible from the conning position.

3.4.2 Ship internal communication systems

Means of communication are to be provided between each SAS station and the SAS control station.

Such communication system is to be such that communication between SAS stations and SAS control station can be maintained in case of equipment single failure.

As a minimum, means of effective ship internal communications are to be provided in accordance with Tab 2.

Table 2 : Internal communications

Position	Conning position	SAS station	SAS control station	Remarks
Conning position		X	X	
SAS station	X		X	Each SAS station is to be able to communicate with the conning position and the SAS control station
SAS control station	X	X		

3.4.3 Ship to ship communications

a) Means are to be provided to allow continuous ship to ship distance measurement during side by side SAS operations.

b) Visual and aural means of communication are to be provided between the ships conducting SAS operations.

c) If some equipment, such as distance line, is to be transferred from one ship to another in order to conduct the SAS operations, the distance line securing points are to be clear of all SAS stations and arranged so that the distance line is visible from the bridge conning position. This requirement may be waived for stern replenishment.

3.5 Fluid transfer

3.5.1 General

a) The filling connections for liquid transfer operations are to be located within the SAS station and are to be fitted with shut-off valves locally operated.

b) Filling connections are to be designed to allow an emergency breakaway as per [2.1.3]. In particular, they are to be provided with quick release coupling.

c) Filling connections are to be provided with pressure sensors monitored from the SAS control station.

d) Emergency stop of the cargo pumps are to be provided at the SAS control station.

3.5.2 Quick release system

When transferring liquids with flash point not greater than 60°C, adequate means are to be provided to rapidly stop the liquid transfer operation if abnormal situation occurs. This system is to operate at two levels:

- stage 1: shut down of cargo pumps and shutting of quick closing valves. Emergency stop is to be provided at SAS control station and at bridge conning position.
- stage 2: release of the quick release couplings.

The quick release system may be connected to the ships automatic emergency breakway system (if any) but, in all cases, is also to be capable of manual activation.

The means of control of the quick release system are to be located at the SAS control station together with the controls for any safety system that may provided additional protection to the ship in the event of a quick release (e.g. deck foam system ...).

In the event of activation of the quick release hose couplings, the hoses are to be adequately supported and protected to prevent potential damage or rupture.

3.5.3 Fire extinguishing arrangement

A SAS station is to be provided with:

- two dry powder fire-extinguishers, each of at least 50 kg
- at least one portable low expansion foam applicator.

3.6 Solid transfer

3.6.1 General

To prevent ingress of water into the ship, sills or alternative equivalent arrangements are to be provided at the entrances to the interior of the ship from each SAS station.

3.6.2 Ship structure

a) Each SAS station intended for solid transfer operations is to be provided with a designated dump area.

The dump area is to be suitably reinforced to withstand the impact loads that may arise due to landing of stores and equipment on board during SAS operations.

b) The dump area is to extend over at least 1 m outside of the largest expected solid cargo foot print. A factor of safety of not less than 3,5 times the maximum load to be transferred is to be used in the design of the structure.

3.7 Electrical installation

3.7.1 The following additional hazardous areas are to be considered when transferring flammable liquids having a flash point not exceeding 60°C or flammable liquids heated to a temperature within 15°C of their flash point:

- Zone 1: Enclosed or semi-enclosed spaces containing SAS equipment unless:
  - fitted with forced ventilation capable of giving at least 20 air changes per hour and having characteristics such as to maintain the effectiveness of such ventilation, or
  - acceptable means are provided to drain or empty the hoses or rigid arms on completion of transfer operations, prior to or after disconnection
- Zone 2: Areas in open deck within 3 m from SAS equipment unless acceptable means are provided to drain or empty the hoses or rigid arms on completion of transfer operations and after disconnection.

Types of electrical equipment allowed within these areas are specified in Pt C, Ch 2, Sec 3, [10].

3.7.2 All the deck mounted electrical equipment and enclosures are to be designed with IP56 ingress protection rating.

3.7.3 Night operation

In order to carry out SAS operation at night in safe conditions, sufficient lighting, including emergency lighting, is to be provided on SAS areas and at control station.

4 Certification, inspection and testing

4.1 Type approval procedure

4.1.1 SAS components are to be type approved according to the following procedure:

- the design is to comply with the requirements of this Section and either national or international standards, or recognized codes or specifications, which are to be indicated
- each component of the SAS equipment is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [4.3]
- types tests are to be carried out as specified under [4.4].

4.2 Inspection at works of the SAS equipment

4.2.1 The materials and equipment are to be inspected and certified as specified in Tab 3.

4.3 Prototype tests

4.3.1 Prototype tests are to be witnessed by a Surveyor from the Society and to include load test of the SAS equipment under a proof load at least equal to 2 times the safe working load defined in [2.1.6].

4.4 Tests on board

4.4.1 General

The SAS arrangements are to undergo the following tests and inspections after their installation on board:

- static load test demonstrating the strength of the complete rigging of SAS equipment under a load condition larger than the operational one;
- after static load test, a visual inspection and functional test to demonstrate that the system is operational and has not suffered damages from the static load tests;
- overload tests to demonstrate proper functioning of the equipment on overload.

These tests are to be carried out according to a test programme submitted to the Society.

Testing and marking of the SAS equipment is to be in accordance with the relevant requirements of NR526 Rules for Lifting Appliances, Sec 10.

4.4.2 Static load tests

Static load tests are to be performed using dedicated test wire rope, different from the ship wire rope used onboard.

The test loads are to be greater than twice the rated SWL of the rigging to be tested. In addition, for tensioned spanwire or highline systems, the test load is not to be less than 20% of the breaking strength of the spanwire or highline.

4.4.3 Overload tests

Repeated load cycles specific to each type of equipment are to be performed according to a test programme submitted to the Society. As a rule, the test load is to be 1,5 times the rated operating load corresponding to the SWL.

On winches with adjustable clutches, the clutch need temporary readjustment in order to perform the overload tests. After completion of the test, the clutch or limiting devices are to be readjusted to the normal value and retested.

Table 3 : Materials and equipment certification

Item	Material certification	Product certification					Remarks
		Design assessment / approval	Examinations and tests			Certification	
			During fabrication	After completion	Running tests		
Lifting appliances: masts, cranes, derricks	C (1)	DA	X (2)	X (2)	X (3)	C	(1) As per NR216 (2) As per relevant provisions of NR526 (3) Shop tests and running tests onboard as per [4.4]
Winches, anti-slack devices, Ram tensioner	C (1)	(2)	X	X	X (3)	C	(1) As per NR216 (2) As a rule, no individual design assessment of winches and RAS equipment (3) Onboard tests as per [4.4]
Electric motors and electrical equipment used for SAS operations (1)	W	DA or TA		X (2)	X (2)	W	(1) Considered as intended for secondary essential services (2) Testing of electric motors includes type tests and routine tests as per Pt C, Ch 2, Sec 4, [3]
Hydraulic cylinders, piping of class I and equipment essential for SAS operation (winches, Ram tensioner)	C		X s	X h		C	
Control systems of winches and essential systems for SAS operation (Ram tensioner)		DA			X (1)	C	(1) According to an agreed programme for onboard tests as per [4.4]
Cargo transfer hoses and pipes couplings, including breakaway couplings	C (1)	TA		X s h (2)	X (3)	C	(1) Only for metallic pieces and couplings (2) Non-destructive and hydraulic tests as per recognized standards or specification to be specified by the manufacturer (3) Emergency breakaway capabilities to be demonstrated onboard
Loose gear and accessories, including blocks, hooks, shackles, swivels …	W	DA (1)		X (2)		C	(1) Only for elements not complying with a national or international standard (2) Proof load as per [4.3]
Steel wire ropes	W			X (1)		C	(1) As per requirement of NR216 or in compliance with a national or international standard (ISO 3178 for instance)

Note 1:
"C" indicates that a Society certificate is required.
"W" indicates that a manufacturer's document is required.
index "h" means that an hydraulic pressure test is required.
index "s" means that non destructive tests are required, as per Rules, standard or specification.
"TA" means a type approval is required.
"DA" means a design approval of the product is required, either for the specific unit produced, or using the type approval procedure.
Note 2: Where nothing is mentioned in the design index assessment column, a design assessment of the specific unit is not required.

Section 4 Centralised Cargo and Ballast Water Handling Installations (CARGOCONTROL)

1 General

1.1 Application

1.1.1 The additional class notation **CARGOCONTROL** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.16.5], to ships carrying liquid cargo in bulk fitted with a centralised system for handling liquid cargo and ballast and complying with the requirements of this Section.

1.1.2 Compliance with these Rules does not exempt the Owner from the obligation of fulfilling any additional requirements issued by the Administration of the State whose flag the ship is entitled to fly.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted to the Society for approval.

The Society reserves the right to require additional plans or information in relation to the specific characteristics of the installations.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Item
1	I	Schematic drawing of the installation
2	I	Plan of the location and arrangement of the control station
3	A	List of remote control devices
4	A	List of alarms
5	I	List of the equipment (sensors, transducers, etc.) and automation systems (alarm systems, etc.) envisaged with indication of the Manufacturer and of the type of equipment or system
6	A	Line diagram of power supply circuits of control and monitoring systems, including: • circuit table, in the case of electrical power supply • specification of service pressures, diameter and thickness of piping, materials used, etc. in the case of hydraulic or pneumatic power supply
(1) A : to be submitted for approval; I : to be submitted for information.		

2 Design and construction requirements

2.1 Control station

2.1.1 Location of control station

a) The control station is to be located such as to allow visibility of the cargo tank deck area, and in particular of the cargo loading and unloading ramps.

b) The station is preferably to be situated in the accommodation area; should this be impracticable, the control station is to be bounded by A-60 class fire-resisting bulkheads and provided with two escapes.

2.1.2 Communications

It is be possible from the control station to convey orders to crew members on deck and to communicate with the navigation bridge, with cargo handling spaces, with the engine room and with the propulsion control room, where the latter is foreseen.

2.1.3 Safety equipment

Where the control station is located in the cargo area, two complete sets of protective clothing in order to protect the skin from the heat radiating from a fire are always to be readily available together with three breathing apparatuses.

2.2 Remote control, indication and alarm systems

2.2.1 Remote control system

It is to be possible to carry out the following operations from the control station:

a) opening and closing of valves normally required to be operated for loading, unloading and transfer of cargo and ballast (however, the opening and closing of valves is not required for the ends of cargo loading and unloading arrangements)

b) starting and stopping of cargo pumps, stripping pumps and ballast pumps (alternative solutions may be considered in the case of pumps powered by turbines)

c) regulation, if foreseen, of the number of revolutions of cargo pumps, stripping pumps and ballast pumps.

2.2.2 Indication system

The control station is to be fitted with indicators showing:

- (open/closed) position of valves operated by remote control
- state (off/on) of cargo pumps, stripping pumps and ballast pumps
- number of revolutions of cargo pumps, stripping pumps and ballast pumps where they may be operated at adjustable speeds
- delivery pressure of the hydraulic plant for the operation of cargo pumps, stripping pumps and ballast pumps
- delivery and suction pressure of cargo pumps, stripping pumps and ballast pumps
- pressure of the ends of cargo loading and unloading arrangements
- oxygen level, temperature and pressure of the inert gas, where the operation of the inert gas system is required or envisaged at the same time as loading/unloading
- level in cargo and ballast tanks (relaxation of this requirement may be permitted for double bottom ballast tanks of reduced capacity and limited depth)
- temperature in cargo tanks provided with heating or refrigeration.

2.2.3 Alarm systems

The cargo control station is to be fitted with visual and audible alarms signalling the following:

- high level, and where requested very high level, in cargo tanks
- high pressure in cargo tanks, if required by the Rules
- low delivery pressure of the hydraulic plant for the operation of pumps and valves
- high vacuum in cargo tanks, if required by the Rules
- high pressure in the cargo and ballast lines
- high and low temperature for cargo tanks fitted with heating and refrigerating systems
- high oxygen level, high temperature, and high and low pressure of inert gas, if foreseen
- high level in a bilge well in cargo and ballast pump rooms
- high concentration of explosive vapours (exceeding 30% of the lower flammable limit) in spaces where cargo is handled
- high temperature of gas-tight seals with oil glands for runs of shafts, where these are foreseen through bulkheads or decks, for the operation of cargo and ballast pumps.

3 Inspection and testing

3.1 Equipment and systems

3.1.1 Equipment and systems are to be inspected and tested in accordance with the applicable requirements of the Rules relative to each piece of equipment of the system used for the centralised control.

3.2 Testing on board

3.2.1 Following installation on board, remote control, indication and alarm systems are to be subjected to operational tests in the presence of the Surveyor.

Section 5 Container Lashing Equipment

1 General

1.1 Additional class notations

1.1.1 In accordance with Pt A, Ch 1, Sec 2, [6.16.6], ships carrying containers and equipped with fixed and portable lashing equipment complying with the requirements of this Section may be assigned one of the following additional class notations:

- **LASHING** as defined in [1.1.2]
- **LASHING-RSSA( )** as defined in [1.1.3] when the ship may be engaged in voyages on specific routes or in specific areas. The specific routes and/or specific areas are to be specified by the Owner and indicated between brackets.

The additional class notations **LASHING** and **LASHING-RSSA( )** may be completed by the notation **-WAF**, as defined in [1.1.4], when the ship may also be engaged in short voyages (less than 72 hours) and is provided with weather dependent lashing procedures.

Examples:

LASHING

LASHING-WAF

LASHING-RSSA(Europe - Asia through Mediterranean sea)

LASHING-RSSA(Baltic sea)-WAF

1.1.2 The additional class notation **LASHING** covers the assessment of lashing patterns in environmental conditions corresponding to unrestricted navigation conditions (i.e. based on the North-Atlantic scatter diagram as per IACS Rec. No. 34 Rev. 2).

1.1.3 The additional class notation **LASHING-RSSA( )** covers the assessment of lashing patterns considering the following environmental conditions:

a) specific route or specific area conditions, for any voyage conducted according to the specific routes or specific areas covered by the notation:

   - The requirements of this Section explicitly specify the loads to be considered for the list of specific routes given in Tab 1. The detailed definition of each specific route is given in Ch 12, App 1.

     These loads may also be applied to alternative routes provided that the criterion given in Ch 12, App 1, [1.2.1] is complied with. In particular, the loads associated to a reference specific route are not to be applied to a route corresponding to a portion of the reference specific route if the criterion given in Ch 12, App 1, [1.2.1] is not complied with.
   - Other specific routes may be specially considered by the Society on a case-by-case basis.
   - The loads associated to a specific area are to be derived on a case-by-case basis by considering the corresponding scatter diagram.

b) unrestricted navigation conditions (i.e. based on the North-Atlantic scatter diagram as per IACS Rec. No. 34 Rev. 1) for any voyage other than voyages defined in item a).

1.1.4 The notation **-WAF** covers the assessment of lashing patterns considering the expected maximum significant wave height and maximum wind speed as given by a weather forecast service provider for a specific short voyage of less than 72 hours.

1.1.5 The procedure for the assignment of the additional class notations defined in [1.1.1] to [1.1.4] includes:

- approval of the lashing plans and approval of fixed and portable securing fittings
- type tests of the fixed and portable securing fittings and issuance of Type Approval Certificates for these fittings
- inspection at the works during manufacture of the fixed and portable securing fittings and issuance of Inspection Certificates for these fittings
- general survey on board of fixed and portable securing fittings and sample test of mounting of fittings
- approval of the lashing software when relevant.

Table 1 : List of the specific routes for the additional class notation LASHING-RSSA( )

	Route No.	Description
Routes through Atlantic ocean	1	North sea - Baltic sea
	2	Northern Europe - Mediterranean sea
	3	Europe - North America (East)
	4	Europe - South Africa
	5	Europe - South America
	6	North America (East) - South America
	7	South America - South Africa
Routes through both Atlantic and Indian oceans	8	Europe - Asia, through Mediterranean sea
	9	Europe - Asia, through Cape of Good Hope
Routes through both Atlantic and Pacific oceans	10	Europe - Asia, through Atlantic and Pacific
	11	North America (East) - Asia through North Pacific (between 40°N and 50°N)
	12	North America (East) - Asia through North Pacific (below 30°N)
Routes through Indian ocean	13	South Africa - Asia
Routes through Pacific ocean	14	North America (West) - Indonesia
	15	North Pacific (between 40°N and 50°N)
	16	North Pacific (between 30°N and 40°N)
	17	South America - Asia
	18	Indonesia - Asia
	19	Asia - Australia

1.2 Definitions

1.2.1 Fixed container securing fittings are used to secure and support containers and are permanently welded to the ship structure.

1.2.2 Portable container securing fittings are used to secure containers and are not categorized as fixed container securing fittings.

1.2.3 The various terms related to securing fittings are defined as follows:

a) The term “fixed securing fitting”, when used, refers to “fixed container securing fitting”.

b) The term “portable securing fitting”, when used, refers to “portable container securing fitting”.

c) The term “securing fitting”, when used, refers to both “fixed container securing fitting” and “portable container securing fitting”.

1.2.4 Minimum Breaking Load corresponds to the minimum load at which the first crack appears in the tested representative samples.

1.2.5 Minimum Proof Load corresponds to the test load, below which visible permanent deformation is not allowed.

1.2.6 Lashing software is an electronic data processing tool for onboard analysis of forces in container stacks and thereby reflects the parameters of the lashing system as described in the Cargo Securing Manual prepared in accordance with the flag Administration requirements.

An approved lashing software is not a substitute for the approved Cargo Securing Manual. It is considered as a supplement to the approved Cargo Securing Manual.

1.3 Documentation to be submitted

1.3.1 The documentation to be submitted to the Society is specified in Tab 2.

These documents are to be duly stamped and kept on-board the ship.

1.3.2 The container securing arrangement plan is to describe lashing arrangements considering the following environmental conditions:

- notation **LASHING**: unrestricted navigation conditions
- notation **LASHING-RSSA( )**: unrestricted navigation and specific route and specific area conditions as applicable.

1.3.3 For ships assigned the additional class notation **LASHING-RSSA( )**, the cargo securing manual is to include:

- list and description of the specific routes and specific areas which are covered by the notation
- operational guidance and limitations for applying the loads associated to the specific routes covered by the notation to alternative routes (see [1.1.3]).

Table 2 : Documentation to be submitted

No.	A/I **(1)**	Description
1	A	Cargo securing manual including: • list and drawings of fixed securing fittings, including all information specified in Article [3] • list and drawings of portable fittings, including all information specified in Article [3] • test reports and certificates of the different fixed and portable securing fittings used on-board.
2	A	Container securing arrangement plan describing **(2)**: • the stowage arrangement of containers in hold, on deck and on hatch covers showing nominal capacity • the maximum design weight of container stacks • design vertical sequences of weights in stacks • summary of ship particulars such as IMO No., length and breadth • summary of loading conditions showing relevant input parameters such as draught and GM • relevant properties of securing fittings, including permissible loads • graphical presentation of container and lashing arrangements in each bay on deck and in holds for sample loading conditions for each container type the ship is allowed to carry • minimum quantity of fittings required to secure containers for the presented sample loading conditions.
3	I	Container stowage plan including the following, for each container type the ship is designed for **(2)**: • longitudinal and athwartship views of under deck and on deck stowage locations of containers including reefers as appropriate • alternative stowage patterns for containers of different dimensions • maximum stack masses • maximum stack heights with respect to approved sight lines • maximum nominal container capacity.
4	A	Arrangement plan of fixed container securing fittings describing: • the type of fixed container securing fittings such as container foundations and lashing eye plates • unambiguous location of installed fittings such as their location relative to clearly described locations of the ship structures.
5	A	Drawings of container supporting structures including: • hatch covers • container stanchions • lashing bridges • cell guides • design loads for structural assessment of container supporting structure and their foundations.
6	A	Cargo safe access plan of the lashing software **(2)**
7	A	Drawings of fixed and portable securing fittings showing: • design loads • materials • dimensions • manufacturer's marking.
8	I	Operation manual of the lashing software
9	A	Test cases of the lashing software, as applicable
(1) A: to be submitted for Approval ; I: to be submitted for Information **(2)** May be included in the Cargo Securing Manual		

1.4 Materials

1.4.1 Steel wires and chains

Materials for steel wires and chains are to comply with the applicable requirements of NR216 Materials and Welding.

1.4.2 Lashing rods

Lashing rods are generally required to be of high strength steel grade, or steel having equivalent mechanical properties.

1.4.3 Securing and locking devices

Securing and locking devices may be made of the following materials:

- high strength steel grade or equivalent
- cast or forged steel having characteristics complying with the requirements of NR216 Materials and Welding, with particular regard to weldability, where required.

1.4.4 Plates and profiles

Plates and profiles for cell guides, are to comply with the applicable requirements of NR216, Materials and Welding.

1.4.5 Other materials

The use of nodular cast iron or materials other than steel is to be specially considered by the Society on a case-by-case basis.

1.5 Cargo Safe Access Plan (CSAP)

1.5.1 Ships which are assigned the service notation **container ship** are to be provided with a Cargo Safe Access Plan (CSAP) in order to demonstrate that personnel will have safe access for container securing operations. This plan is to give detailed description of the arrangements necessary for conducting cargo stowage and securing in a safe manner. It is to include the following for all areas to be worked by personnel:

- handrails
- platforms
- walkways
- ladders
- access covers
- location of equipment storage facilities
- lighting fixtures
- container alignment on hatch covers/pedestals
- fittings for specialized containers, such as reefer plugs/receptacles
- first aid stations and emergency access/egress
- gangways
- any other arrangements necessary for the provision of safe access.

2 Arrangement of containers

2.1 General

2.1.1 Containers are generally aligned in the fore and aft direction and are secured to each other and to the ship structures so as to prevent sliding or tipping under defined conditions. However, alternative arrangements may be considered.

2.1.2 Containers are to be secured or shored in way of corner fittings. Uniform load line stowage is to be considered by the Society on a case-by-case basis.

2.1.3 One or more of the following methods for securing containers may be accepted:

- corner locking devices
- steel wire ropes or chain lashing
- steel rods
- buttresses or shores permanently connected to the hull
- cell guides.

2.1.4 On ships with the service notation **container ship**, containers in holds are generally stowed within cell guides (see Fig 1).

2.1.5 On ships with the additional service feature **equipped for carriage of containers**, containers in holds are generally mutually restrained to form blocks which are shored, transversely and longitudinally, by hull structures, or restrained by securing fittings (see Fig 2).

Figure 1 : Containers in holds within cell guides

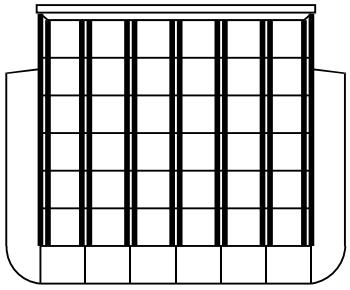
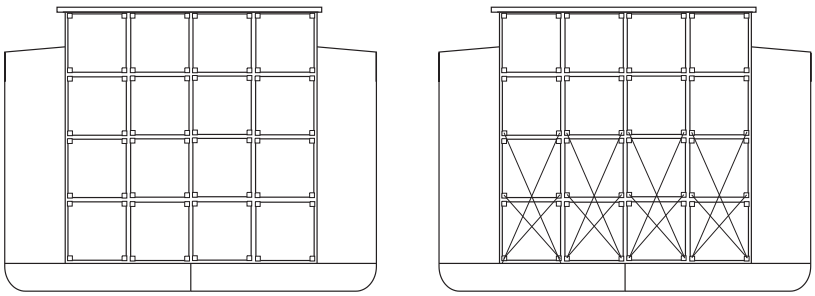


Figure 2 : Container in holds arranged in blocks



2.2 Stowage in holds within cell guides

2.2.1 Fixed cell guides

Cell guides of fixed type are to comply with the requirements of Pt D, Ch 2, Sec 2, [11]

2.2.2 Removable cell guides

When cell guides are of removable type, they are to form a system as independent as possible of the hull structure. They are generally bolted to hull structures.

They are to comply with the provisions on arrangement and strength as applicable to fixed cell guides, given in Pt D, Ch 2, Sec 2, [11].

2.2.3 Mixed stowage

When it is intended to carry 20' containers within 40' cells, removable vertical guides may be fitted at mid-cell length.

When such removable vertical guides are not fitted, the maximum stack weight is to comply with [6.1.2] and the following is to be complied with:

a) In case of 20’ containers topped at least by one 40’ container on single cones:

- 20’ containers are to be of the closed type
- containers are to be secured by single stacking cones, or automatic stackers, at each tier. Cones or stackers are to have a sufficient vertical contact area with the container corner casting
- 40’ containers on top may be full or empty.

b) In case of 20’ containers connected with single cones:

- 20’ containers are to be of the closed type
- containers are to be secured by single stacking cones, or automatic stacker, at each tier

2.3 Stowage in holds without cell guides

2.3.1 Containers are stowed side by side in one or more tiers and are secured to each other at each corner at the base of the stack and at all intermediate levels.

2.3.2 Securing arrangements may be either centring or stacking cones or, if calculations indicate that separation forces may occur, locking devices.

2.3.3 Each container block is to be shored transversely, by means of buttresses acting in way of corners, supported by structural elements of sufficient strength, such as web frames or side stringers or decks.

2.3.4 The number of buttresses is to be determined taking into account the maximum load that can be supported by the corners and end frames of containers (see [6]).

The hull structure in way of buttresses of container blocks is to be adequately reinforced.

Side buttresses are to be capable of withstanding both tension and compression loads and may be either fixed or removable. They are to be fitted with means to adjust tension or compression and their position is to be easily accessible to allow such adjustment.

2.3.5 Each row of containers is to be connected to that adjacent by means of double stacking cones or equivalent arrangements and, if containers are subdivided into separate blocks, connection devices of sufficient strength to transmit the loads applied are to be fitted at shoring points.

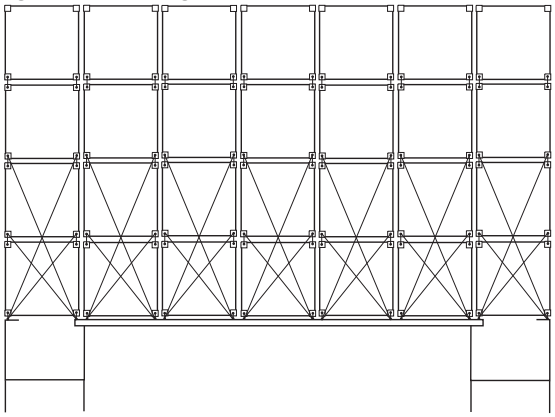
2.3.6 If hull structural elements of sufficient strength to support buttresses are not available, as an alternative to the above, containers may be secured by means of securing fittings, similarly to the arrangements for containers stowed on deck or on hatch covers.

2.4 Stowage on exposed deck

2.4.1 The arrangement and number of containers stowed on exposed deck (see Fig 3) is to be assessed considering the following elements:

- actual mass of containers
- exposure to sea and wind
- stresses induced in the lashing system, in the container structure and in hull structures or hatch covers
- ship's stability conditions.

Figure 3 : Stowage of containers on exposed deck



2.4.2 Containers are generally arranged in several rows and tiers so as to constitute blocks. The arrangement of containers is to be such as to provide sufficient access to spaces on deck for operation and inspection of the securing fittings and for the normal operation of personnel.

2.4.3 Containers are to be secured by locking devices fitted at their lower corners at each tier, and capable of preventing horizontal and vertical movements. Bridge fittings are to be used to connect the tops of the rows in the transverse direction.

Alternatively, securing fittings fitted diagonally or vertically on container corners may be used to prevent vertical movements in addition to centring and stacking cones fitted between the tiers and in way of the base of the stack to prevent horizontal movements.

The upper tier containers are to be secured to the under tier containers by means of locking devices fitted at their corners and located between the two tiers.

For both external and internal securing fittings (see Fig 4), the vertical and horizontal gap between twistlock and container corner socket or support fitting are to be taken into consideration for the calculation of loads applied to the securing fittings.

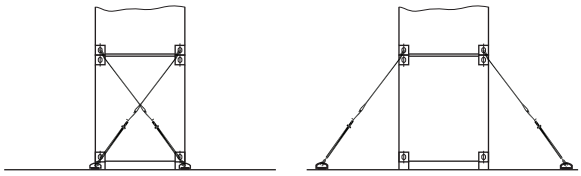
Typical values for vertical gap may be taken as follows:

- 12 mm, for manual and semi-automatic twistlocks
- 20 mm, for fully automatic twistlocks

Typical value for the horizontal gap may be taken as 5 mm.

Other values may be taken depending on the results of the functional test.

Figure 4 : Internal and external lashing



2.4.4 Locking devices are to be used every time the calculations indicate that separation forces may occur.

Where the calculations indicate that separation forces will not occur, double stacking cones may be fitted instead of locking devices at all internal corners of the stack and bridge fittings are to be used to connect the tops of the rows in the transverse direction.

2.4.5 The external containers are not to extend beyond the ship side, but they may overhang beyond hatch covers or other ship structures, on condition that adequate support is provided for the overhanging part.

2.4.6 When cell guides are fitted on deck and it is intended to carry 20' containers within 40' cells on exposed deck, the requirements given in [2.2.3] are to be complied with.

2.5 Uniform line load stowage on deck or hatch covers

2.5.1 Instead of resting on their four lower corners, containers may be arranged on deck or on hatch covers with their bases in uniform contact with the supporting structure. This can be done, for example, by fitting wood planks or continuous metal beams under the lower longitudinal sides (chocks are not allowed), or by inserting the lower corners into special recesses provided on deck or on hatch covers.

A clearance not less than 5 mm is to be left between corners and deck structure, or hatch cover structure underneath (according to ISO Standards, the maximum protrusion of the corner fitting beyond the lower side longitudinal is 17,5 mm).

2.5.2 Such arrangement is, in general, permitted only for a single container or containers in one tier.

For containers in more than one tier, such arrangement may only be accepted if the total mass of the containers above the first tier does not exceed 24 t.

2.5.3 Containers are to be adequately secured to avoid transverse sliding and tipping.

3 Approval of the fixed and portable containers securing fittings

3.1 General

3.1.1 Procedure

Each type of fixed or portable securing fitting is to be approved by the Society. The approval consists of:

- the review of the submitted documents as specified in Tab 2
- a structural analysis including the calculation of loads on containers and securing fittings and their comparison to applicable strength criteria
- the review of type tests and associated certificates
- inspection at works
- inspection onboard.

3.1.2 Documents

The following documentation is to be provided for each kind of device:

- identification of the device (name and model type)
- identification of the manufacturer (name and location, including the country) and of the supplier (if different)
- detailed drawing of the device, showing dimensions and material quality
- intended load conditions for the device (tension, compression, shear)
- value of Safe Working Load (also named MSL for Maximum Security Load) in accordance with the intended load conditions
- value of minimum breaking load
- minimum proof load for batch testing
- copy of any Type Approval Certificate already issued.

3.2 Type tests

3.2.1 Type tests are to be carried out as indicated in the following procedure, or in a procedure considered equivalent by the Society:

- a breaking test is to be carried out on two samples for each type of portable securing fitting
- dimensions and scantlings of the tested samples are to be identical to those given in the detailed drawing of the fitting
- load conditions of the test (i.e. tensile, shear, compression or tangential load) are to be as close as possible to the actual loads in operation.

Supplementary tests may be requested by the Society on a case-by-case basis, depending on the actual conditions of operation.

Tests to be carried out on the most common types of portable securing fittings are indicated in Tab 3 to Tab 5.

Most common types of fixed securing fittings include raised sockets, dovetail foundations, lashing eyes, and any kind of bottom foundation for container corner or devices to which rods or turnbuckles are connected. Cell guides are not to be considered.

3.2.2 When a securing fitting consists of several components, the test is to be carried out on the complete device.

3.2.3 Tests of fixed securing fittings are to be carried out on a stiff rig so as to account for the hull stiffness. A scheme of the arrangement is to be provided.

3.2.4 The minimum breaking load obtained from prototype tests is to be at least equal to the breaking load foreseen by the Manufacturer and indicated on the detailed drawing.

When one of the breaking loads obtained from tests on the two pieces is lower than the value foreseen by the Manufacturer by a value not exceeding 5%, a third piece is to be tested. In such case, the mean breaking load over the three tests is to be not lower than the theoretical value foreseen by the Manufacturer.

3.2.5 The breaking test may be stopped when the piece does not break with an applied load exceeding the breaking load declared by the Manufacturer.

3.2.6 The breaking load is to be equal to at least twice the safe working load (SWL) indicated by the Manufacturer.

3.2.7 A test report is to be issued with the following information:

- identification of the Manufacturer and of the manufacturing factory
- type of device and quantity of tested samples
- identification number of the samples
- materials, with mechanical characteristics
- measured breaking loads and comments on the tests, if any
- safe working load.

3.2.8 When the tests are considered satisfactory, a Type Approval Certificate is issued by the Society.

The following information is to be indicated on the Type Approval Certificate:

- identification of the Manufacturer and of the manufacturing factory
- type of device
- identification number of the samples
- breaking load and safe working load
- reference to the test report (see [3.2.7]), which is to be attached to the Type Approval Certificate.

3.2.9 Each sample is to be clearly identified in the documents kept on board, as required in [1.3.1].

3.3 Additional functional test for fully automatic twistlocks

3.3.1 General

In addition to the requirements in [3.2], the functional test described from [3.3.2] to [3.3.5] is to be carried out for fully automatic twistlocks in order for the Type Approval Certificate to be delivered.

Any modification in the design of the fully automatic twistlocks is to be submitted to the Society for review and reevaluation of the Type Approval Certificate validity.

3.3.2 Test rig

The test rig to be used is described in Fig 5.

Two container top corner fittings are to be fixed on the platform, at a relative distance of 2259 mm (between the centrelines).

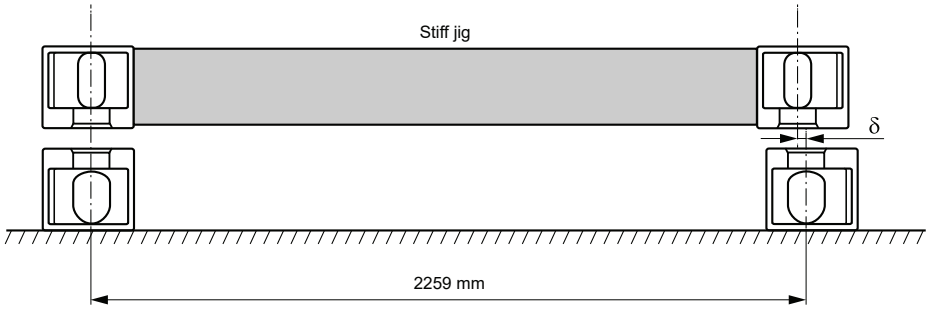
Two container bottom corner fittings are to be secured above the top corners using the fully automatic twistlock. They shall be linked to each other by means of a stiff jig. The relative distance δ between the fitting centrelines is to be reduced, in comparison to the distance between the lower fittings, by:

- $\delta = 5$ mm for the pull test
- $\delta = 4$ mm for the shear test.

All container corner fittings are to be of ISO type and provided in brand new condition. In particular, the maximum aperture of all corner fittings is to be 65 mm.

The direction for the transverse force is always to be taken opposite to the nose of the fully automatic twistlocks (in the opening direction).

Figure 5 : Test rig



3.3.3 Testing principle

Three different samples at least are to be tested.

Two different tests are to be carried out: a pull test and a shear test.

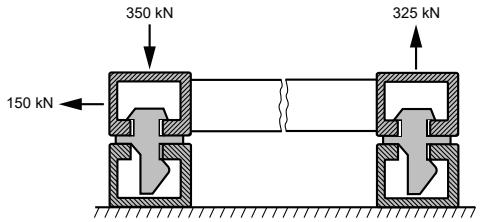
During the tests, no disconnection, permanent deformation, crack or failure may be accepted.

3.3.4 Pull test

The following forces are to be applied successively in this order, in accordance with Fig 6:

- compressive force of 350 kN
- transverse racking force of 150 kN
- lifting force of 325 kN.

Figure 6 : Pull test

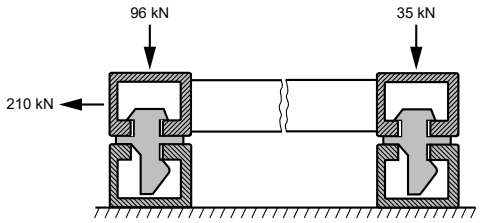


3.3.5 Shear test

The following forces are to be applied successively in this order, in accordance with Fig 7:

- compressive force of 96 kN
- compressive force of 35 kN
- transverse racking force of 210 kN.

Figure 7 : Shear test



3.4 Production testing of the fixed and portable container securing fitting

3.4.1 Securing fitting is to be tested and inspected at the production works with the attendance of a Surveyor from the Society.

3.4.2 Tests are to be carried out under load conditions (i.e. tensile, shear, compression or tangential load) as close as possible to the actual conditions of loading in operation.

Test to be carried out on the most common types of securing elements are indicated in Tab 3 to Tab 5.

3.4.3 It is to be checked that a valid Type Approval Certificate has been issued for the inspected devices, and that the specifications are identical to those described on the Type Approval Certificate.

3.4.4 Portable securing fitting is to be batch-surveyed. The batch includes a maximum of 50 devices.

Two samples per batch (three in the case of wire ropes with their ends) are to be tested at a minimum proof load equal to 1,3 times the safe working load. If mass production does not exceed 50 pieces, the test is to be carried out on at least one sample.

When a securing fitting consists of several components, the test is to be carried out on the complete device.

The tested samples are not to show cracks or permanent deformation.

3.4.5 Fixed securing fitting is to be tested as per one of the following procedures:

- a prototype test (in accordance with [3.2]) is to be carried out each year, or
- a batch test of 2% of the devices of the batch is to be carried out at the minimum proof load (1,3 times the safe working load) on a test rig identical to the one used for the type test. This implies that the tested samples cannot be delivered after the test and are to be replaced.

3.4.6 At least 10% of the devices are to be visually checked.

It is also to be checked that the identification number and the safe working load (SWL) declared by the Manufacturer are indicated on the devices.

3.4.7 The Surveyor may require tests to be repeated or carried out on a greater number of samples, if considered necessary.

3.4.8 If the test proves satisfactory and after examination of the documents describing the batch, a Certificate Of Inspection (COI) is issued, the fitting is identified by the Manufacturer and each piece is stamped by the Surveyor. The reference to the Type Approval Certificate and the quantity of tested samples are indicated on the Inspection Certificate.

Table 3 : Test modes for securing fittings

Test modes for securing fittings	
Lashing rod, chain and steel wire rope Tensile load	**Penguin hook** Tangential load
Turnbuckle Tensile load	**Hook** Tensile load

Table 4 : Test modes for connecting securing fittings between containers

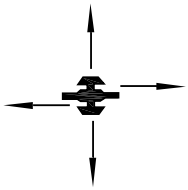
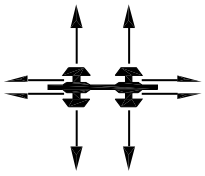
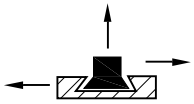
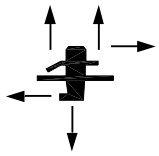
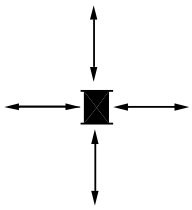
Test modes of securing fittings between containers		
Twistlock  Shear and tensile loads	**Double twistlock**  Shear and tensile loads	**Bridge fitting** Tensile load
Single stacker Shear load	**Double stacker** Shear and tensile loads	**Buttress** Tensile load

Table 5 : Test modes for portable securing fittings

Test modes for portable securing fittings				
Bottom twistlock	**Stacking cone**	**Stacking cone with pin**	**Pillar on deck**	**Intermediate pillar**
				
Shear and tensile load	Shear load	Shear and tensile load	Compression load	Shear, compression and tensile load

3.5 Reception on board of the container securing fitting

3.5.1 The portable securing fittings on board are to be provided with a COI (see [3.4]).

The COI of delivered container securing fittings are to be kept on board and may be included in the Cargo Securing Manual.

Tests of mounting of portable securing fitting in accordance with the conditions of operation and the lashing plan arrangement are to be carried out.

3.5.2 When deemed necessary by the Surveyor, a test of fixed securing fitting onboard may be requested. In that case, the test is to be carried out after the device has been welded at a proof load value equal to 1,1 times the safe working load.

4 Forces applied to containers

4.1 General

4.1.1 Loads to be considered for lashing assessment are the following ones:

- still water and inertial forces (see [4.3])
- wind loads (see [4.5])
- forces imposed by securing fittings (see [4.6]).

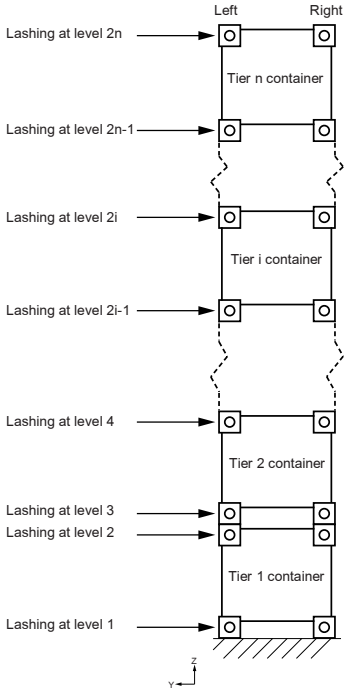
4.2 Definitions

4.2.1 Stack of containers

A stack of containers consists of “n” containers connected vertically by securing fittings.

The container located at the tier “i” within a stack is indicated in Fig 8.

Figure 8 : Container tiers and lashing levels in a stack



4.2.2 Lashing levels

Lashing level "2i" corresponds to the top of the container at tier "i" and lashing level "2i – 1" corresponds to the bottom of the container at tier "i".

4.3 Still water and inertial forces

4.3.1 Still water forces

For the container at tier "i", still water forces are to be taken, in kN, equal to:

$F_{S,i} = -M_i\ g$

where:

M_i : Mass, in t, of the container considered at the tier "i" (see also Pt B, Ch 5, Sec 6, [8.2.2])

g : Gravity acceleration, in m/s^2, taken equal to:

$g = 9{,}81$ m/s^2.

4.3.2 Inertial forces in upright condition

For the container at tier "i", inertial forces in upright condition are to be taken, in kN, equal to:

$F_{W,X,i} = -\beta\ M_i\ a_X$ in x direction

$F_{W,Z,i} = -M_i\ a_Z$ in z direction

where:

M_i : Mass, in t, of the container considered at the tier "i" (see also Pt B, Ch 5, Sec 6, [8.2.2]

β : Coefficient equal to:

- $\beta = 1{,}2$ for containers of the forward block, when the centre of gravity of this block is located forward of 0,75 L from the aft end and is not protected by breakwater structures deemed effective by the Society
- $\beta = 1{,}0$ in the other cases.

a_X, a_Z : Accelerations, in m/s^2, for the upright ship condition, determined according to [4.3.4]

4.3.3 Inertial forces in inclined condition

For the containers at tier "i", the inertial forces in inclined condition are to be taken, in kN, equal to:

$F_{W,Y,i} = -M_i\ a_Y$ in y direction

$F_{W,Z,i} = -M_i\ a_Z$ in z direction

where:

M_i : Mass, in t, of the container considered at the tier "i" (see also Pt B, Ch 5, Sec 6, [8.2.2])

a_Y, a_Z : Accelerations, in m/s^2, for the inclined ship condition, determined according to [4.3.4].

4.3.4 Acceleration values

The accelerations considered in [4.3.2] and [4.3.3] are to be derived at the centre of gravity of the stack, in accordance with Pt B, Ch 5, Sec 3 and considering:

- centre of gravity of each container as defined in Pt B, Ch 5, Sec 6, [8.1.1]
- the value of GM and k_r as induced by the loading condition. When GM and k_r are not known, the values may be taken as defined in Pt B, Ch 5, Sec 3, Tab 4 for the full load condition.

The accelerations for upright and inclined conditions are to be derived according to Pt B, Ch 5, Sec 3, [3] for the following load cases:

LC1 : Upright condition, maximizing positive or negative longitudinal acceleration, as defined in Tab 6

LC2, LC3: Inclined condition, maximizing positive or negative transverse acceleration, as defined in Tab 7

LC4 : Inclined condition, maximizing positive or negative vertical acceleration, as defined in Tab 8 and Tab 9.

The wave parameter to be considered for the calculation of accelerations, is to be calculated in accordance with [4.3.5].

Table 6 : Load case LC1 in upright condition

Transversal stack location	LC1	
	Max	Min
Portside	OVA1-S	OVA2-S
Starboard side	OVA1-P	OVA2-P
Note 1: Stack with centre of gravity located at centreline is considered to be on portside		

Table 7 : Load cases LC2 and LC3 in inclined condition

Transversal stack location	LC2		LC3	
	Max	Min	Max	Min
Portside	BR2-P	BR1-P	BR1-S	BR2-S
Starboard side	BR1-S	BR2-S	BR2-P	BR1-P
Note 1: Stack with centre of gravity located at centreline is considered to be on portside				

Table 8 : Load case LC4 in inclined condition with stack located on portside

Longitudinal stack location	LC4	
	Max	Min
x/L ≤ 0,25	$SPLC_{max}$ **(1)**	$SPLC_{min}$ **(2)**
0,25 < x/L ≤ 0,65	BP2-P	BP1-P
x/L > 0,65	OVA2-S	OVA1-S

Note 1: Stack with centre of gravity located at centreline is considered to be on portside.

(1) $SPLC_{max}$ is a specific load case for vertical acceleration defined with the following load combination factors (LCFs):

$C_{ZH} = 10,72\ f_{TL} - 0,28$

$C_{ZR} = 0$

$C_{ZP} = 1,2 - 6,84\ f_{TL}$

and with the transverse acceleration a_Y associated to $SPLC_{max}$ taken equal to 0.

(2) $SPLC_{min}$ is a specific load case for vertical acceleration defined with the following LCFs:

$C_{ZH} = 0,28 - 10,72\ f_{TL}$

$C_{ZR} = 0$

$C_{ZP} = 6,84\ f_{TL} - 1,2$

and with the transverse acceleration a_Y associated to $SPLC_{min}$ taken equal to 0.

Table 9 : Load case LC4 in inclined condition with stack located on starboard side

Longitudinal stack location	LC4	
	Max	Min
x/L ≤ 0,25	$SPLC_{max}$ **(1)**	$SPLC_{min}$ **(1)**
0,25 < x/L ≤ 0,65	BP2-S	BP1-S
x/L > 0,65	OVA2-P	OVA1-P

Note 1: Stack with centre of gravity located at centreline is considered to be on portside.

(1) See Tab 8 for the definition of $SPLC_{max}$ and $SPLC_{min}$

4.3.5 The wave parameter, as defined in Pt B, Ch 5, Sec 3, [1.1.1] and which is considered for the calculation of accelerations, is to be calculated on the basis of the environmental conditions specified in accordance with [1.1.2] to [1.1.4]:

- for unrestricted navigation conditions, the wave parameter and the navigation coefficient are to be calculated considering the strength assessment and the navigation notation **unrestricted navigation** as defined in Pt B, Ch 5, Sec 3, Tab 1 and Pt B, Ch 5, Sec 3, [1.1.2].

  In addition, the roll angle is to be taken equal to θ_{Lash} defined as follows:

  $\theta_{Lash} = f_{ART}\theta$

Note 1: For ships assigned the additional class notation **PaRoll1** or **PaRoll2**, and **LI-LASHING**, the angle θ_{Lash} may be defined by the Interested Party. In this case, θ_{Lash} is not to be taken less than $f_{ART}\theta$.

- for specific route conditions or specific area conditions, specific values of wave parameter are to be derived on the basis of direct sea-keeping analyses, considering a specific wave scatter diagram related to the considered specific route or specific area. For the specific routes listed in Tab 1, the wave parameter is to be calculated considering the coefficients defined in Tab 10.

  In addition, the roll angle is to be taken equal to θ_{Lash} defined as follows:

  - for the specific routes no 3, 15 and 16, the roll angle is to be calculated according to unrestricted navigation conditions
  - for the other routes:

  $$\theta_{Lash} = \frac{H_{RSSA}}{H} f_{ART}\theta$$

- for ships assigned the notation **-WAF** and for the lashing assessment in scope of short voyages (less than 72 hours), the wave parameter is to be calculated considering the coefficients defined in Tab 11 for the maximum significant wave height made available by the weather forecast service provider.

In addition, the roll angle is to be taken equal to θ_{Lash} defined as follows:

$$\theta_{Lash} = \frac{H_{WAF}}{H} f_{ART} \theta$$

where:

θ : Roll angle, in deg, as defined in Pt B, Ch 5, Sec 3, [2.1.1] to be calculated for the navigation notation **unrestricted navigation**

H : Wave parameter calculated for the unrestricted navigation conditions

H_{RSSA} : Wave parameter calculated for the specific route or specific area conditions

H_{WAF} : Wave parameter calculated for short voyages based on maximum significant wave height given by a weather service provider

f_{ART} : Roll reduction factor according to [4.4]. When the ship is equipped with a passive free-surface anti-roll tank, a roll reduction factor can be used, subject to special examination by the Society.

The reference length L_{ref} used for H, H_{RSSA} and H_{WAF} is to be calculated with:

$$\alpha = \frac{4,6}{T_R^2}$$

$f_\alpha = 1,0$

where:

T_R : Dimensionless roll period, to be taken as defined in Pt B, Ch 5, Sec 2.

Table 10 : Wave parameter coefficients for the specific route conditions

Route No.	Description of the specific route	A_0	A_1	e_1	A_2	e_2	L_c
1	North sea - Baltic sea	0,67	1,38	1,90	0,34	1,12	413
2	Northern Europe - Mediterranean sea	0,83	1,41	1,87	0,40	1,30	517
3	Europe - North America (East) **(1)**	–	–	–	–	–	–
4	Europe - South Africa	0,79	1,43	1,90	0,39	1,30	505
5	Europe - South America	0,82	1,43	1,89	0,39	1,30	509
6	North America (East) - South America	0,60	1,49	1,94	0,39	1,21	356
7	South America - South Africa	0,63	1,50	2,00	0,32	1,18	378
8	Europe - Asia, through Mediterranean sea	0,77	1,43	1,90	0,39	1,31	486
9	Europe - Asia, through Cape of Good Hope	0,75	1,40	1,91	0,39	1,31	486
10	Europe - Asia, through Atlantic and Pacific	0,84	1,45	1,92	0,36	1,24	474
11	North America (East) - Asia through North Pacific (between 40°N and 50°N)	0,84	1,42	1,92	0,39	1,32	504
12	North America (East) - Asia through North Pacific (below 30°N)	0,70	1,49	1,89	0,38	1,24	393
13	South Africa - Asia	0,60	1,58	1,98	0,35	1,10	347
14	North America (West) - Indonesia	0,81	1,46	1,97	0,36	1,29	472
15	North Pacific (between 40°N and 50°N) **(1)**	–	–	–	–	–	–
16	North Pacific (between 30°N and 40°N) **(1)**	–	–	–	–	–	–
17	South America - Asia	0,85	1,42	1,91	0,39	1,31	509
18	Indonesia - Asia	0,73	1,38	1,85	0,39	1,25	441
19	Asia - Australia	0,65	1,49	1,95	0,36	1,18	382

(1) The wave parameter associated to this route is to be taken equal to the wave parameter calculated for the navigation notation **unrestricted navigation** for the strength assessment (see Pt B, Ch 5, Sec 3)

Table 11 : Wave parameter coefficients for the notation -WAF

Maximum significant wave height H_s , in m	A_0	A_1	e_1	A_2	e_2	L_c
1	0,15	2,53	2,95	0,21	1,23	118
2	0,24	2,26	2,73	0,15	1,45	150
3	0,34	1,94	2,51	0,19	1,65	188
4	0,44	1,78	2,29	0,24	1,78	218
5	0,54	1,76	2,26	0,28	1,74	255
6	0,63	1,71	2,19	0,31	1,71	291
7	0,73	1,63	2,08	0,37	1,75	324
8	0,82	1,61	2,06	0,43	1,72	363

Note 1: Wave parameters corresponding to intermediate values of maximum significant wave heights can be obtained by linear interpolation of the coefficients.

For maximum significant wave heights above 8 m, the wave parameter is to be taken equal to the wave parameter calculated for the navigation notation **unrestricted navigation** for the strength assessment (see Pt B, Ch 5, Sec 3).

4.4 Passive free-surface anti-roll tank

4.4.1 General

When the ship is equipped with an anti-roll tank (ART) or a stabilization system, a roll reduction factor f_{ART} may be taken into account to reduce the roll angle used in the calculation of the acceleration values (see [4.3.4]).

4.4.2 Information to be provided

The geometry and the operational guidance of the ART (filling levels according to the loading conditions and the wave periods) are to be provided to the Society. All systems such as filling level sensors and sensors or procedures to evaluate the ship roll periods are to be fully documented and validated by the Society.

4.4.3 Methodology to determine the roll reduction factor

To derive the roll reduction factor, the influence of the ART is to be considered for both the static stability and the evaluation of ship's sea-keeping behaviour.

For the static stability, the loss of stability due to the reduction of metacentric height is to be taken into account. The roll reduction factor evaluated by sea-keeping calculations is by definition the extreme long term roll angle with ART divided by the extreme long term roll angle without ART.

The ship motions equations including the ART are to take into account consistently the non-linearities due to the ART.

The following methodology is to be applied:

a) Evaluation of the hydrodynamic database

Prior to the sea-keeping calculations, an hydrodynamic database is to be evaluated containing the translational and rotational ART motions for different frequencies and amplitudes. This database may be evaluated by using either a numerical CFD method (Computational Fluid Dynamics) or model tests.

b) Short term analysis

The ship motions equations are to be solved for each sea state of the scatter diagram (North-Atlantic) by using a linearisation procedure. An iteration procedure may be applied to take into account consistently the non-linearities due to the ART. The presence of any additional roll reduction effects or devices (e.g. bilge keels, rudder...) is to be taken into account within the linearisation process.

c) Long term analysis

A linear spectral analysis is performed to derive the extreme long term roll angle (θ_{ART}) by combining the roll transfer function for each sea state of the scatter diagram and the corresponding probability of occurence of these sea states.

d) Determination of the roll reduction factor f_{ART}

The roll reduction factor f_{ART} is to be determined as follows:

$f_{ART} = \theta_{ART} / \theta_{wo\text{-}ART}$

where:

θ_{ART} : Direct calculation of the extreme long term roll angle (25 years return period for the North-Atlantic scatter diagram) including the effect of ART

$\theta_{wo\text{-}ART}$: Direct calculation of the extreme long term roll angle (25 years return period for the North-Atlantic scatter diagram) without the effect of ART.

4.5 Wind forces

4.5.1 The forces due to the effect of the wind, applied to one container stowed above deck at tier "i", are to be obtained, in kN, from Pt B, Ch 5, Sec 5, [8], taking the wind speed V_W, as follows:

V_W : Wind speed at 10 m above waterline, to be taken equal to:

- for unrestricted navigation conditions: 35 m/s
- for specific route conditions: see Tab 12
- for ships assigned the notation **-WAF** and for the lashing assessment in scope of short voyages: as given by the weather service provider

Note 1: For specific area conditions, the wind speed is to be defined on a case-by-case basis.

4.6 Forces imposed by securing fittings

4.6.1 The forces due to locking and/or pretensioning of securing fittings are only to be considered where, in a single element, they exceed 5 kN, or where they are necessary for the correct operation of the lashing system.

Table 12 : Wind speed for the specific route conditions

Route No.	Description	Wind speed, in m/s
1	North sea - Baltic sea	30
2	Northern Europe - Mediterranean sea	31
3	Europe - North America (East)	34
4	Europe - South Africa	29
5	Europe - South America	30
6	North America (East) - South America	28
7	South America - South Africa	27
8	Europe - Asia, through Mediterranean sea	29
9	Europe - Asia, through Cape of Good Hope	29
10	Europe - Asia, through Atlantic and Pacific	34
11	North America (East) - Asia through North Pacific (between 40°N and 50°N)	33
12	North America (East) - Asia through North Pacific (below 30°N)	29
13	South Africa - Asia	26
14	North America (West) - Indonesia	32
15	North Pacific (between 40°N and 50°N)	35
16	North Pacific (between 30°N and 40°N)	33
17	South America - Asia	32
18	Indonesia - Asia	30
19	Asia - Australia	29

5 Resulting loads in container securing fittings and container frames

5.1 Calculation hypothesis

5.1.1 The forces to be considered are the following ones:

- to check securing fittings and container racking:
  - in the case of containers stowed longitudinally:
    transverse forces derived as per [5.2.3], and
  - in the case of containers stowed transversely:
    longitudinal forces derived as per [5.2.2]
- to check vertical loads in container frames:
  vertical forces derived as per [5.2.4] for the upright condition
- to check container tipping:
  transverse and vertical forces in inclined condition, derived as per [5.2.3] and [5.2.4], respectively.

5.1.2 The calculations are based on the following assumptions:

- loads due to ship motions (see [4.3]) are independently applied to each stack
- wind loads are applied to each stack, accounting for the number of containers exposed to wind (see [4.5]).

5.1.3 The gaps between stacks are to be large enough to avoid contacts between container corners after deformation.

5.1.4 The wind loads are applied totally or partially in the same direction as the transverse or longitudinal inertial forces. The wind loads are not considered when acting in the opposite direction of the inertial forces.

5.1.5 Interaction between wall-end and door-end frames of a container is not taken into account.

5.2 Distribution of forces

5.2.1 General

For the purpose of the calculation of the securing fittings, longitudinal, transverse and vertical forces are distributed on the container walls.

5.2.2 Longitudinal force

The longitudinal force applied to a container is to be obtained, in kN, from the following formula:

$F_{X, i} = F_{W, X, i} + F_{X, wind, i}$

where:

$F_{W, X, i}$: Inertial force for upright condition, defined in [4.3.2]

$F_{X, wind, i}$: Wind force, if any, defined in [4.5].

The longitudinal force is considered to be equaly subdivided on the four side longitudinal frames of the container.

5.2.3 Transverse force

The transverse force applied to a container is to be obtained, in kN, from the following formula:

$F_{Y, i} = F_{W, Y, i} + F_{Y, wind, i}$

where:

$F_{W, Y, i}$: Inertial force for inclined condition, defined in [4.3.3]

$F_{Y, wind, i}$: Wind force, if any, defined in [4.5].

The transverse force is considered spread over the four container corners of each end transverse frames, with the wind forces $F_{W, wind, i}$ equally subdivided on the four corners of the exposed side and the inertial forces $F_{W, Y, i}$ equally subdivided only at the bottom as follows:

- for the top corners of the exposed side:
  $F_{Y, 2i} = 0,25\ F_{Y, wind, i}$
- for the bottom corners of the exposed side:
  $F_{Y, 2i-1} = 0,5\ F_{W, Y, i} + 0,25\ F_{Y, wind, i}$
- for the bottom corners of the non-exposed side:
  $F_{Y, 2i-1} = 0,5\ F_{W, Y, i}$

5.2.4 Vertical forces

The vertical force applied to a container is to be obtained, in kN, from the following formula:

$F_{Z, i} = F_{S, i} + F_{W, Z, i}$

where:

$F_{S, i}$: Still water force defined in [4.3.1]

$F_{W, Z, i}$: Inertial force for upright or inclined condition, as applicable, defined in [4.3.2] or [4.3.3].

The vertical force is considered spread over the four bottom container corners, with the vertical still water forces $F_{S, i}$ and inertial forces $F_{W, Z, i}$ equally distributed as follows:

- for the top corners on both sides:
  $F_{Z, 2i} = 0$
- for the bottom corner on left side:

$$F_{Z, 2i-1} = 0,25\ F_{S, i} + 0,25\ F_{W, Z, i} - \frac{0,45\ H_i F_{W, Y, i}}{2B}$$

- for the bottom corner on right side:

$$F_{Z, 2i-1} = 0,25\ F_{S, i} + 0,25\ F_{W, Z, i} + \frac{0,45\ H_i F_{W, Y, i}}{2B}$$

where:

H_i : Height, in m, of the container located at tier "i"

B : Breadth, in m, of the container

$F_{W, Y, i}$: Inertial force for inclined condition, defined in [4.3.3].

5.3 Containers only secured by locking devices

5.3.1 Where the containers of a stack are secured to each other and to the base only by means of locking devices fitted at their corners, the reactions on the different supports are to be determined using the equilibrium equations of rigid bodies, equalling to zero the sum of the forces and moments applied to the system.

5.3.2 In particular, a calculation is to be carried out by considering the combination of vertical forces with vertical reactions induced by transverse forces, to determine whether, on some supports, reactions have a negative sign, which indicates the possibility of separation and tipping of containers.

5.3.3 The loads resulting on containers and securing devices are not to exceed the permissible loads defined in Article [6].

5.4 Containers secured by means of securing fittings or buttresses

5.4.1 Where containers are secured by means of securing fittings, the stiffness of both the securing fittings (see [5.5.1]) and the container (see [5.5.3]) are to be taken into account.

5.4.2 The tension in each securing fitting may be calculated imposing equality of displacements of the corner of the container to which the securing fitting is secured and the securing fitting elongation.

The additional elongation in the securing fitting resulting from the vertical and horizontal gap between the twistlock and the corner of the container is to be considered.

When the securing fitting is attached to a lashing bridge, the influence of the lashing bridge in the transverse direction is to be taken into account by means of an equivalent reduced stiffness of the securing fitting. This equivalent reduced stiffness of the securing fitting is to be determined according to [5.5.1] using typical values of stiffness reduction factor depending on the level where the securing fitting is attached.

5.4.3 If more than one lashing rods are attached to a single turnbuckle, the load acting on the turnbuckle is to be taken as the sum of the loads acting within the lashing rods

5.4.4 The loads resulting on containers and securing fittings are not to exceed the permissible loads defined in [6].

5.5 Stiffness values

5.5.1 Securing fitting stiffness

The stiffness of a securing fitting is to be obtained, in kN/mm, from the following formula:

$$K = \alpha_{LB} \frac{A_\ell E_a}{\ell} 10^{-4}$$

where:

A_l : Cross-section of the securing fitting, in cm^2

E_a : Modulus of elasticity of the securing fitting, in N/mm^2, which may be obtained from Tab 13 in the absence of data on the actual value

ℓ : Total length of the securing fitting, including tensioning devices, in m

α_{LB} : Effective stiffness factor of the securing fitting, as defined in [5.5.2].

Table 13 : Modulus of elasticity of securing fittings

Type	E_a, in N/mm^2
Steel wire rope	90 000
Steel chain	40 000
Steel rod (and turnbuckle): • length < 4 m • length ≥ 4 m	 140 000 180 000

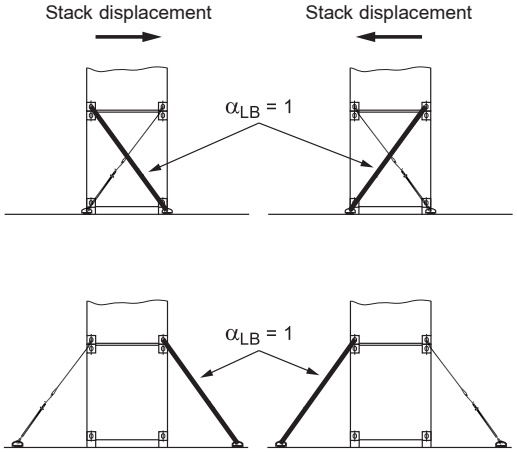
5.5.2 Effective stiffness factor

The effective stiffness factor, α_{LB}, is to be taken equal to 1,0 in the following securing fitting configurations:

- when the device is attached to the deck or to a hatch cover,
- when the device is purely vertical,
- when the device is in tension and restrains only the container lifting (see Fig 9)

For other configurations, the effective stiffness factor α_{LB} is to be less than 1,0 to take into account the reduced efficiency due to the lashing bridge deformation.

Figure 9 : Securing fitting configuration



The effective stiffness factors of any actual securing fitting at lashing level i, may be derived from factors for a reference securing fitting by using the following relation:

$$\alpha_{LB-ACT,i} = \left[1 + F\left(\frac{1}{\alpha_{LB-REF,i}} - 1\right)\right]^{-1}$$

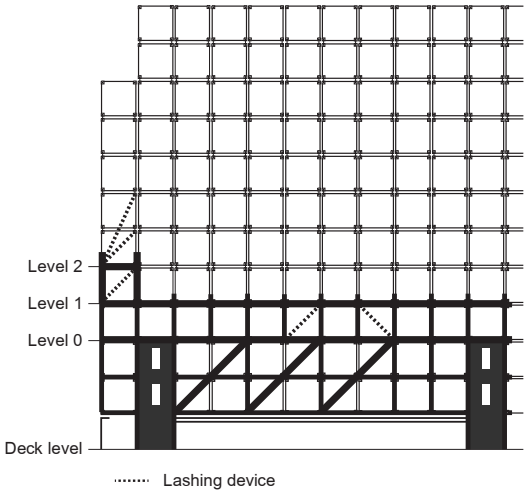
where:

$\alpha_{LB-ACT,i}$: Effective stiffness factor at the lashing level i for the actual securing fitting

$\alpha_{LB-REF,i}$: Effective stiffness factor at the lashing level i for the reference securing fitting

i : Lashing level depending on the vertical location of attachment of the securing fitting to the lashing bridge. The level of reference (level 0) is defined as the lowest level where it is possible to attach the securing fittings over the full width of the lashing bridge (see Fig 10)

Figure 10 : Level of attachment



F : Form coefficient depending on the securing fittings properties, to be taken as:

$$F = \left(\frac{L_{REF}}{L_{ACT}}\right)^3 \left(\frac{\delta_{ACT}}{\delta_{REF}}\right)^2 \left(\frac{E_{ACT}}{E_{REF}}\right)\left(\frac{A_{ACT}}{A_{REF}}\right)$$

L_{REF}, L_{ACT}: Total length, in mm, of the reference and actual securing fittings, respectively

δ_{REF}, δ_{ACT}: Distance, in mm, in the transverse (horizontal) direction for the reference and actual securing fittings, respectively, between the two locations where the securing fitting is attached

E_{REF}, E_{ACT}: Modulus of elasticity, in N/mm^2, of the reference and actual securing fittings, respectively, depending on the total length as defined in Tab 13

A_{REF}, A_{ACT}: Cross-section area, in cm^2, of the reference and actual securing fittings, respectively

The reference device is a securing fitting for which the effective stiffness factors are known. This reference device can be the standard device as defined in Tab 14.

When the reference device is the standard securing fitting and is attached to a lashing bridge compliant with the criteria defined in Pt D, Ch 2, Sec 2, [12.3.2], the effective stiffness factors can be taken equal to the following standard values:

- 0,5 for attachment at level 0 (level of reference)
- 0,3 for attachment at level 1 (one level above the level of reference)
- 0,2 for attachment at level 2 and upper levels.

When the reference device is not the standard securing fitting or is attached to a lashing bridge not compliant with the criteria defined in Pt D, Ch 2, Sec 2, [12.3.2], the effective stiffness factors $\alpha_{LB\text{-}REF,i}$ are to be obtained by calibration with direct calculations.

As an alternative, the effective stiffness factors may be obtained by calibration with direct calculations taking into account properties of either all individual actual securing fittings ($\alpha_{LB\text{-}ACT,i}$) or reference securing fittings ($\alpha_{LB\text{-}REF,i}$), subject to agreement by the Society and provided that the calculations are taking into account the stiffness of the lashing bridge with all containers at maximum load associated to maximum transverse acceleration.

Table 14 : Standard securing fitting

Distance in the transverse direction between the two locations where the securing fitting is attached	2438 mm
Total length	3580 mm
Diameter	24 mm
Modulus of elasticity	140 000 N/mm^2

5.5.3 Stiffness of containers

For the purpose of the calculation, in the absence of data on the actual values, the stiffness of containers may be obtained, in kN/mm, from Tab 15.

Table 15 : Stiffness of containers

Racking stiffness, in kN/mm	
Wall end	Door end
128 / H_0	32 / H_0
Note 1: H_0 : Height of the container, in feet	

6 Strength criteria

6.1 Maximum stack weight

6.1.1 Design value

The total weight of each container stack is to be less than the maximum design value as provided by the designer.

6.1.2 Mixed stowage within cell guides

When it is intended to carry 20 feet containers within 40 feet cells, in hold or on deck, the total weight of the 20' container stack (excluding the 40' container at the top of the stack) is to be not greater than W_{MAX}, in t, obtained, for the relevant case, from the following formula:

a) In case of 20' containers topped at least by one 40' container on single cones:

$$W_{MAX} = \frac{F_1}{a_Y}$$

not to be greater than 240 t

b) In case of 20' containers connected with single cones:

$$W_{MAX} = \frac{F_2}{a_Y}$$

not to be greater than 210 t

where:

F_1,F_2 : Coefficient depending on the number of tiers as defined in Tab 16.

a_Y : Transverse acceleration, in m/s^2, determined according to [4.3.4].

For ships with the service notation **container ship**, a_Y is to be taken as the maximum absolute value of the transverse acceleration from load cases LC2 and LC3 defined in Tab 7.

Table 16 : Coefficients for total weight of 20' container stack topped or not

Number of 20′ containers	F_1 Topped	F_2 Not topped
6 or less	590	536
7	548	500
8	506	464
9	464	428
10	422	392
11	380	356
12	–	320

6.2 Permissible loads on containers

6.2.1 For ISO 20, 30, 40 and 45 feet containers, the lashing arrangement is to be such that maximum loads on each container frame (end and intermediate), in kN, are less than the values indicated in:

- Fig 11 for transverse and longitudinal racking
- Fig 12 and Fig 13 for transverse and vertical compression
- Fig 14 for transverse and vertical tension.

Figure 11 : Permissible transverse and longitudinal racking loads on end frames of 20', 30', 40' and 45' ISO containers

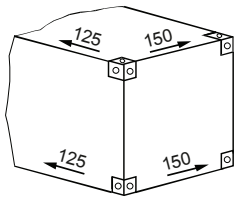


Figure 12 : Permissible transverse and vertical compressions on end frames of 20', 30' and 40' ISO containers

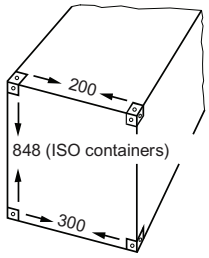


Figure 13 : Permissible transverse and vertical compressions on end and intermediate frames of 45' ISO containers

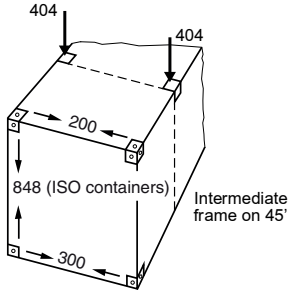
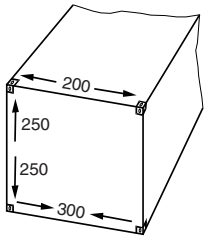


Figure 14 : Permissible transverse and vertical tensions on end frames of 20', 30', 40' and 45' ISO containers



6.2.2 For ISO open containers, the permissible racking load in longitudinal frames (less than 75 kN in general) is to be specified for the review.

6.2.3 For all other containers, the lashing arrangement is to be such that the maximum vertical compression and transverse racking loads on each container frame, in kN, do not exceed the permissible loads in a) and b), derived from the content of the Container Safety Certification plate (CSC plate) affixed to the container:

a) The permissible vertical compression $F_{COMP\ PERM}$, in kN, in container frames is given by:

$$F_{COMP\ PERM} = \frac{W_{AS} \cdot 1,8 \cdot g}{4000}$$

where W_{AS} is the allowable stack weight, in kg, at 1,8g specified on the CSC plate.

b) The permissible transverse racking load $F_{RACK\ PERM}$, in kN, is given by:

$$F_{RACK\ PERM} = \frac{W_{RACK\ TEST} \cdot g}{1000}$$

where $W_{RACK\ TEST}$ is the racking test load, in kg, specified on the CSC plate.

6.2.4 Oversized containers topped on 40’ containers

For oversized containers topped on 40’ containers, the maximum vertical compression load on each container frame, in kN, is to be less than the values indicated in:

- Fig 15 for 45’ ISO containers
- Fig 16 for 48’, 49’ and 53’ containers, where $F_{COMP\ PERM}$ is defined in [6.2.3] a).

Figure 15 : Permissible vertical compression on frames of 45' ISO containers topped on 40' containers

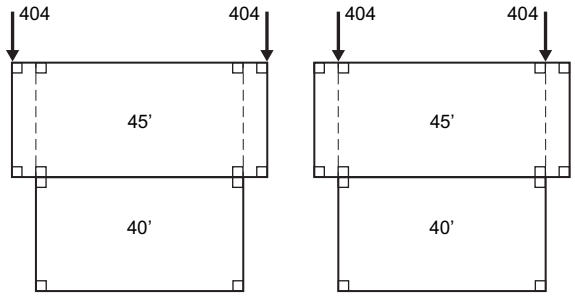
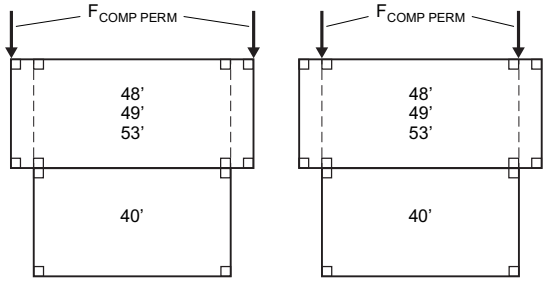


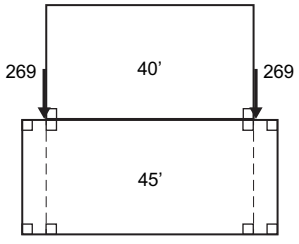
Figure 16 : Permissible vertical compression on frames of 48’, 49’ and 53’ containers topped on 40’ containers



6.2.5 40' containers supported by 45' containers

For 40' containers supported by 45' containers, the maximum vertical compression load on each container frame, in kN, is to be less than the values indicated in Fig 17.

Figure 17 : Permissible vertical compression on frames of 40' containers supported by 45' containers



6.3 Permissible loads induced by securing fitting on container corners

6.3.1 The maximum forces induced by securing fittings and applied on container corner pieces are to be less than the values indicated, in kN, in Fig 18.

6.3.2 In the case of a combination of forces applied on container corners, the resultant force is to be less than the value obtained, in kN, from Fig 19.

Figure 18 : Permissible loads induced by securing fittings on container corners

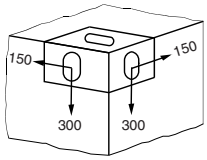
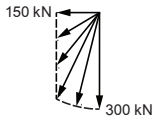


Figure 19 : Resultant permissible load on container corners



6.4 Permissible loads on securing fittings

6.4.1 Twistlocks

The forces applied to each twistlock are to be not greater than:

- 80% of the Safe Working Load (SWL) indicated by the Manufacturer for the vertical tensile force
- the Safe Working Load (SWL) indicated by the Manufacturer for the horizontal shear force

When a vertical securing fitting is fitted with a turnbuckle having a slack reducer, the securing fitting is disregarded and the SWL for the twistlock is to be increased by 160 kN to take into account the actual load in the securing fitting.

6.4.2 Other securing fitting

The forces applied to each piece of securing fitting other than the twistlocks are to be not greater than the Safe Working Load (SWL) indicated by the Manufacturer.

7 Lashing software

7.1 General

7.1.1 The lashing software is a ship specific tool, and the results of the calculations are only applicable to the ship for which it has been approved.

7.1.2 An approved lashing software is to be fitted onboard any ship assigned the additional class notation **LASHING-RSSA( )** or the notation **-WAF**.

7.2 Operation manual

7.2.1 An operation manual is to be provided for the lashing software and be kept on board.

7.2.2 The language of the operation manual is to be the same as the language of the approved Cargo Securing Manual. A translation into another language considered appropriate may be required.

7.2.3 The operation manual is to contain descriptions and instructions, as appropriate, as per the following list:

- a general description of the lashing software
- installation
- function keys
- menu displays
- input and output data
- required minimum hardware to operate the software
- instruction on testing the lashing software with the test loading condition
- a list of all terms, definitions, error messages and warnings likely to be encountered by the user
- in the case of error messages and warnings, there are to be unambiguous.

7.3 Requirements for lashing software

7.3.1 Necessary software inputs

The following data are necessary for the calculation to be carried out:

- GM and draught values resulting from the loading condition (no default value to be considered)
- description of the container loading (type, weight, position, allowable stack weight at 1,8g as indicated on the CSC plate and racking test load as indicated on the CSC plate)
- description of the associated securing fittings (type, quantity, total length of rod and turnbuckles).

Their value might either be input by the user or be direct outputs from an associated loading instrument. In any case, the information is to be clearly accessible to the user.

7.3.2 Requested software outputs

For any loading condition defined, the software is to derive the following results in way of each stack of containers:

The lashing software is to be capable of calculating forces on containers and container securing fittings for any loading condition for each container stack.

It is also to be capable of indicating the respective permissible values in order to assist the master in his/her judgement on whether the ship is loaded within the approved limits. The following parameters are to be presented:

- summary of ship particulars such as IMO No., length, and breadth
- summary of loading conditions showing relevant input parameters such as draught and GM
- stack and container positions
- actual stack weights verified against permissible stack weights
- relevant properties of securing fittings, including permissible loads
- design roll and pitch angles associated with ship loading condition and intended passage. The design angles are the values used for the lashing assessment and are not to be greater than those given by the rules.
- accelerations and other external forces such as wind containers are exposed to
- displacement in way of the four lower corners of each container
- listing of all calculated forces on containers and container securing fittings for any loading condition, for each container stack, and evaluation of compliance of the calculated forces with the corresponding allowable values.

The container and lashing arrangements in each bay on deck and in holds are to be shown graphically.

The data are to be presented on screen and in hard copy printout in a clear and unambiguous manner.

In addition to the printout content, each page of the printout is to contain ship's identification, lashing software name and version number, date and time of the printout, and the title of the loading condition. The printout is to be paginated sequentially, and the total number of printout pages are to be shown.

Units of measurement are to be clearly identified and used consistently.

7.3.3 Environmental conditions

For ships assigned the additional class notation **LASHING**, calculations are to consider unrestricted navigation conditions.

For ships assigned the additional class notation **LASHING-RSSA( )**, choice is to be given to the user to select one of the following environmental conditions:

- specific route or specific area conditions, for any voyage conducted according to the specific route or specific area covered by the notation
- unrestricted navigation conditions for any other voyage.

The relevant conditions are to be considered for the calculations. Conditions considered for the calculations are to be clearly indicated to ther user.

For ships assigned the notation **-WAF** and for the lashing assessment in scope of short voyages, the maximum significant wave height and the maximum wind speed are to be defined by the user according to the information provided by a weather service provider. The calculations are to consider the corresponding significant wave height and wind speed.

7.3.4 Associated checks and warnings

The following checks are to be carried out by the software:

- total stack weight is to be less than the maximum stack weight as given in [6.1]
- loads on containers are to be less than the permissible loads as given in [6.2] and [6.3]
- loads in securing fittings are to be less than the SWL given by the manufacturer.

The user is to be given clear warnings when the results exceed the allowable values.

Clear warnings are also to be given to the user when inputs are incorrect (e.g. ship speed out of the Rule limits, negative container weight,...).

7.4 Approval of a lashing software

7.4.1 Test loading condition

A test loading condition is a printout of lashing software inputs and outputs for a given loading condition (i.e. in particular a given value of GM). The printout is to include as a minimum the inputs defined in [7.3.1] and the outputs defined in [7.3.2].

The lashing software is to be delivered with test loading conditions for selected stacks and bays covering applicable stowage patterns for containers of different dimensions contained in the Cargo Securing Manual, as defined in [7.4.2]

The test loading conditions and their results are to be permanently stored in the computer where the lashing software is installed and are to be protected against unintentional or unauthorized modifications and access.

7.4.2 Documents to be submitted

Different test container loading conditions are to be submitted for review (including all types of containers as detailed in [6.2] for which the lashing software and cargo securing manual are being approved).

They are to include, as a minimum, two different loading conditions with different GM values. The conditions are to be designed so that one of them yields a small value of GM and the other one yields a high value of GM.

Each loading condition is to show container bays on deck and in hold, located aft, amidships and forward.

Among the different stacks, the following is to be provided:

- stacks including containers exposed to wind and stacks including containers protected from wind
- stacks made of 20 feet containers and stacks made of 40 feet containers
- stacks where allowable criteria as given in [7.3.4] are exceeded.

For ships assigned the additional class notation **LASHING-RSSA( )**, results of one of the loading conditions at least are to be given:

- for unrestricted navigation conditions
- for the specific routes and specific areas covered by the notation.

For ships assigned the notation **-WAF**, results of one of the loading conditions at least are to be given for one significant wave height and wind speed.

7.4.3 Approval procedure

The approval of the lashing software is to include:

- verification of type approval, if any
- verification that the latest ship data have been used
- verification and approval of the test loading conditions and their results
- verification if requirements of [7.3.2] and [7.3.4] are satisfied
- checking of proper installation, and verification of the instrument on board in accordance with the approved test loading conditions
- checking the availability of the operation manual on board.

In case of modifications implying changes in the ship's design or container securing arrangement, the software is to be modified accordingly and re-approved.

Any changes in software version related to the container securing calculations are to be reported to and be approved.

Upon installation, the lashing software is to be verified with the approved test loading conditions in the presence of Society surveyor. It is to be checked that the operation manual for the lashing software is available on board.

Verification by the Society does not absolve the Shipowner of responsibility for ensuring that the information supplied into the lashing software is consistent with the current condition of the ship and approved Cargo Securing Manual.

7.4.4 Acceptable tolerance

The accuracy of the computational results from the lashing software for the particular ship, on which the lashing software will be installed, is to be determined by using reference computation results deemed appropriate by the Society.

The tolerance of the accuracy of the results from the lashing software is to be below 1,0% of the allowable values.

However, deviations may be accepted subject to review by the Society provided that there is a satisfactory explanation for the deviation and that there will be no adverse effects on the safety of the ship.

7.4.5 Other requirements

The lashing software and its data are to be protected against unintentional or unauthorized modifications and access.

Section 6 OPEN-HATCH

1 General

1.1 Application

1.1.1 The additional class notation **OPEN-HATCH** may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.16.9] to ships assigned the service notation **general cargo ship** or **container ship** and complying with the requirements of the present Section.

1.1.2 This Section specifies the applicable requirements for general cargo ships or container ships intended to undertake sea voyage with one or several hatch covers not in place.

1.1.3 For any sea voyage undertaken with one or several hatch covers not in place, Administration is to grant an exemption to the International Load Line Convention.

1.1.4 If there is any conflict between the requirements of this Section and statutory requirements or conditions imposed by the Administration, the latter takes precedence. Refer to Pt A, Ch 1, Sec 1, [4.1.3].

1.1.5 For ships assigned:

- the service notation **container ship**, or
- the additional service feature **equipped for carriage of containers**,

the stability and fire safety provisions of MSC/Circ.608/Rev. 1 "Interim guidelines for open top container ships" are to be considered in lieu of:

- the ones defined in Article [4] for stability, considering the intact flooded condition as defined in [2.1.2], item c)
- the ones defined in Article [8] for fire safety.

1.2 Definitions

1.2.1 Maximum sustained speed

Maximum service speed taking into account speed loss due to resistance increase in regular waves. Voluntary speed loss is not taken into consideration.

1.2.2 Minimum ship manoeuvring speed

Minimum speed which maintains directional control and which is consistent with the operating characteristics of the ship.

1.2.3 Green water

Sea water other than spray shipped aboard the ship under normal operating conditions.

2 Loading conditions

2.1 Intact flooded condition

2.1.1 In addition to the loading condition specified in Pt B, Ch 5, Sec 8, intact flooded conditions are to be included in the loading manual. Every hold intended to be left opened in navigation (i.e without hatch cover in place) and all the possible combinations are to be considered and specified.

2.1.2 For the intact flooded conditions, all holds intended to be left opened in navigation are to be filled with a water level defined as follows:

- for ships assigned the service notation **general cargo ship**:

  The water level is to correspond to the volume of water ingress as defined in [4.2.1].

- for ships assigned the service notation **container ship** or the additional service feature **equipped for carriage of containers**:

  The water level is to correspond to the top of the hatch side or hatch coaming or, in the case of a ship fitted with cargo hold freeing ports, to the level of those ports.

3 Freeboard

3.1 General

3.1.1 Minimum freeboard is to be determined by seakeeping characteristics and stability. The following information, obtained by means of model tests and calculations according to the procedure in Article [6], are to be submitted to the Society for information:

a) measured data for the maximum hourly rate of ingress of green water, in m^3/hour, likely to be shipped into each cargo hold

b) evaluation of the adequacy of the discharge rates from cargo hold freeing ports (if they are fitted).

3.1.2 The maximum hourly rate of ingress of green water in any one open hold determined from model testing according to the procedure in Article [6] is not to not exceed the hatch opening area S, in m^2, multiplied by 0,4 m/hour.

3.1.3 A conventional geometrical freeboard and minimum bow height are to be calculated assuming that hatch covers are fitted. The freeboard and bow height assigned to the ship is not to be less than the equivalent geometrical freeboard determined from the International Convention on Load Lines, 1966, as amended.

3.1.4 All seasonal freeboards are to be omitted unless the minimum geometrical freeboard and corresponding seasonal freeboards for which the ship is eligible (assuming hatch covers fitted) are greater than the freeboard for which the model tests were satisfactorily carried out. In that case, the minimum geometrical freeboard and the corresponding seasonal freeboards greater than the freeboard for which the model tests were carried out are to be assigned.

3.1.5 The minimum freeboard and minimum bow height assigned to the ship are not to be less than those corresponding to the model test conditions.

4 Stability

4.1 Intact stability without water ingress

4.1.1 The stability of the ship in all loading conditions, with no water ingress in the cargo hold, is to meet the requirements of Pt B, Ch 3, Sec 2 considering the top of hatch coamings as downflooding points.

4.1.2 Where cargo hold freeing ports are fitted, they are to be considered closed for the purpose of determining the flooding angle, provided that the reliable and effective control of closing of these freeing ports is satisfactory to the Society.

4.2 Intact stability considering water ingress

4.2.1 The factor s_{final} calculated according to Pt B, Ch 3, App 3, [1.6.4] for the ship in intact condition, with water trapped in the cargo hold, is not to be less than 1 under the following conditions:

a) The ship in intact condition before water ingress is loaded at maximum draught for open hatch condition taking into account the maximum allowable vertical center of gravity (VCG) resulting from intact and damage stability criteria.

b) The cargo hold is to be filled with the volume of water V, in m^3, accumulated for 3 hours, and taken equal to (considering a cargo hold permeability of 0,95):

$$V = 3\ (R_{GW} + R_{TR} \cdot S)$$

where:

R_{GW} : Maximum hourly rate of green water (in m^3/hour) shipped in seagoing conditions as established by the comprehensive model testing (see procedure in Article [6])

R_{TR} : Tropical rainfall hourly rate, taken equal to 0,1 m/hour

S : Hatch opening area, in m^2.

4.2.2 For the condition with flooded holds and an intact ship, the free surfaces may be determined as follows:

a) the hold(s) are loaded with cargo but the free surface is to be calculated as if the hold(s) is(are) empty

b) the seawater enters the cargo hold and does not pour out during heeling

c) the maximum value of the free surface moment between the filling limits envisaged in the cargo hold is to be taken into account. As an alternative, the correction to righting lever is suggested to be on the basis of real shifting moment of water in the virtual empty cargo hold. As guidance, the method described in Pt B, Ch 3, Sec 2, [4.7.3] may be applied.

4.2.3 Calculations are to be performed for intermediate phases of hold flooding, each phase comprising an accumulated height of water of 0,25 m until the height corresponding to the volume of water accumulated and calculated according to [4.2.1], item b) is reached.

4.3 Damage Stability

4.3.1 Ships assigned the additional class notation **OPEN-HATCH** are to comply with the subdivision and damage stability criteria of Pt B, Ch 3, Sec 3, considering the top of hatch coamings as downflooding points.

5 Hull

5.1 Hull girder ultimate strength

5.1.1 The hull girder ultimate strength is to be checked according to the requirements in Pt B, Ch 6, Sec 2 for seagoing conditions, considering the loads defined in [5.1.2]and [5.1.3].

5.1.2 Still water loads

The designer is to provide the permissible still water bending moments $M_{sw\text{-}IF\text{-}min}$ and $M_{sw\text{-}IF\text{-}max}$ which are to envelope the maximum and minimum still water bending moments for the intact flooded conditions specified in [2].

5.1.3 Wave loads

The wave loads are to be obtained according to:

- Pt B, Ch 5, Sec 4, [3.1] for ships assigned the service notation **general cargo ship**,
- Pt D, Ch 2, Sec 2 for ships assigned the service notation **container ship**,

replacing

- n by n_{OH} or
- H by H_{OH}

and taking the coeficient f_{ps} equal to 1,

where:

n_{OH} : Navigation coefficient in open hatch condition:
$n_{OH} = H_{OH} / H_{s,unrestricted}$

H_{OH} : Wave parameter for the strength assessment in open hatch condition, as defined in Pt B, Ch 5, Sec 3 and calculated using the coefficients given in Tab 1.

$H_{s,unrestricted}$: Wave parameter as defined in Pt B, Ch 5, Sec 3, [1.1.1] for the strength assessment in normal seagoing conditions and corresponding to the navigation notation **unrestricted navigation**

Table 1 : Wave parameter H_{OH} coefficients for strength assessment in open hatch condition

Navigation notation	Assessment	A_0	A_1	e_1	A_2	e_2	L_c
unrestricted navigation	Strength	0,37	1,46	1,90	0,50	1,34	285
summer zone	Strength	0,37	1,46	1,90	0,50	1,34	285
tropical zone	Strength	0,36	1,46	1,91	0,48	1,31	276
coastal area	Strength	0,36	1,46	1,91	0,48	1,31	276
sheltered area	Strength	0,32	1,49	1,95	0,44	1,32	242

5.2 Hull scantlings

5.2.1 Where deemed necessary, the Society may request justification of local hull strength of cargo holds in intact flooded condition to meet the intent of the Rules. Design loads and strength criteria are to be agreed with the Society.

6 Procedure of model tests

6.1 General

6.1.1 The model test procedure / programme is to be submitted to the Society for information prior model tests are carried out.

6.1.2 The Society may require additional tests.

6.1.3 The model experiments are to be carried out in long-crested, irregular waves. The Pierson-Moskovitz, JONSWAP, or Bretschneider wave spectrum generated for the purpose of these experiments are to have a significant wave height of 8,5 m at the most unfavourable realistic wave period (zero crossing) as determined by calculation or previous testing experience.

6.1.4 For ships operating in restricted areas only, other spectra duly indicated on the model test programme may be accepted by the Society.

6.1.5 The effect of wind generated spray need not be simulated during the tests.

6.1.6 The model experiments are to be carried out for at least the following wave directions based on International Towing Tanks Conference conventions:

- following seas (0° /360°)
- quarter following seas (45° /315°)
- beam seas (90° /270°)
- quarter head seas (135° /225°)
- head seas (180°).

6.1.7 The model experiments are to be carried out for at least the following speeds:

- maximum sustained speed in head seas and quarter head seas
- minimum ship manoeuvring speed in quarter following seas and following seas
- zero ship speed (dead ship condition) in beam seas.

6.1.8 The model experiments are to be carried out with a self-propelled, unrestrained model without the necessity to change course. The time period of each experiment is to correspond to at least one hour real time.

6.1.9 The loading condition used for the tests is to correspond at least to the maximum loaded draught with level trim. If operational trim values differ substantially from level trim, additional trim values are to be included in the model test programme.

6.1.10 The vertical center of gravity (VCG) value selected is to correspond to the actual value most likely to be encountered during the ship's service for the draught close to the maximum loaded draught. If VCG values which may be expected during the operation of the ship differ substantially from this selected VCG value, additional VCG values are to be included in the model test programme.

6.1.11 For each test condition, the cargo hold which ships most water is to be determined by preliminary tests for each combination of heading, trim and VCG. In running tests for the full duration specified in [6.1.8], this least favourable hold is to be simulated as having no cargo, whilst other cargo holds (each cargo hold as a separate entity) may be simulated as completely fully loaded. Cargo such as unit cargo is not to be used as a mean to prevent shipping of water into an empty hold by being stacked outboard of the open hold as some sort of protecting wall. Rain covers for the open holds is not to be simulated in the model tests.

6.1.12 In addition to the usual measured parameters (ship motions, ship speed, relative motions, rudder angles, etc.), the volume of water entering all open cargo holds are to be measured for each experiment. The quantities of water taken aboard the model are to be removed and measured after each test run so that the metacentric height, moment of inertia and displacement are not appreciably disturbed by any accumulation of water during the testing programme.

6.1.13 Where freeing ports are fitted, an additional model test to comply with [3.1.1] is to be conducted at a draught which corresponds to the condition of the ship fully loaded with cargo and open holds flooded to the static equilibrium level with freeing ports open. A hold permeability of 70% by volume is to be assumed. Tests are to be conducted at zero speed in beam seas.

6.1.14 The Society may require an observer to witness the tests. A comprehensive report is to be submitted to the Society for information.

7 Ship arrangement

7.1 Hold bilge dewatering system and freeing ports

7.1.1 The bilge pumping system is to have a required capacity to pump the greater of:

- the maximum hourly rate of green water shipped in seagoing conditions as established by the comprehensive model testing specified according to the procedure in Article [6]
- a rainfall of 100 mm/hour regardless of the installation of rain covers
- the amount of shipped green water measured during the seakeeping model tests according to the procedure in Article [6] for the dead ship condition in beam seas, multiplied by safety factor 2
- four-thirds of the amount of water required for fire-fighting purposes in the largest hold
- an amount equal to the capacity required for ships with closed cargo holds.

7.1.2 The pumping of hold bilges is to be possible by at least three bilge pumps.

7.1.3 At least one of these pumps is to have a capacity of not less than the required capacity as defined in [7.1.1] and is to be dedicated to bilge and ballast service only. It is to be located in such a way that it will not be affected by a fire or other casualty in the space containing the pumps required in [7.1.4] or the space containing the main source of power. Moreover, it is to be supplied from the emergency source of power as required in Pt C, Ch 2, Sec 3, [2.3].

7.1.4 The combined output of at least two further pumps is not to be less than the required capacity as defined in [7.1.1]. These pumps are to be supplied from the main source of electrical power required by Pt C, Ch 2, Sec 3, [2.2], or any other source of power independent of the emergency source of power as required in Pt C, Ch 2, Sec 3, [2.3].

7.1.5 The bilge pumping system, including the piping system, is to incorporate sufficient redundancy features so that the system is fully operational and capable of dewatering the hold spaces at the required capacity in the event of failure of any one system component.

7.1.6 The bilge pumping system is to be arranged to be effective within the limiting angles of inclination required for the emergency source of electrical power by Pt C, Ch 2, Sec 2, [1.6], and bilge wells are to be readily accessible for cleaning.

7.1.7 All open cargo holds are to be fitted with high bilge level alarms. The alarms are to annunciate in the machinery spaces and the manned control location and be independent of bilge pump controls.

7.1.8 If the loss of suction prevents the proper functioning of the bilge system, special measures to prevent this are to be considered, as for instance, the installation of level indicators.

7.1.9 Open cargo hold drain wells are to be designed to ensure unobstructed discharge of water and easy access for cleaning under all conditions.

7.1.10 Where tween decks are fitted and form wells, ample provisions are to be made for rapidly freeing the tween decks from water and for draining them through evenly distributed openings. The minimum freeing port area on the tween decks fitted along the holds are to be calculated in accordance with Pt B, Ch 11, Sec 12, [6], considering the height of the bulkwark h_B as the mean height between the tween deck and the top of hatch coaming.

7.1.11 If provided, freeing ports are to be fitted on both sides of each open cargo hold, subject to the following:

- the number, size and location of the freeing ports on each side of each open hold is to be sufficient to prevent the accumulation of water above the level defined in [6.1.13]
- efficient means of closure to prevent the accidental ingress of water are to be provided. Such means are to be operated from above the freeboard deck. In the case of a ship operating in areas where icing is likely to occur, these arrangements are to be suitable to enable the ports to operate efficiently under such conditions.

8 Fire protection

8.1 Fire insulation

8.1.1 Open hatch cargo holds are to be considered as enclosed cargo holds for the purpose of applying Part C, Chapter 4, except that no fire division is required between an open hatch cargo hold and open deck, notwithstanding the requirements of Pt C, Ch 4, Sec 5, [1.4].

8.1.2 The fire detection system is to be designed and arranged to account for the specific hold configuration and ventilation arrangement.

8.2 Water-spray system

8.2.1 Open hatch cargo holds are to be protected by a fixed water-spray system complying with the requirements of the present sub-article.

Note 1: The Society may exempt open hatch cargo holds from this requirement if constructed and solely intended for the carriage of non-combustible cargoes. When such exemptions are granted, this will be reported on the Certificate of Classification

8.2.2 The water-spray system is to be subdivided into sections, with each section consisting of a ring-line at deck level covering a complete cargo hold.

8.2.3 The system is to be capable of spraying water into the cargo hold from deck level downward.

8.2.4 The water-spray system is to be capable of spraying the outer vertical boundaries of any one cargo hold and of cooling the adjacent structure. The uniform application density is to be not less than 1,1 litres/min/m^2.

8.2.5 At least one dedicated fire extinguishing pump for the hold water-spray system is to be provided, with a capacity sufficient to serve any one open hatch cargo hold. The pump is to be installed outside the open hatch area.

Failure of any one dedicated pump is not to result in a reduction of the water flow capacity by more than 50%. In addition, the spray patterns in the open hatch cargo holds in this configuration are to ensure a uniform water application. In the case of a single dedicated water-spray pump, this may be achieved by an interconnection to an alternative means of pumping from the weather deck. The interconnection valve is to be located outside the open hatch area and is to remain easily accessible in case of a fire in this area.

8.2.6 Water-spray nozzles are to be of an approved type.

8.3 Dangerous goods

8.3.1 Open hatch cargo holds intended for the carriage of dangerous goods are to comply with the requirements of Pt C, Ch 4, Sec 12 considering the hold as an enclosed cargo space not specifically designed for the carriage of freight containers, but intended for the carriage of dangerous goods in packaged form, including goods in freight containers and portable tanks. The hold is not to be considered as a weather deck.

9 Testing

9.1 Onboard tests

9.1.1 Water-spray system

The water-spray system is to be checked for leakage at normal operating pressure and to undergo an operational test. The testing is to include verification of the functionality of the drainage arrangements.

9.1.2 Hold dewatering system

A functional test of the hold dewatering system is to be carried out.

Section 7 Efficient Washing of Cargo Tanks (EWCT)

1 General

1.1 Application

1.1.1 The additional class notation **EWCT** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.16.10], to ships granted with the service notation **Oil Tanker**, **FLS Tanker** or **Chemical Tanker** fitted with efficient washing arrangements complying with this Section.

1.2 Documents to be submitted

1.2.1 The documents listed below are to be submitted.

- cargo tank arrangement
- coatings
- shadow diagrams
- cargo piping system diagram
- cargo tank cleaning system diagram
- tank washing machine specifications
- operation manual.

The Society reserves the right to require additional plans or information in relation to the specific characteristics of the installation.

2 Design requirements

2.1 Cargo tanks

2.1.1 Tanks are to be designed with smooth bulkheads to reduce any possibility of accumulation of residues. In principle, stiffeners and brackets that could accumulate residues and prevent efficient cleaning are not acceptable.

2.1.2 Bulkheads may be corrugated but special care is to be taken over the design of the corrugations especially those which are horizontal. The angle of the corrugations is to be such as to ensure that the washing jet from the fixed washing machines have the necessary cleaning impact on the surface. The location of the washing machines and the shadow areas are to be taken into account.

2.1.3 Cargo tanks are to be either effectively coated or of stainless steel construction.

2.1.4 Heating coils are to be of corrosion resistant materials, stainless steel or equivalent.

2.2 Cargo piping system

2.2.1 Cargo piping are to be either effectively coated internally or of stainless steel construction.

2.2.2 Cargo pumps are to be of the deep-well type individual to each tank with one or more units per tank and located with the necessary suction wells for adequate drainage.

2.3 Cargo tank cleaning system

2.3.1 The tank cleaning heater is to be capable of maintaining a minimum temperature of 85°C with adequate throughput to clean the largest tank.

2.3.2 Tank washing machines are to be permanently installed and give no less than 96% coverage of each tank based upon 70% of the washing jet length at its normal operating pressure. Tank fittings such as ladders heating coils need not be included as shadow areas.

2.3.3 Portable tank washing machines and the necessary openings and equipment are to be provided along with the necessary guidance how to tackle any shadow areas. The use of the portable tank cleaning machines should not require tank entry by personnel.

Section 8 Increased Admissible Cargo Tank Pressure (IATP)

1 Application

1.1 Ships covered by this section

1.1.1 This Section applies to ships or units intended to carry or store methane (LNG) whose maximum cargo tank design pressure does not exceed 70 kPa and that are designed and built so as to allow the pressure in the tanks to increase above 25 kPa.

Ships or units with IATP additional class notation are characterized by:

- a dual setting of the cargo tanks pressure relief valves, or

Note 1: The operational conditions and limitations for both setting pressures are to be specified in a memorandum.

- a boil-off handling system whose available capacity can be lower than 100% of the nominal boil-off rate of the ship or unit during the periods referred to in [4.3.2], or
- both.

1.2 Scope

1.2.1 This section covers:

- the ship's structure
- the cargo tanks pressure relieving system
- the boil-off gas management system.

2 Documentation to be submitted

2.1 Drawings and documents to be submitted to the Society

2.1.1 The following drawings and documents are to be submitted to the Society for review:

- Cargo tanks venting system specification, where the different values of the pressure relief valves setting and the related high pressure alarm levels are indicated.
- Pressure relief valves drawings for cargo tanks.
- Calculation of the maximum filling level for each cargo tank depending on the setting of the pressure relief valves.
- Justification of the reduction of the available gas handling system capacity referred to in [4.3.3].

2.1.2 The following documents are to be submitted to the Society for information:

- Cargo functional diagrams when all the tanks are not operated at the same pressure.
- Cargo operation manual and procedures, including:
  - procedure associated with changing the set pressure of the cargo tanks relief valves
  - cargo handling procedures when all the tanks are not operated at the same pressure.
- Ship to ship transfer procedure if relevant.

3 Definitions

3.1

3.1.1 Nominal boil-off gas rate (NBOG)

For the purpose of this Section, the nominal boil-off gas rate means the maximum boil-off rate considering an ambient temperature of 45°C, as specified by the cargo containment system designer.

3.1.2 Boil-off gas handling system

For the purpose of this Section, the gas handling system means all the equipment installed on board the gas carrier and allowing the boil-off gas disposal. Boil-off gas handling system includes gas or dual fuel engines, gas turbines, boilers, Gas Combustion Units (GCU) and reliquefaction installations, or other gas consuming equipment, as appropriate.

4 General design requirements

4.1 Ship design

4.1.1 Ship's structure

The ship's structure is to be designed and tested according to Part D, Chapter 9, taking into consideration the maximum service pressure in the cargo tanks.

When cargo tank pressure relief valves with dual setting pressure are installed, in accordance with [4.2.3], the ship's structure is to be designed and tested for both setting pressure depending on the operational condition.

The case where the pressure in one or several cargo tanks is the atmospheric pressure while the pressure in the other cargo tanks is at the highest allowable service pressure is to be considered, if necessary.

4.2 Cargo tanks pressure relieving system

4.2.1 General arrangement of the cargo tank pressure relieving system

The following requirements apply to ships whose cargo tanks are provided with pressure relief valves with single or dual setting values.

Installations with more than 2 pressure relief valves settings will be subject to special examination by the Society.

4.2.2 Installation with single setting of the pressure relief valves

When single setting cargo tanks pressure relief valves are installed, the pressure relieving system is to be designed according to the appropriate requirements of IGC Code and Part D, Chapter 9.

4.2.3 Installation with dual setting of the pressure relief valves

Cargo tanks pressure relief valves with dual setting pressure are to be in accordance with IGC code 8.2.7.

If three way valves are used for the selection of the pressure setting, positive locking devices are to be provided.

If an auxiliary pilot unit is installed on the permanently installed pilot, its setting is not to be modified when it is handled and it must be sealed as required in IGC Code.

When not in use, the auxiliary pilots are to be safely stored so as to minimize the risks of mechanical damage and/or modification of setting.

4.2.4 Visual indication of the safety valve setting

When dual setting pressure relief valves are installed, arrangements are to be made in order to allow a visual verification of the setting of the pressure relief valves.

4.2.5 Modification of the pressure relief valves setting at sea

When dual setting pressure relief valves are installed, the changing of the setting is not to be done automatically and is to require a manual operation.

The changing of the set pressure during laden voyage is to be carried out under the supervision of the master in accordance with the procedures included or referred to in the cargo operation manual requested in [2.1.2].

Before changing the setting value of the safety valves of one tank, the master is to make sure that the level in the tank is not above the maximum filling limit corresponding to the new setting pressure.

The level in the tank may be assessed by the following means:

- level switches
- level indicating devices
- level gauging devices.

Note 1: The master is to pay attention to the fact that the accuracy of the level indicating and level gauging devices may be impaired at sea due to the liquid motion in the tanks.

4.3 Boil-off gas management system

4.3.1 Normal navigation condition

In normal navigation condition, the cargo handling system of the ship is to be able to dispose at least 100% of the nominal boil-off gas rate.

4.3.2 Reduction of the boil-off gas disposal

Subject to the agreement of the flag Administration, the available capacity of the ship's boil-off gas handling system may be below the nominal boil-off gas rate during the following periods on condition that the pressure in the cargo tanks can be maintained below the set pressure of the safety relief valves for at least 21 days:

- when the gas engines are stopped or running at low load
- for the vessels fitted with a reliquefaction installation for boil-off gas disposal, when a part of this installation is out of service.

4.3.3 Capacity reduction of the boil-off gas handling system

During the periods the boil-off gas handling system is reduced in accordance to [4.3.2], the available capacity of the system is however not to be less than 50% of the NBOG.

The following arrangement may be considered:

- Ship equipped with gas engines and GCU: the capacity of the GCU is not to be less than 50% of NBOG
- Ship equipped with reliquefaction installation (without GCU): the reliquefaction installation is to consist of 2 trains, each having at least a 50% NBOG capacity
- Other arrangement where at least 50% of the NBOG can be handled at any time.

Note 1: The minimum reduced capacity of GCUs or reliquefaction installations may be required to be greater than 50% if necessary to achieve the 21 days condition stated in [4.3.2].

5 Control, monitoring and safety systems

5.1 Cargo tanks pressure alarms

5.1.1 Pressure alarms levels, and other associated parameters if any, are to be adjusted in the cargo control system when cargo tank relief valves settings are changed.

The selection on the console is to be carried out by means of a single switch with key lock which will select the appropriate pressure alarms and associated parameters.

The necessary information about these parameters is to be available at the request of the operators.

5.2 Indication of the cargo tanks pressure setting

5.2.1 A permanent indication of the setting of the pressure relief valves is to be displayed on the mimic diagrams on the appropriate screens.

6 Other

6.1 Shop and gas trials

6.1.1 During the ship gas trials the functional test of the gas management system is to be carried out at the lower and at the higher set pressure of the pressure relief valves.

The functional test of the pressure relief valves for cargo tanks is to be carried out at manufacturer's test shop or at gas trials.

6.2 Ship to ship transfer

6.2.1 Means and/or measures are to be provided to prevent overpressure in the cargo tanks of the discharging or receiving ship.

Section 9 Electric Vehicle Onboard Charging (EVOC)

1 General

1.1 Application

1.1.1 The additional class notation **EVOC** may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.16], to ships having the service notation **ro-ro passenger ship** and complying with the requirements of the present section for the purpose of charging electric vehicles carried on board.

1.1.2 The electric vehicles considered in this Section include any electrically propelled vehicles including cars (plug-in hybrid electric vehicles or battery electric vehicles), drones, forklifts, bikes, scooters, motorcycles, buses and trucks.

1.1.3 For the purpose of this Section, the recharging area is expected to be part of a closed ro-ro space or ro-ro weather deck. Other arrangements will be considered on a case-by-case basis.

1.1.4 The scope of **EVOC** additional class notation excludes the following operational conditions:

- Recharging of electric vehicles during loading or unloading operations
- Use of non-ship owned cables, unless:
  - they are provided by an original equipment manufacturer, and
  - they are compliant with IEC 62196, and they are free of visible damage.

1.2 Definitions and abbreviations

1.2.1 Electric Vehicle (EV)

Electric vehicle means any vehicle propelled by an electric motor, drawing current from a rechargeable energy storage system such as batteries.

1.2.2 Plug-in Hybrid Electric Vehicle (PHEV)

Plug-in hybrid electric vehicle means an electric vehicle that can charge its rechargeable electrical energy storage device from an external electrical source and also derives part of its energy from another onboard source.

1.2.3 EV charging station

EV charging station means a stationary apparatus connected to the supply network, aiming to supply electric energy to an EV for charging.

1.2.4 Recharging area

Recharging area means the part of a ro-ro or vehicle space where electric vehicles may be connected to charging stations for recharging purposes.

1.2.5 Cable assembly

Cable assembly means an assembly consisting of flexible cable or cord fitted with a plug and/or a vehicle connector used to establish the connection between an EV and its charging station.

1.3 Documents to be submitted

1.3.1 The documents to be submitted are listed in Tab 1.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Document
1	A	General arrangement of electrical installation of car deck including charging stations and the zone where vehicles are intended to be charged
2	A	Diagram of the supply and monitoring of the charging system
3	I	Electrical power balance
4	A	Charging stations technical specifications, datasheet and certificates
5	I	Onboard procedures (fire-fighting, safety patrols, vehicle charging, …)
6	I	Electric cables storage plan
7	A	Arrangement, diagrams and specifications of the fixed fire detection and fire alarm system
(1) A : To be submitted for approval; I : To be submitted for information		

No.	A/I **(1)**	Document
8	A	Hazardous area layout including positions of charging stations
9	A	Diagram and arrangement for the video television surveillance system
10	I	Risk analysis report as detailed in [2.2]
11	I	Charging equipment cables and sockets maintenance plan
12	A	Fire control plan
13	A A A I	In the case of a recharging area located on weather deck: • Details of the water monitors, including their capacity, range and trajectory of delivery • Plan of the water monitor seating arrangements • Water monitor control system diagram • Water monitor operating manual.
14	A A A I	In the case of a recharging area located in a closed ro-ro or vehicle space: • Arrangement of the water-based fixed fire-extinguishing system, including pipe routing, nozzle location, section arrangement and surface areas of protected zones • Details of the pumps, piping and nozzles (capacity, service pressures, material etc.) • System control diagram • System operating manual.
15	A	In the case of a recharging area located in a closed ro-ro or vehicle space: Particulars of the ventilation system, including arrangement of the fan rooms, characteristics of the fans and volume of the ventilated spaces.
(1) A : To be submitted for approval; I : To be submitted for information		

2 Arrangement and safety assessment

2.1 Recharging area arrangement

2.1.1 Charging stations are to be located either in closed vehicle spaces or on weather decks, in areas dedicated to the transportation of vehicles.

2.1.2 Charging stations, are to be located, as far as practicable, away from the means of escape.

2.1.3 A locker or specific storage area is to be provided in the vicinity of the charging station in order to allow storing the electric cables intended for vehicle charging while not in use, in such a way that they are protected from damage due to loading and unloading operations.

2.1.4 Clearly visible signs and markings are to be provided in the recharging area and next to each charging station.

2.2 Risk assessment

2.2.1 A risk assessment is to be conducted in order to ensure that any risks arising from EV charging affecting persons on board, the environment or the integrity of the ship are addressed. Consideration is to be given to the hazards associated with installation, operation and maintenance following any foreseeable failure.

2.2.2 Hazards are to be identified using acceptable and recognised hazard identification techniques. The risk assessment is to address at least the following:

- Loss of containment due to potential thermal runaways and gas and liquid leaks from the vehicles' batteries
- Electrical hazards caused by power management and charging issues, thermal runaways, electrical failures, etc.
- Operational hazards including those linked to commissioning, installation and maintenance of the charging stations in the vehicle space
- Emergency situations and impact on/from adjacent areas involving toxic gases emissions, fire hazards or explosions.

2.2.3 The risks are to be analysed using acceptable and recognised risk analysis techniques. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. If mitigation solutions are operational, details of risks, and the means by which they are mitigated, are to be included in the operating manual.

3 Electrical installation

3.1 General

3.1.1 The electrical power available for EV charging supply is to be sufficient to simultaneously recharge the batteries of all potential vehicles to be connected to the charging stations fitted for this purpose.

3.1.2 The installation of charging stations is to be such that their number and capacity is calculated according to the surplus of power available on board in respect of the vessel's essential services and services for habitability. The safety of the ship and its essential services are to have priority over EV charging.

3.1.3 At least one charging cable complying with [3.3] is to be provided for each charging station.

3.1.4 Electromagnetic compatibility

The charging station installation and associated components are not to cause electromagnetic disturbance and are to comply with Pt C, Ch 2, Sec 2, [3].

3.1.5 All electrical components are to be so designed and manufactured that they are capable of operating satisfactorily under the normally occurring variations in voltage and frequency specified in Pt C, Ch 2, Sec 2, [2].

3.1.6 The electronic components of the charging stations are to be constructed to withstand the tests required in Pt C, Ch 3, Sec 6.

3.1.7 The charging station is to be capable of functioning according to the network parameters taking into consideration the adaptation of the transmission voltage and frequency of the vehicle to that of the ship and station.

3.1.8 The minimum required degree of protection for charging equipment is IP55 in closed vehicle spaces and IP56 on weather decks.

3.1.9 The equipment for charging is to be designated for charging and with a protection against mechanical damage. It is to be capable of being disconnected when any potential fault is anticipated (e.g. by means of an isolation switch between the charging station and the vessel's main distribution system).

3.1.10 An isolating transformer, adapted to the performance parameters of the charging station is to be provided in order to create an earthed distribution network. For an enhanced circuit protection scheme, a residual current device (RCD) is to be provided for each charging station to ensure the disconnection of the faulty circuit before the earth fault develops into full grounding of a distribution phase.

3.1.11 Means for detection and protection for earth faults, overloads and short-circuit faults are to be provided on electric circuits with an audible and visual alarm to the safety centre and central control station.

3.1.12 Means are to be provided to avoid failures due to overload or short-circuits both within the main power distribution system and downstream at the level of the connection of the charging vehicles.

3.2 Sockets and outlets

3.2.1 Socket-outlets and plugs are to comply with the relevant provisions of Pt D, Ch 12, Sec 4, [3.4].

3.2.2 A lockable cover is to be provided on the connector/plug of charging stations with a detachable cable in order to prevent unauthorized use and inappropriate connections.

3.2.3 Socket-outlets, regardless of their rating, are to be provided with a switch and be interlocked such that the plug cannot be inserted or withdrawn whenever the switch is on. Vehicles can only be plugged into the charging station before the switch is on.

3.2.4 All sockets intended for recharging purposes are to be capable of being disconnected from the shipboard power system from a central location outside the vehicle space or weather deck.

3.3 Electrical cables and connections

3.3.1 The cables are to be long enough to reach the EV's charge port without being physically strained or blocking the access to car deck passages. Where cables need to be laid in access ways, means (e.g. cable ducts…) are to be provided to prevent impairing passage on those access ways.

3.3.2 A maintenance plan is to be prepared for electrical cables and their sockets and associated equipment in the vehicle spaces intended for vehicles charging.

3.3.3 Electrical cables used for vehicles' charging are to be of a type approved by the Society, according to IEC 62196.

3.3.4 Electrical cables intended for vehicles charging are to be armoured or metal-sheathed unless otherwise mechanically protected.

3.3.5 Electrical cables intended for vehicles charging that may be damaged during loading and unloading operations are to be mechanically protected, even when armoured, unless the ship's structure already provides protection. Any metal casings used for mechanical protection of cables are to be protected against corrosion and earthed.

3.3.6 For AC charging, cables may be either detachable or tethered; while only tethered cables are allowed for DC charging.

3.4 Charging station

3.4.1 The charging station is to be of a type approved by the Society.

3.4.2 Among the different types of charging plugs available for electric vehicles, the charging station is to offer at least the plug type 2, as described in EN 62196-2:2017, with the adapters suitable for other types of plugs also specified in the same standard.

3.4.3 The charging station is to have at least the same resistance to vibration as required for all other electrical installations on board.

3.4.4 The charging station is to be integrated into the ship's power management system (PMS), and the functionality of communication between the charging station and the PMS is to be established. In case of high power demands, it is to be automatically disconnected from the electric grid until sufficient power is available again.

3.4.5 It is also to be integrated into the ship's alarm and monitoring system such that, in the event of failure, an audible and visual alarm is triggered at the navigation bridge or in a continuously manned central control station. The alarm involving malfunctions in the charging station, the connection or the EV battery is to be different from other alarms in the vehicle space.

3.4.6 A test current determining the circuit integrity is to be carried out automatically at each electric vehicle before launching its charging process. This test is to be integrated into the control system of the charging stations.

3.4.7 It is to be possible to manually disconnect the charging station from the grid by the crew. This manual disconnection is to be located in a non-hazardous area.

3.4.8 A remote shutdown of the charging station is to be available in case of an accident (e.g. a nearby fire hazard).

3.4.9 The charging station is to be provided with the following electrical protection features:

- Short-circuit protection
- Overcharging protection ensuring a shutdown if the battery overcharges
- Temperature monitoring triggering disconnection in case of overheating or damage
- Emergency shutdown in the event of a hazard
- Internal cooling of the charging station or cable, if needed.

3.4.10 Individual visual signals are to be associated with the charging stations in order to identify the vehicles in a current charging status. Such indicators are to be fitted in an easily visible position.

4 Fire safety

4.1 Fire detection

4.1.1 A fixed fire detection and fire alarm system, providing combined heat and smoke detection in the recharging area, and complying with the requirements of Pt C, Ch 4, Sec 15, [8], is to be installed.

In case the recharging area is located on a weather deck, a fixed fire detection and fire alarm system approved based on IMO Circular MSC.1/Circ.1242, according to Pt C, Ch 4, Sec 15, [8.2.3], item a) 7), may be considered. The type of detectors is to be adequate to detect battery fires on open decks.

4.1.2 The ship's electrical supply to the charging vehicles is to be automatically cut off upon activation of two fire detectors.

4.1.3 The recharging area is to be easily identifiable on the fixed fire detection and fire alarm control panel.

4.1.4 A video television surveillance system is to be provided, covering the recharging area and allowing continuous video monitoring for fire location identification. The number and arrangement of the cameras is to be such that all parts of the recharging area(s) are visible and easily identifiable. Thermal imaging cameras are acceptable for this purpose.

4.1.5 The video television surveillance system is to provide immediate playback capability at the navigation bridge and in the safety centre.

4.2 Fixed fire-extinguishing systems

4.2.1 The recharging area is to be covered by one of the following water-based fixed fire-extinguishing system:

- A fixed water based fire-fighting system for ro-ro spaces and special category spaces, complying with Pt C, Ch 4, Sec 15, [6.1.4], for a recharging area located in a closed vehicle space, or
- Fixed water monitors complying with the requirements of [4.2.4] for a recharging area located on the weather deck.

4.2.2 Controls allowing to cut-off electrical power supply to the charging vehicles are to be available close to the controls of the water-based fixed fire extinguishing system required in [4.2.1].

4.2.3 Recharging area located in a closed vehicle space

One or several dedicated sections of the fixed water based fire-fighting system are to cover the recharging area. These sections are to be clearly identified at the system release station.

4.2.4 Recharging area located on a weather deck

a) Fixed water monitors are to be provided on the weather deck where the recharging area is installed, capable of delivering water to:

- the recharging area; and
- the area, including superstructure boundaries, located within 8 m measured horizontally from the recharging area.

b) The combined capacity of all water monitors is to be such as to provide an average coverage of 2 L/min per square meter of protected area. In addition, the output of each monitor is to be at least 1250 L/min.

c) Water monitors are to be of a type approved by the Society and are to be capable of throwing a continuous full water jet without significant pulsations and compacted in such a way as to be concentrated on a limited surface.

Monitors are to be capable of withstanding the reaction forces of the water jet.

d) The seatings of the monitors are to be of adequate strength for all modes of operation.

e) The strengthening of the structure of the ship, where necessary to withstand the forces imposed by the water monitor system when operating at its maximum capacity in all possible directions of use, is to be considered, on a case-by-case basis, by the Society.

f) It is to be possible to remotely operate the fire monitors from a safe position in case of a fire on the weather deck.

g) The distance from the monitor to the farthest extremity of the protected area forward of that monitor is not to be more than 75% of the monitor throw in still air conditions.

h) The capacity of the pump and arrangement of the piping system supplying water to the water monitors is to be sufficient to achieve the full throw of any one monitor and to ensure coverage of the whole protected area at the flowrate indicated in item b).

i) Where the ship's required fire pumps are used to feed the water monitors:

- it is to be possible to segregate the ship's fire main from the water monitors by means of a valve in order to operate both systems separately or simultaneously
- the capacity of the pumps is to be sufficient to serve both systems simultaneously.

j) Where the pump dedicated to the fixed water based fire-fighting system required by Pt C, Ch 4, Sec 13, [5] is used to feed the water monitors, it is to be possible to segregate both systems by means of a valve and both systems need not be able to operate simultaneously.

k) Scupper or freeing ports, sized to remove no less than 125% of the combined capacity of both the monitor(s) and the required number of fire hose nozzles, are to be provided to ensure efficient drainage of water accumulating on deck surfaces when the fire monitors are in operation.

4.3 Portable equipment

4.3.1 At least one portable thermal imaging device is to be available on board.

4.3.2 At least one fire blanket is to be available close to each recharging area. The size of the fire blanket is to be sufficient to cover completely any electrical vehicle intended to be charged on board.

4.3.3 At least 3 water fog applicators are to be available close to any recharging area located on the weather deck.

5 Prevention of explosion and limitation of the consequences of toxicity

5.1 Sources of ignition

5.1.1 All electrical equipment related to the charging system, including connectors, sensors and control units, are to be of a certified safe type suitable for use in the hazardous areas defined in Pt D, Ch 12, Sec 4.

5.2 Ventilation

5.2.1 Closed vehicle spaces containing recharging areas are to be fitted with a mechanical ventilation system, capable of providing at least 10 air changes per hour on a continuous basis while electrical vehicles are under recharging.

5.2.2 The fans and fire dampers are to be operable from outside the vehicle space.

6 Testing

6.1 Type testing

6.1.1 Water monitors

The following characteristics are to be tested for each type of water monitor and are to comply with the requirements in [4.2.4], item b):

- minimum discharge rate
- length of throw in still air conditions
- angular range of throw.

6.2 Workshop tests

6.2.1 Tests of water monitors are to be carried out following requirement in [4.2.4], item b) regarding minimum discharge rate in still air conditions.

6.2.2 Before installation, the following workshop tests are to be carried out at the manufacturers' premises:

- Testing of charging stations according to Pt C, Ch 2, Sec 7, Tab 2. Tests on charging stations are to be attended by the Surveyor.
- Testing of charging cables according to the relevant parts of Pt C, Ch 2, Sec 9, [3].
- Testing of the connectors, socket-outlets and plugs according to IEC 62196 standard.

6.3 Shipboard test

6.3.1 Fire monitor system

After assembly on board, the fire monitor system required by [4.2.1] is to be checked for leakage at normal operating pressure, and is to undergo an operational test to check their characteristics and performances.

6.3.2 Video television surveillance

The video television surveillance system required by [4.1.4] is to undergo an operational test in order to check that all parts of the recharging area(s) are visible and easily identifiable. This test is to be carried out with an arrangement representative of a fully loaded cargo deck.

6.3.3 Charging stations

A working test is to be carried out on the charging stations and their associated safeties required in [3.4] (i.e. remote disconnection, automatic trip, etc.).

Appendix 1 Definition of Specific Routes for the Notation LASHING-RSSA

1 General

1.1 Definition of the reference specific routes and crossed areas

1.1.1 The loads specified in Ch 12, Sec 5, [4] are given for the specific routes described in Tab 1.

The definitions of areas that may be crossed by a specific route are defined in Tab 2 and depicted on Fig 1.

The portion of time and the areas crossed by each specific route are detailed in Tab 3 to Tab 21.

1.2 Allowance criterion for deviations from the reference specific routes

1.2.1 The loads definitions given in Ch 12, Sec 5, [4] are applicable to any alternative route deviating from the reference specific route defined in [1.1] providing the following criterion is complied with:

$$\frac{1}{2}\sum_{i}|P_{ref}(i) - P_{alt}(i)| \leq 0{,}30$$

where:

$P_{ref}(i)$: Portion of time in the area i for the reference specific route, as defined respectively in Tab 2 and Tab 1

$P_{alt}(i)$: Portion of time in the area i, as defined in Tab 2, for the alternative route.

Table 1 : List of the specific routes

	Route No.	Description	Crossed Areas
Routes through Atlantic ocean	1	North sea - Baltic sea	see Tab 3
	2	Northern Europe - Mediterranean sea	see Tab 4
	3	Europe - North America (East)	see Tab 5
	4	Europe - South Africa	see Tab 6
	5	Europe - South America	see Tab 7
	6	North America (East) - South America	see Tab 8
	7	South America - South Africa	see Tab 9
Routes through both Atlantic and Indian oceans	8	Europe - Asia, through Mediterranean sea	see Tab 10
	9	Europe - Asia, through Cape of Good Hope	see Tab 11
Routes through both Atlantic and Pacific oceans	10	Europe - Asia, through Atlantic and Pacific	see Tab 12
	11	North America (East) - Asia through North Pacific (between 40°N and 50°N)	see Tab 13
	12	North America (East) - Asia through North Pacific (below 30°N)	see Tab 14
Routes through Indian ocean	13	South Africa - Asia	see Tab 15
Routes through Pacific ocean	14	North America (West) - Indonesia	see Tab 16
	15	North Pacific (between 40°N and 50°N)	see Tab 17
	16	North Pacific (between 30°N and 40°N)	see Tab 18
	17	South America - Asia	see Tab 19
	18	Indonesia - Asia	see Tab 20
	19	Asia - Australia	see Tab 21

Table 2 : Definitions of the areas

Area	Latitude range	Longitude range
1	65°N - 75°N	10°E - 30°E
2	60°N - 70°N	45°W - 60°W
3	60°N - 70°N	15°W - 45°W
4	60°N - 70°N	10°W - 15°W
5	53°N - 65°N	13°E - 30°E
5a	53°N - 65°N	10°E - 30°E
6	55°N - 60°N	130°W - 160°W
7	50°N - 55°N	134°W - 170°W
8	50°N - 60°N	30°W - 60°W
9	50°N - 60°N 55° N - 60°N	10°W - 30°W 3°W - 10°W
10	50°N - 55°N	3°W - 10°W
11	51°N - 60°N	3°W - 8°W
11a	50°N - 60°N	3°W - 10°W
12	50°N - 55°N	160°E - 190°E
13	40°N - 50°N	130°W - 170°W
14	40°N - 48°N	123°W - 130°W
15	40°N - 45°N 40°N – 50°N	60°W - 70°W 40°W – 60°W
16	40°N - 50°N	8°W - 40°W
17	43°N - 50°N	0°W - 8°W
18	35°N - 50°N	128°E - 140°E
19	40°N - 50°N	143°E - 150°E
19a	40°N - 50°N	140°E - 150°E
20	40°N - 50°N	150°E - 190°E
21	30°N - 40°N	130°W - 170°W
22	20°N - 40°N	105°W - 130°W
23	30°N - 42°N	70°W - 80°W
24	30°N - 40°N	40°W - 70°W
25	30°N - 40°N	5°W - 40°W
26	30°N - 43°N	5°W - 13°W
27	30°N - 40°N	13°E - 36°E
28	30°N - 40°N	119°E - 128°E
29	30°N - 35°N 30°N - 40°N	128°E - 140°E 140°E - 145°E
30	30°N - 40°N	145°E - 190°E
31	20°N - 30°N	130°W - 170°W
32	20°N - 30°N	81°W - 98°W
33	20°N - 30°N	60°W - 81°W
34	20°N - 30°N	40°W - 60°W
35	20°N - 30°N	20°W - 40°W
36	10°N - 30°N	10°W - 20°W
37	10°N - 30°N	32°E - 47°E

Area	Latitude range	Longitude range
38	23°N - 31°N	47°E - 56°E
39	20°N - 28°N	56°E - 73°E
40	10°N - 30°N	105°E - 121°E
41	20°N - 30°N	121°E - 130°E
42	20°N - 30°N	130°E - 150°E
43	20°N - 30°N	150°E - 190°E
44	10°N - 20°N	140°W - 180°W
45	10°N - 20°N	110°W - 140°W
46	10°N - 15°N 10°N - 20°N	84°W - 90°W 90°W - 110°W
47	10°N - 20°N 15°N - 20°N	61°W - 84°W 84°W - 90°W
48	10°N - 20°N	40°W - 61°W
49	10°N - 20°N	20°W - 40°W
50	10°N - 20°N	47°E - 78°E
51	10°N - 23°N	78°E - 98°E
52	10°N - 20°N	121°E - 150°E
53	10°N - 20°N	150°E - 180°E
54	10°S - 10°S	135°W - 175°W
54b	10°S - 10°S	110°W - 135°W
55	0°S - 10°S	80°W - 90°W
55a	0°S - 10°S	75°W - 90°W
55b	0°S - 10°S	90°W - 110°W
56	0°S - 10°S	40°W - 60°W
57	0°S - 10°S	18°W - 40°W
58	0°S - 10°S	10°W - 18°W
59	10°S - 12°S	40°E - 50°E
60	0°S - 10°S	50°E - 80°E
61	0°S - 10°S	80°E - 99°E
62	0° - 10°N 10°N - 14°N	99°E - 117°E 98°E - 105°E
62b	0°S - 10°S	117°E - 130°E
63	0°S - 10°S	130°E - 160°E
63b	0°S - 10°S	160°E - 185°E
64	0°S - 10°S	85°W - 110°W
65	0°S - 20°S	70°W - 85°W
66	0°S - 10°S	30°W - 50°W
67	0°S - 20°S	10°W - 30°W
68	0°S - 20°S	10°W - 10°W
69	0°S - 10°S	50°E - 80°E
70	0°S - 10°S	80°E - 103°E
70b	0°S - 10°S	103°E - 150°E
71	0°S - 10°S	150°E - 185°E

Area	Latitude range	Longitude range
72	10°S - 20°S	130°W - 180°W
73	10°S - 20°S	85°W - 130°W
74	10°S - 30°S	30°W - 50°W
75	12°S - 30°S	30°E - 50°E
76	10°S - 30°S	50°E - 90°E
77	10°S - 30°S	90°E - 110°E
78	10°S - 30°S	110°E - 130°E
78b	10°S - 30°S	130°E - 142°E
79	10°S - 30°S	142°E - 156°E
80	10°S - 30°S	156°E - 180°E
81	20°S - 30°S	145°W - 180°W
82	20°S - 30°S	110°W - 145°W
82b	20°S - 30°S	85°W - 110°W
83	20°S - 40°S	70°W - 85°W
84	20°S - 30°S	10°W - 30°W
85	20°S - 40°S	10°E - 20°E
86	30°S - 40°S	175°E - 240°E
86b	30°S - 40°S	85°W - 120°W
87	30°S - 40°S	40°W - 62°W
88	30°S - 40°S	15°W - 40°W
89	30°S - 40°S	10°W - 15°W
90	30°S - 40°S	20°E - 40°E
91	30°S - 40°S	40°E - 110°E
92	30°S - 40°S	110°E - 147°E
93	30°S - 40°S	147°E - 175°E
94	40°S - 50°S	120°W - 150°W
94b	40°S - 50°S	90°W - 120°W
95	40°S - 50°S	70°W - 90°W
96	40°S - 50°S	50°W - 70°W
97	40°S - 50°S	10°W - 50°W
98	40°S - 50°S	10°W - 40°W
99	40°S - 50°S	40°E - 90°E
100	40°S - 50°S	90°E - 140°E
101	40°S - 50°S	140°E - 173°E
102	40°S - 50°S	173°E - 210°E
103	50°S - 60°S	60°W - 80°W
104	50°S - 55°S	30°W - 60°W
106	55°N - 62°N	162°E - 200°E
112	50°N - 55°N	134°E - 160°E
126	43°N - 50°N	0°W - 13°W
127	40°N - 46°N	13°E - 27°E
128	40°N - 48°N	27°E - 42°E

Figure 1 : Map of areas for the definition of the specific routes

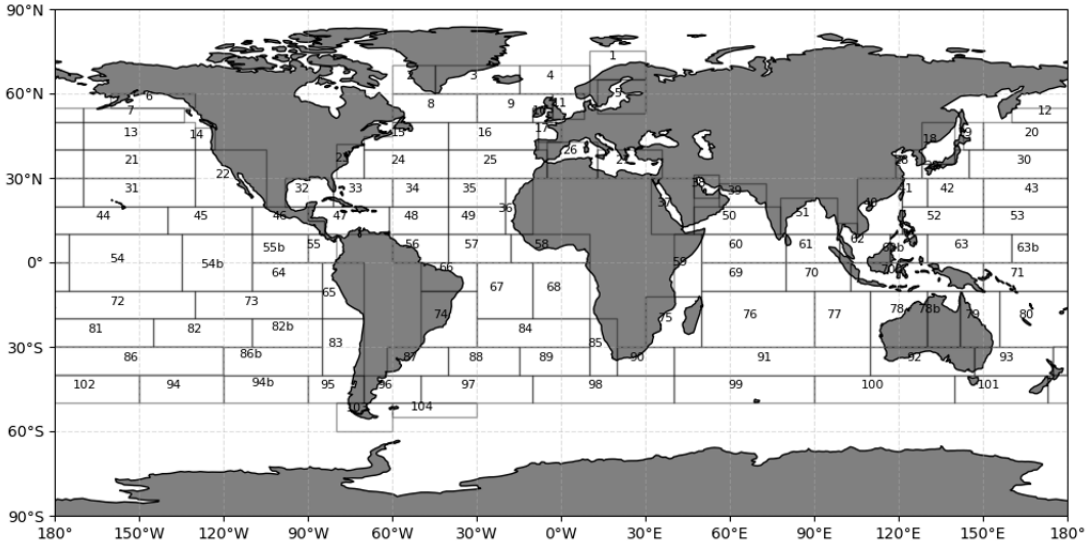


Table 3 : Specific route North sea - Baltic sea

Crossed area	% time
5	58%
11	42%

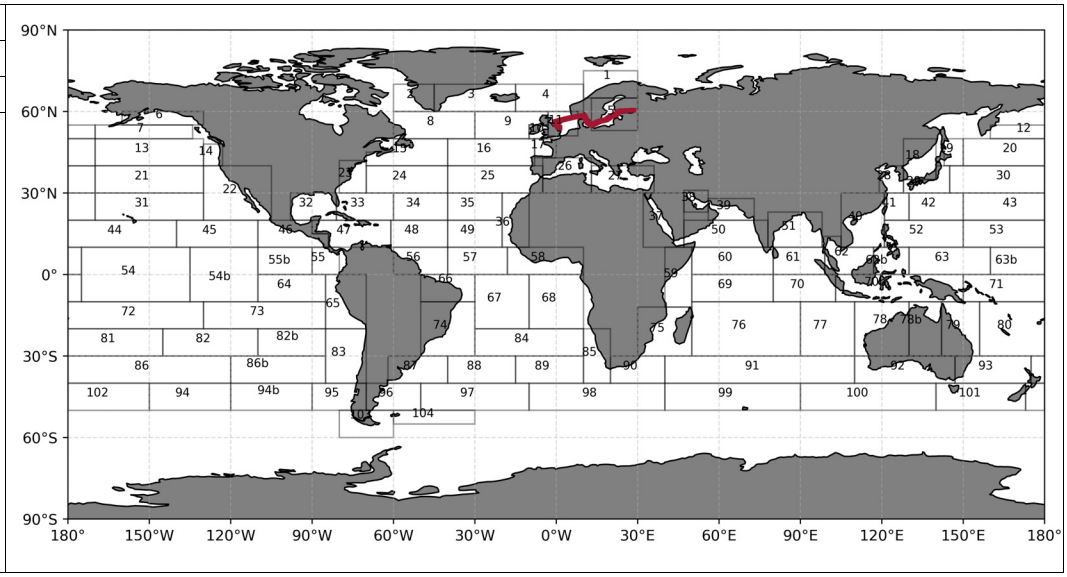


Table 4 : Specific route Northern Europe - Mediterranean sea

Crossed area	% time
11	7%
16	16%
17	7%
25	17%
26	27%
27	26%

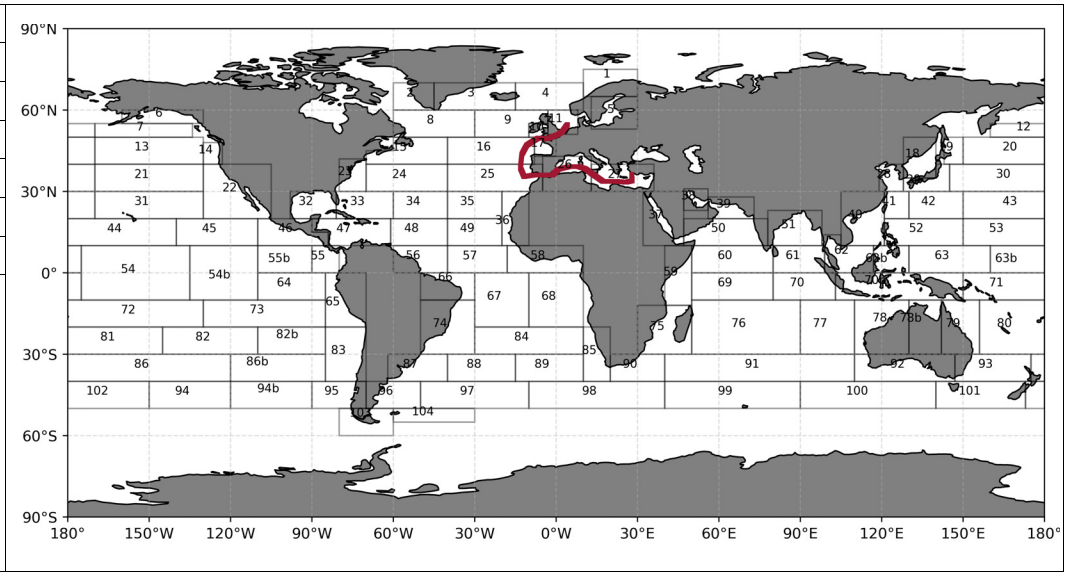


Table 5 : Specific route Europe - North America (East)

Crossed area	% time
11	6%
15	35%
16	32%
17	5%
23	18%
33	24%

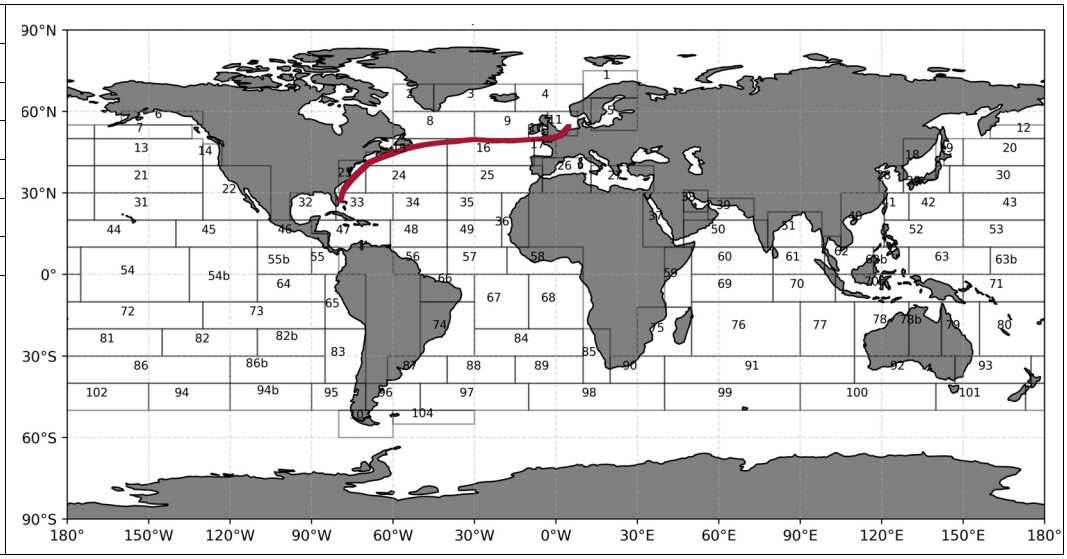


Table 6 : Specific route Europe - South Africa

Crossed area	% time
16	8%
17	3%
25	10%
35	1%
36	13%
49	6%
57	2%
58	13%
68	25%
84	6%
85	13%

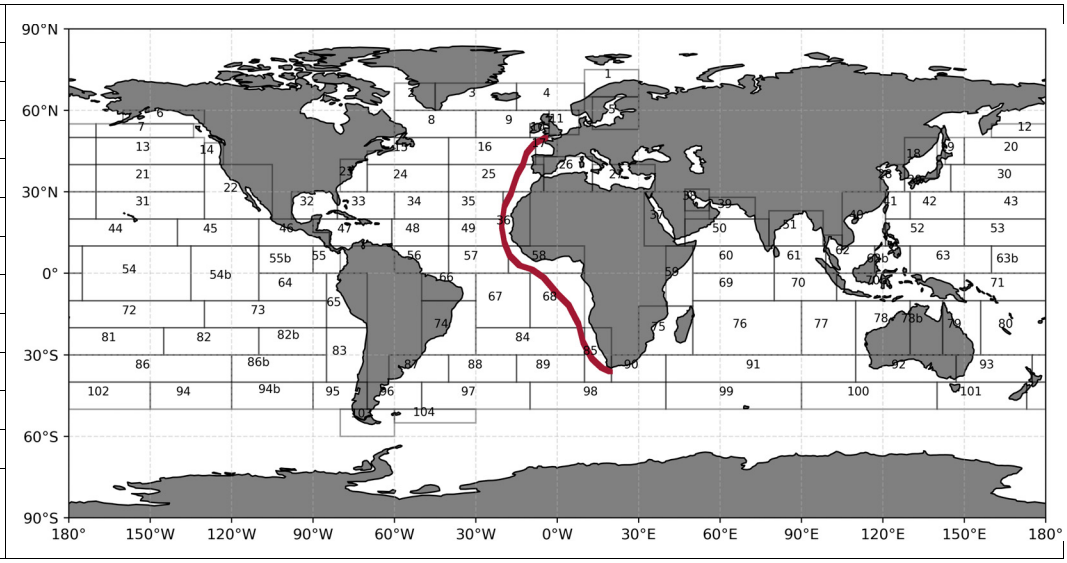


Table 7 : Specific route Europe - South America

Crossed area	% time
16	15%
17	1%
25	12%
35	12%
49	12%
57	12%
66	12%
74	24%

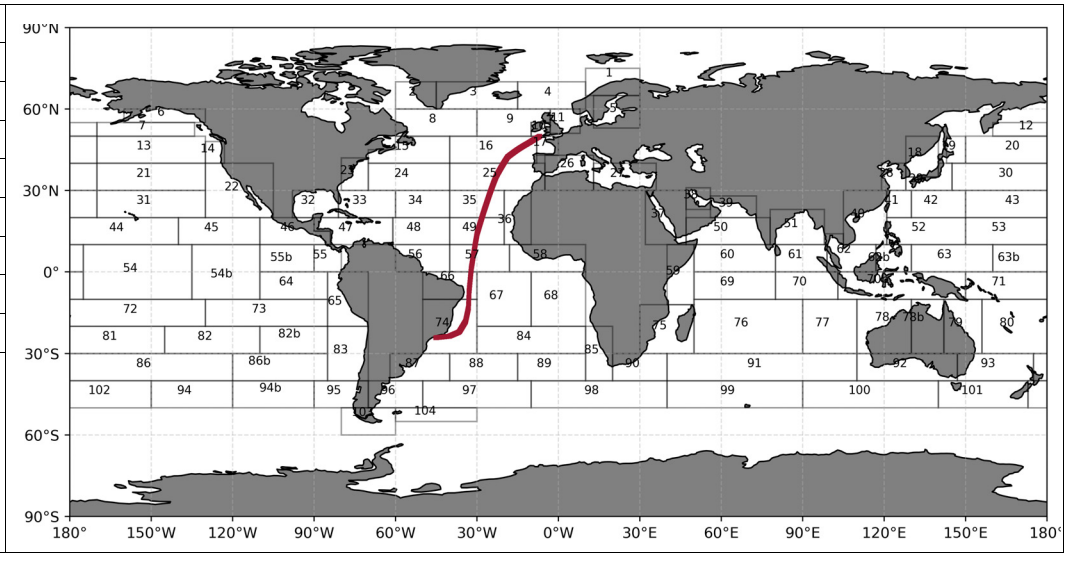


Table 8 : Specific route North America (East) - South America

Crossed area	% time
23	12%
33	18%
34	3%
48	15%
56	11%
57	7%
66	12%
74	22%

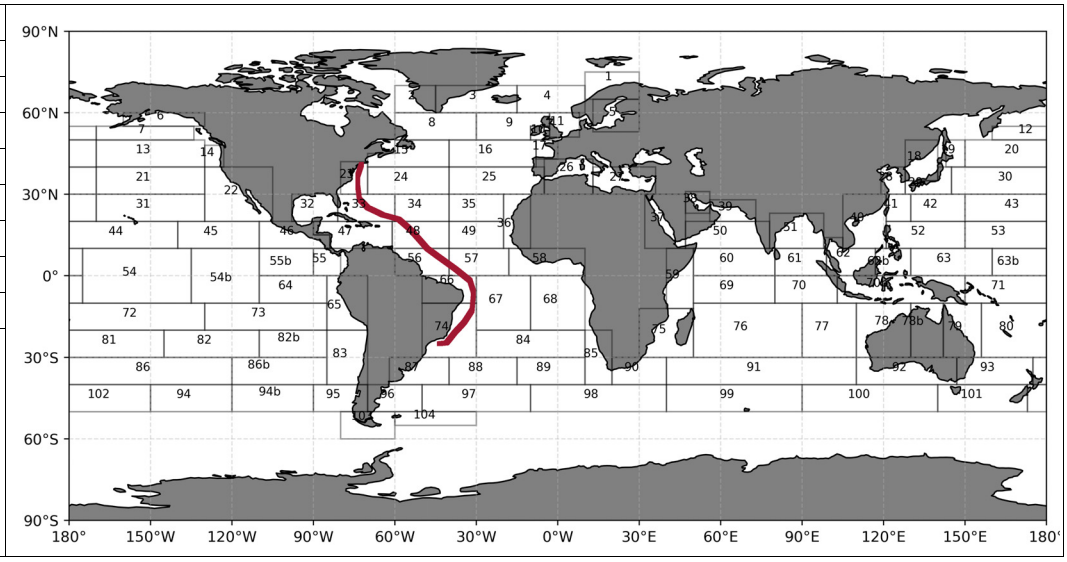


Table 9 : Specific route South America - South Africa

Crossed area	% time
67	19%
68	17%
74	18%
84	4%
85	17%
87	13%
90	4%
96	8%

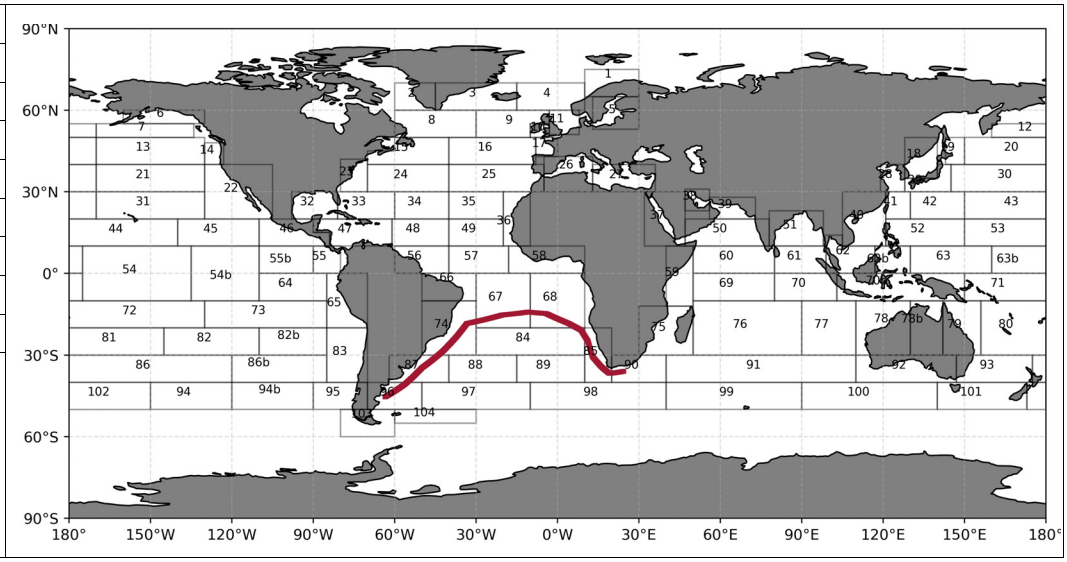


Table 10 : Specific route Europe - Asia, through Mediterranean sea

Crossed area	% time
11	2%
16	4%
17	2%
25	4%
26	8%
27	10%
28	3%
37	13%
40	7%
41	5%
50	10%
60	9%
61	11%
62	10%
70b	2%

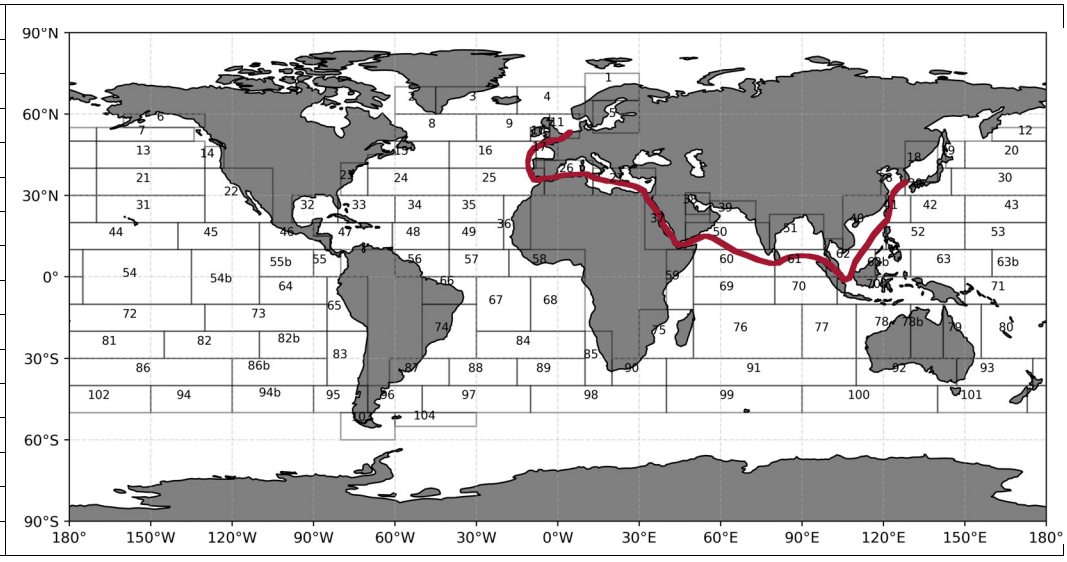


Table 11 : Specific route Europe - Asia through Cape of Good Hope

Crossed area	% time
11	3%
16	3%
17	2%
25	4%
28	2%
29	4%
36	8%
40	8%
41	1%
42	1%
58	5%
61	6%
62	7%
68	9%
70	6%
75	5%
76	13%
84	1%
85	6%
90	6%

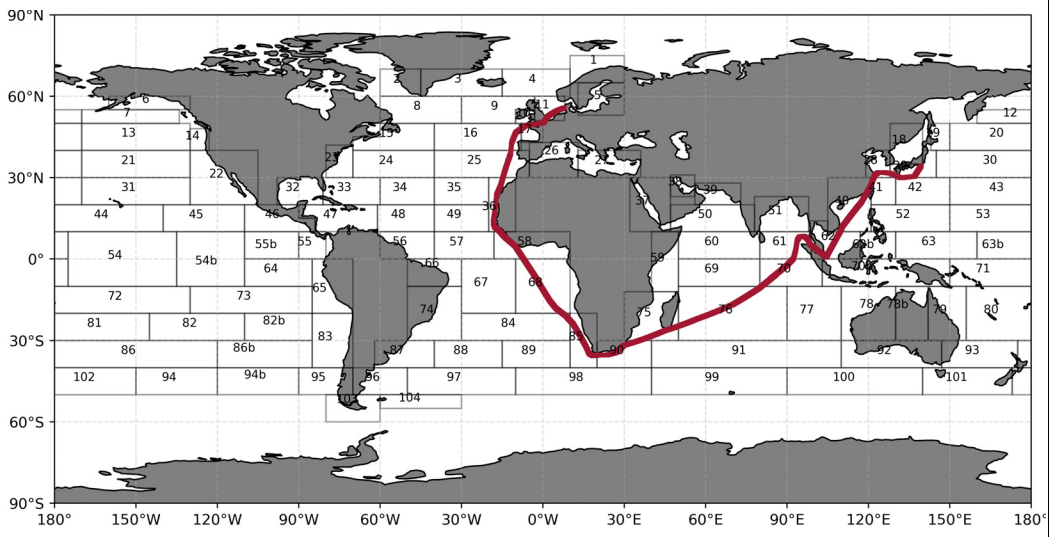


Table 12 : Specific route Europe - Asia, through Atlantic and Pacific

Crossed area	% time
7	6%
8	3%
9	5%
10	1%
11	1%
12	5%
13	5%
14	3%
15	9%
17	2%
18	5%
19	2%
20	3%
22	11%
23	5%
29	2%
32	3%
33	3%
40	2%
41	5%
46	9%
47	5%
55	5%

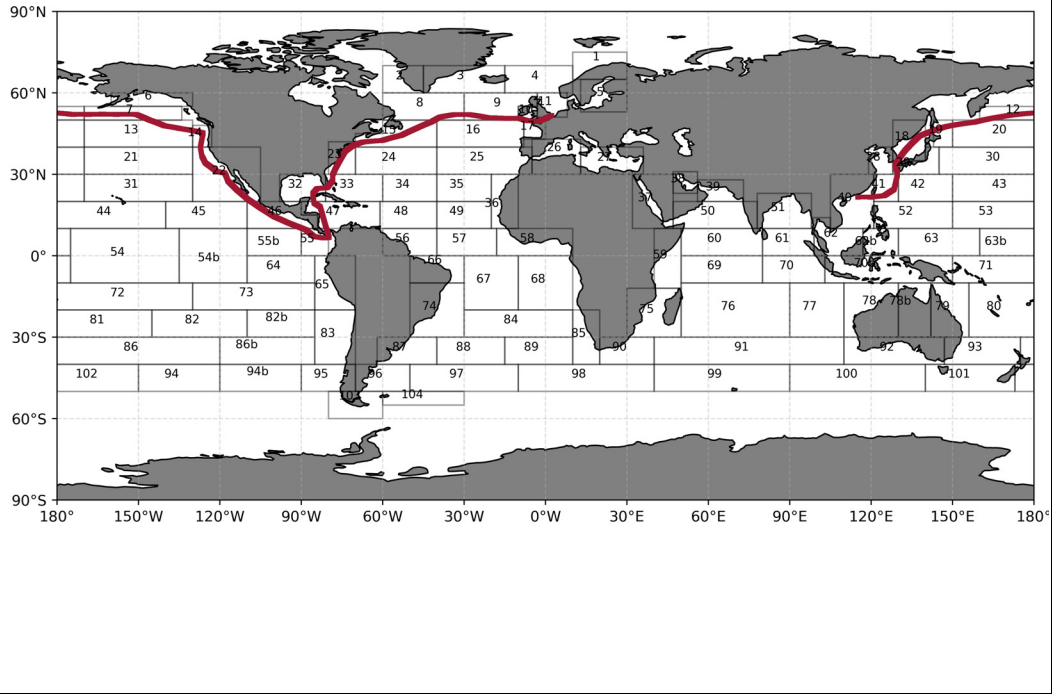


Table 13 : Specific route North America (East) - Asia through North Pacific (between 40°N and 50°N)

Crossed area	% time
13	14%
14	2%
18	6%
19	3%
20	10%
22	13%
23	6%
29	3%
32	5%
33	5%
40	3%
41	5%
42	4%
46	9%
47	6%
55	5%
55b	1%

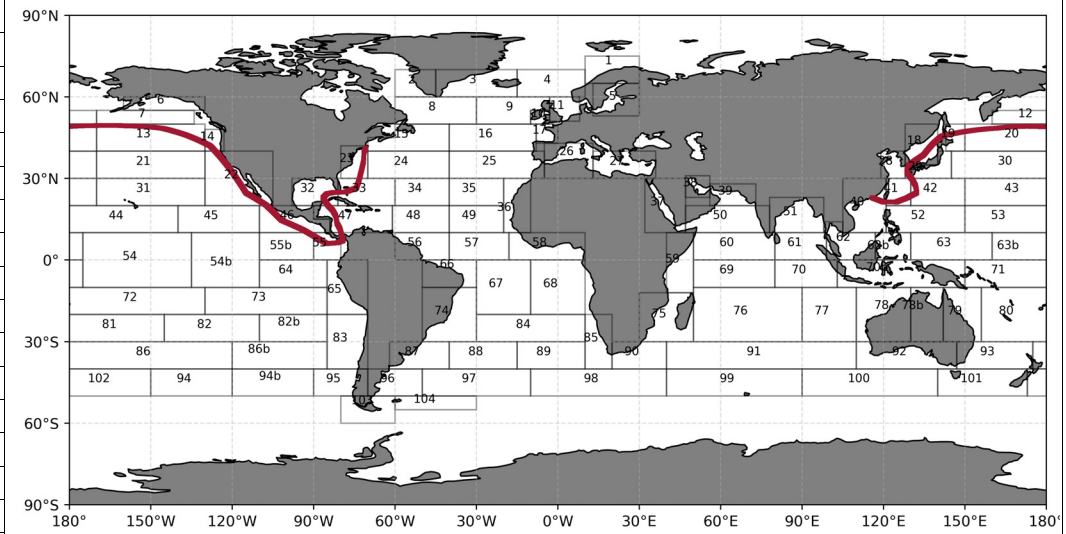


Table 14 : Specific route North America (East) - Asia through Southern North Pacific (below 30°N)

Crossed area	% time
18	1%
23	2%
28	3%
29	4%
33	6%
40	3%
41	2%
42	6%
43	5%
44	7%
47	9%
53	10%
54	15%
54b	12%
55	5%
55b	10%

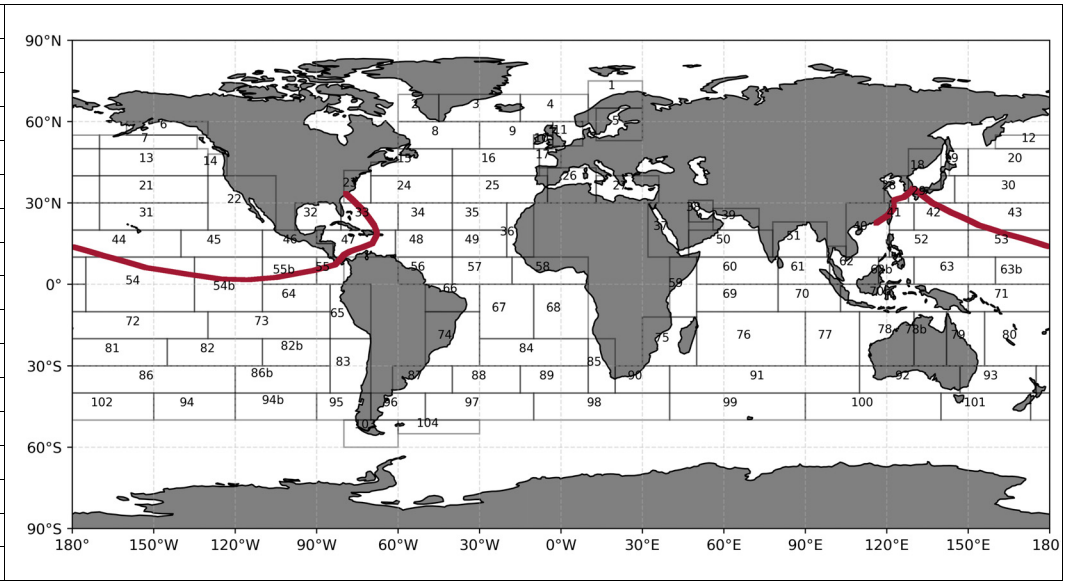


Table 15 : Specific route South Africa - Asia

Crossed area	% time
61	17%
62	7%
69	7%
70	9%
75	13%
76	30%
90	17%

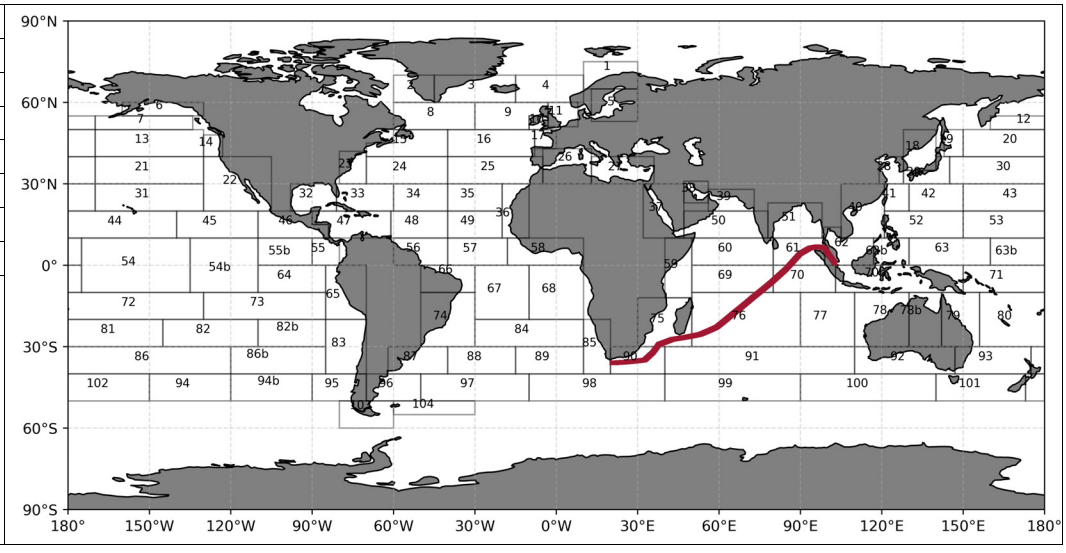


Table 16 : Specific route North America (West) - Indonesia

Crossed area	% time
7	14%
12	9%
13	7%
14	7%
18	9%
19	4%
20	6%
22	8%
29	4%
40	13%
41	10%
62	9%

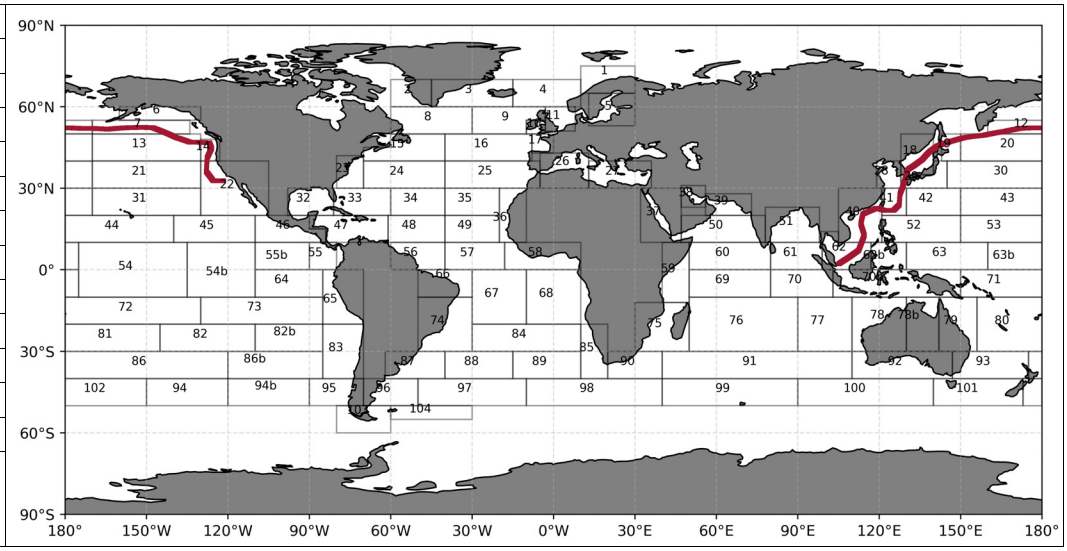


Table 17 : Specific route North Pacific (between 40°N and 50°N)

Crossed area	% time
13	29%
14	8%
19	7%
20	11%
22	6%
29	39%

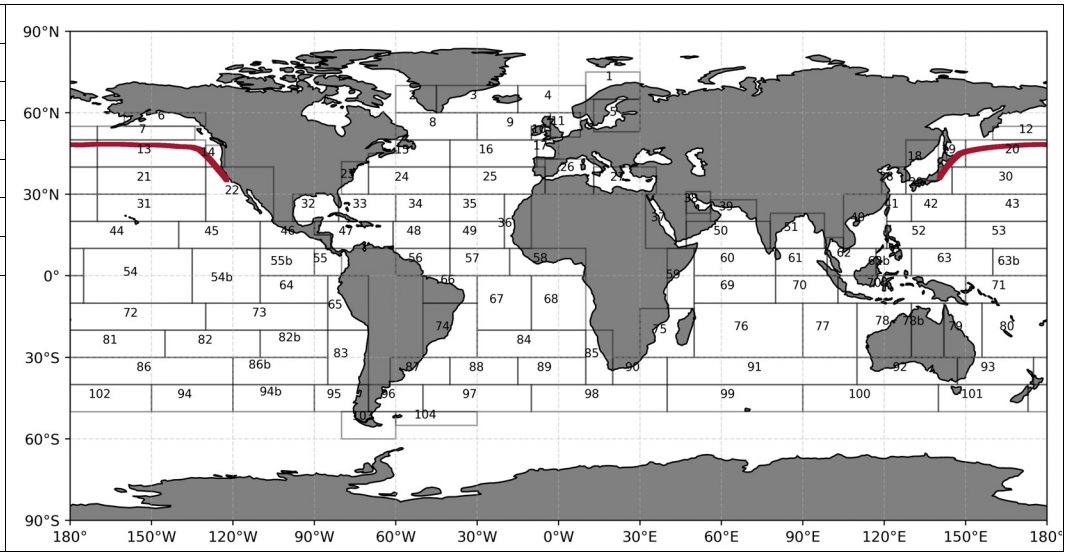


Table 18 : Specific route North Pacific (between 30°N and 40°N)

Crossed area	% time
21	35%
22	10%
28	1%
29	16%
30	31%
40	1%
41	6%

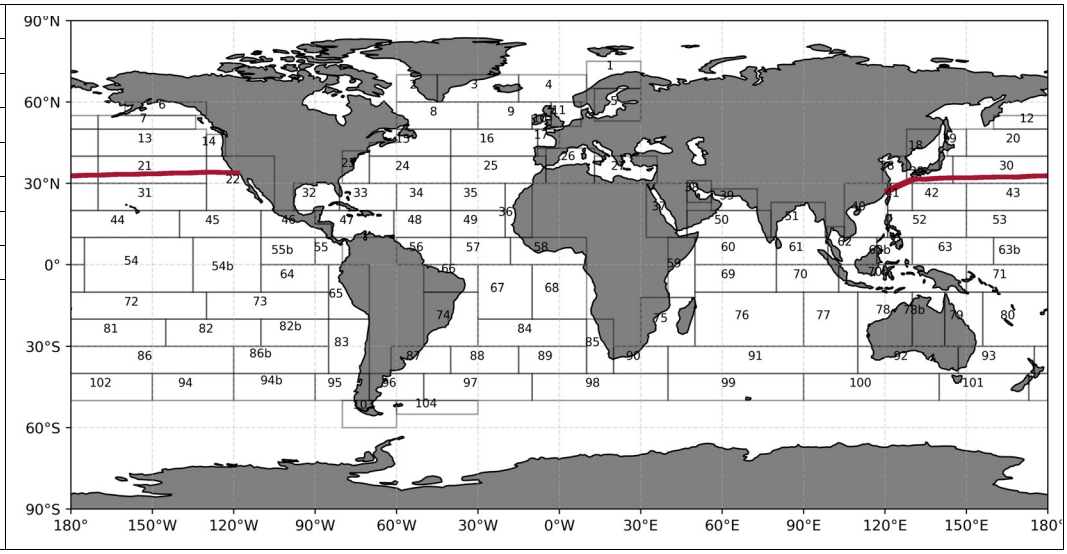


Table 19 : Specific route South America - Asia

Crossed area	% time
13	16%
14	3%
19	3%
20	13%
22	15%
29	3%
46	13%
55	6%
65	12%
83	12%
95	4%

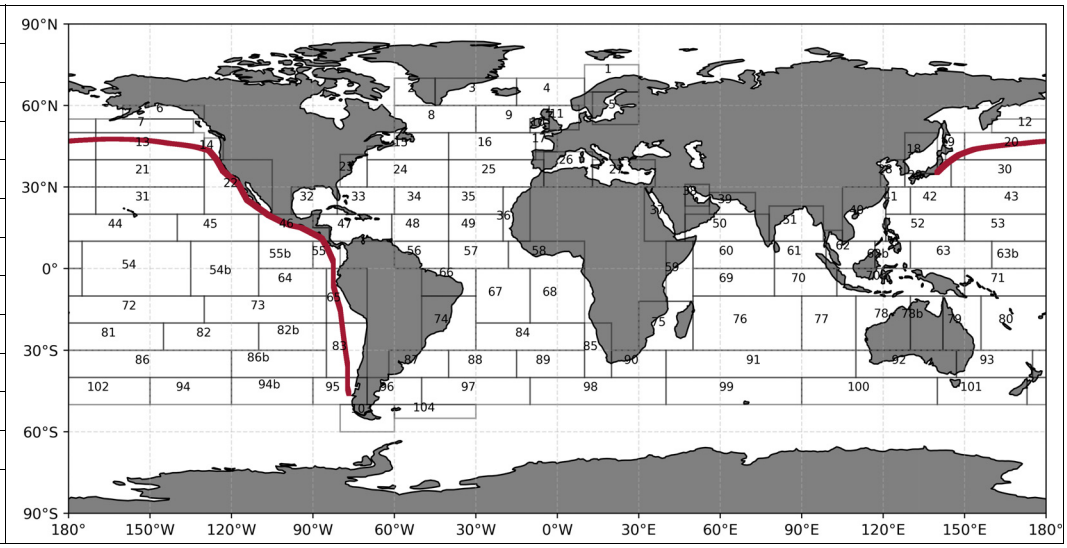


Table 20 : Specific route Indonesia - Asia

Crossed area	% time
28	10%
29	20%
40	35%
41	6%
62	19%
70b	10%

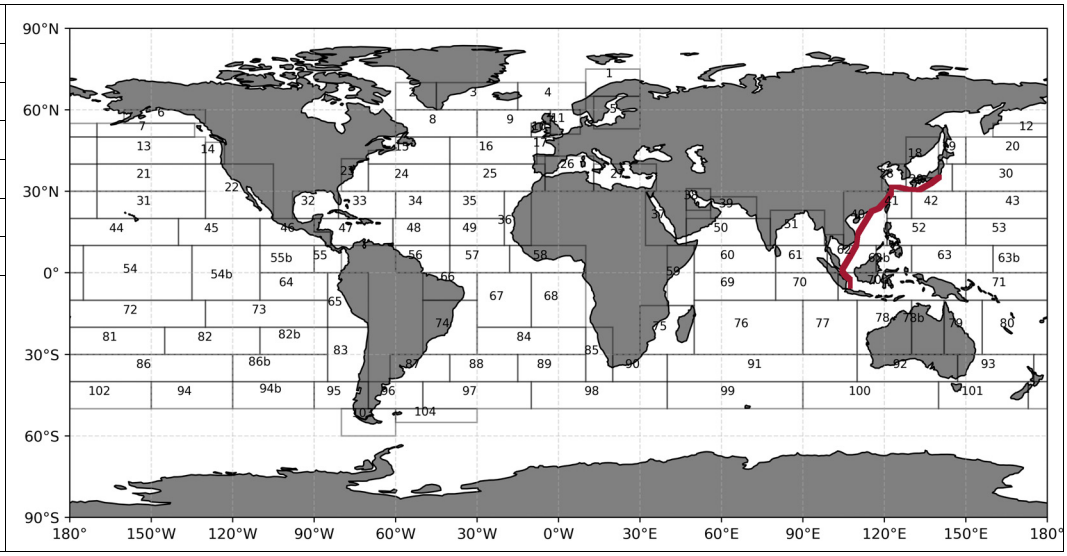
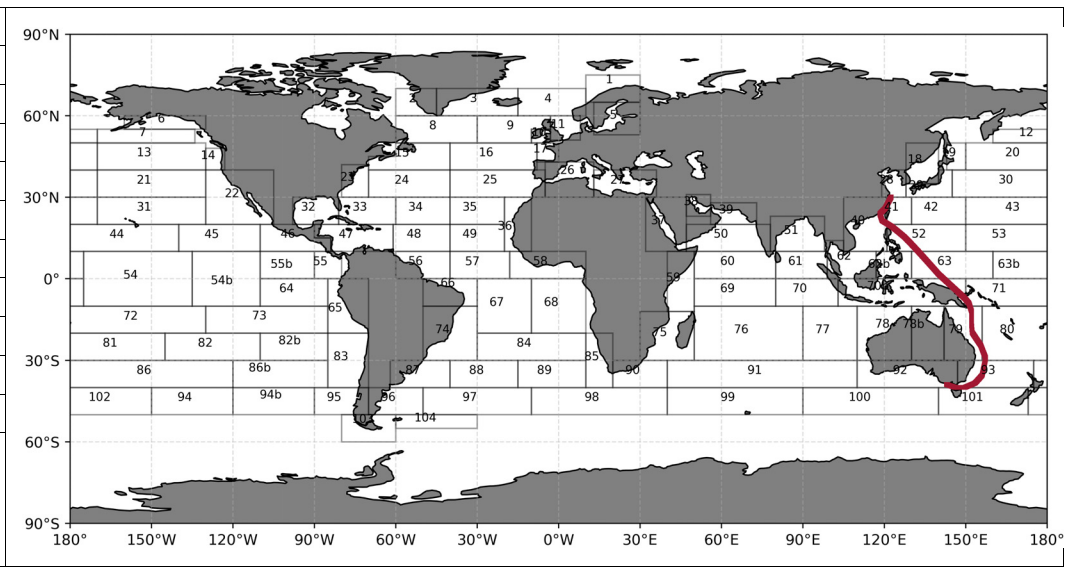


Table 21 : Specific route Asia - Australia

Crossed area	% time
40	9%
41	4%
52	16%
63	14%
70b	12%
71	3%
79	18%
80	5%
92	4%
93	15%



CHAPTER 13
ADDITIONAL NOTATION FOR FIRE PROTECTION

Section 1 Enhanced Fire Protection (EFP-AMC)

Section 2 Enhanced Cargo Fire Protection for Container Ships (ECFP)

Section 3 Cofferdam Ventilation (COVENT)

Section 4 Enhanced Fire Protection for Ships carrying Electrical Vehicles (EVFP)

Section 1 Enhanced Fire Protection (EFP-AMC)

1 General

1.1 Application

1.1.1 The following additional class notations may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.19.1] to ships complying with the requirements of this Section:

- **EFP-A** for cargo ships and tankers having enhanced fire safety protection in accommodation spaces (see applicable requirements in Article [2])
- **EFP-M** for cargo ships, tankers and passenger ship having enhanced fire safety protection in machinery spaces (see applicable requirements in [3])
- **EFP-C** for cargo ships and tankers having enhanced fire safety protection in cargo area (see applicable requirements in [4])
- **EFP-AMC** for cargo ships and tankers complying with all the requirements of this Section.

2 Protection of accommodation spaces (EFP-A)

2.1 Application

2.1.1 This article is applicable to cargo ships and tankers assigned the additional class notation **EFP-A** or **EFP-AMC**.

2.2 Prevention of fire

2.2.1 Furniture in stairway enclosures

Furniture in stairway enclosures is to be limited to seating. It is to be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk determined in accordance with the Fire Test Procedures Code, and is not to restrict the escape route. Furniture is not to be permitted in corridors forming escape routes in cabin areas. In addition to the above, only lockers of non-combustible material, providing storage for non-hazardous safety equipment required by the regulations, may be permitted.

2.3 Detection and alarm

2.3.1 A fixed fire detection and fire alarm system of addressable type is to be so installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors, stairways and escape routes within accommodation spaces. Heat detectors in lieu of smoke detectors may be installed in galleys and refrigerated spaces. Spaces having little or no fire risk such as voids, public toilets, private bathrooms, carbon dioxide rooms and similar spaces need not be fitted with a fixed fire detection and alarm system.

2.4 Containment of fire

2.4.1 Method of protection in accommodation area

Only method of protection IC, in accordance with Pt C, Ch 4, Sec 5, [1.4.1], is to be adopted in accommodation and service spaces and control stations.

2.4.2 Subdivision

a) All divisional bulkheads, linings, ceilings in accommodation spaces, service spaces and control stations are to be of at least B-15 class. Private sanitary units are considered as part of the cabin in which they are located, and the corresponding bulkhead and door reduced to C-class division.

b) Corridors in accommodation spaces are to be divided by self-closing class B-15 doors at a maximum distance of 20m from each other. When transversal corridors and longitudinal corridors are connected to each other, self-closing class B-15 doors are also to be provided if the total corridor length exceeds 20 m.

2.4.3 Fire integrity of bulkheads and decks

a) All decks in accommodation spaces, including corridors, and service spaces are to be of minimum A-0 class.

b) All bulkheads and decks separating the accommodation spaces from machinery spaces, cargo holds and ballast and cargo pump rooms, as applicable, are to have an A-60 rating. This requirement does not apply to fire category 7 machinery spaces located within the accommodation spaces and only serving accommodation and service spaces, such as air conditioning spaces and service trunks.

2.4.4 Doors in fire-resisting divisions

All doors fitted in the corridor bulkheads (providing access to cabins, public spaces, etc.) are to be of self-closing type. Service hatches and normally locked doors need not to comply with this requirement.

2.5 Escape

2.5.1 Dead-end corridors

A corridor, lobby, or part of a corridor from which there is only one route of escape is prohibited. Dead-end corridors used in service areas which are necessary for the practical utility of the ship, such as fuel oil stations and athwartship supply corridors, are permitted, provided such dead-end corridors are separated from accommodation areas. Also, a part of a corridor that has a depth not exceeding its width is considered a recess or local extension and is permitted.

2.5.2 Means of escape

Spaces exceeding 30 m^2 are to be provided with at least two means of escape, as widely separated as possible. Both means of escape are to be a door having direct access to a corridor, a stairway or an open deck.

3 Protection of machinery spaces (EFP-M)

3.1 Application

3.1.1 This Article is applicable to ships having the assigned class notation **EFP-M** or **EFP-AMC**.

3.2 Machinery spaces general arrangement

3.2.1 Segregation of thermal oil heaters and incinerators

Oil fired thermal oil heaters and incinerators are subject to the same segregation requirements as for purifiers (see Pt C, Ch 4, Sec 6, [4.1.2]). They are to be placed in a separate room, enclosed by steel bulkheads extending from deck to deck and provided with self-closing steel doors.

3.2.2 Location of hydraulic power units

The requirement of Pt C, Ch 1, Sec 10, [14.3.3] is replaced by the following requirement:

- Hydraulic power units are to be located outside main engine or boiler rooms.

3.3 Detection and alarm

3.3.1 Fixed fire detection and fire alarm system

a) All machinery spaces, including auxiliary machinery spaces, are to be covered by the fixed fire detection and fire alarm system.

b) Fire detectors of more than one type are to be used for the protection of machinery spaces of category A. Flame detectors are to be provided in addition to smoke detectors, in way of engines, heated fuel oil separators, oil fired boilers and similar equipment.

c) Smoke detectors located in workshops are to be connected to a timer function which automatically resets after maximum 30 minutes.

3.3.2 TV monitoring system

Machinery spaces of category A are to be provided with a color TV monitoring system, covering all hot spots, such as engines with rated power above 375 kW, heated fuel oil separators, oil fired boilers and emergency diesel engine when it is used in port (Ch 2, Sec 3, [2.4]). Monitors are to be located in a manned control station or in an engine control room.

3.4 Ventilation system

3.4.1 In machinery spaces of category A, at least one exhaust ventilation fan is to have a supply from the emergency source of power, in order to permit, after a fire, the release of smoke and gaseous extinguishing agent, if any.

3.5 Fixed water-based local application fire-fighting system

3.5.1 The fixed water-based local application fire-fighting system is to be provided with an automatic release.

3.5.2 The system release is to be controlled by a combination of flame and smoke detectors. The detection system is to provide an alarm upon activation of any single detector and discharge if two or more detectors activate. The detection system zones are to correspond to the extinguishing system zones.

3.5.3 The fixed water-based local application fire-fighting system is to be supplied from both the main and emergency source of power.

3.6 Escape

3.6.1 Escape from machinery control rooms, workshops and auxiliary machinery spaces

Two means of escape are to be provided from a machinery control room located within a machinery space, at least one of which will provide continuous fire shelter to a safe position outside the machinery space. This is also applicable to workshops, and, as far as practicable, to auxiliary machinery spaces.

3.7 Central control station

3.7.1 Cargo ships and tankers

Controls required:

- in items a) to d) of Pt C, Ch 4, Sec 2, [2.1.2]
- in Pt C, Ch 4, Sec 4, [3.2.1]
- in Pt C, Ch 4, Sec 5, [4.2.2], and
- the controls for any required fire-extinguishing system and CCTV system controls,

are to be located in a central control station, having a safe access from the open deck.

However, controls for release of the fixed fire-extinguishing system in machinery spaces of category A and controls for closing of oil fuel valves are to be readily accessible but may be located outside the central control station.

3.7.2 Passenger ships

The controls for the TV monitoring system required in [3.3.2] are to be located in the safety centre required by Pt C, Ch 4, Sec 14.

4 Protection of cargo decks and cargo spaces (EFP-C)

4.1 Cargo ships

4.1.1 Application

This sub-article is applicable to dry cargo ships assigned the additional class notation **EFP-C** or **EFP-AMC**.

4.1.2 Fire detection system

A fixed fire detection and fire alarm system complying with the requirements of Pt C, Ch 4, Sec 15 or a sample extraction smoke detection system complying with the requirements of Pt C, Ch 4, Sec 15 is to be installed in all dry cargo holds.

4.1.3 Fire fighting

Cargo spaces are to be protected by a fixed carbon dioxide or inert gas fire-extinguishing system, in compliance with Pt C, Ch 4, Sec 6, [6].

The exemption clause, as referred to in Pt C, Ch 4, Sec 6, [6.1.4], is not applicable to ships intended for the additional class notation **EFP-C** or **EFP-AMC**.

4.2 Ro-ro cargo ships, PCTC and PCC

4.2.1 Application

This sub-article is applicable to ships assigned the additional class notation **EFP-C** or **EFP-AMC** and the service notation **ro-ro cargo ship** or **PCTC** or **PCC**.

4.2.2 Fire detection system

A fixed fire detection and fire alarm system of addressable type is to be so installed and arranged as to provide smoke detection in all ro-ro spaces.

4.3 Oil tankers, FLS tankers and chemical tankers

4.3.1 Application

This sub-article is applicable to ships assigned the additional class notation **EFP-C** or **EFP-AMC** and one of the following service notations: **oil tanker**, **FLS tanker** or **chemical tanker**.

4.3.2 Fire detection system in cargo pump rooms

A fixed fire detection and fire alarm system complying with the requirements of Pt C, Ch 4, Sec 15 and approved for use in gas hazardous atmosphere is to be so installed and arranged as to provide smoke detection in cargo pump rooms. Controls are to be located in the cargo control room, if any, and in the wheelhouse.

4.3.3 Fire main

The fire main on deck is to be arranged as a ring main laid to the port and starboard side. Isolation valves are to be globe valves of steel or fire safe butterfly valves. Main fire pumps are to be remote-controlled from the wheelhouse.

4.3.4 Foam system

a) For oil tankers of less than 4000 GT, foam from the fixed foam system is to be supplied by means of monitors and foam applicators. Use of applicators only, as per Note 2 in Pt D, Ch 7, Sec 6, [3.2.1], item d), is not applicable.

b) Tankers of 4000 GT and upwards need an independent foam main, arranged along the centreline as a single line with foam outlet branches to both port and starboard arranged just aft of each monitor. At least two foam mixing units and two foam concentrate pumps are to be provided, placed together with the storage tank for foam concentrate in a dedicated room. Foam concentrate sufficient for 30 minutes of continuous foam production are to be stored onboard. Two foam monitors at each side of the accommodation front and monitors covering the cargo manifold are to be remote-controlled from the bridge or from another safe area with a good visibility to the monitors coverage area.

4.3.5 Water-spray protection of lifeboats

If lifeboats are not separated by steel bulkheads from the cargo area, a manual water-spraying system giving an effective average distribution of water of at least 10 l/min/m^2 over the sides and top of each lifeboat is to be provided. It may be taken from the fire main with the isolating valve located outside the protected area, if the capacity of the fire pumps is sufficient for simultaneous activation of the water-spraying system and the fire main system. In any case, the system is to be remote-controlled from the wheelhouse.

4.3.6 Inert gas system

An inert gas system complying with Pt D, Ch 7, Sec 6, [5] or Pt D, Ch 8, Sec 9, [2], as applicable, is to be provided for all tankers assigned additional class notation **EFP-C** or **EFP-AMC**, even if less than 8000 DWT. This is however not applicable to oil tankers having the additional service feature **flash point > 60°C**.

4.4 Liquefied gas carriers

4.4.1 Application

This sub-article is applicable to ships assigned the additional class notation **EFP-C** or **EFP-AMC** and the service notation **liquefied gas carrier**.

4.4.2 Fire detection system

A fixed fire detection and fire alarm system complying with the requirements of Pt C, Ch 4, Sec 15, [8] and approved for use in gas hazardous atmosphere is to be so installed and arranged as to provide smoke detection in enclosed spaces / areas containing cargo handling equipment, such as compressor and pump rooms, reliquefaction room, regasification spaces, and electric motor room within the cargo area. Controls are to be located in the wheelhouse.

4.4.3 Fixed fire-extinguishing system in electrical rooms

Enclosed spaces/areas containing cargo handling equipment, such as compressor and pump rooms, reliquefaction room, regasification spaces, and electric motor room within the cargo area should be provided with a fixed gas fire extinguishing system complying with the requirements of Pt C, Ch 4, Sec 15, [4] taking into account the necessary concentrations required for extinguishing gas fires or water-mist fire extinguishing system complying with the requirements of Pt C, Ch 4, Sec 15, [6].

4.4.4 Fire main

The fire main on deck is to be arranged as a ring main laid to the port and starboard side. Isolation valves are to be globe valves of steel or fire safe butterfly valves. Main fire pumps are to be remote-controlled from the wheelhouse.

4.4.5 Dry chemical powder fire-extinguishing system

The dry chemical powder fire-extinguishing system complying with the requirements of Pt D, Ch 9, Sec 11, [1.4.2] is subject to the following additional requirement:

- Sufficient dry powder quantity is to be stored on board to provide 60 s operation.

4.4.6 Fire extinguishing arrangement in vent mast of gas carriers

A fixed system for extinguishing a fire at the vent outlet is to be provided inside venting masts for cargo tank venting system. Nitrogen, CO_2 or any other suitable medium is acceptable.

4.4.7 Water-spray protection of lifeboats

If lifeboats are not separated by steel bulkheads from the cargo area, a manual water-spraying system giving an effective average distribution of water of at least 10 l/min/m^2 over the sides and top of each lifeboat is to be provided. It may be taken from the fire main with the isolating valve located outside the protected area, if the capacity of the fire pumps is sufficient for simultaneous activation of the waterspraying system and the fire main system. In any case, the system is to be remote-controlled from the wheelhouse.

5 Onboard testing

5.1 Hot spot verification

5.1.1 Compliance with the requirements of Pt C, Ch 1, Sec 1, [3.7.1] is to be confirmed through thermal imaging scanning of engines, boilers, steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers or other equipment where hot surfaces above 220 °C may be expected. This verification is to be carried out with the engines or concerned equipment under steady and normal operating conditions.

5.1.2 Thermal imaging measurements are to be performed:

- in accordance with a recognized methodology accepted by the Society
- with suitably calibrated equipment
- by qualified personnel.

The society may require that the measurements be witnessed by a surveyor.

Section 2 Enhanced Cargo Fire Protection for Container Ships (ECFP)

1 General

1.1 Application

1.1.1 This Section applies to ships fitted with equipment, systems and arrangements improving the ability to manage a container cargo fire.

A ship complying with the requirements of this Section may be assigned one of the following additional class notations:

- **ECFP-1** when the ship is fitted with portable equipment and arrangements, as per Article [2], that may be considered as retrofit for an existing ship
- **ECFP-2** when, in addition to the requirements for the notation **ECFP-1**, the ship is fitted with equipment, systems and arrangements, as per Article [3], which constitute an extensive set of mitigation measures deemed effective and available with standard technologies
- **ECFP-3** when, in addition to the requirements for the above-mentioned notations, the ship is fitted with equipment, systems and arrangements as per Article [4], which include measures that are deemed relevant using innovative technologies.

In general, the additional class notations **ECFP-1**, **ECFP-2** or **ECFP-3** may be assigned to ships having the service notation **container ship**.

In general, the additional class notation **ECFP-1** may also be assigned to ships assigned the additional service feature **- equipped for carriage of containers**.

Tab 1 details equipment, systems and arrangements to be considered for the assignment of notations **ECFP-1**, **ECFP-2** and **ECFP-3**.

1.1.2 The additional class notations **ECFP-2** and **ECFP-3** are to be completed by the notation (**Area 1, X_1m; …; Area n, X_nm**), where:

- **Area n** indicates the cargo holds where the maximum flooding level $\mathbf{X_n}$ is allowed
- $\mathbf{X_n}$ corresponds to the maximum flooding level in area n, in meters, with respect to the bottom of the hold (see [3.8]).

Examples:

ECFP-2(All cargo holds, 20m)

ECFP-3(Holds 1 to 4,16m; Holds 5 to 8, 20m; Holds 9 to 12, 15m)

Table 1 : Applicable requirements to assign the ECFP notations

Item	Additional class notation		
	ECFP-1	**ECFP-2**	**ECFP-3**
Water-mist lances	[2.2.1]		
Portable fire-fighting devices for stacked containers **(1)**	[2.2.2]		[4.3.1]
Fire fighter's outfits	[2.2.3]		[4.3.2]
Equipment for fire patrols	[2.2.4]		
Compressed air system for breathing apparatus	[2.3]		
Central control station	–	[3.2]	[4.2]
Fire detection system **(1)**	–	[3.3]	[4.4]
Water supply	–	[3.4]	
Mobile water monitors **(1)**	–	[3.5]	
Fixed water monitors covering the on-deck cargo stowage area **(1)**	–	[3.6]	
Water-spray system below hatch cover **(1)**	–	[3.7]	[4.5]
Flooding system for the cargo hold **(1)**	–	[3.8]	
Water-spray system for the protection of the superstructure block **(1)**	–	[3.9]	
Ventilation **(1)**	–	[3.10]	[4.6]
(1) For onboard tests, reference is made to [5.3]			

1.2 Innovative technologies

1.2.1 Special consideration may be given to innovative technologies proposed in lieu of, or as an improvement of, the systems required by this Section, especially regarding:

- fire detection, see [4.4]
- cargo hold fire protection, see [3.7.1].

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 2 are to be submitted.

Table 2 : Documentation to be submitted

No	I/A **(1)**	Document
1	I	General arrangement showing the disposition of all fire-fighting equipment
2	A	Natural and mechanical ventilation systems showing the location of dampers, means of closing, arrangements of fans or air conditioning rooms
3	A	Automatic fire detection systems and manually operated call points
4	A	Fire pumps and fire main including pump's head and capacity, hydrant and hose locations
5	A	Arrangement of the water-based systems and flooding system required by [3.6], [3.7], [3.8] and [3.9] **(2)**
6	A	Details of the water monitors, including their capacity, range and trajectory of delivery
7	A	Plan of the water monitor seating arrangements
8	A	Diagram of control systems for the water-based systems and flooding system required by [3.6] [3.7], [3.8] and [3.9]
9	I	Operating manuals for the water-based systems and flooding system required by [3.6], [3.7], [3.8] and [3.9]
10	A	Fire control plan showing the portable equipment, spaces covered by, and particulars of, the systems required in the present Section, including the cargo holds covered by: • the water-spray system below hatch cover described in [3.7] • the cargo hold flooding system described in [3.8]
11	I	Cargo hold flooding control booklet as detailed in [3.8.12]

(1) A : to be submitted for approval; I : to be submitted for information

(2) Plans are to be schematic and functional and to contain all information necessary for their correct understanding and verification such as:

- service pressures
- capacity and head of pumps and compressors, if any
- materials and dimensions of piping and associated fittings
- volumes of protected spaces, for gas and foam fire-extinguishing systems
- surface areas of protected zones for automatic sprinkler and pressure water-spraying, low expansion foam and powder fire-extinguishing systems
- capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, automatic sprinkler, foam and powder fire-extinguishing systems
- type, number and location of nozzles of extinguishing media for gas, automatic sprinkler, pressure water-spraying, foam and powder fire-extinguishing systems.

All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.

2 Requirements for the notation ECFP-1

2.1 General

2.1.1 Ships intended to be assigned with the notation **ECFP-1** are to comply with the requirements of [2.2] and [2.3].

2.2 Portable equipment

2.2.1 Water-mist lances

The ship is to be equipped with a water-mist lance complying with the requirements of Pt C, Ch 4, Sec 6, [6.3.1].

2.2.2 Portable fire-fighting device for stacked containers

In addition to the water-mist lance required in [2.2.1], the ship is to be equipped with a portable fire-extinguishing device of a type approved by the Society according to [5.1], capable to reach the highest level of containers or the 5th tier of containers above the upper lashing bridge, whichever is the lowest. This device is to be able to pierce the wall of a standard container and of spraying water inside the container when connected to the fire main and raised at this level.

2.2.3 Fire-fighter's outfits

At least 6 fire-fighter's outfits are to be available on board. Two spare charges are to be available for each breathing apparatus.

The air breathing apparatus provided for these fire-fighter's outfits may be combined with those required by Pt C, Ch 4, Sec 12, [2.7.3].

2.2.4 Equipment for fire patrols

A portable thermal imaging camera is to be available on board.

2.3 Compressed air system for breathing apparatuses

2.3.1 The ship is to be equipped with at least two breathing air compressors supplied from the main and emergency switchboard, or independently driven, complete with all fittings necessary for refilling the bottles of air breathing apparatuses. The compressors are to be located in at least two sheltered and widely separated locations.

2.3.2 The aggregate capacity of the compressors is to be sufficient to allow the refilling of 2 bottles for air breathing apparatuses in no more than 10 min.

2.3.3 The air suctions of the compressors are to be fitted with a suitable filter. The outlets of the compressors are to be fitted with oil separators and filters capable of preventing passage of oil droplets or vapours to the air bottles.

3 Additional requirements for the notation ECFP-2

3.1 General

3.1.1 In addition to the requirements of Article [2], ships intended to be assigned the notation **ECFP-2** are to comply with the requirements of [3.2] to [3.10].

3.2 Central control station

3.2.1 Control and monitoring functions for the safety systems required in this article are to be grouped in a continuously manned central control station as summarized in Tab 3. The continuously manned central control station, as defined in Pt C, Ch 4, Sec 1, [2.17.1], may be the wheelhouse or a dedicated fire control station continuously manned by a responsible member of the crew.

Table 3 : Monitoring and controls required in the continuously manned central control station

Parameter		Monitoring		Control	Rule reference
		Alarm	Indication		
Fire detection		X	X (Location of detection)	-	[3.3.1], [4.4]
Fixed water monitors covering the on-deck cargo stowage area	Pump			X	[3.6.5]
Water-spray below hatch cover	Pump			X	[3.7.2]
Flooding system for the cargo holds	Sea water level in cargo hold	H, HH	X		[3.8.5]
	Isolating valves		X (Position of the valve)	X	[3.8.4]
	Pump			X	[3.8.4]
Water-spray for the protection of the superstructure blocks	Valves			X	[3.9.6]
	Pumps			X	[3.9.6]

3.3 Fire detection

3.3.1 Fire detection in cargo holds

Under deck cargo holds are to be fitted with either a fixed fire detection and fire alarm system or a sample extraction smoke detection system complying with the requirements of Pt C, Ch 4, Sec 15.

3.4 Water supply systems

3.4.1 General system design

This requirement applies to the systems specified in [3.6] to [3.9].

Pipes are to be designed and manufactured according to the requirements of Pt C, Ch 1, Sec 10.

Steel pipes are to be protected against corrosion, both internally and externally, by means of galvanising or equivalent method.

Suitable drainage cocks are to be arranged and precautions are to be taken in order to prevent clogging of spray nozzles by impurities contained in pipes, nozzles, valves and pumps.

3.4.2 Arrangement of the fire main

The fire main is to be arranged as a ring main laid to the port and starboard side with isolation valves installed at regular intervals. As a minimum it is to be possible to isolate the following sections from the rest of the fire main:

- Sections of the fire main serving accommodation, machinery, service spaces and control stations located in each superstructure block or in the forecastle
- Sections of the fire main serving cargo holds and cargo stowage areas on deck located aft of superstructure blocks, between two superstructure blocks or forward of the superstructure blocks.

Isolation valves are to be steel globe valves or fire safe butterfly valves.

Arrangements are to be made to ensure immediate availability of a supply of water from the fire main at the required pressure either by permanent pressurization or by suitably placed remote arrangements for the fire pumps.

The quantity of water delivered is to be capable of supplying four nozzles of a size and at pressures as specified in Pt C, Ch 4, Sec 6, [1.2.6] and Pt C, Ch 4, Sec 6, [1.4.3].

3.4.3 Fire hydrants

The arrangement of the hydrants and fire hoses is to allow reaching any part of the cargo holds and stowage areas on deck when empty with two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose.

The number of hydrants required by Tab 4 is to be provided forward and aft of each container bay, distributed over both sides of the ship.

Table 4 : Mobile water monitors and hydrants between container bays

Ship width B, in m	Number of hydrants forward and aft of each container bay	Number of mobile water monitors
$B \leq 30$	2	4
$30 < B \leq 45$	3	6
$45 < B \leq 60$	4	8
$B > 60$	5	10

3.4.4 Fire main capacity

The capacity of the fire pump and the fire main diameter are to be sufficient for the simultaneous use of the following combinations of systems, whichever is the most demanding:

a) Combination of:
- fire main four nozzles as required by [3.4.2], and
- water-spray system below hatch cover as required by [3.7], if the main water supply to this system is from the fire pumps, and
- one water monitor as required by [3.6], if the main water supply to this system is from the fire pumps, and
- superstructure block protection water-spray system, or alternative solution, as required by [3.9], if the main water supply to this system is from the fire pumps.

b) Combination of:
- fire main four nozzles as required by [3.4.2], and
- the water-mist lance required by [2.2.1] or the portable fire-fighting device for stacked containers required by [2.2.2] or [4.3.1], and
- mobile water monitors required by Pt C, Ch 4, Sec 6, [6.3], considering the most demanding flowrate of:
  - All water monitors required by [3.5] at their minimum capacity, or
  - Water monitors ensuring 4 L/min/m^2 water application rate on the largest projected area (width x height) of exposed containers in a bay.

3.5 Mobile water monitors

3.5.1 The ship is to be equipped with the number of mobile water monitors required by Tab 4. The mobile water monitors required by Pt C, Ch 4, Sec 6, [6.3.2] may be included in this number.

3.5.2 The mobile water monitors are to be of a type approved by the Society according to IMO Circular MSC.1/Circ.1472.

3.6 Fixed water monitors covering the on-deck cargo stowage area

3.6.1 A system of fixed water monitors is to be provided on board in order to protect the cargo stowage area on deck.

3.6.2 The arrangement, height and length of throw of the monitors are to be such that any point on the top of the container stacks can be reached by the water jet from one monitor, taking into account the maximum height of the container stacks. The monitors are to be located such that the water jet is free from obstacles, including ship's structure and equipment.

Note 1: The length and height of throw of the monitors are to be measured from the monitor position to the mean impact area.

3.6.3 The capacity of the pump and arrangement of the piping system supplying water to the water monitors is to be sufficient to achieve the full throw of any two monitors simultaneously.

The system may be fed by the fire pumps provided their capacity is in accordance with [3.4.4].

3.6.4 Water supply redundancy

Water supply to the system is to comply with one of the following alternatives

a) The system is to be fed by the fire pumps and compliance with [3.4.4] is to be ensured; or

b) The system is to be fed by dedicated pumps and as a backup the main supply line of the system is to be connected to the fire main through a stop valve located as far as possible from the container cargo holds and stowage area on deck; or

c) The system is to be provided with a redundant means of pumping. The capacity of the redundant means is to be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity by more than 50%. Switch over to redundant means of pumping may be manual or automatic.

3.6.5 Controls

The controls of the pump supplying water to the water monitors are to be available locally and from the continuously manned central control station. Controls for the fixed water monitors are to be available locally.

3.6.6 Water monitors are to be of an approved type and are to be capable of throwing a continuous full water jet without significant pulsations and compacted in such a way as to be concentrated on a limited surface.

Monitors are to be capable of withstanding the reaction forces of the water jet.

3.6.7 The seatings of the monitors are to be of adequate strength for all modes of operation.

3.6.8 The strengthening of the structure of the ship, where necessary to withstand the forces imposed by the water monitor system when operating at its maximum capacity in all possible directions of use, is to be considered by the Society on a case-by-case basis.

3.6.9 Scuppers

Scuppers are to be fitted so as to ensure that the water is rapidly discharged overboard. Means are to be provided to prevent the blockage of drainage arrangements and any obstruction to the flow of water towards the scuppers, e.g. due to horizontal structures on deck, is to be avoided.

3.7 Water-spray system below hatch cover

3.7.1 Means are to be provided for effectively cooling the under-deck cargo holds specified by the Owner or Designer taking into account the fire risk in each cargo hold by at least 5 L/min per square metre of the horizontal area of cargo spaces by a fixed arrangement of spraying nozzles. At least one cargo hold is to be provided with a water-spray system and cargo holds adjacent to low flashpoint or gaseous fuels containment system, or adjacent to surrounding cofferdam if any, are to be provided with a water-spray system.

Alternatively, equivalent water-mist systems may be considered on a case-by-case basis, based on fire testing to the satisfaction of the Society.

3.7.2 Controls

It is to be possible to operate the drainage valves required by [3.7.9] from a position close to the location of the isolating valves required by [3.7.5]. The pump controls necessary to activate the system are to be available in the continuously manned central control station.

3.7.3 The system supply equipment and piping are to be located outside the protected cargo holds and all power supply components (including cables) are to be installed outside of the protected cargo holds.

3.7.4 It is to be possible to feed each nozzle in any cargo hold from piping located on either side of the ship. The piping system should be sized in order to ensure the availability of the flows and pressures required for correct performance of the system, considering that water is supplied from both sides.

3.7.5 Isolating valves

Isolating valves are to be provided to separate the section of the system located inside each cargo hold from the rest of the system. The isolating valves are to be located outside of the protected cargo hold.

3.7.6 Pump capacity

The capacity of the system water supply is to be sufficient to feed the water-spray system in any one cargo hold.

The system may be fed by the fire pumps provided their capacity is in accordance with [3.4.4].

3.7.7 Water supply redundancy

Water supply to the water-spray system is to comply with one of the following alternatives:

a) The system is to be fed by the fire pumps and compliance with [3.4.4] is to be ensured; or

b) The system is to be fed by dedicated pumps and as a backup the main supply line of the system is to be connected to the fire main through a stop valve located as far as possible from the container cargo holds and stowage area on deck; or

c) The system is to be provided with a redundant means of pumping. The capacity of the redundant means is to be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity by more than 50%. Switch over to redundant means of pumping may be manual or automatic.

3.7.8 International shore connection

An international shore connection as defined in Pt C, Ch 4, Sec 15, [2] is to be available on each side of the ship, allowing quick connection of the water-spray piping to an external water supply.

3.7.9 Bilge drainage

The drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces. The drainage system is to be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles.

The drainage system valves are to be operated from outside the protected cargo hold at a position in the vicinity of the extinguishing system controls.

Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40m in each watertight compartment. If this is not possible, the adverse effect upon stability of the added weight and free surface of water are to be taken into account to the extent deemed necessary by the Society in its approval of the stability information.

For cargo holds where the carriage of dangerous goods of classes 3 (FP < 23°C), 6.1 (liquids) or 8 (liquids) is intended, the drainage arrangements are to comply with the provisions of Pt C, Ch 4, Sec 12, [2.6].

3.8 Flooding system for the cargo holds

3.8.1 Means are to be provided to allow flooding with sea water of any one of the under-deck cargo holds specified by the Owner or Designer taking into account the fire risk in each cargo hold, up to the maximum flooding level defined for each cargo hold. As a minimum, cargo holds adjacent to low flashpoint or gaseous fuels containment system, or adjacent to surrounding cofferdam if any, are to be covered by the flooding system. However, cargo holds adjacent to hold spaces for low flashpoint or gaseous fuels type C tanks covered by a water-based fixed fire-extinguishing system need not necessarily be provided with means for flooding.

A piping connection from the ballast system is acceptable for this purpose.

Note 1: Simultaneous flooding of several cargo holds is not considered.

3.8.2 Maximum flooding level

The maximum flooding level in one cargo hold is the maximum allowable water level in this specific hold, and is to comply with the requirements of [3.8.9] to [3.8.11]. The maximum flooding level with respect to the bottom of the hold, X_n, in m, is to be specified by the Owner or the Designer.

$$X_n = z_{MAWL} - z_{n,Bottom}$$

where:

$z_{n,Bottom}$: Height above the baseline, in m, of the lowest point in cargo hold n

z_{MAWL} : Height above the baseline, in m, of the maximum flooding level in the considered cargo hold

3.8.3 Redundancy of water supply

Water supply for the flooding system is to comply with one of the following alternatives:

a) The system is to be fed by the fire pumps and compliance with [3.4.4] is to be ensured; or

b) The system is to be fed by dedicated pumps and as a backup the main supply line of the system is to be connected to the fire main through a stop valve located as far as possible from the container cargo holds and stowage area on deck; or

c) The system is to be provided with a redundant means of pumping. The capacity of the redundant means is to be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity by more than 50%. Switch over to redundant means of pumping may be manual or automatic; or

d) Gravity filling arrangements may be considered on a case-by-case basis.

3.8.4 Means of control

Each cargo hold covered by the flooding system is to be served by one or several isolation valves which are to be located in a safe location outside of the protected hold. It is to be possible to remotely open or close these valves from the continuously manned central control station. In addition, indication of the position of these valves is to be provided at the continuously manned central control station.

The isolation valves are to be of a fail-close design and suitable marking should be provided to ensure that they will not be opened during normal ship operation.

It is to be possible to remotely start the pumps serving this system from the same location.

In case dangerous goods of Class 4.3 are intended to be carried in a cargo hold, an instruction plate is to be provided close to the controls of the system, informing that these cargoes may react with water.

3.8.5 Water level detectors are to be provided in the cargo hold and are to trigger high and high high level alarms at the continuously manned central control station. The setting of the alarms is to be consistent with the maximum flooding level defined in [3.8.2].

3.8.6 Drainage

a) Removable gratings, screens or other means are to be installed over each drain opening in the cargo holds to prevent debris from blocking the drain. The gratings or screens are to be raised above the deck or installed at an angle to prevent large objects from blocking the drain.

b) For cargo holds where the carriage of dangerous goods of classes 3 (FP < 23°C), 6.1 (liquids) or 8 (liquids) is intended, the drainage arrangements are to comply with the provisions of Pt C, Ch 4, Sec 12, [2.3] and Pt C, Ch 4, Sec 12, [2.6]. Alternatively, provisions for external discharge of the flooding water may be considered.

3.8.7 The provisions of Pt C, Ch 1, Sec 10, [5.5] for the prevention of progressive flooding are to be applied.

3.8.8 The total cross-sectional area of the ventilation openings of the cargo holds is not to be less than 1,25 times the cross-sectional area of the pipes that will be used to flood the cargo holds.

3.8.9 Loading conditions

a) Loading conditions

The following loading condition is to be considered:

FH : Loading condition defined in Pt D, Ch 2, Sec 2, [6.1] with any one cargo hold flooded up to the maximum flooding level.

b) Still water hull girder loads

The permissible still water vertical bending moments $M_{SW\text{-}CHF\text{-}max}$ and $M_{SW\text{-}CHF\text{-}min}$ and vertical shear forces $Q_{SW\text{-}CHF\text{-}max}$ and $Q_{SW\text{-}CHF\text{-}min}$ for cargo hold flooding at any longitudinal position are to envelop the maximum and minimum vertical bending moment and shear force in FH condition calculated for each of the cargo holds covered by the cargo hold flooding system and based on the loading condition defined in Pt D, Ch 2, Sec 2, [6.1].

The permeability of the container cargo holds when flooded is to be taken equal to 0,7.

c) Design load scenario

In addition to the requirements of Pt B, Ch 5, Sec 7, the design load scenario defined in Tab 5 is to be taken into account for the verification of the hull local scantlings.

3.8.10 Structural strength

a) Hull girder strength

The hull girder strength is to be checked according to Pt B, Ch 6, Sec 1, [3.5], taking into account the following values for the partial safety factors for load combination and permissible stress.

- γ_2 = 2,1 for bending strength assessment in seagoing operation
- γ_2 = 2,2 for shear strength assessment in seagoing operation

For this purpose the permissible still water vertical bending moment $M_{SW\text{-}CHF}$ and vertical shear force $Q_{SW\text{-}CHF}$ defined in [3.8.9], item b) are to be combined with permissible torsional still water moment $M_{sw\text{-}t}$ in seagoing condition, without taking into consideration any wave hull girder loads.

b) Hull local scantlings

In addition to the requirements of Part B, Chapter 7, the local scantlings of the cargo holds and adjacent compartments are to be sufficient to withstand the design load set specified in Tab 6.

c) Direct strength analysis

In addition to the requirements of Part B, Chapter 8, cargo hold structural strength analysis is to be carried out in the loading condition detailed in Tab 7. The weight of immersed containers may be reduced by 30% of the buoyancy acting on each container considered empty. The analysis is to verify that stress levels are within the acceptance criteria for yielding and that buckling capability of plates and stiffened panels are within the acceptance criteria for buckling. The AC-3 acceptance criteria are to be applied.

Table 5 : Additional design load scenario for the verification of hull local scantlings

Load components			Design load scenario
			Cargo hold flooded (A: S)
Hull girder	VBM		$M_{sw\text{-}CHF}$
	HBM		–
	VSF		–
	HSF		–
	TM		$M_{sw\text{-}t}$
Local loads	P_{ex}	Exposed decks / Outer shell / Sides of superstructures and deckhouses	–
	P_{in}	Cargo hold boundaries	P_{hf} **(1)**
	P_{dk}	Exposed and non-exposed decks for uniform cargo	–
	F_u	Exposed and non-exposed decks for unit cargo	–

(1) The static pressure P_{hf}, in kN/m^2, in a cargo hold flooded for fire-fighting purposes is to be taken as:
$P_{hf} = \rho_{SW}\, g\, (z_{MAWL} - z)$
without being taken less than 0
where:
z_{MAWL} is the height of the maximum flooding level above the baseline, in m, in the considered cargo hold
ρ_{SW} is the sea water density to be taken as 1,025 t/m^3
g is the gravity acceleration, in m/s^2, as defined in Pt B, Ch 1, Sec 3, [1.1.5]

Table 6 : Additional design load set for local scantling check

Item	Design load set	Load component	Acceptance criteria	Design load scenario / Loading condition
Cargo hold boundaries	FH-1	P_{in}	AC-3	Cargo hold flooded

Table 7 : Additional loading condition for cargo hold and ballast tanks strength check

Loading condition	Description	Loading pattern	Container loading	Draught	SWBM	SWSF
FH	One cargo hold flooded		Heavy cargo 20' Any cargo hold covered by the cargo hold flooding system is flooded	$\leq 0{,}9T_{SC}$	$M_{sw\text{-}CHF\text{-}min}$	$Q_{sw\text{-}CHF}$

3.8.11 Ship stability

The adverse effect upon stability of the added weight and free surface of water created by the flooding of any one cargo hold up to the maximum flooding level is to be taken into account in the intact stability calculations, at least for the load cases mentioned in [3.8.12].

3.8.12 Cargo hold flooding control booklet

A dedicated addendum to the loading manual is to be available on board, covering the cargo hold flooding. This booklet is to include:

- Drawings of the piping, valves and pumps to be used for filling and emptying the holds
- Detailed instructions covering the operations to flood and empty the hold
- Typical sequences covering the flooding of a cargo hold. The typical flooding sequences are to be developed so as not to exceed applicable strength limitations and paying due attention to the flooding rate and deballasting capacity.

3.8.13 Loading instrument

The loading instrument is to be able to:

- Perform hull girder strength check according to the requirements of [3.8.10], item a) and taking into account the actual loading of the ship, and
- Perform intact stability calculations according to the requirements of [3.8.11].

3.9 Water-spray system for the protection of the superstructure block

3.9.1 A fixed water-spraying system is to be installed to cover:

- exposed superstructure vertical boundaries facing container stowage areas, except boundaries of the forecastle spaces
- foundations of the monitors required in [3.6]
- exposed lifeboats, liferafts and muster stations facing container stowage areas.

Alternative solutions, such as using the fixed water monitors required in [3.6], if they can be oriented for this purpose, or portable water monitors in conjunction with suitably located fire hydrants and properly sized fire main and fire pumps, may be considered on a case-by-case basis by the Society provided it is demonstrated that they provide an equivalent level of protection of the superstructure blocks.

3.9.2 The system is to be capable of covering the areas mentioned in [3.9.1] with a uniformly distributed water application rate of at least 10 L/min/m^2 for the largest projected horizontal surfaces and 4 L/min/m^2 for vertical surfaces.

In case the fixed water monitors required in [3.6] are used for superstructure block protection, water supply to the system is to be sufficient to achieve simultaneously the full throw of one monitor for fire-fighting purposes in the container stowage area and protection of the most demanding superstructure block area.

The system may be fed by the fire pumps provided their capacity is in accordance with [3.4.4].

3.9.3 Sections

The fixed water-spraying system may be divided into sections so that it is possible to isolate sections covering surfaces which are not exposed to radiant heat.

The pumps of the water-spraying system are to have a capacity sufficient to spray water at the required pressure on all the areas facing either the cargo stowage area located aft or the cargo stowage area located forward of a superstructure block.

3.9.4 Spray nozzles

The number and location of spray nozzles are to be suitable to spread the sprayed water uniformly on areas to be protected.

3.9.5 Water supply redundancy

Water supply to the superstructure block protection water-spray system is to comply with one of the following alternatives:

- The system is to be fed by the fire pumps and compliance with [3.4.4] is to be ensured; or
- The system is to be fed by dedicated pumps and as a backup the main supply line of the system is to be connected to the fire main through a stop valve located as far as possible from the container cargo holds and stowage area on deck; or
- The system is to be provided with a redundant means of pumping. The capacity of the redundant means is to be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity by more than 50%. Switch over to redundant means of pumping may be manual or automatic.

3.9.6 Controls

The valve controls and pump controls necessary to activate the system are to be grouped together in the continuously manned central control station.

3.10 Design of the ventilation system

3.10.1 Ventilation of the cargo holds

The ventilation openings located in the hatch covers are to be provided with quick closing devices.

4 Additional requirements for the notation ECFP-3

4.1 General

4.1.1 In addition to the requirements of Articles [2] and [3], ships intended to be assigned the notation **ECFP-3** are to comply with the requirements of [4.2] to [4.6].

4.2 Central control station

4.2.1 In addition to the control and monitoring functions required by Tab 3, the control and monitoring functions listed in Tab 8 are to be available at the continuously manned central control station.

Table 8 : Additional monitoring and controls required in the continuously manned central control station for ECFP-3 additional class notation

Parameter		Monitoring		Control	Rule reference
		Alarm	Indication		
Water-spray system below hatch cover	Isolating valves			X	[4.5.3]
	Pump			X	[4.5.3]
	Drainage valves			X	[4.5.3]
Ventilation	Ventilation inlet closing device			X	[4.6.1]
	Power ventilation for the container cargo holds			X	[4.6.2]

4.3 Portable equipment

4.3.1 Portable fire-fighting device for stacked containers

In addition to the requirements of [2.2.2], the portable fire-extinguishing device for stacked containers is to be able to reach the highest tier of containers, and is to be capable of spraying water inside a confined space when connected to the fire main and raised at this level.

4.3.2 Air breathing apparatuses

In addition to the requirements of [2.2.3], four air breathing apparatuses are to be available on board, with 2 spare charges for each breathing apparatus.

4.4 Fire detection

4.4.1 Fire detection in cargo holds

Means are to be provided in the cargo holds to detect and locate heating cargo or a cargo fire at an early stage and identify the container or containers where the seat of the fire or exothermal reaction is located. An audible and visual alarm is to be triggered in case:

- The temperature exceeds the temperature setting, i.e. 54°C; or
- At a lower temperature when an abnormal temperature gradient is detected. Spatial and time domain temperature gradients are to be considered.

The alarm is to indicate the location of the concerned container.

For this purpose, linear heat detection coupled with energy flow analysis as specified in [4.4.3] may be used.

Other innovative solutions may also be considered on a case-by-case basis, such as: fiber optics, heat detection system, thermal imaging cameras, video-based fire detection. In this case:

- The efficiency and reliability of the system are to be documented to the satisfaction of the Society
- The system is to comply with the principles detailed in Pt C, Ch 4, Sec 15, [8] as applicable
- The components of the system are to comply with the requirements of Part C, Chapter 3 as applicable and are to be approved according to a recognized standard.

4.4.2 Fire detection on deck

Means are to be provided to detect a cargo fire on deck. For this purpose, innovative solutions may be considered, such as: thermal imaging cameras, flame detection systems, video-based fire detection, linear heat detection.

The efficiency and reliability of the system are to be documented to the satisfaction of the Society.

The system is to comply with the applicable requirements of Pt C, Ch 4, Sec 15, [8].

The components of the system are to comply with the requirements of Part C, Chapter 3 as applicable and are to be approved according to a recognized standard.

4.4.3 Linear heat detection coupled with energy flow analysis

a) The system is to include heat detector cables the output of which is retrieved and analyzed by an energy flow analysis software at least every 5 seconds.

b) Installation

- Heat detector cables are to be installed, providing one sensor per container as well as supplementary temperature sensors measuring the hull temperature at every container tier level.

Note 1: In case installation on open deck is foreseen, the hull temperature sensors are to be replaced by outside temperature sensors.

- All sensors covering one bay of containers as well as the associated hull or outside temperature sensors are to be sampled synchronously
- The sensors are to be approximately facing the center of the container doors and are not to be further than 200 mm away from the container wall. The sensors are to be thermally insulated from the ship structure.
- The sensors are to be protected from direct sunlight.

c) All the components of the system are to comply with the requirements of Part C, Chapter 3 as applicable.

d) The system is to comply with the applicable requirements of Pt C, Ch 4, Sec 15, [8].

e) The individual sensors are to be approved according to EN54-5 Class A1 and in addition:

- The standard deviation of the measured values at a constant temperature is to remain below 0,1°C; and
- The response time of the sensors is to be between 5 and 10 min when submitted to 0,6 K/min rise or air temperature, according to the procedure specified in EN54-5 Clause 5.5.

f) All the data retrieved from the heat detector cables is to be recorded in a mass storage medium and retained for at least 30 days.

4.5 Water-spray system below hatch cover

4.5.1 The water-spray system below hatch cover required by [3.7] may be divided into sections. The fire detection system in cargo holds required by [4.4.1] is to allow identifying easily in which section a fire or temperature rise has been detected.

4.5.2 The water-spray system below hatch cover required by [3.7] is to be able to spray water at 20 L/min per square meter of the horizontal cargo spaces over the most demanding section.

4.5.3 Controls

The isolating valves required by [3.7.5] and the drainage valves required by [3.7.9]are to be capable of remote operation. The isolating valves controls, drainage valve controls and pump controls necessary to activate the system are to be grouped together in the continuously manned central control station.

4.6 Design of the ventilation system

4.6.1 Superstructure block

Separate and redundant means of air supply are to be provided for the accommodation spaces and control stations. Air inlets of the sources of supply are to be arranged on opposite sides of the superstructure blocks, so that the risk of both inlets drawing in smoke simultaneously is minimized in the event of a cargo fire. This requirement need not apply to forecastle spaces.

Means of remotely closing each inlet are to be provided at the continuously manned central control station.

Note 1: The purpose of this requirement is to ensure supply of air free of smoke in all cases. Air conditioning need not be maintained in this case.

4.6.2 Ventilation of the cargo holds

Power ventilation for the container cargo holds is to be fitted with controls so grouped that all fans serving one cargo hold may be stopped at once from the continuously manned central control station. It is to be possible to close all ventilation openings, except those located in the hatch covers, from the same location.

5 Certification and testing

5.1 Type approval of portable fire-fighting devices for stacked containers

5.1.1 Design requirements

The device is to be capable to drill a hole in a standard steel container door located at the requested height, then spray water in the container.

It is to be possible to connect the device to the ship's fire main through standard hydrants and fire hoses.

The weight of the device in working order is not to exceed 23 kg.

5.1.2 Type testing

The fire-fighting devices for stacked containers are to undergo a type test showing that the device can drill a hole into a standard container door and spray water inside a container stacked at height.

For the purpose of the test:

- A standard container door is to be installed at the testing height. The container door is to consist of at least 2 mm thick weathering steel plating and to be of a design type-approved according to ISO 668 for a 20 ft or 40 ft container.
- A representative specimen of the portable fire-fighting device is to be connected to water supply through a standard fire hose
- The device is then to be raised up to the container door by its lifting and fixation system
- The device is then to be activated and should drill a hole in the container door in less than one minute, then spray water.

The following data are to be recorded:

- Pressure at the hydrant
- Length of throw at the level of the floor of the container corresponding to the pierced door
- Duration of the penetration phase
- Water flow rate during the water-spraying phase.

5.2 Type testing of fixed water monitors

5.2.1 The following characteristics are to be tested for each type of water monitor and are to be indicated on the type approval certificate:

- Discharge rate
- Length of throw in still air conditions
- Angular range of throw.

5.3 Onboard tests

5.3.1 Fixed fire-fighting systems

After assembly on board, the following systems are to be checked for leakage at normal operating pressure:

- water-spray system below hatch cover as required by [3.7]
- on deck fire-fighting system as required by [3.6]
- superstructure block protection water-spray system as required by [3.9].

The following systems are to undergo an operational test on board the ship, to check their characteristics and performances:

- water-spray system below hatch cover as required by [3.7]. The testing should include verification of the functionality of the drainage arrangements
- on deck fire-fighting system as required by [3.6]
- cargo hold flooding system as required by [3.8]. The testing should include verification of the functionality of the drainage arrangements and of the high and high high level alarm in the cargo hold
- superstructure block protection water-spray system as required by [3.9].

5.3.2 The operational performance of each mobile water monitor is to be tested on board. The test is to verify that:

- the mobile water monitor can be securely fixed to the ship structure
- the mobile water monitor jet reaches the top tier of containers with all required monitors and water jets from fire hoses operated simultaneously.

5.3.3 Ventilation

The means of remotely closing the superstructure block ventilation inlets and remote control for the cargo hold power ventilation are to be functionally tested.

5.3.4 Fixed fire-detection system

The fixed fire detection systems required by [3.3] or [4.4] are to be functionally tested after installation on board using adequate smoke or heat sources as relevant.

5.3.5 Portable fire-fighting devices for stacked containers

The performance of the portable fire-fighting devices for stacked containers is to be demonstrated by an operational test on board the ship. It is to be checked that:

- the fire-fighting device can be effectively risen and installed at its nominal height
- the required pressure can be delivered from the water main to the fire-fighting device in this configuration, with 4 water jets from other fire hoses and the mobile water monitors operating simultaneously.

Section 3 Cofferdam Ventilation (COVENT)

1 General

1.1 Application

1.1.1 The additional class notation **COVENT** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.19.3], to ships having all cofferdams in the cargo area provided with fixed ventilation systems complying with the requirements of this Section.

1.1.2 For the purpose of this Section, the cargo area is that portion of the ship included between the forward bulkhead of the machinery space and the collision bulkhead.

In the case of ships with machinery spaces located amidships, the cargo area is also to include that portion of the ship between the aft bulkhead of the engine space and the after peak bulkhead, excluding the shafting tunnel.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted to the Society for approval.

The Society reserves the right to require additional plans or information in relation to the specific characteristics of the installations.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Item
1	I	Schematic drawing of the installations
2	A	Calculation of number of air changes per hour for each cofferdam in cargo area
3	A	Line diagram of power supply circuits of control and monitoring systems, including circuit table
4	A	List and type of equipment and in particular type of fans and their arrangement in ducts
3	I	Plan of the location and arrangement of the control station, if any
3	A	List of remote control devices, if any
4	A	List of alarms
(1) A : to be submitted for approval; I : to be submitted for information.		

2 Design and construction

2.1 Arrangement

2.1.1 Number of air changes

a) The ventilation system is be capable of supplying at least 4 complete air changes per hour, based on the cofferdam gross volume.

b) For cofferdams adjacent to spaces where dangerous mixtures may be present, such as cargo tanks of oil carriers, chemical carriers and gas carriers, the minimum number of air changes per hour is to be increased to 8.

2.1.2 Type of ventilation

The ventilation is to be of the negative pressure type for cofferdams adjacent to dangerous spaces, as indicated in [2.1.1] b). Other cofferdams may have ventilation of the positive pressure type.

2.1.3 Avoidance of stagnation zones

In order to avoid air stagnation zones, air exhaust ports inside the cofferdam are to be adequately distributed and the various landings are to consist of grates or perforated flats; inlet ducts are generally to end at the top of the cofferdam and outlet ducts are to extend below the floor plates, with suction ports at the level of the upper edge of ordinary floors or bottom longitudinals.

Particular attention is to be paid to the arrangement of inlet and outlet ducts in cofferdams surrounding cargo tanks of double hull tankers, where, due to the particular shape of the cofferdams and the presence of stiffening inside, the formation of stagnant zones is likely.

2.1.4 Cofferdams that may be used as ballast tanks

Provision is to be made to blank the inlet and outlet ventilation ducts when cofferdams are used for the carriage of ballast.

2.2 Other technical requirements

2.2.1 Ventilation inlets and outlets

Ventilation inlets and outlets leading to the open air from cofferdams adjacent to dangerous spaces are to be fitted with wire net flame arresters and protective screens recognised as suitable by the Society. The spacing between them and from ignition sources, openings into spaces where ignition sources are present, openings into cargo tanks and air inlets and outlets of different spaces is to be not less than 3 m.

2.2.2 Fans

a) Ventilation fans are to be of non-sparking construction of a type approved by the Society.

b) Where ventilated cofferdams are adjacent to a dangerous space, the electric motors driving the ventilation fans are not to be located in the ventilation ducts.

2.2.3 Lighting

Where cofferdams are provided with electric lighting appliances, the ventilation system is to be interlocked with the lighting such that the ventilation needs to be in operation to energise the lighting.

2.2.4 Alarms

An audible and visual alarm is to be activated in the event of failure of the ventilation.

2.2.5 Additional requirements

For chemical tankers and gas carriers, the requirements in Pt D, Ch 8, Sec 12 and Pt D, Ch 9, Sec 12, respectively, are also to be applied.

3 Inspection and testing

3.1 Equipment and systems

3.1.1 Equipment and systems are to be inspected and tested in accordance with the applicable requirements of the Rules relative to each piece of equipment of the system used for the ventilation of the cofferdams.

3.2 Testing on board

3.2.1 Following installation on board, the ventilation systems are to be subjected to operational tests in the presence of the Surveyor.

Section 4 Enhanced Fire Protection for Ships carrying Electrical Vehicles (EVFP)

1 General

1.1 Application

1.1.1 This Section applies to vehicle carriers fitted with equipment, systems and arrangements which enhance the ability to manage a fire in the presence of electric vehicles as defined in [1.2].

As a rule, the additional class notations defined in [1.3] may be assigned only to ships complying with the requirements of Part D, Chapter 1 and assigned the service notation **PCTC** or **PCC**.

1.2 Electrical vehicles (EV)

1.2.1 For the purpose of this Section:

- An electric vehicle (EV) is a vehicle that uses one or more electric motors for propulsion.
- An EV is autonomously powered by a battery. Most commonly, the battery is of Li-Ion type.

1.3 Classification notations

1.3.1 Ships complying with the requirements of this Section may be assigned one of the following additional class notations:

- The additional class notations **EVFP-1** is assigned to ships fitted with equipment and arrangements complying with the requirements of Article [2] and, as applicable, Article [5]. The requirements of Article [2] may be considered as a retrofit for an existing ship.
- The additional class notations **EVFP-2** is assigned to ships fitted with equipment, systems and arrangements which constitute an extensive set of mitigation measures using standard technologies. The requirements of Articles [2], [3] and, as applicable, Article [5], apply to these ships.
- The additional class notations **EVFP-3** is assigned to ships fitted with equipment, systems and arrangements which include measures using more advanced technologies. The requirements of Articles [2] to [5] apply to these ships.

1.4 Documentation to be submitted

1.4.1 The documentation to be submitted for assignment of notations **EVFP-1**, **EVFP-2** or **EVFP-3** is listed in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	I	Ship's operational manual or loading procedure
2	A	Fire control plan showing, as applicable for notations **EVFP-1**, **EVFP-2** or **EVFP-3**: • the portable equipment • for the systems required: - spaces covered by the systems and decontamination area - particulars of these systems - areas covered by the fixed water-based fire-fighting systems
3	I	General arrangement showing the dedicated area for electric vehicles
4	A	General arrangement showing the location of all fire-fighting equipment
5	A	Particulars of the video surveillance system including the system arrangement
6	A	General arrangement and calculation of the drainage system
7	A	Arrangement of the fixed fire-fighting water-based systems **(2)**
8	A	Diagram of control systems for the fixed water-based fire-fighting systems **(2)**
9	I	Operating manuals for the fixed water-based fire-fighting systems **(2)**
10	A	Fixed gas detection systems **(2)**
11	A	Mechanical smoke extraction system including ventilation sizing **(3)**
12	A	Natural and mechanical ventilation systems showing the location of dampers, means of closing, arrangements of fans or air conditioning rooms **(3)**

(1) A: to be submitted for approval; I: to be submitted for information
(2) As applicable for notations **EVFP-2** or **EVFP-3**
(3) For notation **EVFP-3**

2 General requirements

2.1 Operational manual

2.1.1 The ship's operational manual is to include the verification and record of the state of charge of EV batteries.

2.2 Area for the storage of electric vehicles (EV storage area)

2.2.1 A dedicated area is to be defined for the storage of electric vehicles. This area is to be identified on the fire control plan as well as locally at each entrance.

2.2.2 The EV storage area is not to be adjacent to tanks containing fuel or other flammable liquids.

2.2.3 The EV storage area is to be considered as a hazardous area Zone 2 and electrical equipment installed in this area is to be of a certified safe type suitable for use in Zone 2 and have explosion group and temperature class at least IIC and T2.

2.2.4 If internal combustion engine vehicles (ICEV) or hybrid vehicles are also meant to be stored in the EV storage area, electrical equipment installed in this area is also to comply with Pt D, Ch 1, Sec 4.

2.3 Detection and alarm

2.3.1 A fixed fire detection and fire alarm system, providing combined heat and smoke detection in the EV storage area, and complying with the requirements of Pt C, Ch 4, Sec 15, [8], is to be installed.

2.3.2 A video monitoring system is to be arranged to monitor the EV storage area. The cameras' field of view is to encompass all the area and minimize blind spots as far as practicable. The monitoring control station is to be located at the fire control station and at the continuously manned central control station.

2.3.3 Two sets of portable thermal cameras are to be provided and stored in the fire control station. They are to be designed and tested in accordance with recognized standards and suitable for use in zone 2 hazardous area.

2.4 Fire-fighting systems

2.4.1 In addition to the fire-fighter outfits requested by SOLAS or other requirements in Part C, Chapter 4, two sets of outfits complying with EN 469:2020 level 2 are to be provided including hoods complying with EN 13911:2017.

2.4.2 In addition to the portable foam fire extinguishers requested by SOLAS and other requirements in Part C, Chapter 4, two portable foam fire extinguishers are to be provided at each entrance of the dedicated area for the storage of EV.

2.4.3 Two sets of portable water curtain nozzles are to be available to isolate a fire.

The portable water curtain nozzles are to be of a type approved by the Society according to [6.2.1].

2.4.4 The fire main system is to be capable of supplying simultaneously:

a) Two fire hoses of a size and at pressures as specified in Pt C, Ch 4, Sec 6, [1.2.6] and Pt C, Ch 4, Sec 6, [1.4.3] and

b) Two portable water curtain nozzles.

2.4.5 The drainage arrangement is to be such as to prevent the build-up of free surfaces, taking into account the water flow rate of two fire hoses and two portable water curtain nozzles operating simultaneously.

3 Additional requirements for notation EVFP-2

3.1 General

3.1.1 In addition to the requirements defined in Article [2], ships to be assigned the notation **EVFP-2** are to comply with the requirements of [3.2] to [3.4].

3.2 Decontamination area

3.2.1 An area for decontamination of the fire-fighter outfits is to be provided including a decontamination shower and brushes.

3.3 Detection and alarm

3.3.1 In addition to the requirements in [2.3], the requirements of [3.3.2] to [3.3.6]] are to be complied with.

3.3.2 The fixed fire detection and fire alarm system required in [2.3.1] is to be capable of remotely and individually identifying each detector and manually operated call point.

3.3.3 The video monitoring system required in [2.3.2] is to include a flame recognition software which is to trigger an alarm in case of flame detection. The video monitoring system is to be capable of remotely and individually identifying each camera triggering the alarm.

3.3.4 A fixed hydrogen detection system is to be arranged in the EV storage area. It is to be designed, installed and tested in accordance with a recognized standard accepted by the Society (e.g. ISO 26142:2010) and of a type approved by the Society according to [6.3.1]. The alarm level is to be set at 20% of LEL for hydrogen.

3.3.5 A fixed carbon monoxide detection system is to be arranged in the EV storage area. The carbon monoxide detectors are to comply to standards accepted by the Society (e.g. EN 50291-1:2018 and EN 50291-2:2019) and of a type approved by the Society according to [6.3.1]. The alarm level is to be set at 30 ppm for carbon monoxide.

3.3.6 Two portable gas detectors capable of detecting hydrogen and carbon monoxide are to be provided.

3.4 Fire-fighting systems

3.4.1 In addition to the requirements in [2.4], the requirements of [3.4.2] to [3.4.4] are to be complied with.

3.4.2 A fixed water-based fire-fighting system is to be arranged in the EV storage area. This system is to comply with Pt C, Ch 4, Sec 13, [5.1.1], item c). The deck drainage system is to be designed according to Pt C, Ch 1, Sec 10, [6] and Pt D, Ch 1, Sec 3, [1].

3.4.3 Control and monitoring functions for the water-based fire-fighting system and the detection and alarm systems are to be grouped in a continuously manned central control station.

3.4.4 Two sets of fire blankets complying with EN 1869:2019 are to be provided. The size of the blankets is to be sufficient to cover an area of three vehicles by three vehicles.

4 Additional requirements for notation EVFP-3

4.1 General

4.1.1 In addition to the requirements defined in Articles [2] and [3], ships to be assigned the notation **EVFP-3** are to comply with the requirements of [4.2] to [4.4].

4.2 Arrangement, prevention of fire and structural integrity

4.2.1 Bulkheads and decks surrounding the ro-ro or vehicle space where the EV storage area is located are to be A-60 class divisions.

4.2.2 When the space on the other side of the division is a void or tank containing non-flammable liquid, the rating of the division may be reduced to A-0 standard.

4.3 Smoke extraction systems

4.3.1 Mechanical smoke extraction is to be provided in the EV storage area. The exhaust is to be independent from ventilation ducts serving other spaces and is to be led to a safe area on open deck. Ducts are to be fully welded. Smoke temperature monitoring is to be arranged in the exhaust duct. The fans are to be sized such that the entire volume within the space can be exhausted in 10 min or less.

4.3.2 The mechanical smoke extraction system is to be provided with a filter for the capture of flammable gases.

4.3.3 The smoke extraction system is to be connected to the fixed gas detection systems required in [3.3.4] and [3.3.5]. Automatic start-up of the smoke extraction system is to be set up at 40% of LEL for hydrogen and 50 ppm for carbon monoxide or by smoke detection. Manual control is to be provided from the navigation bridge and fire control station.

4.3.4 The smoke extraction system is to shut down automatically if the temperature rises above 300°C in the extraction ducts.

4.4 Fire-fighting systems

4.4.1 In addition to the requirements in [2.4] and [3.4], the requirements of [4.4.2] to [4.4.5] are to be complied with.

4.4.2 The fixed water-spray system required in [3.3.2] is to be connected to a fresh water tank. This tank is to have a capacity of 20 minutes at the required discharge rate of any section of the system.

4.4.3 Upward water-spay system

A water-spray arrangement to water the underside of the vehicles is to be provided in the EV storage area.

This upward water-spray system may be:

a) A fixed installation with nozzles installed on deck. The nozzles are to be of a type approved by the Society based on the relevant sections of appendix A to Circular MSC/Circ.1165,

b) A set of two portable devices of a type approved by the Society according to [6.2.2] and connected to fire hoses.

4.4.4 Upward water-spray supply system

The upward water-spray supply system is to comply with one of the following alternatives:

a) The system is to be fed by the fire pumps; or

b) The system is to be fed by dedicated pumps and as a backup the main supply line of the system is to be connected to the fire main through a stop valve; or

c) The system is to be provided with a redundant means of pumping. The capacity of the redundant means is to be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity by more than 50%. Switch over to redundant means of pumping may be manual or automatic.

4.4.5 Fire main capacity

The capacity of the fire pump and the fire main diameter are to be sufficient for the simultaneous use of the following combinations of systems, depending on the type of the upward water-spray system:

a) Combination of:
- the most demanding section of the fixed water-based fire-fighting system as required in [3.4.2]
- two nozzles connected to the fire main system
- two portable water curtain nozzles as required in [2.4.3]
- the most demanding section of the upward fixed water-spray system

b) Combination of:
- the most demanding section of the fixed water-based fire-fighting system as required in [3.4.2]
- two nozzles connected to the fire main system
- two portable water curtain nozzles as required in [2.4.3]
- two portable upward water-spray devices

5 Testing

5.1 Onboard Tests

5.1.1 Fire Fighting Systems

a) After assembly on board, the following systems are to be checked for leakage at normal operating pressure:
- fixed water-based fire-fighting system specified in [3.4.2], if applicable
- fixed upward water-spray system specified in [4.4.3], if applicable

b) The following systems are to undergo an operational test on board the ship, to check their characteristics and performances:
- portable water curtain nozzles specified in [2.4.3]
- portable upward water-spray devices specified in [4.4.3], if applicable
- fire main system performance as specified in [2.4.4], [4.4.4] and [4.4.5] as applicable.

5.1.2 Smoke extraction system

The smoke extraction system is to undergo a functional test to confirm the rate of ventilation specified in [4.3.1], as well as the automatic and manual control of the system.

5.1.3 Fixed fire detection systems

a) Functional test of the video monitoring system specified in [2.3.2] is to be carried out

b) Functional test of the flame recognition software specified in [3.3.3] is to be carried out.

c) Functional test of the gas detection system specified in [3.3.4] and [3.3.5] is to be carried out.

6 Certification of portable devices and gas detection systems

6.1 General

6.1.1 Product certification requirements are defined in [6.2] and [6.3].

A summary is provided in Tab 2.

6.2 Specific tests for type approval of portable fire-fighting devices

6.2.1 Portable water curtain nozzles

The portable water curtain nozzles specified in [2.4.3] are to:

a) Be equipped with a coupling allowing connection to the vessel's fire hydrants via a fire hose

b) Undergo a type test showing that the minimum flow capacity is 60 m^3/h at a pressure of 7 bar.

6.2.2 Portable upward water-spray devices

Portable upward water-spray devices specified in [4.4.3]are to:

a) Be equipped with a coupling allowing connection to the vessel's fire hydrants via a fire hose

b) Undergo a type test showing that the minimum flow capacity is 60 m^3/h at a pressure of 7 bar.

6.3 Type approval of gas detection systems

6.3.1 Fixed gas detection systems required in [3.3.4] and [3.3.5] are to be of a type approved by the Society.

Table 2 : Product certification

Item	Product Certification			
	Design assessment/ approval	Raw Material Certificate	Examination and testing	Product certificate
Portable water curtain nozzles	TA		X	C
Portable upward water-spray devices	TA		X	C
Fixed gas detection systems	TA		X	C
Note 1: "C" indicates that a Society certificate is required. "X" indicates that examinations and tests are required. "TA" means that a type approval is required.				

CHAPTER 14
ELECTRIC PROPULSION OR POWER SUPPLY

Section 1 Electric Hybrid

Section 2 Electric Hybrid Prepared

Section 3 Hybrid Mechanical Propulsion Systems (HMPS)

Section 4 HMPS-PREPARED

Section 5 Onshore Power Supply (OPS)

Section 6 OPS-PREPARED

Section 1 Electric Hybrid

1 General

1.1 Application

1.1.1 The additional class notation **ELECTRIC HYBRID** may be assigned in accordance with Pt A, Ch 1, Sec 2, [6.20.1] to ships provided with an Energy Storage System (ESS) used to supply the electric propulsion and/or the main electrical power distribution system of the ship.

The notation **ELECTRIC HYBRID** is to be completed, between brackets, by at least one of the following complementary notations:

- **PM** when at least one of the following Power Management functions is available:
  - load smoothing
  - peak shaving
  - enhanced dynamic response,

  as defined in [1.3.3].
- **PB** when Power Backup function, as defined in [1.3.4], is available.
- **ZE MODE** when Zero Emission mode, as defined in [1.3.5], is available.

Examples of notations are given below:

ELECTRIC HYBRID (PB)

ELECTRIC HYBRID (PM, ZE MODE)

1.1.2 The ESS aims to assist the electric propulsion and/or the main electrical distribution system with the power demand, and/or to take over from the main source of electrical power.

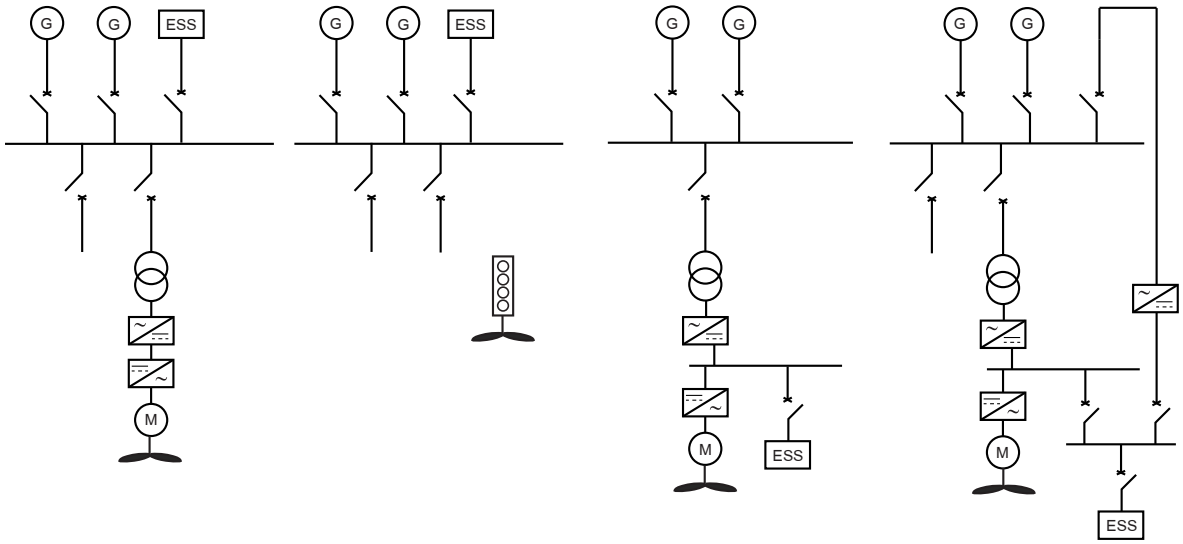
1.1.3 The notation **ELECTRIC HYBRID** applies to the following cases, as illustrated in Fig 1:

- the ESS supplies the main switchboard, or
- the ESS supplies a propulsion switchboard, or
- the ESS supplies both the main switchboard and a propulsion switchboard.

1.2 Documents to be submitted

1.2.1 The documents to be submitted are listed in Tab 1.

Figure 1 : Typical ESS supply arrangements



The examples given in Fig 1 are for an AC network. The same principles apply to a DC network.

Table 1 : Documents to be submitted

No.	I / A **(1)**	Documents
1	I	General description of the ESS and the different operating modes and functions
2	I	Power balance, see **(2)**
3	A	Failure Mode and Effect Analysis (FMEA) regarding the availability of ship propulsion and main electrical source of power
4	A	List of alarms and defaults. This list is to describe alarms and defaults directly connected to the battery system and interfaces with other ship systems
5	I	Operation manual of ESS
6	A	Test programs related to type approval, factory test and onboard tests including the standards used for design and testing procedures
7	I	Reports related to test programs for type approval, factory test and onboard tests
8	I	Maintenance manual and maintenance schedule
9	I	For ZE Mode: Electrical load balance and specified design autonomy period, see [3.5.3]
10	I	For PB function: Electrical load balance(s) for power back up, see [3.5.2]

(1) I = to be submitted for information.
A = to be submitted for approval.
(2) The load balance is to include the battery charging phase. See [2.2.10].

1.3 Definitions

1.3.1 Electric Energy Storage System (ESS)

The ESS is a system based on battery packs, semiconductor converter (if any) and transformer (if any). It is used to supply the electric propulsion and/or the main electrical power distribution system of the ship.

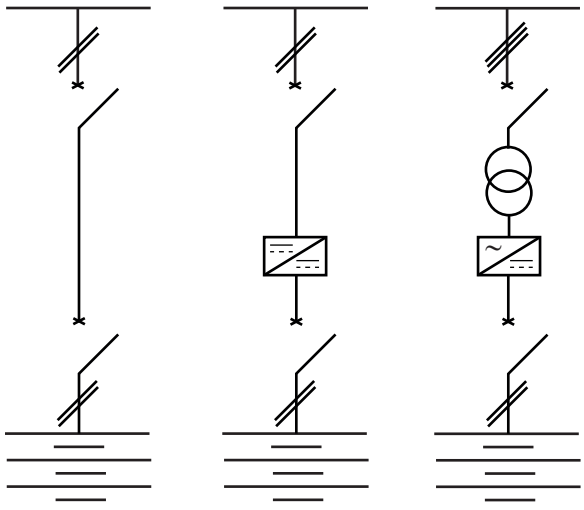
The ESS may be based on the following configurations (see Fig 2):

- direct supply (DC switchboard), or
- supply through a DC/DC semiconductor converter (DC switchboard), or
- supply through an DC/AC semiconductor converter and/or a transformer (AC switchboard).

1.3.2 Energy Control System (ECS)

The energy control system ensures the overall control and monitoring of the ESS: battery, converter, transformer and circuit breaker.

Figure 2 : ESS possible configurations



1.3.3 Power Management function (PM)

For the purpose of this Section, the term PM function is used for one of the following power management functions (see Fig 3):

a) Load smoothing:

Load smoothing is a function allowing the ESS to be charged and discharged all the time to compensate for the network load variations within a given amplitude above or below the average. This will result in limited load fluctuations of the main generating sets, allowing optimised fuel consumptions and reduced exhaust gas emissions.

Note 1: This function is also named load optimising function.

b) Peak shaving:

Peak shaving is a function dedicated to instant power demand. The goal is to supply peaks of a highly variable load (e.g. during manoeuvring) and to avoid the connection of an additional main generating set.

c) Enhanced dynamic response:

Enhanced dynamic response is mainly related to gas fuel or dual fuel generating sets. In case of sudden load increase, the ESS instantaneously supplies the corresponding power demand, thus enhancing the generator dynamic performance, and, for dual fuel engines, preventing the possible switch-over to fuel oil due to ramping-up.

1.3.4 Power Back up function (PB)

The PB function is a function where the ESS is permanently connected to the main electrical power distribution system of the ship and is able to deliver power immediately in case of failure of one main generating set.

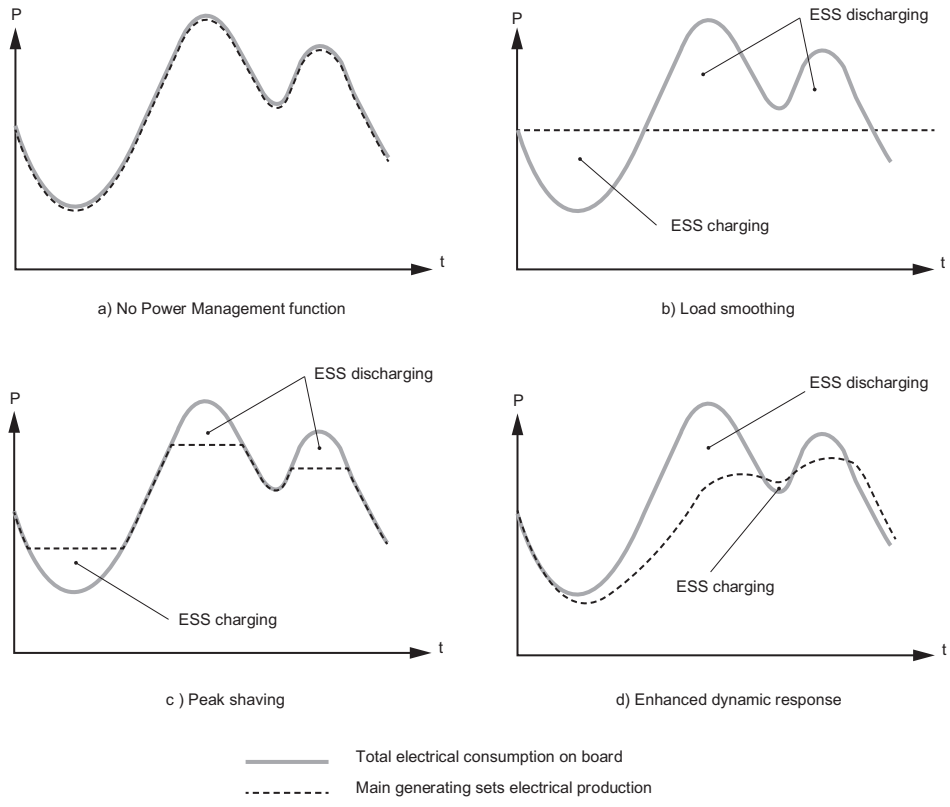
Note 1: This function is also named spinning reserve function.

1.3.5 Zero Emission mode (ZE MODE)

The ZE mode is a mode where the ESS is temporarily the only source of power connected to electrical network. This mode allows stopping all the main generator sets, the main diesel engines, boilers and incinerators, if any, and the associated emission of exhaust gas for a specified period of time (manoeuvring, ship at berth).

Note 1: The ZE mode, unlike the PB function, is activated on a voluntary basis.

Figure 3 : Power Management functions (PM)



2 System design

2.1 Quality of power supply

2.1.1 Characteristics of power supply at the main switchboard or at the propulsion switchboard may be outside the limits defined in Pt C, Ch 2, Sec 2, [2] (e.g. due to battery voltage drop), provided it is compensated for through the semiconductor converters supplying the essential services. Alternatively, the electrical devices are to be designed to operate outside of these limits and justifications are to be transmitted by the manufacturers to the Society.

2.2 Power distribution

2.2.1 The ESS is not considered as forming part of the main source of electrical power, as defined in Pt C, Ch 2, Sec 3, [2.2].

2.2.2 The ESS is to remain independent of the emergency source or transitional source of power, if any, required in Pt C, Ch 2, Sec 3, [2.3].

2.2.3 For PM function, where generators can be paralleled, a Power Management System (PMS) is to be provided. The system is to include automatic start, synchronising, connecting and load sharing.

Where the number of generators in service is to vary according to operating condition, starting and connecting of supplementary generators, entailed by the use of equipment during manoeuvring, is not to require intervention in machinery spaces.

2.2.4 For PB function, the ESS is to be able to maintain without a break the continuity of the power supply, in case of failure of one main generating set.

2.2.5 A Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC Publication 60812:2018 or any other recognised standard in order to demonstrate the availability of ship propulsion and main electrical source of power in case of failure of the ESS.

2.2.6 The ESS may be used in addition to the emergency source or transitional source to supply services other than those listed in Pt C, Ch 2, Sec 3, [3.6].

2.2.7 The ESS is to be able to be charged either by the ship electrical network, or at quay through a shore supply.

2.2.8 In all operating modes, the electrical protection selectivity of the distribution system is to be ensured.

2.2.9 The short circuit current calculation is to take into account the ESS. In calculating the maximum prospective short-circuit current, the source of current is to include the most powerful configuration of generators which can be simultaneously connected (as far as permitted by any interlocking arrangements), and the maximum number of motors which are normally simultaneously connected in the system.

2.2.10 PB function and ZE mode

An electrical load balance corresponding to battery charging mode is to be submitted for information.

The maximum battery charging current is to be taken into account.

3 Electric Energy Storage System (ESS)

3.1 General

3.1.1 Battery system is to be in accordance with Pt C, Ch 2, Sec 7, Pt C, Ch 2, Sec 11, [6] and Pt C, Ch 2, Sec 12, [5].

3.2 ESS semiconductor converter

3.2.1 The ESS semiconductor converter, if any, is to be in accordance with Pt C, Ch 2, Sec 6.

The semiconductor converters may be rated for intermittent power demand. The rating is to be determined on the basis of the operating profile of the ship.

3.3 ESS transformer

3.3.1 The ESS transformer, if any, is to be in accordance with Pt C, Ch 2, Sec 5.

The transformer may be rated for intermittent power demand. The rating is to be determined on the basis of the operating profile of the ship.

3.4 Energy Control System (ECS)

3.4.1 The ECS is to be independent of:

- the Battery Management System (BMS), and
- the Power Management System (PMS)

3.4.2 The electronic components of the ECS are to be constructed to withstand the tests required in Pt C, Ch 3, Sec 6.

3.5 ESS capacity

3.5.1 PM function

In power management function, the capacity of the ESS is to be such that it covers the operating profile of the ship in normal operation during 24 hours, including at least one manoeuvring cycle, without reaching the ESS state of charge low level.

3.5.2 PB function

An electrical load balance corresponding to power backup function is to be submitted for information. Load shedding of non-essential services and services for habitability may be considered for definition of this load balance.

The capacity of the ESS for PB function is to be sufficient to supply, in this condition, the main switchboard during at least twice the time necessary to start a stand-by source (see Pt C, Ch 2, Sec 3, [2.2.7] or Pt C, Ch 2, Sec 3, [2.2.8], as applicable).

3.5.3 ZE mode

An electrical load balance corresponding to zero emission mode is to be submitted for information.

The capacity of the ESS is to be such that ZE mode can be maintained in this condition during a design autonomy period specified by the designer and at least twice the time necessary to start a stand-by source (see Pt C, Ch 2, Sec 3, [2.2.7] or Pt C, Ch 2, Sec 3, [2.2.8], as applicable).

3.6 ESS charging

3.6.1 After partial or full discharge, the charging current of the batteries will be limited due to the high temperature of the battery cells.

Therefore, in PB and ZE mode, the charging current and the time to charge completely the batteries is to be evaluated during a charging test, just after the ESS has been discharged in the conditions of load balance for PB or ZE mode, as defined in [3.5.2] and [3.5.3] respectively.

3.7 ESS control and instrumentation

3.7.1 The ESS is to be easily disconnectable from the main machinery control room. Further to this operation, starting of a stand-by source, if necessary, is to be automatic.

3.7.2 The following information is to be permanently displayed at the main machinery control room:

- Active operating function/mode (Load smoothing, Peak shaving, Enhanced dynamic, Power back up, Zero emission)
- Charging/Discharging status of the ESS
- State of charge of the ESS
- Remaining autonomy for ZE mode and PB function
- State of health of the ESS
- Values of the current/voltage of the ESS
- Values of the current/voltage at the battery pack
- Active power delivered.

3.7.3 ESS parameters are to be monitored or controlled according to Tab 2.

Table 2 : Energy storage system

Symbol convention H = High, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required,	Monitoring	Automatic control		
		Energy storage system	Main generating set	Propulsion motor
Identification of system parameter	Alarm	Shut-down	Standby Start	Slow-down
Short-circuit current I max	I	X	X **(1)**	
Overload	I	X	X **(1)**	
Overvoltage	I	X	X **(1)**	
Undervoltage	I	X	X **(1)**	
State of charge	L		X **(1)**	X **(1)**
	LL			
Converter **(2)** air cooling temperature	H			
Transformer **(2)** air cooling temperature	H			
Converter **(2)** ventilation fan failure	G			
Transformer **(2)** ventilation fan failure	G			
(1) Applicable only for ZE mode and PB function. **(2)** If any.				

3.7.4 Additional control and instrumentation for ZE mode and PB function

a) The ESS state of charge low level alarm is to correspond to, at least, the minimum state of charge allowing the time necessary to start a stand-by main generating set.

This alarm is to be indicated on the navigation bridge.

b) The ESS state of charge low level alarm is to correspond to an imminent stop of the ESS.

This alarm is to be indicated on the navigation bridge.

c) Automatic starting and connecting to the main switchboard of stand-by generator(s) of sufficient capacity with automatic restarting of the essential auxiliaries, in sequential operation if required, is to be carried out in the following cases:

- Failure of the ESS
- State of charge low level alarm of the ESS.

4 Testing

4.1 Factory acceptance tests

4.1.1 Each individual component is to be tested separately:

- ESS battery pack, see Pt C, Ch 2, Sec 7, [1.5]
- ESS semiconductor converter, see Pt C, Ch 2, Sec 6, [3]
- ESS transformer, see Pt C, Ch 2, Sec 5, [2].

4.2 Onboard tests

4.2.1 The following items, at least, are to be checked:

- proper working of monitoring systems
- proper working of alarms and defaults and related functions and/or interfacing to the other ship systems
- quality of the power supply in the different modes (see Pt C, Ch 2, Sec 4, [2.2.5])
- disconnection of the ESS (see [3.7.1]) in different operating modes, and automatic start of a stand by source, if necessary

4.2.2 Tests to be carried out for PM function

In power management function, the following tests are at least to be carried out:

- Increasing load steps. The ESS is to deliver power to the grid, to compensate for the load steps. In case of continuous load, the load is to be gradually transferred to the running diesel engine. The load is to be shared equally between the diesel engines (see Pt C, Ch 2, Sec 4, [2.2.5]).
- Additional increasing load steps. The load dependant start of a stand by main generating set is to be activated.
- Checking of the operation if the ESS during 6 hours at least in normal working condition. The ESS state of charge is not to be less than 80% at the end of the 6 hours period.

  A load analysis curve corresponding to this period is to be submitted for information. This document is to detail the total electrical production on board, the main generating sets electrical production and the ESS electrical production (with charging and discharging cycles).

4.2.3 Tests to be carried out for PB function

The following tests are at least to be carried out with the power backup function activated:

- failure of one generator and automatic connection of the ESS
- failure of one generator and ESS autonomy measurement (starting of the stand by generator is blocked).
- automatic start of a stand by source in case of failure of the ESS or low state of charge of the ESS
- charging test, see [3.6.1].

4.2.4 Tests to be carried out for ZE mode

In zero emission mode, the following tests are at least to be carried out:

- load discharge test with ESS autonomy measurement up to ESS state of charge low level,
- automatic start of a stand by source in case of failure of the ESS or low state of charge of the ESS.
- charging test, see [3.6.1].

4.3 Tests of battery room and fire-extinguishing system

4.3.1 Test defined in Pt C, Ch 2, Sec 15, [4.8.4] are to be carried out.

Section 2 Electric Hybrid Prepared

1 General

1.1 Application

1.1.1 The additional class notation **ELECTRIC HYBRID PREPARED** may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.20.2], to new ships that are designed with specific arrangements intended to accommodate an Electric Hybrid installation in the future.

The pieces of equipment intended for conversion to electric hybrid need not be provided onboard at newbuilding stage.

1.1.2 The additional class notation **ELECTRIC HYBRID PREPARED** is to be complemented by one or by a combination of the following complementary notations:

- **PM** when at least one of the following Power Management functions is intended to be available:
  - load smoothing
  - peak shaving
  - enhanced dynamic response,

  as defined in Ch 14, Sec 1, [1.3.3].
- **PB** when Power Backup function, as defined in Ch 14, Sec 1, [1.3.4], is intended to be available.
- **ZE MODE** when Zero Emission mode, as defined in Ch 14, Sec 1, [1.3.5], is intended to be available.

1.1.3 When the ship is effectively converted to electric hybrid operation, the additional class notation **ELECTRIC HYBRID PREPARED** will be replaced by the additional class notation **ELECTRIC HYBRID**, provided that all the applicable requirements are complied with, as applicable at the conversion date. See Pt A, Ch 1, Sec 2, [6.20.1].

In case the **ELECTRIC HYBRID** complementary notations are different from the originally assigned **ELECTRIC HYBRID PREPARED** complementary notation, the installation is to comply with all the requirements from Ch 14, Sec 1 corresponding to the **ELECTRIC HYBRID** complementary notations.

1.1.4 Electrical equipment already installed

When electrical equipment within the scope of the additional class notation **ELECTRIC HYBRID** are already installed at newbuilding stage, the requirements defined in Ch 14, Sec 1 are to be complied with.

1.2 Definitions and abbreviations

1.2.1 ESS - Energy Storage System as defined in Ch 14, Sec 1, [1.3.1].

1.2.2 ECS - Energy Control System as defined in Ch 14, Sec 1, [1.3.2].

1.2.3 An electric hybrid installation typically includes:

- batteries
- converters
- transformers
- cables and cable trays
- switchboards.

1.3 Documents to be submitted

1.3.1 The documents to be submitted are listed in Tab 1.

1.3.2 Dimensioning analysis

The dimensioning analysis:

- specifies the dimensioning of the components of the electric hybrid installation already installed and those to be installed in the future for conversion to electric hybrid; and
- justifies the dimensioning of the electrical components of the ship (bus bars, cables, etc.) and the selection of the protections (short circuit current) which will be impacted by the conversion to electric hybrid

- specifies and justifies the spaces and volumes necessary for the installation the future pieces of equipment, to be taken into account in the initial design of the ship, see [4.1.2]
- specifies the following elements for overall review of the decks supporting the equipment:
  - the design pressures considered on the decks where related equipment will be installed at conversion stage
  - the anticipated maximum weight of equipment together with their expected location and minimum surface projected on deck

This document is to be submitted to the Society for approval.

Table 1 : Document to be submitted

No.	I/A **(1)**	Documents
1	I	General description of the future installation, with the different Electric Hybrid functions
2	I	General arrangement drawing of the ship showing the Electric hybrid installation, either fitted at the newbuilding stage or planned at a subsequent stage **(2)**
3	I	Power balance expected in the different Electric Hybrid functions
4	A	Power balance with ESS in charging mode
5	A	Dimensioning Analysis
6	I	Feasibility and Impact analysis
7	A	Failure Mode and Effect Analysis (FMEA) regarding the availability of ship propulsion and main electrical source of power

(1) A : To be submitted for approval; I : To be submitted for information.

(2) The equipment and systems installed at the newbuilding stage and those intended to be installed at a subsequent stage are to be clearly identified on the drawing.

1.3.3 Feasibility and impact analysis

The feasibility and impact analysis is a document which describes the next steps to be followed in order to convert the ship to electric hybrid. This document is to contain the following information:

- list of the main electrical devices or equipment scheduled to be installed for conversion to electric hybrid, for instance, the semiconductor converter, the transformer, the Energy Control System (ECS), the cable trays, the cables
- for each equipment, the design specification and any restriction or limitation to be taken into account for the selection and installation of the future equipment is to be clearly specified, in accordance with [2]
- overall diagram of the electric hybrid, detailing:
  - the pieces of equipment already installed
  - the future installations
  - the interconnection and interfaces between above installations
- drawing showing the foreseen routing of the cables
- the procedure for future installation, considering the practical impact on the ship, detailing foreseen necessary conversion work (such as, for instance, dismantling of ceilings or hull opening)
- identified restrictions or limitations in the installation of the ship which may appear at the time of the conversion to electric hybrid.

This document is to be submitted to the Society for information.

1.4 Documents to be submitted when requesting additional class notation ELECTRIC HYBRID

1.4.1 When conversion to electric hybrid is foreseen, all documents required in Ch 14, Sec 1 are to be submitted in order to request the additional class notation **ELECTRIC HYBRID**.

Alternatively, the following set of documents may be submitted:

- all documents already submitted for obtaining the **ELECTRIC HYBRID PREPARED** additional class notation. These documents are to be updated taking into account the actual installation. In addition, a gap analysis highlighting the changes with respect to the original revision is to be submitted
- list of alarms and defaults. This list is to describe alarms and defaults directly connected to the battery system and interfaces with other ship systems
- detailed specification of the ESS, with its operating manual
- test programs related to type approval, factory test and onboard tests including the standards used for design and testing procedures (for equipment which have not yet been tested)
- reports related to test programs for type approval, factory test and onboard tests (for equipment which have not yet been tested)
- maintenance manual and maintenance schedule
- FMEA required in [2.1.5]. This document is to be updated to take into account the actual design options taken at the conversion stage (detailed design, technology, installation).

1.4.2 In addition, the following elements are to be submitted for review of the stability and of the local strength of existing decks and added equipment foundations and reinforcements:

- detail of integration of the equipment
- list of weights and the centre of gravity (longitudinal, transversal and vertical) of all the equipment which will be fitted onboard at their final location.

2 System design

2.1 Ship design

2.1.1 One spare incoming feeder is to be provided in the main switchboard for each foreseen connection between the ESS and the main switchboard.

Note 1: These spare incoming feeders are not required to be equipped (for instance with a circuit breaker, protection relay). However, spare spaces are to be available in the main switchboard.

2.1.2 A sufficient number of spare I/O modules is to be provided into the control alarm and monitoring system of the ship to allow all the foreseen connections of the ECS and of the alarms and controls of the ESS required in Ch 14, Sec 1, Tab 2.

Note 1: No programming nor configuration of the control alarm and monitoring system is required when granting the **ELECTRIC HYBRID PREPARED** notation.

2.1.3 An electrical load balance including batteries charging mode is to be submitted for information. The maximum predictive battery charging current is to be taken into account.

2.1.4 The short circuit calculation of the ship is to take into account the prospective short circuit current coming from the ESS.

2.1.5 A Failure Mode and Effects Analysis (FMEA), as required in Ch 14, Sec 1, [2.2.5], is to be carried out. This document is to be based on the information already available concerning the electric hybrid installation and will have to be completed at the conversion stage. At least, it is to cover the risks coming from the locations foreseen for the different ESS components and is to demonstrate the availability of ship propulsion and main electrical source of power in case of failure of the ESS.

2.2 Cables

2.2.1 The characteristics of the cables used in the dimensioning analysis are to be specified. Cable characteristics include: voltage class, temperature class, insulation material characteristics, number of cores, conductor cross section (mm^2), special properties (flame retardant/fire resistant, etc).

2.2.2 Cables hypothesis are to fulfil the provisional load balance in the different Electric Hybrid functions (PM, PB, ZE MODE).

3 Electric energy storage system (ESS)

3.1 ESS Batteries

3.1.1 The following design parameters of the batteries intended to be installed at conversion to electric hybrid stage are to be specified in the dimensioning analysis:

- technology
- nominal voltage
- nominal capacity
- discharging rates (C rate): Continuous Discharge Current, Pulse Discharge Current corresponding to the installation in the different functions (PB, ZE MODE)
- autonomy in the different functions (PB, ZE MODE).

3.1.2 When all the parameters required in [3.1.1] are not yet defined (for instance because new developments in battery technologies are anticipated and installed battery power may be more important), battery parameters hypothesis are to be specified and used in the dimensioning analysis.

3.1.3 The specified battery parameters are to fulfil the applicable requirements in Ch 14, Sec 1 for the provisional load balance in the different Electric Hybrid functions (PM, PB, ZE MODE).

3.2 ESS semiconductor converter and transformer

3.2.1 The design parameters of ESS semiconductor converter and transformer are to be specified in the dimensioning analysis. It includes nominal power, voltage, technology and service factor if any.

3.2.2 ESS semiconductor converters and transformer are to fulfil the provisional load balance in the different Electric Hybrid functions (PM, PB, ZE MODE).

3.3 ESS Control and instrumentation

3.3.1 The integration of the ECS of the ESS into the control alarm and monitoring system of the ship is to be anticipated. Foreseen interfaces and their technologies are to be described in the feasibility and impact analysis, see [1.2.3]. This includes the connection of the ECS to the PMS and the connections of alarms and controls required in Ch 14, Sec 1, Tab 2.

4 Installation on board

4.1 Spaces

4.1.1 Spaces are to be allocated for the equipment to be installed later within the scope of the **ELECTRIC HYBRID** additional class notation.

4.1.2 The volumes of these spaces are to be justified. For devices in constant evolution (for instance batteries where energy density increases significantly), the volume allocated will be based on the current state of the art.

Calculation and justification of the volume needed is to be detailed in the feasibility and impact study, see [1.2.3].

4.1.3 The battery room is to be in accordance with Pt C, Ch 2, Sec 11, [6]. In particular, ventilation, fire boundaries and fixed fire-extinguishing system are to be installed.

4.1.4 When water cooled components are intended to be installed (batteries, converter, transformer), a connection to the water cooling circuit is to be provided into or close to the rooms where they are installed.

4.1.5 When the spaces intended for later installation of **ELECTRIC HYBRID** related equipment are used for another purpose (for instance, storage) before the ship is effectively converted to electric hybrid, they are to fulfil the corresponding requirements for this specific use as required by Part C, Chapter 4, or other Rules as applicable.

5 Testing

5.1 Factory acceptance tests

5.1.1 Each individual component already installed is to be tested separately according to the requirements of Part C, Chapter 2, as relevant or other Rules as applicable.

For instance:

- ESS battery pack, see Pt C, Ch 2, Sec 7, [1.5]
- ESS semiconductor converter, see Pt C, Ch 2, Sec 6, [3]
- ESS transformer, see Pt C, Ch 2, Sec 5, [2].

5.2 On-board tests

5.2.1 On-board test is to be performed at the conversion to electric hybrid stage, when all equipment are installed and connected, in line with the requirements of Ch 14, Sec 1, [4.2].

Section 3 Hybrid Mechanical Propulsion Systems (HMPS)

Symbols

ESS : Electrical Storage System.

PTI : Power Take In.

PTO : Power Take Off.

1 General

1.1 Application

1.1.1 The additional class notation **HMPS** may be assigned in accordance with Pt A, Ch 1, Sec 2, [6.20.3] to ships provided with a propulsion plant which combines a diesel mechanical propulsion system and an electric propulsion system.

1.1.2 In hybrid propulsion, the diesel mechanical propulsion system and the electric propulsion system may be used separately or together.

Hybrid propulsion configuration offers a higher flexibility and efficiency of the propulsion system, over a range of operating modes, for slow speed operation up to boosting mode.

1.1.3 In addition to the additional class notation **HMPS**, the additional notation **ELECTRIC HYBRID** may be granted to the ship when an ESS is used and the ship complies with the requirements of Ch 14, Sec 1.

1.2 Definitions

1.2.1 PTI Fully electric mode

This mode describes the functionality of an electrical rotating machine used as motor for propulsion and working alone, i.e. with the diesel engine stopped.

1.2.2 PTI Booster mode

This mode describes the functionality of an electrical rotating machine used as motor for propulsion and working in parallel to the diesel propulsion engine.

1.2.3 PTO Mode

This mode describes the functionality of an electrical rotating machine used as a generator. A part of the energy generated in the main engine is taken off by the generator to produce electricity as an alternative to the generating sets. This mode is also called shaft generator mode.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents
1	I	General description of the propulsion systems with their different operating modes
2	I	Operation manual of the hybrid propulsion system
3	I	Operating procedure to switch from one propulsion system to an other one
4	A	Power balance in diesel propulsion mode Power balance in PTI fully electric mode Power balance in PTI booster mode, if any
5	A	List of alarms and defaults

(1) A : To be submitted for approval; I : To be submitted for information

2 System design

2.1 Propulsion systems

2.1.1 The propulsion arrangements defined in Fig 1 are accepted. Batteries may be considered instead of diesel generators. Other arrangements may be considered on a case by case basis.

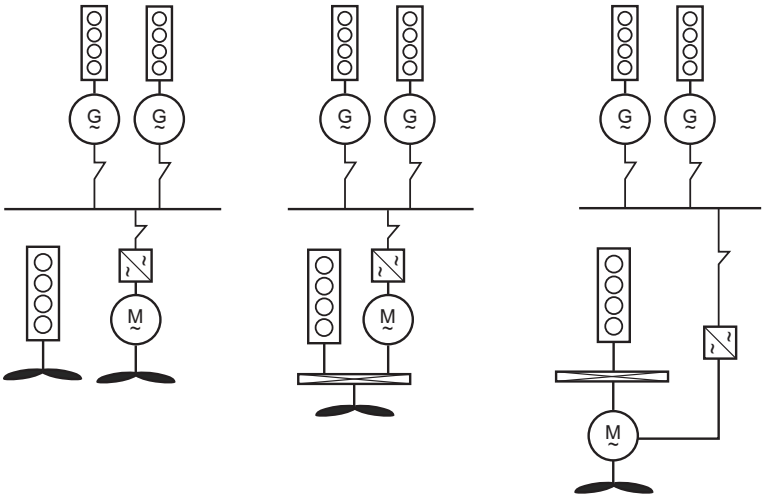
2.1.2 The following propulsion modes are to be made available:

- diesel propulsion mode
- PTI Fully electric mode.

Note 1: For the purpose of granting the additional class notation **HMPS**, the PTI Booster mode is considered as optional.

2.1.3 As a general principle, the diesel propulsion mode is considered as the main propulsion mode and has priority over the electric propulsion mode.

Figure 1 : Propulsion arrangements



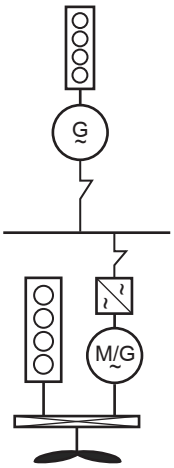
2.2 Electric Production systems

2.2.1 If the electric motor can work as a generator, it may be accepted as forming part of the main source of electrical power, provided it complies with Pt C, Ch 2, Sec 3, [2.2.12].

2.2.2 In PTI fully electric mode and in addition to [2.2.1], it is not required to have a main source of electrical power complying with Pt C, Ch 2, Sec 3, [2], when the rotating machine is reversible and can work in PTI mode or PTO mode (see Fig 2), provided that:

- the main source of electrical power complies with Pt C, Ch 2, Sec 3, [2.2], in diesel propulsion mode; and
- upon loss of power of one generator, the rotating machine used in PTI mode switches automatically to PTO mode and connects to the main switchboard in less than 30 sec.

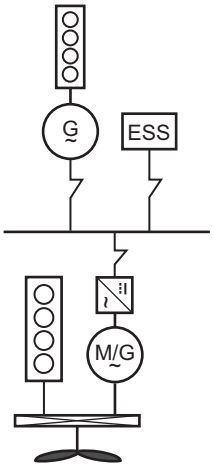
Figure 2 : Specific arrangement of electrical production with PTO mode



2.2.3 Where the number of generators in service is intended to vary according to operating conditions, the installation is to include automatic start, synchronising, connecting and load sharing.

2.2.4 A longer time than defined in [2.2.2] may be accepted provided that the ship is granted with the additional class notation **ELECTRIC HYBRID (PB)** (see Ch 14, Sec 1). For this particular case, the autonomy of the ESS in PB function is to be twice the time necessary to switch from electric motor to shaft alternator (see Fig 3).

Figure 3 : Electrical production with ESS



2.3 Diesel propulsion systems

2.3.1 The diesel propulsion system is to comply with the requirements of:

- Pt C, Ch 1, Sec 2
- Pt C, Ch 1, Sec 9
- the relevant section of Part F, Chapter 3 if an **AUT** additional class notation is to be granted to the ship.

2.4 Electrical propulsion systems

2.4.1 The electric propulsion system is to allow the ship to proceed at a reference speed in the reference weather conditions, taking into account the foreseen operational area and operational profile. Both the reference speed and the reference weather conditions are to be defined by the Owner.

2.4.2 The electric propulsion system is to comply with Pt C, Ch 2, Sec 14 and the relevant section of Part F, Chapter 3 if an **AUT** additional class notation is to be granted to the ship.

2.4.3 When compliance with [2.4.2] is not fulfilled, the switch over from the electric propulsion mode to diesel propulsion mode is to be done in less than 45 sec.

In addition, and as a minimum, the electric propulsion is to be in accordance Pt C, Ch 2, Sec 14, [4].

2.5 Combined diesel and electric propulsion systems

2.5.1 In the case of diesel engines and electric motors acting in parallel on the propeller, provisions are to be made to allow isolating the electric motors from the reduction gear (for instance by mean of a clutch or bolted link). In case of failure of the electric motor, it is to be possible to isolate the electric motor from the reduction gear and start the diesel engine in less than 30 minutes.

3 Control of propulsion machinery

3.1 Remote control from navigation bridge of the propulsion machinery

3.1.1 Arrangements are to be made to allow each propulsion mode to be started from the navigation bridge.

3.1.2 It is to be possible to control separately each propulsion mode (diesel propulsion mode, PTI fully electric mode, PTI booster mode, if any) along all the propulsion power range.

3.1.3 Functionalities are to be provided in the navigation bridge to set the diesel propulsion engine in stand-by mode (diesel engine started, running, not clutched).

3.1.4 The type of propulsion in use is to be clearly indicated at each control position.

3.1.5 The control may be performed by:

- a single lever combining the diesel propulsion mode, PTI fully electric mode, PTI booster mode if any
- two levers, one for the PTI fully electric mode, one for the diesel propulsion mode.

3.1.6 Emergency stops required in Pt C, Ch 3, Sec 2, [4.2.7] are to be independent and separated for both propulsion systems. Two separate buttons, installed close to each other, are required.

3.1.7 The propulsion control system is to ensure that the shaft power does not exceed the limit for which it has been designed (see Pt C, Ch 1, Sec 6 to Pt C, Ch 1, Sec 9).

3.2 Local control of the propulsion machinery

3.2.1 The diesel and PTI fully electric modes are to be provided with direct local controls. The direct local control is to be independent from the remote control circuits, and to take over any remote control.

3.3 Switch over from one propulsion type mode to another one

3.3.1 The switch over from one propulsion to the other one is to be feasible from the navigation bridge. It is not to necessitate any human intervention in the machinery.

3.3.2 The switch over is to require a limited number of actions on the control system. Starting of the auxiliaries necessary for each propulsion mode (cooling, lubricating, etc...) is to be automatic.

When transferring the propulsion mode from one type to an other one (for instance from diesel mode to PTI fully electric mode), no significant alteration of the propeller thrust is to occur.

3.3.3 When only 1 lever is used to control the propulsion, the propulsion mode is to switch automatically from PTI fully electric mode to diesel propulsion mode when the propulsion power request exceeds the capacity of the PTI fully electric mode.

3.3.4 When 2 levers are used to control the propulsion, the propulsion mode is to switch automatically from PTI fully electric mode to diesel propulsion mode when the diesel propulsion lever is used.

3.3.5 It is to be possible to switch manually from one propulsion mode to the other one locally.

3.3.6 The local control is to have priority over the remote control. The principles of control transfer, as specified in Pt C, Ch 3, Sec 2 are applicable for both propulsion modes.

3.4 Displays and alarms

3.4.1 In addition to the monitoring required in Pt C, Ch 3, Sec 2, the following information is to be displayed at each control position:

- indication that diesel propulsion engine is running
- indication that electric propulsion motor is running
- indication of the diesel engine ready to start
- indication of the electrical motor ready to start
- indication of the diesel engine in “stand-by” mode.

4 Testing

4.1 Onboard tests

4.1.1 The following propulsion modes are to be tested:

- PTI fully electric propulsion mode and PTI booster mode, if available, according to Pt C, Ch 1, Sec 18, [3.9]
- diesel propulsion mode, according to Pt C, Ch 1, Sec 18, [3.5].

4.1.2 The following tests are to be carried out on the control system:

a) Proper working of alarms and defaults and related functions and/or interfacing to the other ship systems

b) Manual switch from diesel propulsion mode to PTI fully electric mode and to PTI booster mode, if available

c) Manual switch from PTI fully electric propulsion mode and from PTI booster mode, if available, to diesel propulsion mode

d) Transfer of control between the different control positions

e) Automatic switch from PTI fully electric propulsion mode to diesel propulsion Mode (see [3.3.3] and [3.3.4]).

Section 4 HMPS-PREPARED

1 General

1.1 Application

1.1.1 The additional class notation **HMPS-PREPARED** may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.20.4], to new ships that are designed, in accordance with the requirements of this Section, with specific arrangements intended to accommodate a hybrid mechanical propulsion installation at a later stage (see [1.1.3]).

The requirements of this Section:

- aims at controlling the impact on the existing installation of a conversion to hybrid mechanical propulsion system by considering the main design requirements.
- gives the opportunity to the shipowner to delay the installation on board of the hybrid mechanical propulsion and their associated equipment to anticipate new developments in hybrid mechanical propulsion systems.

Note 1: Assignment of the additional class notation **HMPS-PREPARED** to existing ships may be specially considered.

1.1.2 Equipment already installed before conversion to hybrid mechanical propulsion

In accordance with [1.1.1], when equipment within the scope of the additional class notation **HMPS** (see [1.1.3]) are already installed at newbuilding stage, the applicable requirements defined in Ch 14, Sec 3 are to be complied with.

1.1.3 Conversion to hybrid mechanical propulsion

After conversion to hybrid mechanical propulsion, the additional class notation **HMPS-PREPARED** will be replaced by the additional class notation **HMPS,** as defined in Pt A, Ch 1, Sec 2, [6.20.3], provided that all the applicable requirements of Ch 14, Sec 3 are complied with.

The conversion to hybrid mechanical propulsion corresponds to the installation on board of all the equipment required to have a fully operational hybrid mechanical propulsion installation where:

- the installation is in compliance with the applicable requirements set out in Ch 14, Sec 3, as applicable at the date of conversion
- each equipment are in compliance with the applicable requirements of Ch 14, Sec 3 at the time of its actual installation on board
- All documents required in Ch 14, Sec 3, Tab 1 are submitted for review for the assignment of the additional class notation **HMPS**.

1.2 Definitions and abbreviations

1.2.1 The definitions given in Ch 14, Sec 3 for hybrid mechanical propulsion systems apply to this Section.

1.3 Documentations to be submitted

1.3.1 The documentation to be submitted is listed in Tab 1.

1.3.2 Dimensioning Analysis

The dimensioning analysis:

- specifies the dimensioning of the components of the hybrid mechanical propulsion installation already installed and those to be installed in the future for conversion to hybrid mechanical propulsion
- justifies the dimensioning of the electrical components of the ship (bus bars, cables, etc.) and the selection of the protections (short circuit current) which will be impacted by the conversion to hybrid mechanical propulsion
- specifies and justifies the spaces and volumes necessary for the installation the future pieces of equipment, to be considered in the initial design of the ship, see [3.1]
- is to detail the following elements for overall review of the decks supporting the equipment:
  - the design pressures considered on the decks where related equipment will be installed at later stage
  - the anticipated maximum weight of equipment together with their expected location and minimum surface projected on deck.

The characteristics of the cables used in the dimensioning analysis are to be specified.

Note 1: Cable characteristics include voltage class, temperature class, insulation material characteristics, number of cores, conductor cross section (in mm^2), special properties (flame retardant/fire resistant).

1.3.3 Feasibility and impact analysis

The feasibility and impact analysis is a document which describes the next steps to be followed in order to convert the ship to hybrid mechanical propulsion. This document is to contain the following information:

- list of the main electrical and mechanical devices or equipment scheduled to be installed for conversion to hybrid mechanical propulsion, for instance, generator/motor the AC/DC converter, the transformer, filters, cable trays, cables
- for each equipment, the design specification and any restriction or limitation to be taken into account for the selection and installation of the future equipment are to be clearly specified, in accordance with [2]
- overall diagram of the hybrid mechanical propulsion, detailing:
  - the pieces of equipment already installed
  - the pieces of equipment to be installed at a later stage
  - the interconnection and interfaces between above pieces of equipment
- drawing showing the foreseen routing of the cables
- the procedure for future installation, considering the practical impact on the ship, detailing future necessary conversion work (such as, for instance, dismantling of ceilings or hull opening)
- identified restrictions or limitations in the installation of the ship which may appear at the time of the conversion to hybrid mechanical propulsion.

Table 1 : Documentation to be submitted

No.	A/I **(1)**	Documentation
1	I	General description of the propulsion systems with their different operating modes, assuming that the hybrid mechanical propulsion installation is installed on board
2	I	Operating procedure to switch from one propulsion system to another one
3	I	• Power balance in PTO propulsion mode • Power balance in PTI fully electric mode • Power balance in PTI booster mode, if any
4	A	Dimensioning analysis (See [1.3.2]) and preliminary structural modification
5	A	Feasibility and impact analysis (See [1.3.3])
6	A	List of alarms and defaults for the contemplated hybrid mechanical propulsion installation
7	I	General arrangement drawing of the ship showing the hybrid mechanical propulsion installation, either fitted at the newbuilding stage or planned at a later stage **(2)**

(1) A: to be submitted for approval; I: to be submitted for information

(2) The equipment and systems installed at newbuilding stage and those intended to be installed at a later stage are to be clearly identified on the drawing.

2 System design

2.1 Ship design

2.1.1 The future hybrid mechanical propulsion installation is to comply with the requirements of Ch 14, Sec 3, [2] for the system design.

2.1.2 Spare incoming feeders are to be identified or provided in the main switchboard and power generation system. These feeders are to be able to accommodate the following components for potential future hybrid mechanical propulsion integration.

These spare incoming feeders are not required to be equipped (for instance with a circuit breaker, protection relay). However, spare spaces are to be available on the main switchboard.

2.1.3 A sufficient number of spare I/O modules is to be identified or provided into the control alarm and monitoring system of the ship to allow all the foreseen connections of the hybrid mechanical propulsion required in Ch 14, Sec 3.

Note 1: No programming nor configuration of the control alarm and monitoring system is required when assigning the **HMPS-PREPARED** notation.

2.1.4 The short circuit calculation of the ship is to take into account the prospective short circuit current coming from the power generator and is to comply with the requirements of Pt C, Ch 2, Sec 3, [7].

2.1.5 The transformer construction is to be in accordance with Pt C, Ch 2, Sec 5.

2.2 Cables

2.2.1 Cables hypothesis are to be in line with the provisional load balance in the different hybrid mechanical propulsion modes (PTI Fully electric, PTI Booster, PTO).

2.2.2 Cables are to comply with the requirements of Pt C, Ch 2, Sec 9.

2.3 Safety

2.3.1 The impact of the installation of the hybrid mechanical propulsion system on:

- Space categorization and fire insulation,
- fire-fighting systems and equipment and on fixed fire alarm and fire detection systems,
- escape routes,
- ventilation systems,

is to be assessed.

Note 1: These system, equipment and arrangement as foreseen after installation of the hybrid mechanical propulsion system are to comply with the requirements of:

- Pt C, Ch 4, Sec 5 for space categorization and fire insulation
- Pt C, Ch 4, Sec 3, Pt C, Ch 4, Sec 6 and Pt C, Ch 4, Sec 15 for fire-fighting systems and equipment and on fixed fire alarm and fire detection systems
- Pt C, Ch 4, Sec 8 for escape routes
- Pt C, Ch 4, Sec 5, [6] for ventilation systems.

3 Installation on board

3.1 Spaces

3.1.1 Spaces are to be allocated for the equipment to be installed later within the scope of the **HMPS** additional class notation.

3.1.2 When water-cooled components are intended to be installed (batteries, converter, transformer), a connection to the water-cooling circuit is to be identified or provided into or close to the rooms where they are installed. The impact on the water-cooling system is also to be assessed.

3.1.3 When the spaces intended for later installation of hybrid mechanical propulsion related equipment are used for another purpose (for instance, storage) before the ship is effectively converted to hybrid mechanical propulsion, they are to fulfil the corresponding requirements for this specific use.

3.1.4 The number of electrical equipment to be installed in the ship's hazardous area is to be minimized.

4 Testing

4.1 Type tests

4.1.1 Cables are to be of a type approved by the Society according to the requirements of Pt C, Ch 2, Sec 9, [3.1].

4.1.2 Routine tests are to be carried out on cables in compliance wit Pt C, Ch 2, Sec 9, [3.2].

Section 5 Onshore Power Supply (OPS)

1 General

1.1 Application

1.1.1 General

The additional class notation **OPS** (Onshore Power Supply) is assigned in accordance with Pt A, Ch 1, Sec 2 to ships fitted with shore connection systems complying with the requirements of this Section, and allowing the ship to plug into an onshore power source when berthed.

The additional class notation **OPS** is completed between bracket by the one or several shore supply characteristics the ship's installation is designed to receive:

- when main power distribution is AC: power supply voltage the ship can connect to, completed by AC and ship's main frequency
- when main power distribution is DC: power supply voltage the ship can connect to, completed by DC.

Examples:

OPS(440 V AC 50 Hz)

OPS(1 kV DC)

OPS(440 V AC 60 Hz / 6,6 kV AC 60 Hz / 1 kV DC)

Note 1: Standards IEC 80005-1:2019 and 80005-3:2016 specify 400 V AC, 440 V AC, 690 V AC, 6.6 kV AC and 11 kV AC as the standard voltages of shore supply.

1.1.2 Additional class notation **OPS** is mandatory for ships fitted with HV Shore Power supply systems.

1.1.3 Scope

The requirements of the present section apply to the design, construction and testing of shipboard electrical and control engineering arrangements installed to permit operation of services by connection to an external electrical power supply in port, in addition to the requirements of Pt C, Ch 2, Sec 3, [3.7].

Except if the OPS system is arranged for non-standard power voltages (see Note 1), a ship assigned the additional class notation OPS is compliant with the ship requirements and installation requirements articles of IEC 80005-1:2019 or IEC 80005-3:2016 as applicable.

For shore supplies not complying with the above-mentioned IEC standards, a case-by-case study is to be carried out for the implementation of specific power supplies (e.g. DC power shore supply).

1.2 Definitions

1.2.1 Abbreviations

LV : Low-Voltage

HV : High-Voltage

OPS : Onshore Power Supply

HVSC : High-Voltage Shore Connection

LVSC : Low-Voltage Shore Connection

CMS : Cable Management System

1.2.2 Onshore power supply (OPS)

Onshore power supply (OPS) system is the equipment that supplies onshore power to ships berthing in port, including ship-side installations and shore installations.

The requirements of this Section apply for the ship-side part of the OPS system.

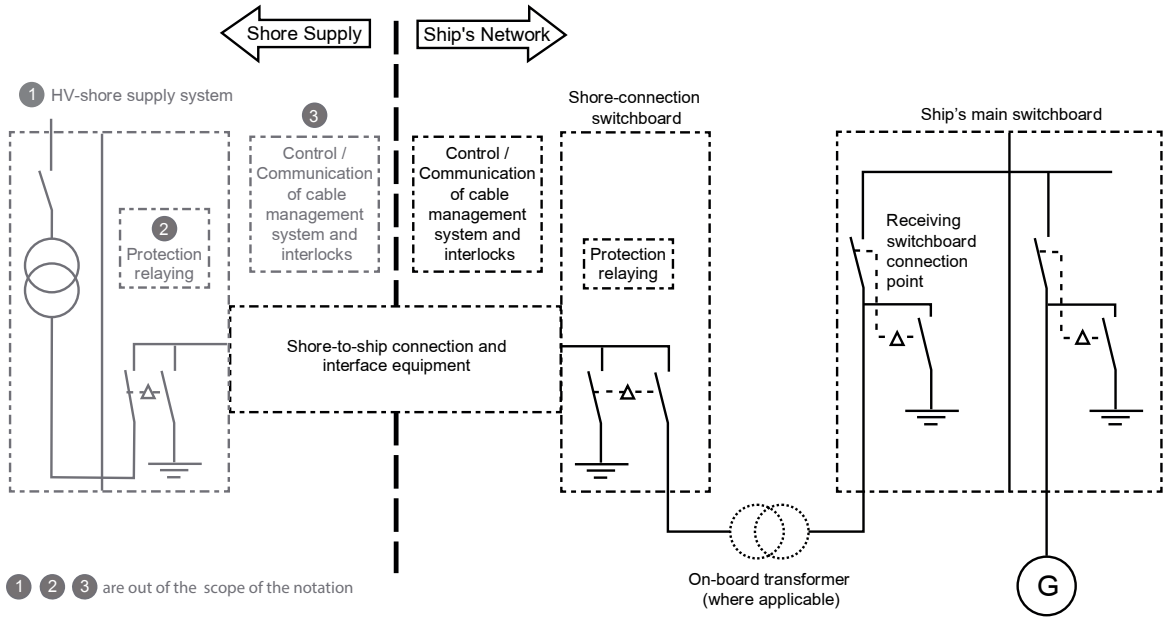
1.2.3 OPS System components

An OPS System described in this section typically consists of the following hardware components (see Fig 1):

- HV or LV Shore supply equipment
- Transformer

- Static / rotating convertor, where applicable (for instance, when the shore and vessel have different frequencies)
- Cables and cables management equipment including plug and socket-outlet
- Shore connection switchboard
- On board transformer, where applicable (for instance when the vessel has a low-voltage main switchboard)
- Ship receiving switchboard (in general, a section of the main switchboard).

Figure 1 : Diagram of a typical OPS arrangement



1.2.4 Cable Management System

All equipment designed to control, monitor and handle the flexible and control cables and their connection devices (cable reels, crane, etc...).

1.2.5 Equipotential bounding

Provision of electric connections between conductive parts, intended to achieve equipotentiality.

1.2.6 Plug and socket-outlet

A means enabling the connection of a flexible cable (with plug) to fixed wiring (with socket-outlet).

1.3 Documentation to be submitted

1.3.1 Drawings and related information

The documentation to be submitted for the additional class notation **OPS** is listed in Tab 1.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Documents
1	A	One line diagram of the onshore connection system
2	A	Selectivity and coordination of the electrical protections
3	A	Diagrams of control, alarm, ship-shore communication and safety systems
4	A	Drawing of CMS when applicable
5	A	Details of supplementary arrangements required to protect equipment from exposure to moisture, condensation or temperatures outside their rating
6	I	General arrangement showing the location of the connection equipment, cabinets, routing of the cables, movable parts, openings and accesses
7	I	Services to be supplied and electrical load analysis in shore supply condition
8	I	Operating manuals describing the method of connection, the limiting environmental conditions, the CMS capacity, the operating and the monitoring instructions (including the interlocking procedure of earth-switches, breakers)
9	I	Operational and construction details of Connection Equipment, including any flexible or adjusting arrangements, including plugs and socket-outlets
10	I	Risk assessment for ships listed in [2.1.2], item g)
(1) A: to be submitted for approval; I: to be submitted for information.		

2 Electrical Installations

2.1 General requirements

2.1.1 Design Requirements

a) Warning notices indicating the presence of shore connection equipment are to be provided at locations along connection equipment routes including at connection locations.

b) Effective means are to be provided to prevent accumulation of moisture and condensation, even if equipment is idle for appreciable periods.

c) Shore power is to be supplied by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically upon failure of the shore power.

d) Each failure is to be identified by an alarm at a continuously manned central control station.

e) Protection and safety systems (e.g. emergency shutdown, socket-outlet limit switches) are to be designed based on the fail safe principle, hard-wired.

f) OPS system components are to be of a type approved by the Society following requirements of Pt C, Ch 2, Sec 1, [4] and requirements of [3.1.1].

2.1.2 Location and Construction

a) Shore connection equipment is to be suitable for the environmental conditions in the space(s) where it is expected to operate. Ship equipment is to comply with the applicable requirements of IEC 60092-101:2018 and IEC 60092-503:2021.

b) The installation of electrical equipment located in the ship's hazardous area is to be minimized.

c) If some of the equipment cannot be located in a non-hazardous area, then it is to be certified as a safe type compliant with Pt C, Ch 2, Sec 3, [10] or located in a gas-free, safe, pressurised space (e.g. connection point on tankers or LNGC) provided with interlock when the compartment is open.

d) Shore connection system is to be compatible with forces, moments and deflections resulting from the movement of the moored ship under normal operational circumstances.

e) Shore connection system is to be located outside of areas where it could be damaged by in-port activities or ship activities under normal operational circumstances.

f) An earth connection is to be provided for connecting the hull to the shore power earth electrode.

g) For ships assigned one of the following service notations:

- **oil tanker**
- **FLS tanker**,
- **chemical tanker**,
- **liquefied gas carrier** or **liquefied gas carrier -FSRU** or **liquefied gas carrier -FSU**,
- **supply**,
- **oil recovery**,

a risk assessment is to be provided for the determination of the location of OPS system components in hazardous areas to ensure safe installation and connection to shore supply.

2.1.3 Electrical load transfer

a) Load transfer between operation using ship sources of electrical power and an external electrical power supply is to be provided via black out or synchronization between the two sources.

b) In case of load transfer via black out, means are to be provided to ensure that the shore supply can only be connected to a dead switchboard.

2.1.4 Electrical load transfer via short time parallel running

Where the ship's electrical system is designed for temporary parallel connection for load transfer with shore power, the following requirements are to be complied with:

a) Means to automatically synchronize a ship source of electrical power with an external electrical power supply and connect them in parallel for load transfer are to be provided.

b) The load transfer is to be completed in a time as short as practicable without causing machinery or equipment failure or operation of protective devices. This time is to be used as the basis for defining the transfer time limit.

c) The transfer time limit is to be defined and made available to responsible personnel. The transfer time limit may be adjustable to match with the ability of the external source of electrical power to accept and shed load.

d) When transferring of load between ship sources of electrical power and an external electrical power supply exceeds a defined Transfer Time Limit then, means are to be provided to:
   - abort the transfer
   - remove the load from the ship sources of electrical power or external electrical power supply that was intended to take the load
   - open the connection circuit-breaker.

e) An alarm is to be provided at a machinery control station that is attended when connected to an external electrical power supply when the Transfer Time Limit is exceeded and is to indicate the return to previous operating conditions.

2.1.5 Ship power restoration

During a failure of the shore power connection (including activation of emergency shutdown or electrical system protective device activation) leading to the shutdown of ship's main source of electrical power the shore connection switchboard circuit-breaker is to automatically open followed by:

a) Starting of the emergency source of electrical power to supply emergency services equivalent to SOLAS CH II-1/D, Reg. 42 for passenger ships or 43 for cargo ships

b) Automatic connection of the transitional source of electrical power to emergency services, equivalent to SOLAS CH II-1/D, Reg. 42 for passenger ships or 43 for cargo ships, and

c) Starting and connecting to the main switchboard of the main source of electrical power and sequential restarting of essential services, in the shortest time practical. This is to be automatic in the event of emergency shut-down activation.

2.1.6 Additional requirements for HV systems

a) HV pieces of equipment are to be installed in access-controlled spaces and in general are to be compliant with Pt C, Ch 2, Sec 13.

b) Marking is to be arranged at the entrance of spaces where HV electrical equipment is installed indicating the presence of HV equipment and that access is restricted. Similar marking is to be arranged on HV electrical equipment when installed outside of dedicated spaces.

2.1.7 Additional requirements of DC systems

For DC OPS, a case by case study is to be carried out including selection of DC-compatible pieces of equipment. In such system, the following requirements are to be applied, and specific risks associated with DC usage is to be considered, especially in hazardous areas:

a) Instrumentation and monitoring listed in [2.3] is to be compatible with DC installation.

b) Protective equipment, including overcurrent protection devices, earth leakage current protection devices, and reverse current prevention devices are to be compatible with DC electrical installations.

c) All switches are to be certified for DC use.

2.2 Ship to Shore installation

2.2.1 Plugs and socket-outlets

a) Connection plug and socket-outlets are to be designed according to IEC 80005-1:2019 for HV systems or IEC 80005-3:2016 for LV systems. Other standards will be considered on a case by case basis.

b) The plug and socket-outlet is to be fitted with a mechanical-securing device that locks the connection in engaged position.

c) The plugs and socket-outlets are to be designed so that an incorrect connection cannot be made.

d) Socket-outlets and inlets are to be interlocked with the earth switch so that plugs or connectors cannot be inserted or withdrawn without the earthing switch in closed position. The earthing contacts are to make contact before the power contacts do when inserting a plug.

e) Plugs are to be designed so that no strain is transmitted to the terminals, contacts and cables.

f) Power connection plug and socket-outlets are to be of a type approved by the Society complying with requirements listed in [3.1.1].

g) The number of sockets is to be designed based on electrical load analysis and design characteristics of the electrical equipment and cables.

h) HV plugs and socket-outlets are to be of a type approved by the Society complying with requirements listed in [3.1.1].

2.2.2 Onboard receiving switchboard

A panel in the main switchboard is to be provided as an onboard receiving switchboard. Alternatively, the onboard receiving switchboard can be a separate panel located in a dry space.

The switchboard is to include a circuit-breaker with built-in disconnection function compliant with Pt C, Ch 2, Sec 10, [1.2].

a) For LV switchboards:
   1) The switchboard is to comply with Pt C, Ch 2, Sec 8, [1] for LV systems.

b) For HV switchboards:

1) The switchboard is to comply with Pt C, Ch 2, Sec 13, [6] for HV systems.

2) An earthing switch is to be installed in the shore connection panel if the main switchboard rated voltage exceeds 1000 V AC or 1500 V DC.

3) The switchboard is to be tested in accordance with internal arc classification (IAC) procedure in IEC 60271-200:2011 Annex A, Accessibility class A, or the access to the room is to be prevented if the switchboard is energized.

2.2.3 Transformer

a) The ship onboard receiving transformer, if installed, is to be of separate winding type for primary and secondary side.

b) If the ship onboard transformer is between HV and LV networks, an earthed shield winding is to be provided between HV and LV windings.

2.2.4 Cables

a) Permanently fixed cables are to be provided between the shore connection switchboard and the ship receiving switchboard connection point.

b) Cables are to comply with requirements of Pt C, Ch 2, Sec 9 and Pt C, Ch 2, Sec 3, [9].

c) In addition, for HV systems, cables are to comply with requirements of Pt C, Ch 2, Sec 13, [5] and Pt C, Ch 2, Sec 13, [7].

d) All cables are to be of a type approved by the Society following Pt C, Ch 2, Sec 9, [3.1].

2.2.5 Cable management system

A cable management system enabling the connection of cables between the shore connection switchboard and the ship receiving switchboard is to be provided. When the CMS is arranged onboard, it is to comply with the following requirements:

a) Cable management system cables are to be equipped with warning notices to highlight the presence of moving parts, obstacles, risks of fall.

b) The cable management system is to be arranged to provide an adequate movement compensation (due to ship movement, tidal changes …) and to maintain an optimum length of cable which avoids slack cable or exceeding of tension limits.

c) The cable management system is to ensure that the cable tension does not exceed the permitted design value.

d) The cable management system is to be equipped with a device (e.g. limit switches), independent of its control system, to monitor maximum cable tension and deployed cable length.

e) Cable management system cables are to be physical protected against heavy seas and mechanical damages.

f) Power connections with external electrical power supply arrangements may be made with socket-outlets and plugs in accordance with [2.2.1].

g) Power, control and monitoring cables is to be at least of a flame-retardant type in accordance with the requirements given in IEC 60332-1-2:2015. The outer sheath is to be oil- resistant and resistant to sea air, seawater, solar radiation (UV) and non-hygroscopic.

h) Power, control and monitoring may be based on a single cable or cables in bunch.

i) Arrangements are to be provided to stow the cable management system and associated cable when not in operation.

j) A mooring break is not to lead to a damage of the installation.

2.3 Monitoring

2.3.1 Instrumentation on ship's receiving switchboard

a) When load transfer is carried out via parallel connection (see [2.1.3]), the ship receiving switchboard is to be equipped with the following instrumentation:

- two voltmeters
- two frequency meters
- one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase
- phase sequence indicator and
- one synchronizing device.

Note 1: One voltmeter and one frequency meter shall be connected to the switchboard's busbars; the other voltmeter and frequency meter shall enable the voltage and frequency of the shore connection to be measured.

b) When load transfer is carried out via blackout, the ship receiving switchboard is to be equipped with at least following instrumentation:

- one voltmeter
- one frequency meter
- one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase and
- phase sequence indicator.

2.3.2 Instrumentation on shore connection switchboard

The shore connection switchboard is to be equipped with at least following instrumentation:

- voltmeter: all three phases
- earth-fault indicator.

2.3.3 Communication

a) Monitoring of electrical insulation between connection equipment conductors and between the conductors and earth is to be provided.

b) The measuring point for all instrumentation related to the shore power is to be on the upstream side of the incoming circuit breaker that isolates the shore power from the ship's power system.

c) An independent means of voice communication is to be provided between the ship and the shore control locations.

2.4 Protection

2.4.1 Protection devices and alarms

a) The ship receiving switchboard is to be equipped with protections compliant with Pt C, Ch 2, Sec 10, [1.3] and with the following alarms:
   - Short-circuit: tripping with alarm
   - Over-current in two steps: alarm and tripping with alarm
   - Earth fault: alarm and tripping if required by the type of isolation system used
   - Over / under voltage in two steps: alarm and tripping with alarm
   - Over / under frequency in two steps: alarm and tripping with alarm
   - Reverse power: tripping with alarm
   - Directional over-current: tripping with alarm
   - Phase sequence protection with alarm and interlock.

b) Arrangements are to be provided to ensure that the shore connection circuit-breakers cannot be operated when:
   - One of the earthing switches is closed (shore-side/ship-side)
   - The pilot contact circuit is not established
   - Emergency-stop facilities are activated
   - Ship or shore control, alarm or safety system self-monitoring properties detect an error that would affect safe connection
     The data-communication link between shore and ship is not operational
   - The high-voltage supply is not present
   - Earth fault is detected
   - Phase synchronisation is not achieved between ship’s power and shore power
   - Shore supply incompatibility with the ship’s electrical network.

c) The shore connection switchboard is to be equipped with protections and with following alarms:
   - short-circuit devices: tripping and alarm
   - overcurrent devices: tripping and alarm
   - earth-fault alarm; and
   - unbalanced protection for systems with more than one ship inlet.

2.4.2 Emergency Shutdown

a) The emergency shutdown facilities are to be activated in the event of:
   - loss of equipotential bonding, via the ground check relays
   - over-tension on the flexible cable (mechanical stress)
   - loss of the emergency shutdown control circuit
   - activation of any emergency-stop buttons
   - activation of protection relays provided to detect faults on the shore power connection cable or connectors
   - dis-engaging of power plugs from socket-outlets while shore power connections are live (before the necessary degree of protection is no longer achieved or power connections are broken).

b) Activation of the emergency shut down is instantaneously to:
   - Connect to earth the shore power connections.
   - Open all shore connection circuit breaker.

c) Emergency stops are to be provided:

- at ship's continuously manned station during shore connection system operation
- at active cable management system control locations
- at shore connection switchboard
- at close to onboard shore power socket-outlets if applicable.

d) Additional manual activation facilities may also be provided at other locations where it is considered necessary. The means of activation are to be visible and prominent, prevent inadvertent operation and require a manual action to reset.

e) An alarm indicating activation of the Emergency Shut-Down is to be provided at a Ship's control station manned during shore connection system operation. The alarm is to indicate the cause of the activation.

3 Testing and trials

3.1 Equipment Testing

3.1.1 Type testing

a) All HV Systems components are to be type tested and routine tested according to the relevant IEC standards, in particular IEC 62271-200:2011.

b) HV plugs and socket-outlets are to be tested following:

- Electrical tests:
  - partial discharge test: 10 pC at 10kV in accordance with IEC 60502-4:2010
  - A.C. voltage test: 28 kV for 5 minutes in accordance with IEC 60502-4:2010
  - short time and peak withstand current test in accordance with IEC 62271-200:2011
  - lighting impulse withstand test 75 kV 10 impulse in accordance with IEC 60502-4:2010
  - temperature rise test in accordance with IEC 60309-1:2022 clause 22
- Mechanical tests:
  - mechanical strength test IK10 in accordance with IEC 62262:2002
  - normal operation test in accordance with IEC 60309-1:2022 clause 21 (5000 cycles; for main contacts only off-load, for pilot contacts on-load)
  - degree of protection in accordance with IEC 60529:2019
  - ageing of gasket and insulator in accordance with IEC 60309-1:2022 clause 13
  - corrosion and resistance to rusting in accordance with IEC 60309-1:2022 clause 28
  - environmental tests to demonstrate compliance with IEC 60092-101:2018, Annex B and IEC 60721-3-6:1996 for the ship environment following IEC TR 60721-4-6:2001
  - pilot contact is to be tested according to IEC 60947-5-1:2016. The degree of protection is to be at least IP20 when not plugged

c) In case of DC OPS systems, electrical equipment is to be of a type approved for DC use

d) LV electrical shore connection equipment on board are to be of a type approved by the Society as per requirements of Part C, Chapter 2.

3.2 Initial tests

3.2.1 Factory Acceptance Tests

a) Electrical and control engineering equipment is to be surveyed at manufacturer's works and undergo survey and operational trials on board in accordance with the approved test schedules and applicable testing requirements in Part C, Chapter 2 and Part C, Chapter 3.

3.2.2 Onboard Tests

a) Tests are to be carried out to demonstrate that the electrical system, control, monitoring and alarm systems have been correctly installed and are in good working order before being put into service. Tests are to be realistic and simulations avoided as far as practicable.

b) Following tests are to be carried out after completion of the installation:

- Visual inspection
- HV Test
- Insulation resistance measurement
- Measurement of the earthing resistance
- Function test including correct settings of the protection devices
- Function test of the protection devices, including interlocks
- Function test of the control equipment including emergency stops
- Load transfer (blackout and synchronization, if applicable) at shipyard or at first opportunity after delivery
- Earth-fault-monitoring test
- Phase-sequence test
- Function test of the cable management system where applicable
- Power frequency test for switchgear assemblies and voltage test for cable following IEC 60092-401:1997 for LV equipment, and IEC 62271-200:2011 and IEC 60502-2:2014 for HV equipment.
- Test according to Pt C, Ch 2, Sec 13, [7.2.6] for HV cables
- Test of restoration of the main or emergency source of power after a failure of the shore power
- Record of Load Transfer Time for short time parallel running
- Record of emergency disconnection time.

Section 6 OPS-PREPARED

1 General

1.1 Application

1.1.1 In accordance with Pt A, Ch 1, Sec 2, [6.20.6], the additional class notation **OPS( )-PREPARED** may be assigned to:

- new ships complying with the requirements of this Section and designed with specific arrangements to accommodate an Onshore Power Supply (OPS) System installation at a later stage.
- existing ships when the installation of a shore connection is considered during a future retrofit.

The additional class notation **OPS( )-PREPARED** is completed between bracket by the one or several shore supply characteristics the ship's installation is considered to receive:

- when main power distribution is AC: power supply voltage the ship can connect to, completed by AC and ship's main frequency
- when main power distribution is DC: power supply voltage the ship can connect to, completed by DC.

The additional class notation **OPS( )-PREPARED** may be completed by **-C** when the cables for connection between the shore connection receiving box and the ship main switchboard and to the relevant electrical pieces of equipment (e.g. transformer) are already installed on board in accordance with [3].

Example:

OPS(440 V AC 60 Hz / 11 kV DC)-PREPARED-C

1.1.2 The additional class notation **OPS( )-PREPARED** aims at limiting the impact of the future installation of a shore connection system on the ship arrangement and systems by considering:

- the technical design features of the considered OPS equipment
- the applicable Rules when assigning the notation **OPS( )-PREPARED**, as defined in Pt A, Ch 1, Sec 2, [6.20.5]
- the application of IEC 80005-1:2019 and IEC 80005-3:2016 to the ship's equipment, if relevant.

1.1.3 After the installation of the system on board in accordance with the requirements of Ch 14, Sec 5, the ship may be assigned the additional class notation **OPS( )** as defined in Pt A, Ch 1, Sec 2, [6.20.5].

1.2 Definitions and abbreviations

1.2.1 Onshore Power Supply (OPS)

Onshore Power Supply (OPS) system refers to the system on board the ship, allowing the supply of the ship with electrical power from shore.

1.3 Documentation to be submitted

1.3.1 The documentation to be submitted for the additional class notation **OPS( )-PREPARED** is listed in Tab 1.

1.3.2 Dimensioning analysis

The dimensioning analysis:

- specifies the dimensioning of the components of the shore connection installation already installed and those to be installed at a later stage
- justifies the dimensioning of the electrical components of the ship (e.g. bus bars, cables, transformers) and the selection of the protections (short circuit current) which will be impacted by the installation of a shore connection system
- specifies and justifies the spaces and volumes necessary for the installation of the future pieces of equipment, to be taken into account in the initial design of the ship, see [2.2.1]
- specifies the elements necessary for the strength assessment of the superstructure enclosing the OPS installation, when a dedicated room for shore connection components is intended to be added (e.g. container), see [2.3.1]

Table 1 : Documents to be submitted

No.	A/I **(1)**	Documents
Ship general documentation		
1	I	General arrangement drawing of the ship showing: • the hazardous areas • the OPS installation, either fitted at the newbuilding stage or planned at a later stage **(2)**, including location of the connection equipment, cabinets, transformer if any, shore connection container if any, routing of the cables, movable parts, openings and accesses
2	I	Power balance in shore supply condition
3	A	Dimensioning analysis (See [1.3.2]) and preliminary structural modification
4	I	Feasibility and impact analysis (See [1.3.3])
Onboard shore connection installation		
5	A	One-line electrical diagram including the ship's side OPS system
6	I	Overview of arrangements to protect equipment from exposure to moisture, condensation or temperatures outside their rating
(1) A: to be submitted for approval; I: to be submitted for information **(2)** The equipment and systems installed at newbuilding stage and those intended to be installed at a later stage are to be clearly identified on the drawing		

1.3.3 Feasibility and impact analysis

The feasibility and impact analysis describes the next steps preparing the installation of the shore connection system on board. This document is to contain the following information:

- list of the main electrical devices or equipment to be installed to allow shore connection (e.g. converter, transformer, shore connection switchboard, cable trays layout, high-voltage cables)
- for each piece of equipment:
  - the design specification, including dimensions, maintenance area, IP grade, control and any restriction to be considered for the installation
  - ship's compartments or areas where equipment will be installed
- overall diagram of the shore connection installation detailing the interconnection and interfaces between the pieces of equipment to be installed at a later stage and the existing installation of the ship
- basic design drawings showing the foreseen routing of cables
- the procedure for future installation, considering the practical impact on the ship, detailing foreseen necessary conversion work
- identification of limitations which may appear at the time of the installation of the shore connection system, including need for cabling or piping re-routing or protection
- identification of the ship's safety systems and arrangement modifications which may be necessary at the time of the shore connection installation, as applicable:
  - space categorization
  - fixed fire alarm and fire detection systems
  - ventilation system
  - escape routes.

The modifications that may be necessary to accommodate the installation of the shore connection system are to be detailed in order to demonstrate the feasibility.

The feasibility and impact analysis will provide a basis for the review of the relevant documentation at the time of actual installation on board, in view of assigning the additional class notation **OPS**.

2 Requirements for OPS( )-PREPARED

2.1 General

2.1.1 The general ship design requirements given in [2.2] and [2.3]are to be complied with prior to the assignment of the additional class notation **OPS( )-PREPARED**.

The detail design requirements given in [2.4] are to be complied with:

- either prior the assignment of the additional class notation **OPS( )-PREPARED**, or
- at OPS installation stage. In this case the necessary modifications are to be documented in the feasibility and impact analysis.

2.2 General ship design - arrangement

2.2.1 Spaces or areas are to be allocated for the equipment of the foreseen shore connection system, complying with the applicable requirements of Ch 14, Sec 5. The volumes of these spaces are to be specified based on the design of shore connection system (containerized unit or standalone system) and taking into account:

- the required clearance above switchboard as per IEC 62271-200:2021
- access for maintenance and installation.

The calculation and explanation of the volume needed are to be detailed in the feasibility and impact study.

2.2.2 OPS system components are in general not to be located in ship's hazardous areas.

If the installation of equipment such as OPS connection box cannot be done outside of hazardous areas, alternative solution may be accepted by the Society considering the demonstration of an equivalent safety level: e.g. an over pressurized box for the shore power socket space.

2.2.3 Where a shell door is intended to be created, it is not to interfere with the launching arrangements for survival craft or rescue boats.

2.3 General ship design - electrical system design

2.3.1 A section is to be available in the main switchboard for later use as the onboard receiving switchboard. The feasibility and impact analysis is to mention whether the cabinet is empty and list the necessary items to be added at OPS system installation.

2.4 Detailed design

2.4.1 General arrangement and local strength

a) Where a dedicated room is to be created to accommodate the shore connection components, the strength of this superstructure, and means for securing if applicable - e.g. in the case of a container-, is to be assessed according to Part B, Chapter 7.

b) Structural integrity

Where new openings in the ship's structure are foreseen at the time of the installation of the OPS components for cables or duct passage, or any other purpose, they are to comply with the requirements of Pt B, Ch 4, Sec 5, [6], and Pt B, Ch 6, Sec 1, [1].

Particular attention is to be paid in areas where openings already exist.

Additional checks may be required depending on the locations of the new openings and the service notation assigned to the ship.

c) Watertightness and weathertightness

Where new openings in the ship's structure are foreseen at the time of the installation of the OPS components for cables or duct passage, or any other purpose, they are to comply with the requirements of:

- Pt B, Ch 2, Sec 1, [6] for openings in watertight bulkheads and decks
- Pt B, Ch 11, Sec 5, [1.5] for openings in weathertight boundaries.

2.4.2 Electricity and automation

a) The impact of the installation of the OPS system on the emergency lighting fittings, public address system, general alarm system and fire detectors is to be assessed. These items will have to be provided as foreseen after installation of the OPS system in the spaces or areas where the OPS components are planned to be installed.

b) The electrical equipment of the shore connection system is to comply with the requirements of Ch 14, Sec 5.

c) For HV OPS system, installation is to comply with the requirements of Pt C, Ch 2, Sec 13.

2.4.3 Safety

a) The impact of the installation of the OPS system on fire insulation requirements is to be assessed. Space categorization and fire insulation as foreseen after installation of the OPS system is to comply with Pt C, Ch 4, Sec 5.

b) The impact of the installation of the OPS system on fire-fighting systems and equipment and on fixed fire alarm and fire detection systems is to be assessed. These systems as foreseen after installation of the OPS system are to comply with the requirements of Pt C, Ch 4, Sec 3, Pt C, Ch 4, Sec 6 and Pt C, Ch 4, Sec 15.

c) The impact of the installation of the OPS system on escape routes is to be assessed. Escape routes as foreseen after installation of the OPS system are to comply with Pt C, Ch 4, Sec 8

d) The impact of the installation of the OPS system on ventilation systems is to be assessed. Ventilation systems as foreseen after the installation of the OPS system are to comply with the requirements of Pt C, Ch 4, Sec 5, [6].

3 Additional requirements for notation -C

3.1 Cable routing

3.1.1 Permanently fixed cables of adequate rating are to be provided for connecting the shore connection receiving box to the ship main switchboard and to the relevant electrical pieces of equipment (e.g. transformer).

3.1.2 Cables are to comply with the requirements of Pt C, Ch 2, Sec 3, [9]; Pt C, Ch 2, Sec 9 and Pt C, Ch 2, Sec 13, [5], as applicable.

3.1.3 High-voltage cables are to be subjected to a voltage withstand test and to insulation tests according to Pt C, Ch 2, Sec 13, [7.2].

CHAPTER 15
OTHER ADDITIONAL CLASS NOTATIONS

Section 1 Strengthened Bottom (STRENGTHBOTTOM)
Section 2 Grab Loading (GRABLOADING)
Section 3 In-Water Survey Arrangements (INWATERSURVEY)
Section 4 Permanent Means of Access (ACCESS)
Section 5 Helideck (HEL)
Section 6 Man Overboard Detection (MOB)
Section 7 FSRU-READY
Section 8 Sustainable Ships

Section 1 Strengthened Bottom (STRENGTHBOTTOM)

Symbols

L : Rule length, in m, defined in Pt B, Ch 1, Sec 3, [2.1.1]

σ_g : Hull girder normal stresses in stranded condition defined in [1.1.3]. For ships less than 90 m, σ_g is to be taken equal to: $\sigma_g = 0$.

1 General

1.1 Application

1.1.1 The additional class notation **STRENGTHBOTTOM** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.18.1], to ships built with specially strengthened bottom structures so as to be able to be loaded and/or unloaded when properly stranded and complying with the requirements of this Section.

1.1.2 The assignment of additional class notation **STRENGTHBOTTOM** assumes that the ship will only be grounded on plane, soft and homogeneous sea beds with no rocks or hard points and in areas where the sea is calm such as harbours or sheltered bays.

1.1.3 As a general rule, the requirements of this Section are applicable to ship having a length less than or equal to 90 m.

Ships greater than 90 m in length may be considered by the Society on a case-by-case basis, taking into account the specific hull girder loads induced by loading and unloading when stranded.

The general configuration of the ship and the conditions of grounding during loading and unloading operations having an effect on the hull girder loads are to be specified. The longitudinal distribution of bending moment is to be calculated, and the hull girder normal stresses, σ_g, for elements contributing to the hull girder longitudinal strength in stranded condition are to be calculated.

2 Primary supporting members arrangement

2.1 General

2.1.1 The number and size of holes on floors and girders are to be kept as small as possible, and are to be such as to allow complete inspection of double bottom structures. See also Pt B, Ch 4, Sec 5, [6.3].

2.2 Ships with a longitudinally framed bottom

2.2.1 Floors and side girders are to be fitted with a maximum spacing not greater than $0,9\ L^{0,25}$.

2.3 Ships with a transversely framed bottom

2.3.1 Side girders are to be fitted with a maximum spacing not greater than $0,9\ L^{0,25}$.

3 Bottom scantlings

3.1 Plating

3.1.1 Plating

The net thickness of the bottom and bilge platings obtained from Pt B, Ch 7, Sec 4 or the thickness obtained from NR600, as applicable, are to be increased by 20% and in no case are to be less than 8 mm.

The values of the corrosion addition are to be taken as defined in Pt B, Ch 4, Sec 3 for plating calculated according to Pt B, Ch 7, Sec 4.

3.2 Stiffeners

3.2.1 The net section modulus Z, in cm^3, and the net shear section area A_{shr}, in cm^2, of longitudinal or transverse bottom stiffeners are to be not less than the greater of the following values:

- the values obtained from Pt B, Ch 7, Sec 5 or NR600, as applicable

- the values obtained from Pt B, Ch 7, Sec 5 considering:
  - σ_g instead of σ_L
  - χ equal to 1,25
  - β_S equal to 0,65
  - C_t equal to 0,48 or 0,58 respectively for acceptance criteria AC-1 or AC-2.

3.3 Primary supporting memers

3.3.1 The net section modulus Z, in cm^3, and the net shear section area A_{shr}, in cm^2, of primary supporting members are to be not less than the greater of the following values:

- the values obtained from Pt B, Ch 7, Sec 6 or NR600, as applicable
- the values obtained from Pt B, Ch 7, Sec 6 considering:
  - χ equal to 1,25
  - C_s, C_t and C_{comb} equal to 0,45 or 0,55 respectively for acceptance criteria AC-1 or AC-2.

Section 2 Grab Loading (GRABLOADING)

1 General

1.1 Application

1.1.1 The additional class notation **GRABLOADING** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.18.2], to ships with holds specially reinforced for loading/unloading cargoes by means of buckets or grabs and complying with the requirements of this Section.

2 Scantlings

2.1 Inner bottom plating

2.1.1 The net thicknesses of:

- inner bottom plating, where no continuous wooden ceiling is fitted
- hopper tank sloped plate and transverse stools, if any, up to 1,5 m from the inner bottom
- bulkhead plating, if no stool is fitted, up to 1,5 m from the inner bottom,

is to obtained, in mm, from the following formula:

$t = t_1 + t_G$

where:

t_1 : Net thickness, in mm, to be obtained from Pt B, Ch 7, Sec 4 or NR600, as applicable

t_G : Additional net thickness for taking account of grab impacts, to be taken equal to 3,5 mm. For inner bottom plating, where no continuous wooden ceiling is fitted, t_G includes the 2 mm required in Pt B, Ch 7, Sec 4, [6.3.1] or NR600, as applicable.

Above 1,5 m from the inner bottom, the net thicknesses of the above plating may be tapered to those obtained from the formulae in Pt B, Ch 7, Sec 4 or NR600, as applicable. The tapering is to be gradual.

Section 3 In-Water Survey Arrangements (INWATERSURVEY)

1 General

1.1 Application

1.1.1 The additional class notation **INWATERSURVEY** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.25.1].

1.2 Documentation to be submitted

1.2.1 Plans

Detailed plans of the hull and hull attachments below the waterline are to be submitted to the Society for approval. These plans are to indicate the location and/or the general arrangement of:

- all shell openings
- the stem
- rudder and fittings
- the sternpost
- the propeller, including the means used for identifying each blade
- anodes, including securing arrangements
- bilge keels
- welded seams and butts
- marking as per [2.1] with type, position, size, paint, tank abbreviation table.

The plans are also to include the necessary instructions to facilitate the divers' work, especially for taking clearance measurements.

Moreover, a specific detailed plan showing the systems to be adopted when the ship is floating in order to assess the slack between pintles and gudgeons is to be submitted to the Society for approval.

1.2.2 Photographs

As far as practicable, photographic documentation of the following hull parts, used as a reference during the in-water surveys, is to be submitted to the Society:

- the propeller boss
- rudder pintles, where slack is measured
- typical connections to the sea
- directional propellers, if any
- other details, as deemed necessary by the Society on a case-by-case basis.

1.2.3 Documentation to be kept on board

The Owner is to keep on board the ship the plans and documents listed in [1.2.1] and [1.2.2], and they are to be made available to the Surveyor and the divers when an in-water survey is carried out.

2 Structure design principles

2.1 Marking

2.1.1 Identification marks and systems are to be supplied on the outer surface of the shell below the summer load waterline in order to facilitate the in-water survey by showing clearly the positions of watertight bulkheads.

2.1.2 Markings are to be at least 300 mm long and 30 mm wide, and be made in high contrast colour and surrounded by weld bead. The use of antifouling paint is advised.

Anodes or external attachments on the hull may replace markings, provided they are identified accordingly on the plans submitted for approval according to [1.2.1].

2.1.3 Every tank and bulkhead is to be clearly identified on the shell below the summer load waterline (side shell and bottom) with markings generally arranged as follows:

- distributed along the bulkhead length at regular intervals
- at every angle formed by a bulkhead
- at every bulkheads intersection

The abbreviated name of each tank is to be painted beside one of the boundaries markings.

2.2 Rudder arrangements

2.2.1 Rudder arrangements are to be such that rudder pintle clearances and fastening arrangements can be checked.

2.3 Tailshaft arrangements

2.3.1 Tailshaft arrangements are to be such that clearances (or wear by poker gauge) can be checked.

3 Sea inlets and cooling water systems of machinery

3.1

3.1.1 Means should be provided to enable the diver to confirm that the sea suction openings are clear. Hinged sea suction grids will facilitate this operation, preferably with revolving weight balance or with a counter weight, and secured with bolts practical for dismantling and fitting while the ship is afloat.

Section 4 Permanent Means of Access (ACCESS)

1 General

1.1 Application

1.1.1 The additional class notation **ACCESS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.25.2] to ships defined in [1.1.2] for which permanent means of access comply with the requirements of:

- Regulation II-1/3-6 of SOLAS as amended - Access to and within spaces in, and forward of, the cargo area of oil tankers and bulk carriers
- IMO Resolution MSC.133(76) - Adoption of technical provisions for means of access for inspections
- IMO Resolution MSC.158(78) - Adoption of amendments to the technical provisions for means of access for inspections
- IACS UI SC 191, latest revision - Unified Interpretation for the application of amended SOLAS regulation II-1/3-6 (resolution MSC.151(78)) and revised Technical provisions for means of access for inspections (resolution MSC.158(78)).

1.1.2 The ships to which additional class notation **ACCESS** may be assigned are:

- oil tankers of 500 gross tonnage and over, having integral tanks for carriage of oil in bulk, which is contained in the definition of oil in Annex 1 of MARPOL 73/78 as amended
- bulk carriers (as defined in regulation IX/1 of SOLAS as amended) of 20000 gross tonnage and over.

1.1.3 The alternative, movable or portable means of access are outside the scope of the additional class notation **ACCESS**.

1.2 Definitions

1.2.1 Permanent Means of Access

They are permanent means of access provided to enable, throughout the life of a ship, overall and close-up inspections and thickness measurements of the ship's structures to be carried out by the Administration, the Society, the Owner and the ship's personnel and others as necessary.

Section 5 Helideck (HEL)

1 General

1.1 Application

1.1.1 The additional class notation **HEL** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.25.3], to ships fitted with helicopter facilities and complying with [1.2.1], in addition to the requirements from Part B and Part C, as applicable to helicopter facilities.

1.2 Reference standard

1.2.1 The design and arrangement of the helicopter facilities are to be in accordance with the Civil Aviation Publication 437 "Offshore Helicopter Landing Areas - Guidance on Standards" (CAP 437)".

The following chapters of CAP 437 are applicable, except where it refers to operational procedures or training, and where applicable for design and safety equipment on the unit:

- Chapter 3 Helicopter landing areas – Physical characteristics
- Chapter 4 Visual aids
- Chapter 5 Helideck rescue and fire fighting facilities
- Chapter 7 Helicopter fuelling facilities – Systems design and construction
- Chapter 9 Helicopter landing areas on vessels
- Chapter 10 Helicopter winching areas on vessels and on wind turbine platforms.

Section 6 Man Overboard Detection (MOB)

1 Application

1.1 General

1.1.1 The additional class notation **MOB** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.25.14] to self-propelled ships arranged with means capable of automatically detecting a person going overboard and instantaneously alert the ship's personnel in compliance with the requirements of this Section.

These requirements do not cover man overboard detection systems that require the passengers or crew members to wear or carry a device to trigger an MOB event.

1.1.2 This notation developed for passengers ships may be assigned to cargo ships at the discretion of Society.

1.2 Reference to other regulations and standard

1.2.1 The man overboard detection system covered by this Section is to comply with the requirements of the following standard: ISO/PAS 21195: Ships and marine technology - Systems for the detection of persons while going overboard from ships (Man overboard detection).

1.3 Definitions

1.3.1 Man overboard (MOB) detection system

System designed to automatically detect a person who has gone overboard from the ship.

1.3.2 Man overboard (MOB) event

Incident in which person(s) has accidentally or intentionally gone over the side/front/back of a ship and into the water.

1.3.3 MOB data

Information captured and/or generated by the MOB detection system.

1.3.4 Man overboard (MOB) verification data

System data that may be used by user to acknowledge, deny, confirm, or terminate an MOB alert or alarm at the control station.

1.3.5 False alert

System activation not caused by an actual MOB event.

1.3.6 Sensor unit

Devices or system of devices that detects and responds to one or more physical stimuli.

1.3.7 Control station

Equipment that provides the facilities for human observation and control of the MOB detection system.

1.3.8 Accessible open area

Any area of the ship that is accessible to either passengers or crew members and open to the outside.

1.4 Documents to be submitted

1.4.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documentation
1	A	Plan of the ship showing the location of sensor units and the detection envelope of the sensor units
2	A	Functional block diagram of the MOB detection system
3	I	List and specification of components of the MOB detection system (Manufacturer, type...)
4	A	Interconnection diagram with navigational equipment (ECDIS)
5	A	List of MOB alarms
6	I	Operating manual
7	A	Test program including test method
(1) A: to be submitted for approval ; I : to be submitted for information		

2 General design requirements

2.1 System description

2.1.1 The man overboard detection system is to consist of a control station, sensor units, cables, and associated software.

All alarms and data are to be available at the control station. Moreover the system is to provide the capability for an operator to manually select an imaging sensor and timeline for playback at the control station.

2.1.2 The system is to detect persons that pass through the MOB detection zone specified in [2.2] while going overboard, under the environmental conditions specified in [3.3.1] and encountered by the ship during operation.

2.1.3 The control station of the MOB detection system is to be installed in a continuously manned control station.

2.1.4 MOB detection system is to be of a type approved by the Society. Type approval is obtained subject to successful outcome of:

- performance tests as per requirements specified in this Section and ISO/PAS 21195 Clause 6
- environmental tests in accordance with Pt C, Ch 3, Sec 6.

2.2 MOB detection zone

2.2.1 The MOB detection zone is to be designed to cover the entire periphery of the ship where passengers or crew members may have access and is to be extended outside the ship at a distance not less than 5 m from the periphery of the ship.

The periphery of the ship is defined as the widest part of the ship at any location and is extended to include lifeboats.

2.2.2 The sensors units are to be located at or below the lowest accessible open area.

2.2.3 The sensor units are to be installed so as to prevent any mechanical damages when the ship is in port.

2.3 MOB alert and alarm

2.3.1 Based on data captured from the sensor units the system is to be designed to initiate automatically and immediately at the control station an MOB alert when a person falls down.

2.3.2 Audible and visual signals are to be activated when an MOB alert is initiated. The visual signal is to remain active until the MOB alert has been acknowledged at the control station. The audible signal is to remain active until the alarm has been deactivated or silenced.

2.3.3 System is to allow the readily identification of the sensor unit(s) that initiated the MOB alert.

2.3.4 Within five seconds of the initiation of an MOB alert, MOB data in the form of still or video image is to be made available at the control station.

2.3.5 System is to generate an MOB alarm log when an MOB alert is initiated. The MOB alarm log is to contain the following information:

- date and time (UTC time) of alleged MOB event
- current ship heading
- current ship position
- current ship speed
- identification of the sensor unit(s) that detect the MOB event
- username(s) of any individual logged into the system.

2.3.6 The MOB verification data is to permit the operator to deny or confirm an MOB alert from the control station. When an MOB alert is confirmed by an operator, the system escalate the MOB alert to an MOB alarm and is to automatically notify the navigation officers by generating a sound notification and by displaying on the integrated bridge system (IBS) or the electronic chart and information display (ECDIS) the original position when the MOB alert occurs. For that purpose, the system is to generate a NMEA (National Marine Association Message) message (see [2.6.1]).

2.4 Data storage

2.4.1 The data listed in [2.4.2] are to be stored in a resilient and redundant device. The data is to stamped with date and time. The time code input is to be from a valid coordinated universal time (UTC) feed.

In order to allow post MOB incident analysis, the storage device is to have a capacity to store the required system data for a minimum of 30 days.

The recorded data are to be protected against deletion or overwriting.

2.4.2 The following data are to be recorded:

- operational status of the system
- operational status of each sensor unit
- data capture from each sensor unit
- any active MOB alarm log (see [2.3.5])
- MOB log entries
- security log (see [2.4.3]).

2.4.3 Each event on the system (at least: logons, logoffs, data export, software modifications, and system setting changes) is to be recorded in a security log with date and time.

2.5 Control system

2.5.1 The MOB detection system is to be supplied by the transitional source of emergency electrical power. Failure of power supply is to generate an alarm.

2.5.2 The MOB detection system is to be provided with self-check capability. An alarm is to be activated at the control station when an internal fault is detected.

2.5.3 The system is to monitor the operational status of the MOB detection system. A display showing the operational status of each components is to be available at the control station.

2.5.4 The system is to be designed in order to minimize the false alerts caused by external events such as wave action, birds, object falling from the vessel, etc….

2.5.5 Access to the control station is to be restricted to users with appropriate credentials. Individuals accessing the system are not to have the possibility to alter or delete recorded data. The system is to log user actions.

2.6 Events markers

2.6.1 The MOB NMEA event messages described in [2.3.6] is to be compatible with the Integrated Bridge System (IBS) and Electronic Chart Display and Information System (ECDIS). Any connection to the IBS or ECDIS is to be such that the IBS or ECDIS suffers no deterioration, even if the MOB detection system develops faults.

MOB event messages are to be compliant with NMEA 0183 or NMEA 2000® communication protocols.

The MOB event messages are to be relayed to the IBS or ECDIS provided that the requirements for these systems are not compromised.

Note 1: IEC 61162 series provides additional information on the application of NMEA 2000® aboard SOLAS vessels.

2.7 Voyage Data Recorder

2.7.1 The MOB detection system is to be fitted with an interface that is compatible with the voyage data recorder (VDR). Any connection to VDR is to be such that the VDR suffers no deterioration, even if the MOB detection system develops faults.

The MOB alarm log is to be recorded in a format that complies with international digital interface standards set forth in IEC 61162 using approved sentence formatters.

The MOB alarm log is to be recorded on the VDR provided that the requirements for the recording and storage of the specified data selections are not compromised.

3 Survey onboard

3.1 General

3.1.1 Before an installation is put into service and after modification of an existing installation, performance of the MOB detection system is to be evaluated based on the execution of tests in accordance with requirements specified in this Article. Tests are to be carried out under the supervision of Society Surveyor according to an agreed test procedure.

3.2 MOB testing manikin

3.2.1 The system is to be evaluated by using a manikin having a basic human shape that contains two arms, two legs, a torso, and a head. The manikin is to have a mass of 40 kg and a height of 1,467 m, plus or minus 25%. The manikin may be modified to represent the features of a human body for particular sensing modality, such as a warm body for thermal cameras.

3.3 Environmental conditions

3.3.1 As a minimum the system is to be evaluated under the following environmental conditions:

- tests during navigation at different speed, from 0 knots to the ship's rated speed
- tests at different time of the day (night and day) and different sunshine conditions
- tests at different distance from ship's side (from 0 to 5m).

3.4 Probability of detection

3.4.1 The probability of detection of an MOB manikin is to be greater or equal to 95% within the range of environmental conditions set out in the test procedure.

3.5 Testing

3.5.1 The following tests are to be carried out to check the proper functioning of the MOB detection system:

a) at least 100 drop tests with the MOB manikin under environmental conditions described in [3.3.1] at different locations within each detection zones of the ship

b) functional test of the control station (activation of MOB alert, MOB alarm log, availability of MOB data, etc…)

c) behavior of the system in case of internal fault

d) behavior of the system in case of power failure

e) transfer of MOB alarm at the navigation bridge

f) transfer of MOB alarm to the Voyage data Recorder

g) consequence of failure of MOB detection system on external systems

h) Access controls of control station

3.5.2 For each drop test required in [3.5.1] the following information is to be collected and recorded in the test report:

- test date and time
- ship location and heading
- area of the ship where the test has been done
- sensor unit(s) that initiated the MOB alert
- environmental conditions (wave height, weather conditions, etc…).

3.6 False alerts

3.6.1 False MOB alerts are to be collected over a period of 90 days and average over that period. The following parameters are to be captured and recorded with each false alert:

- date and time
- ship location and heading
- sensor unit(s) that initiated the MOB alert
- false alarm reason
- environmental conditions.

3.6.2 During normal operating conditions, the average number of false alerts over a period of 90 days is not to exceed four per day.

Section 7 FSRU-READY

1 General

1.1 Application

1.1.1 The additional class notation **FSRU-READY** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6], to ships having the service notation **liquefied gas carrier** that are designed and built with specific arrangements in view of accommodating future installation of a regasification system, in accordance with the requirements of this Section.

1.1.2 The additional class notation **FSRU-READY** may be completed between brackets by one, or by a combination, of the following notations:

- **P** when specific arrangements for piping and process systems are taken into account during the initial design of the ship in order to consider additional capacity for a future conversion
- **R** when the regasification system, or main pieces of equipment, are defined at the time of assignment of the notation
- **I** when the ship is designed and built in order to allow on-site in-water survey without dry-docking once converted into FSRU and subject to acceptance from Authorities.

Note 1: Examples of notations are given below:

- **FSRU-READY**
- **FSRU-READY(P)**
- **FSRU-READY(P, R, I)**

1.2 Definition

1.2.1 Site condition

The site condition is the environmental condition expected during the on-site operation phase under regasification mode, and the resulting loads acting on the unit.

1.3 Plans and documents to be submitted

1.3.1 The documentation required in the scope of the additional class notation **FSRU-READY** is to be submitted to the Society for information unless drawings describe items actually installed on board at the time of assignment of the notation.

1.3.2 The plans and documents to be submitted are listed in Tab 1.

1.4 Conversion to FSRU

1.4.1 The conversion to FSRU corresponds to the actual installation onboard of all the pieces of equipment required to have a fully operational regasification unit.

Note 1: Guidelines for conversion to FSRU are given in NI 655, LNG Carrier Conversion to FSRU or FSU.

1.4.2 The installation is to be in compliance with the applicable requirements of the **liquefied gas carrier - FSRU** (or **FSRU**) notation set out in NR645, as applicable at the date of conversion.

Each equipment is to be in compliance with the applicable Rule requirements at the time of its actual installation onboard.

1.4.3 When the liquefied gas carrier is converted to a floating regasification unit, notations will be replaced as follow:

a) the service notation **liquefied gas carrier** is replaced by the service notation **liquefied gas carrier - FSRU** (or **FSRU**), provided that all the applicable requirements are complied with (see NR645 Rules for the classification of floating storage regasification units and floating storage units).

b) the additional class notation **FSRU-READY** is deleted

c) the additional service feature **REGAS** is assigned to the unit, provided that all the applicable requirements are complied with the requirements of NR645, Section 10.

Table 1 : Plans and documents to be submitted

Notation	No.	Plans and documents to be submitted	Approval status (A/I) **(1)**
FSRU-READY	1	General arrangement drawing of the ship showing the regasification spaces and installations, either fitted at the new building stage or planned at a subsequent stage **(2)**, in particular: • regasification skid • foundations for the support of regasification skid	A
	2	Design data for operation on-site, in particular: • site environmental data or, • specific navigation notation for the site condition	I
	3	Drawing showing the hazardous areas and their classification, taking into account the foreseen regasification system	A
	4	Details of electrical equipment installed in the hazardous areas, including the list of certified safe equipment	A
	5	Arrangement of accesses to the regasification spaces	I
	6	HAZID analysis (see [2.2.5])	I
P	7	Schematic diagram and arrangement of the piping systems	A
	8	Schematic diagram and arrangement of the fire protection systems (including the future installations of regasification)	A
	9	Specific arrangement of spaces for modification of systems, in particular: • ventilation systems • electrical installations • fire fighting systems	A
R	10	Documents of the regasification plan listed in NR645, Sec 10, Tab1	I/A **(4)**
I	11	Specific in-service inspection program in accordance with NR645, Sec 15	I
	12	Specific arrangements (see NR645, Sec 14), paying particular attention to: • cargo tanks • safety valves • cargo pumps • regasification plant **(3)** • electrical equipment • inert gas system	A

(1) A : Document to be submitted for approval
I : Document to be submitted for information.

(2) The equipment and systems installed at the time of assignment of the notation and those intended to be installed at a subsequent stage are to be clearly identified on the drawing.

(3) When the additional class notation **FSRU-READY** is completed by the notation **R**

(4) Depending on the approval status required in NR645, Sec 10, Tab 1.

Note 1: No additional or duplication of documents are required to be submitted when above technical contents are already presented and included in typical standard unit's drawing.

2 Requirements for the additional class notation FSRU-READY

2.1 Assumption for site condition

2.1.1 Assumed site conditions for FSRU operation are to be defined at the time of assignment of the notation. Navigation notations may be used as a reference for this purpose in order to cover a variety of possible site conditions.

Details of the site specifications, consisting in the name of field and/or geographical area and/or the most unfavorable sea conditions where the unit is intended to operate may also be used to cover specific site condition.

Note 1: The navigation notation **sheltered area** may be assigned after conversion to **liquefied gas carrier-FSRU** or **FSRU** for operation on site to cover a number of site conditions (i.e. harbours, estuaries, roadsteads, bays, lagoons and generally calm stretches of water).

In both cases, the data, limitations and assumptions used for the assessment of the unit on site are to be stated in the Design Criteria Statement, as defined in NR645, Sec 1, [8.1], which is to be referred to in a memorandum.

2.2 General arrangement

2.2.1 The design of the ship is to take into account the necessary spaces or zones to accommodate the following installations:

- regasification skid(s)
- foundations for the support of regasification skid(s).

2.2.2 The arrangement and location of the regasification area are to comply with the provisions of NR645, Section 10.

2.2.3 Accesses to, and escape routes from, the regasification area are to comply with the provisions of NR645, Section 10.

2.2.4 The hazardous / non-hazardous area classification in the regasification area is to be defined in accordance with the provisions of NR645, Section 10.

The types of electrical equipment permitted, depending on the zone where they are installed, are specified in Pt C, Ch 2, Sec 3.

2.2.5 A HAZID analysis is to be conducted to ensure that risks arising from regasification operations are addressed. Relevant hazards and risks scenarios with respect to regasification operations are to be identified as defined in NR645, Sec 10, [1.4.1], as applicable.

2.3 Hull and stability

2.3.1 The ship stability is to be assessed for preliminary loading conditions, and is to comply with the relevant provisions of NR645, Sec 3, [2].

2.3.2 The hull structure of the ship in way of the regasification skid(s) is to be protected against cryogenic spill. See NR645, Sec 10, [1.6.4].

2.3.3 The local structural reinforcements in way of the regasification skid(s) are to be justified by calculations and effectively fitted on board the ship.

2.4 Design loads

2.4.1 Loading conditions are to be representative of every configuration of weight distribution and the assessment of the structure is to consider relevant loads depending on the assumption for site condition defined in [2.1].

2.4.2 For each loading condition the load cases defined in NR645, Section 5 are to be considered taking into account the assumption for site condition defined in [2.1].

2.5 Structural strength

2.5.1 The structural strength of the ship is to be assessed assuming the regasification installation in ready-for-use condition, and is to comply with the requirements given in NR645, Section 7 taking into account the assumption for site condition defined in [2.1].

2.6 Sloshing on-site

2.6.1 As defined in NR645, Sec 9, [2], all cargo tanks are to be checked for several relevant partial filling levels.

Note 1: Subject to the acceptance of the Society, direct sloshing calculations need not be performed for site areas where the extreme 100 years return period significant wave height is less than 1,5 m.

3 Additional requirements for notations P, R and I

3.1 Notation P

3.1.1 The initial design of the ship is to take into account the spaces intended for the future installations of regasification and associated piping systems.

3.1.2 Piping installations fitted to the ship at the initial design stage and which will be used for the future regasification installation are to be in accordance with the requirements given in NR645, Sec 10, [1.7].

3.1.3 The initial design of the ship is to take into account the space for modification of fire fighting systems (fire main and hydrants, water-spray systems and dry chemical powder system) in order to consider additional capacity.

3.1.4 The initial design of the ship is to take into account the space for modification of ventilation systems in order to consider additional capacity.

3.1.5 The initial design of the ship is to take into account the space for modification of power generation and distribution system in order to consider additional capacity.

Electrical installations fitted to the ship at the initial design stage and which will be used for the future regasification installation are to be in accordance with requirements of NR645, Section 11.

3.2 Notation R

3.2.1 The foreseen regasification skid, and main pieces of equipment, are to be in accordance with the requirements given in NR645, Section 10.

3.3 Notation I

3.3.1 The initial design of the ship is to allow the surveys and tests, as defined in NR645, Section 15, to be undertaken to the required extent, paying particular attention to sea water system, cargo tanks, safety valves, cargo pumps, electrical equipment in hazardous areas and inert gas system as defined in NR645, Sec 14, [2.2] to [2.4].

3.3.2 When the additional class notation **FSRU-READY** is completed by the notation **R**, arrangements are to be made at design stage to allow internal and external inspections of the pieces of equipment of the future regasification installation when the plant is in operation.

3.3.3 A specific in-service inspection program for future use in regasification mode is to be approved by the Society and is to be listed in a memorandum.

Section 8 Sustainable Ships

1 General

1.1 Scope

1.1.1 The additional class notation **SUSTAINABLESHIP-1** or **SUSTAINABLESHIP-2** may be assigned to ships that are designed, built and equipped according to the requirements of this Section focusing on the following sustainability aspects:

- prevention of sea and air pollution
- protection of the marine environment
- reduction of greenhouse gases emissions
- preparation for ship recycling
- enhancement of people well-being on board.

1.2 Documents to be submitted

1.2.1 The documentation to be submitted for the additional class notations **SUSTAINABLESHIP-1** and **SUSTAINABLESHIP-2** is listed in Tab 1.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Document
1	A	EEDI technical file
(1) A: to be submitted for approval; I: to be submitted for information		

1.3 Notation SUSTAINABLESHIP-1

1.3.1 The requirements for the assignment of the additional class notation **SUSTAINABLESHIP-1** are those corresponding to a combination of class notations, their applicable associated requirements and any additional requirements, covering the sustainability aspects.

The required combination includes all the following class notations, their applicable associated requirements and any additional requirements, as detailed below for each of the sustainability aspects:

a) Prevention of sea and air pollution:

- **CLEANSHIP**
- For ships having an aggregate fuel oil tank capacity of less than 600 m^3:

  PROTECTED FO TANK
- For ships fitted with scrubber:

  EGCS SCRUBBER

  with the additional requirement that the scrubber is to be of a closed-loop type
- **VCS**, for ships which are assigned at least one of the service notations **oil tanker**, **FLS tanker**, **chemical tanker**, **liquefied gas carrier**, **combination carrier/OOC**, **combination carrier/OBO**.

b) Protection of the marine environment:

- For ships to which IMO BWM Convention applies:

  BWT

c) Reduction of greenhouse gases emissions:

The following requirement applies to the ship's Energy Efficiency Design Index (EEDI) as defined in MARPOL Annex VI Chapter 4:

- The Attained EEDI value is to comply with the required EEDI Phase 3 which means the EEDI reference line with the reduction factors for phase 3 as defined in IMO Resolution MEPC.328(76) for the applicable ship type.

Note 1: This requirement does not apply to ships not submitted to IMO EEDI.

d) Preparation for ship recycling:

GREEN PASSPORT or **GREEN PASSPORT EU**.

1.4 Notation SUSTAINABLESHIP-2

1.4.1 The requirements for the assignment of the additional class notation **SUSTAINABLESHIP-2** are those corresponding to a combination of class notations, their applicable associated requirements and any additional requirements, covering the sustainability aspects.

The required combination includes all the following class notations, their applicable associated requirements and any additional requirements, as detailed below for each of the sustainability aspects:

a) Prevention of sea and air pollution

- **CLEANSHIP SUPER** completed between brackets by three additional class notations among those referred to as "eligible" for assignment of the notation **CLEANSHIP SUPER** in Ch 9, Sec 1
- For ships having an aggregate fuel oil tank capacity of less than 600 m^3:

  PROTECTED FO TANK
- **NDO-x days**, which is an eligible class notation for **CLEANSHIP SUPER**
- **OWS-x ppm**, which is an eligible class notation for **CLEANSHIP SUPER**
- For ships fitted with scrubber:

  EGCS SCRUBBER

  with the additional requirement that the scrubber is to be of a closed-loop type.
- **VCS**, for ships which are assigned at least one of the service notations **oil tanker**, **FLS tanker**, **chemical tanker**, **liquefied gas carrier**, **combination carrier/OOC**, **combination carrier/OBO**.
- For ships fitted with internal combustion engine(s):

  TIER III

b) Protection of the marine environment:

- For ships to which IMO BWM Convention applies:

  BWT, which is an eligible class notation for **CLEANSHIP SUPER**
- **URN**

c) Reduction of greenhouse gases emissions:

- One of the following class notations is applicable:
  - **battery system** or **ELECTRIC HYBRID** or **HMPS** or
  - **fuelcell** or
  - **WIND PROPULSION-1** or **WIND PROPULSION-2** or
  - **LNGfuel** or **CNGfuel** or **LPGfuel** or **methanolfuel** or **ammoniafuel** or **hydrogenfuel**.
- The following requirement applies to the ship's Energy Efficiency Design Index (EEDI) as defined in MARPOL Annex VI Chapter 4:

  The Attained EEDI value is to comply with the required EEDI Phase 3 which means the EEDI reference line with the reduction factors for phase 3 as defined in IMO Resolution MEPC.328(76) for the applicable ship type.

Note 1: This requirement does not apply to ships not submitted to IMO EEDI.

d) Preparation for ship recycling:

- **GREEN PASSPORT** or **GREEN PASSPORT EU**

e) Enhancement of people well-being on board

- **HABITABILITY**
- **COMF-NOISE**
- **COMF-VIB**.

1.5 Initial survey

1.5.1 The survey requirements for the assignment of the additional class notations **SUSTAINABLESHIP-1** and **SUSTAINABLESHIP-2** are those respectively applicable to each required class notation of the combination.

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